Federal Lands Highway

Project Development and Design Manual

U.S. Department of Transportation

Federal Highway Administration

Chapter 1 – INTRODUCTION

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PREFACE

Federal Lands Highway (FLH) has developed the *Project Development and Design Manual (PDDM)* to provide current policies and guidance for the interdisciplinary project development and design related activities performed by FLH Divisions and their consultants. It also serves as a guide for administrators, public officials and others, both within and outside FLH, who are responsible for advancing projects through the project development process.

The purpose of the *PDDM* is to:

- Provide current policies, standards, criteria and guidance for development and design of FLH projects;
- Be easily accessed by internal and external participants in the project development process;
- Be user-friendly with useful navigation and search tools;
- Provide immediate access to approved external references; and
- Be frequently updated to maintain credibility.

A primary goal of the *PDDM* is clarifying what is expected for FLH projects and delivering an end product that meets these expectations. The previous edition of the manual has been converted from a policy/procedures hard copy format manual to a policy/best practices, interactive web-based document with electronic links. Most theory-specific procedures or recommended methods, including computer software, are included in the updated *PDDM* by reference only. This manual is not intended to be a technical "how to" instructional guide.

The *PDDM* is a complete PDF web-based document allowing faster downloading, clearer formatting, word searches through Adobe Acrobat and hypertext links to reference documents and technical information. The manual defines FLH policies, standards and standard practices, criteria, guidance and discretionary expectations for project development.

The FLH Discipline Champions and their respective teams prepared this edition of the *PDDM*, with assistance from engineering consultants. The FLH Discipline Champions wish to express their appreciation to all contributors who assisted in the development of this manual, specifically the contributions of the following:

- FLH Division Engineers and Directors,
- FLH Branch Chiefs,
- FLH Staff,
- Materials furnished by other State and Federal agencies,
- Research publications and materials furnished by the private sector,
- Consultants who contributed to the preparation, and
- Federal land management agency partners and other reviewers.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Approximately one-third of the total land area of the United States is owned or controlled by the Federal Government. One of the world's largest highway networks has been constructed to serve these Federal lands.

Several Federal agencies are responsible for managing public lands and consequently are also responsible for managing a part of this vast network of Federal roads. The role of the Federal Highway Administration (FHWA) and Federal Lands Highway in designing and constructing highway facilities on Federal lands is well defined in existing legislation and supplemental national interagency agreements (see Section 1.3).

The Office of Federal Lands Highway is headquartered at FHWA in Washington D.C. and also maintains three Federal Lands Highway (FLH) Division offices. See Exhibit 1.1–A for a geographical breakdown of FLH Division offices. For more than 100 years, FLH and its predecessor offices have offered their expertise to other Government agencies for the planning, location, design and construction of highways, parkways, roads and trails in the Federal domain. Many foreign countries have also been assisted in the development and construction of road systems.

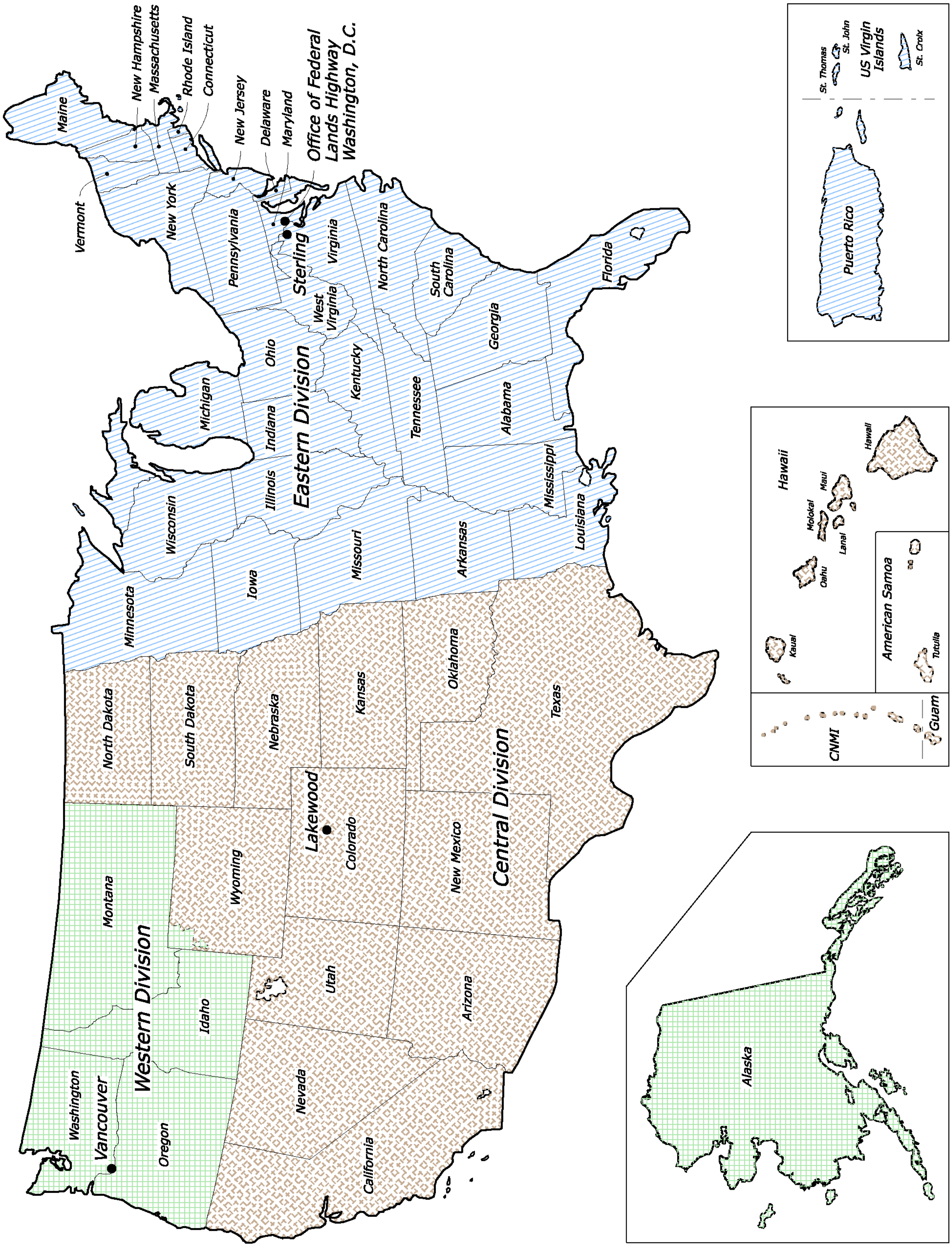
One primary goal of the FLH program is to provide safe, cost-effective and environmentally sound highways and roads to serve our nation's Federal Lands. FLH uses context sensitive solutions (CSS) and sound engineering practice to achieve this goal. This requires a collaborative, interdisciplinary approach to roadway planning, design and construction, involving all partners, stakeholders and the public to ensure that transportation projects are in harmony with communities and that they preserve environmental, scenic, aesthetic and historic resources. The effective application of CSS techniques when using the *PDDM* achieves these goals while providing safe and efficient access to our nation's Federal lands.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

1.1.1 PURPOSE

The *PDDM* has been developed to provide information and guidance to internal FLH employees, our partner and stakeholder agencies and our consultants involved with project development and design of highways. It is a key reference tool that is useful to both the veteran manager and the entry-level designer. Its use requires an interdisciplinary team approach. Users of this edition of the *PDDM* will find links between the manual's chapters that will allow them to be aware of related information in chapters other than those of their own discipline. Additionally, the *PDDM* serves as a portal for numerous external technical manuals and reports through the use of links to other websites. The manual identifies those policies, standard

Exhibit 1.1–A FEDERAL LANDS HIGHWAY DIVISION OFFICES



practices, criteria, guidance and references approved for use in carrying out the highway and bridge design responsibilities in the Federal Lands Highway Programs (FLHP). In this regard, the following definitions will be used:

1. **Policy**. Guiding principle; general course of action to be followed without exception. Where policy is cited the source of the policy is also referenced, when applicable and appropriate. Policy statements are presented in **bold** type.
2. **Standard**. A fixed reference to guide the outcome and content (product) of the work. FLH Standards are fixed references that the Office of Federal Lands Highway impose to guide the content of FLH products. Standards are established where there is a consistent level of risk, or there is a consistent technical or performance expectation, for a specific product to work well in most cases. FLH standards are based on successful past performance on FLH projects after meeting goals of risk management, quality, and efficiency. Variances to FLH Standards are not uncommon, but they need always be justified in writing. Attention to this and guidance on how to do it are included in this manual.
3. **Criteria**. Tests or indicators, in addition to standards, used to measure/judge achievement of applicable policy or standard objectives. Criteria may vary from project-to-project. The *PDDM* provides typical criteria, with guidance on how to select criteria for specific project types and/or conditions.
4. **Standard Practice**. FLH Standard Practices are established methodology that the Office of Federal Lands Highway imposes to guide the approach to the work, and which will generally produce a consistent outcome that meets FLH expectations. Standard Practices are established where a certain process or method is necessary, in addition to or as assurance, for achieving a sufficient end result product (see Standard). FLH Standard Practices have a history of demonstrated quality and successful use. Variances from FLH Standard Practices may sometimes be appropriate, but require written justification.
5. **Guidance**. Suggested actions to meet policies and standards, and expectations for applying discretion. Considerations for selecting appropriate standards and design criteria are included in the manual.
6. **Discretion**. Where the practitioner is expected to exercise engineering judgment to apply an optimum technique or solution that is within an acceptable range of values.

Policies, standards and criteria are condensed and written for the user. Where appropriate, relevant procedures, instructional aids and publications are referenced. References to specific computer programs, AASHTO guidelines, manuals and regulations are included in this manual. It is expected that the user will be knowledgeable in the use of the referenced items. The *PDDM* does not detail technical methods or procedures. Users are expected to consult the documents referenced for such purposes, and otherwise stay informed of current technologies.

Compliance with all policies and standards in the *PDDM* is essential to ensure consistency in project development throughout FLH. Although policy cannot be compromised, flexibility of standards is sometimes necessary to meet project specific objectives. Deviation from standards cited within this manual will require formal justification and approval. Division variances in standards, criteria and guidance are typically found in the Division Supplements at the end of the various chapters.

1.1.2 PHILOSOPHY AND TECHNICAL POLICIES

Policies presented in the *PDDM* are interpretations of agency directives and objectives, based on legislation and federal regulations pertaining to the FHWA and FLH programs. This section describes the FLH project development philosophy and technical policies that are to be followed at all times in the conduct of project development work for FLH projects. The sources of the philosophy and technical policies are found in Section 1.2.

The technical activities for FLH project development can be very challenging, since projects are located from the Atlantic to the Pacific and from the tropics to the arctic. The natural settings and technical issues vary tremendously; however, an equal challenge comes from the variety of projects and stakeholders. Some projects are multi- lane divided highways and bridges, but much of the work deals with low volume roads on resource sensitive public lands. These areas have significant and diverse stakeholders, regulations, management goals, environmental resources, cultural resources, wildlife, scenic beauty and intrinsic value. Furthermore, FLH is a partner with federal land management agencies and other government property managers and owners, but does not own or manage federal land, or the improvements it designs and constructs. Upon successful completion, another agency accepts FLH projects and agrees to maintain them. Therefore, technical work should embrace the following key FLH project delivery objectives:

- Be respectful of the land, partner agency goals, tribal values, cultural significance of landforms and sites, wildlife, and habitat;
- Provide a safe passage for residents, travelers, visitors, tourists, recreationists, and wildlife;
- Minimize impacts to existing features and conditions in a “lightly on the land” manner; blend improvements into the setting with as little impact as possible; and
- Complete quality work within budget constraints, recognizing that funding is often comparatively less for low-volume, rural public access roads serving federal lands than for higher volume state and municipal projects.

The combination of protecting cultural and environmental resources; accommodating public lands stakeholders and their values/regulations; providing safety and quality; and working within limited funding means searching for technical solutions that are both context-sensitive and cost effective. Dealing with the variability of FLH projects, terrains, climates and partner agency constraints requires flexibility, resourcefulness, and collaboration. FLH roadway design philosophy and context sensitive solutions are further described in Section 9.1.5.

This section provides guidance in identifying and planning appropriate levels of technical practice to fit the unique circumstances and challenges posed by FLH projects. The highest-level guidance is in the form of policy, which is followed without exception. The following FLH *technical policies* represent the FLH project development philosophy to be followed by the technical practitioner:

1. **Support the mission, vision and program management objectives of FLH and FHWA.** FLH policy is to support the mission, vision and program management objectives of FLH and the FHWA. The technical practitioner does so by performing work that is consistent with prevailing laws and regulations, executive orders, DOT orders, FHWA regulations and administrative rules, and FLH mission and vision statements. This is the ultimate technical policy and the other technical policies help to fulfill it.

2. **Meet the technical scope requirements defined by this PDDM.** FLH policy is to meet the technical scope defined by the standards and guidance presented in this PDDM regarding project development activities, including investigation, analysis, reporting, PS&E development, construction support, technical support and other agency needs. This defines that project development and technical work is guided by the contents of this PDDM.

3. **Advance the state of practice by seeking and implementing new technology.** FLH policy is to evaluate, promote and implement new technology and to continually update technical capabilities. This conveys a guiding principle for utilizing advances in technology.

4. **Demonstrate environmental stewardship in planning and designs.** FLH policy is to perform technical investigations and develop design recommendations that minimize environmental impacts and demonstrate environmental, cultural and natural resource stewardship while meeting other project objectives. This conveys environmental stewardship responsibility. Chapter 3 provides further environmental guidance.

5. **Conduct work safely and seek safety improvement solutions.** FLH policy is to conduct work in a manner that is safe for workers and the public, and to seek solutions that improve safety and minimize roadside hazards on federal and tribal lands. Appropriate safety applications are to be incorporated while respecting the associated natural resource impacts and historic, cultural and community values. This intends to protect the general public, FHWA personnel and contractors, and public and private property. It applies to work conducted as part of technical activities from planning through construction, as well as the safety of the completed project with respect to technical issues. Some partner agencies may have standards and requirements that could limit the implementation of safety features. The FLH Safety Memorandum 2004 describes the philosophy of enhancing safety through collaborative effort, integrating technical standards, environmental stewardship and partner agency requirements. The practitioner or technical discipline leadership will seek clarification within FHWA when confronted with situations that are not adequately defined. More detail of the FLH safety philosophy is presented in Section 8.1.1.

6. **Achieve quality through established quality control, quality assurance and oversight procedures.** FLH policy is to strive for quality through established quality control and quality assurance (QA/QC) procedures and through oversight of technical work performed by others. This technical policy includes performing QA/QC and managing outsourced work. A quality control and assurance program must be maintained and applied to all project work. Every functional discipline performing work is

responsible for the technical adequacy of their project development and design activities. Technical consultants shall also follow an established QA/QC process, either their own approved process or a FLH internal QA/QC process. Unless specific arrangements are made to the contrary, the FLH does not provide QC or QA for the work of its consultants, but still retains responsibility for independent quality assurance and oversight for the project delivery.

7. **Demonstrate financial stewardship, risk assessment, and workforce and resource management.** FLH policy is to coordinate and manage project development work by multi-disciplinary and multi-agency project teams and within jointly established scopes, schedules, budgets, quality, and project criteria and constraints. Usually more than one option exists to achieve the functional requirements for the project. Evaluations of design options include the assessment of risk and consequences as well as performance and cost. This includes assessing risk, planning and managing project development work, personnel, and resources, both workforce and technical resources.

1.1.3 RISK

Risk is inherent in the delivery and operation of FLH projects, and it has several forms. Risk is incurred with respect to cost when decisions are made regarding the scope of investigation and analysis. A greater investigation scope generally means fewer unknowns are carried into construction, thereby reducing the risk of bidding and construction cost escalation. Risk is incurred with respect to serviceability when designs are advanced that do not fully address all possible performance demands. Risk is incurred with respect to safety whenever recommendations are incorporated into geometric designs and structures such as culverts, bridges, walls, and rock slopes. The practitioner’s responsibility lies in identifying risks incurred through analysis of all pertinent issues, informing project team members and partners of these risks, and assisting in evaluating whether the risks are tolerable.

Risks are more tolerable when they are low relative to the potential benefit of the action incurring the risk. Risk assessment is the process of assessing the probability and severity of adverse consequences associated with activities, recommendations or designs. For most FLH projects the risk assessment is not a complicated quantitative assessment, but rather a simplified practical assessment based on experience, engineering judgment and historical standard of practice on previous partner agency projects.

It is not feasible or intended for highway projects to be entirely risk-free, as there are potential rewards to the project when risk is taken. Knowledge of physical conditions, traffic and safety conditions for each project, as well as the basis and assumptions underlying the standards, is essential in order to understand the risks associated with decisions involving the selection and application of the standards and criteria. In many cases, the risks associated with decisions can be mitigated with inclusion or enhancement of other features, which may offset the risk. To the extent possible, risks should be quantified, both on the basis of their potential probability and for their potential consequences.

On a project-by-project basis, a consistent level of safety, operational, and project delivery risk should be maintained from programming through construction. Where risk levels vary with different design or construction options, these risks must be fully explained, especially where there are disagreements over cost, impacts, safety, service life, aesthetics, etc. For each of the engineering disciplines involved in the project development, the operational and long-term performance risks (i.e., functionality, service life, maintenance, safety) of various engineering solutions, and the level of risk associated with performing varying levels of engineering analysis during the design, should be assessed continuously. Within the project development process the costs, time and resources that are devoted to the process should be evaluated continuously with respect to the demands and risks for a successful project delivery and adherence to established schedule, budget, scope of work, and quality expectations.

The evaluation of potential risk and benefit is not solely a single discipline practitioner responsibility, as it is an interdisciplinary process requiring involvement of the Project Manager and other team members and stakeholders, as appropriate, based on all issues and participation in evaluation of the tolerability of the risk. Risk levels may vary between different disciplines or may impact other disciplines, or may cause risks to arise later in the project delivery process. Decisions resulting from risk-driven conflicts must be fully discussed and documented by the interdisciplinary project development team. The Project Manager will generally lead the decision-making process using a collaborative interdisciplinary approach to resolve disagreement over the acceptable level of risk. The FLH Branch Chiefs will normally oversee and endorse the level of risk taken to achieve a consistent office-wide level of risk acceptance over time. Where risks are elevated, the endorsement of the Project Manager, the Division Functional Managers, Division Branch Chiefs, Directors or Division Engineer may be necessary.

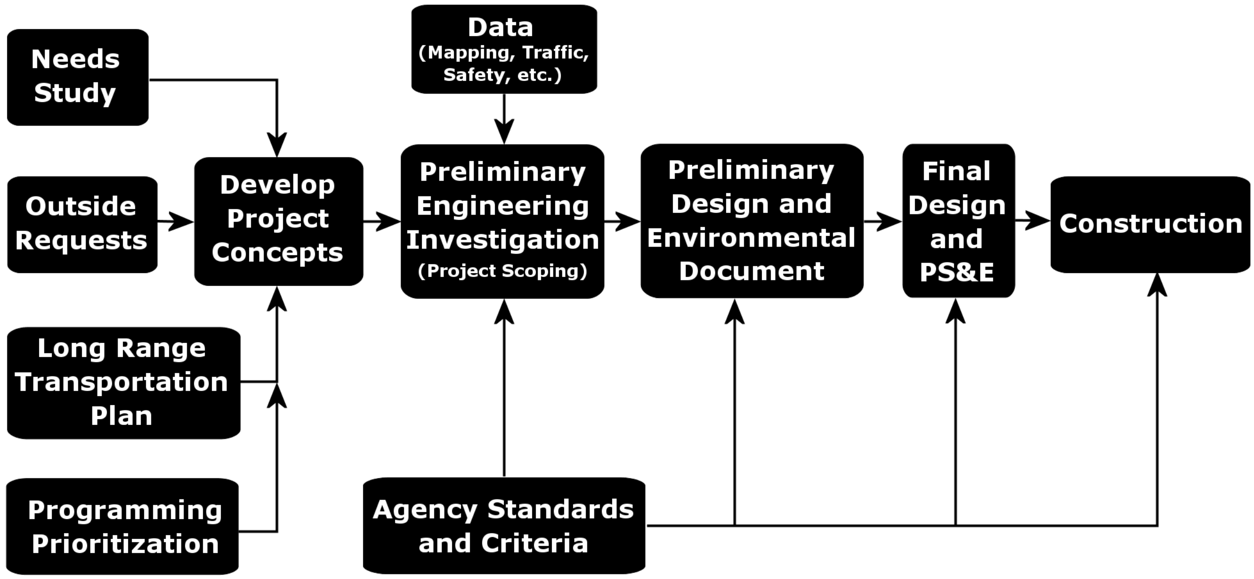
1.1.4 FORMAT

The *PDDM* is divided into thirteen chapters, each dealing with a major category of project development work. See Exhibit 1.1–B for a diagram of the project development work process. Each chapter has its own table of contents and is subdivided into sections. Policy and criteria are presented in each chapter as they relate to the specific subject matter. Links are provided to outside resources throughout the manual. Links with a solid underline identify links to a resource or chapter outside the current chapter of the PDDM. Links with a dotted underline identify a link to another portion of the current chapter which may also be a consolidated listing of outside resources.

The manual is available in electronic format for download from the Internet either in its entirety or by individual chapter. The electronic version of the *PDDM* and its revisions will be considered the official document in contracts with A/E consultants.

The manual is published in US Customary (English) units followed by SI (metric) units in square brackets. All design work is to be produced in units as specified by the partner agency. The decision on which units to use will be project specific and determined at the time the project is programmed.

Exhibit 1.1–B PROJECT DEVELOPMENT WORK PROCESS



1.1.5 REVISIONS AND UPDATES

The FLH Discipline Champions (the “Champions”) are responsible for maintaining the *PDDM* and its contents. WFLHD maintains the electronic version of the manual. Periodically, chapters will be reviewed for adequacy and need for revision. As changes in policies, standards and/or criteria occur, modifications will be made electronically.

Each *PDDM* user may contribute to its continuing improvement and is encouraged to submit suggestions to make it more useful and practical. Provide the appropriate Champion and associated team with a reason why the change is needed, what precipitated the change, and provide a description of the change either with new text or redline/strikeout of existing text and/or exhibits, links, etc.

Minor modifications such as adding links to new FHWA guidance, improving linkages between chapters, and other minor content or editorial changes that have full support of the affected disciplines, will be processed by the Champion with no additional approvals required.

Otherwise, the discipline team evaluates the proposed change by looking at the consequences of the change, including its conflicts, benefits, risks, cost and feasibility. In some cases the team may not have enough information to decide on the change. The team may then have to determine the in-house and contract resources, funding, and time required to develop needed information and provide recommendations. When the discipline team has reached agreement to make the change, the Champion prepares a recommendation memorandum via e-mail to all the effected Branch Chiefs for their review and approval. Once approved by the Branch Chiefs (BC) the Champion prepares the modification and distributes the PDDM Modification Approval Form for signatures and final approval by the Office of Federal Lands Highway. See Exhibit 1.1–D for an example modification approval form completed by the Hydraulics Champion. The Branch Chiefs then notify their staff that a *PDDM* modification has been implemented. For the rare occasion where the Branch Chiefs do not agree on a modification the Board of Directors (BOD) will determine if the modification is required FLH-wide for Division alignment. If the Board of Directors determines alignment is not necessary, those Branch Chiefs in agreement with the modification prepare Division Supplements to the manual. See Exhibit 1.1–E for the detailed process and Exhibit 1.1–C for a flowchart summarizing the modification development process.

When revisions are made, the PDDM Revisions Log will be updated. All revised material will be indicated by a change line in the *PDDM*. The change lines within any given chapter will remain until the next revision, at which time all change lines in that chapter will be removed. The Champions and their respective teams will check all external links on an annual basis to ensure they are still accurate. Internal links will be checked when there is a significant addition or deletion (i.e., new page, deleted section) from the manual. The manual will have either a publication date or revision date on each page to allow the user to determine if they are using the most recent document.

Exhibit 1.1–C PDDM MODIFICATION DEVELOPMENT PROCESS

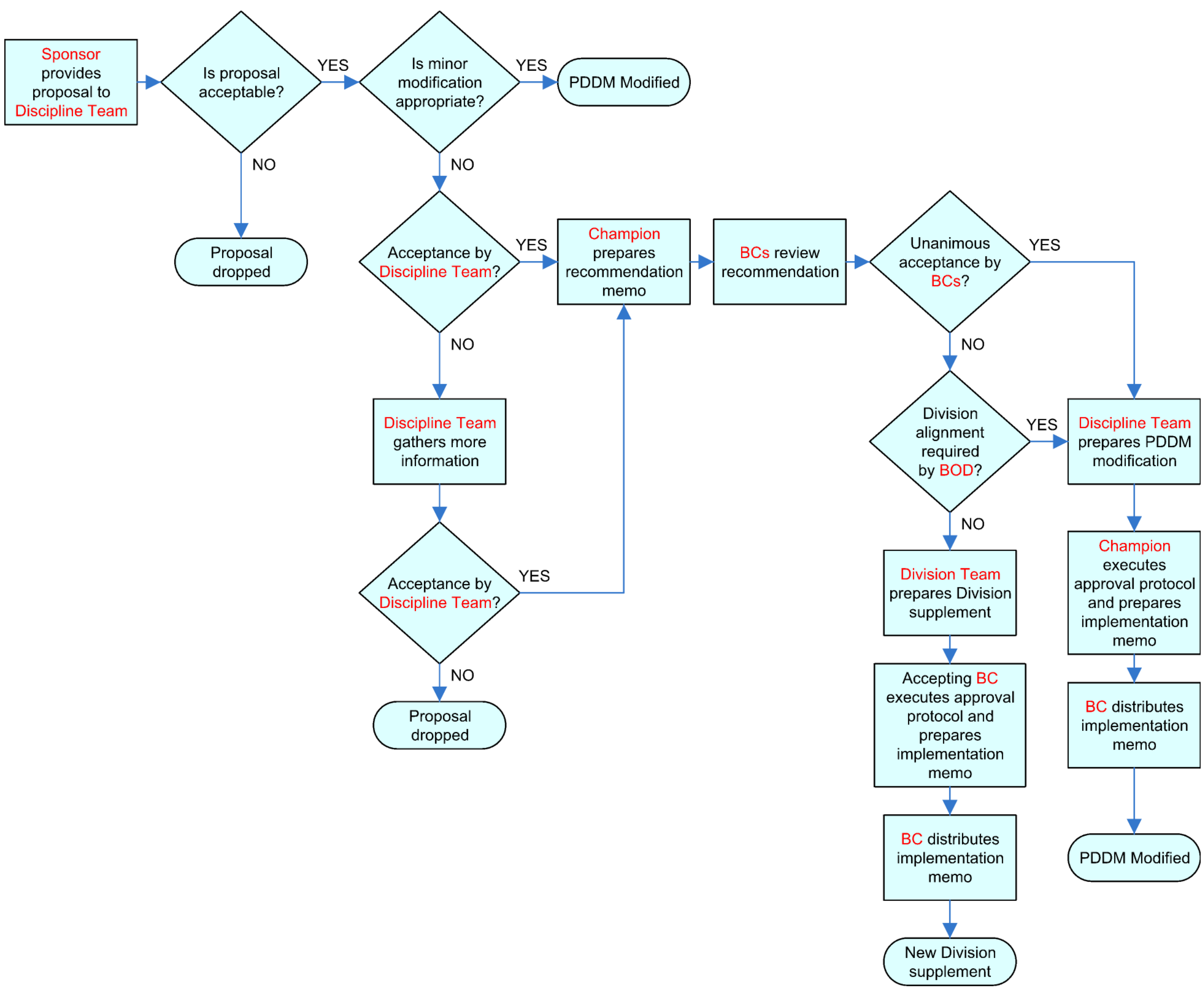


Exhibit 1.1–D PDDM MODIFICATION APPROVAL

Discipline: Hydraulics

Section / Subsection(s): Chapter 7

Reason for modification: Update / Expand policy and standards to clarify national guidance for the development and delivery of FLH programs and projects. Remove operational and procedural guidance from manual.

Expected consequences: Improve accountability and quality of deliverables from FLH Hydraulics, their contractors and consultants. Increase effectiveness of guidance.

Modification Text:

See PDDM Chapter 7.

Completed Coordination:

- ☒ Technical Services Branch Chiefs
- ☒ Project Development Branch Chiefs
- ☒ Design Discipline Champion
- ☒ Bridge Discipline Champion
- ☒ Geotechnical Discipline Champion
- ☒ Environmental Discipline Champion
- ☐ XXXXXXXX Discipline Champion
- ☐ XXXXXXXX Discipline Champion

Certification: I certify to the following:

- Above coordination was completed and all comments / concerns have been addressed and resolved in a manner satisfactory to all applicable parties. Comments and resolutions are on file with FLH Discipline Champion.
- All research and development documentation needed to support above modification(s) is on file with certifying FLH Discipline Champion.

________________________ ____________
FLH Discipline Champion Date

Assurance: I assure the above certification is valid:

________________________ ____________
Supervising Director Date

Approval: The above described modification(s) is approved for immediate implementation:

________________________ ____________
Director, Office of Program Development Date

Exhibit 1.1–E DEVELOPMENT PROCESS FOR PDDM MODIFICATIONS

Source - Person with the idea.

Sponsor - Person that champions idea/develops Justification for Review.

Suggested content of Sponsor Justification for Review:

- Describe change to discipline practice, standard, etc. Why is it needed, what precipitated the change?
- Propose revised text and/or exhibits, links, etc. using redline/strikeout.
- Describe expected impacts of change (e.g., conflicts with current operations).

Level 1 Review: Discipline Team (lead by Sponsor with Discipline Champion support) evaluates proposed change and recommends future actions/time frames, including need for Level 2 review.

Suggested Level 1 Review Process Objectives:

- Identify affected disciplines and coordinate with Discipline Champions and appropriate others
- Identify conflicts, benefits, risks, other consequences of change
- Judge feasibility/cost-effectiveness of implementing change
- Thumbs up/down on pursuing
- Determine if streamlined process* is appropriate.

Level 1 Result

Acceptance:	Discipline Champion prepares Recommendation Memo to discipline BC(s), or under streamlined process, Discipline Champion prepares and implements PDDM modification.
Rejection:	Drop Idea
Split:	Sponsor initiates Level 2 Review

(Acceptance/Rejection > two-thirds majority; Split: > 50/50 acceptance, but less than two-thirds majority. Quorum needed for a valid vote to be defined by discipline-specific charter.)

Level 2 Review: Discipline Team (lead by Sponsor with Discipline Champion support) prepares scope of work; defines level of effort, sources (in-house: Discipline Champions, FA; contract: Industry, Academia, Individual), necessary funding and funding sources (e.g., TD), and time required to develop needed information and provide recommendations; coordinates with affected Discipline Champions and appropriate others.

Level 2 Results

Acceptance/Split:	Discipline Champion prepares Recommendation Memo to discipline BCs
Rejection:	Drop idea

Recommendation Memo - Discipline Champion conveys justification and support for change (via email) to discipline BC(s), including results of Level 2 analysis, if applicable.

BC Feedback

Unanimous Approval:	Discipline Team (led by Sponsor with Discipline Champion support) prepares PDDM modification. Discipline Champion executes approval protocol and prepares. Implementation Memo on behalf of HQ.
Unanimous Disapproval:	Drop Idea (expected to be a very rare occurrence at this stage).
Not Unanimous:	Escalate to BOD for decision on Division alignment.

Escalation Decision:

Division Alignment Required: Discipline Team (led by Sponsor with Discipline Champion support) prepares PDDM modification. Discipline Champion executes approval protocol and prepares Implementation Memo on behalf of HQ.

Division Alignment Not Required: Division Discipline Team Leader(s) in favor of change prepares Division Supplement. Discipline BC(s) in favor of change executes approval protocol and prepares Implementation Memo on behalf of HQ.

Approval Protocol - Reference "PDDM Modification Approval" form.

Implementation Memo - Upon receiving Headquarters' approval, appropriate BC(s) notify Division Staffs of effective change to PDDM (via email). (Under streamlined process* changes will be documented per PDDM revision process.)

*The streamlined process is appropriate for changes such as adding links to new FHWA guidance, improving linkages between chapters, and other minor content or editorial changes that have full support at the technical level for all of the affected disciplines. No approvals are required.

1.1.6 DIVISION SUPPLEMENTS

It is a FLH goal to have alignment between Divisions whenever it is practical. However, the Divisions do have differences in organizational structure and each has its own base of institutional experience developed through years of work within its region of the country, with state and county partners, and with the regional representation of the Federal Land Management Agencies. Each Division has unique project planning, management and scheduling tools, and has minor variations in the utilization and management of contracted A/E consultant services. The Division Supplements listed throughout the PDDM detail the differences in practice among the Divisions. These references and supplements should be used within the Divisions and by their consultants whenever applicable.

Supplements will be issued by the appropriate Division office in a compatible format to this manual. Links to the Division Supplements are provided when available at the end of each major section. The electronic versions will be identified by Division's reference at the bottom of each page as noted below:

- Eastern Federal Lands Highway Division, (EFLHD),
- Central Federal Lands Highway Division, (CFLHD), and
- Western Federal Lands Highway Division, (WFLHD).

Informational electronic copies of Division Supplements should be distributed to the other Division offices and appropriate Champions on a routine basis upon issuance.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

1.2 GUIDANCE AND REFERENCES

The *PDDM* supplements Federal laws and regulations relative to the development and design of highways. It is intended to be used in conjunction with current engineering practices and procedures issued by the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), State highway agencies, Federal land management agencies and other select organizations. Applicable laws are set forth in Title 23, United States Code (USC) “Highways”. The governing regulations are found in Title 23, Code of Federal Regulations (CFR). As described below, additional guidance on applicable policy and standards may be found in the *Federal-aid Policy Guide*, the *Federal Lands Highway Manual*, national and project interagency agreements and AASHTO or other recognized publications.

Other acceptable guides and publications may be referenced in specific chapters. Publications referenced in this manual are available for use by each Division office, as appropriate.

1.2.1 CODE OF FEDERAL REGULATIONS (CFR)

The *Code of Federal Regulations* is a codification of the general and permanent rules published in the *Federal Register* by agencies of the Federal Government. The code is divided into 50 titles representing broad areas of Federal regulations. Title 23 CFR “Highways” is the volume representing those current regulations applicable to FHWA and the FLH Program. The following are the parts of 23 CFR that are most relevant to the development and design of highways:

- Part 620, Subpart A. Highway Improvements in the Vicinity of Airports.
- Part 625, Design Standards for Highways.
- Part 626, Pavement Policy.
- Part 627, Value Engineering.
- Part 630, Preconstruction Procedures.
- Part 636, Design-Build Contracting.
- Part 650, Bridges, Structures and Hydraulics.
- Part 652, Pedestrian and Bicycle Accommodations and Projects.
- Part 655, Traffic Operations.
- Part 660, Special Programs (Direct Federal) Forest Highways and Defense Access Roads.
- Part 668, Subpart B, Emergency Relief Program Procedures for Federal Agencies for Federal Roads.
- Part 752, Landscape and Roadside Development.
- Part 771, Environmental Impact and Related Procedures.
- Part 772, Procedures for Abatement of Highway Traffic and Construction Noise.

- Part 777, Mitigation of Impacts to Wetlands and Natural Habitat.
- Subchapter L, Federal Lands Highways.

1.2.2 FEDERAL-AID POLICY GUIDE (FAPG)

The *Federal-Aid Policy Guide (FAPG)* is an official Federal Highway Administration (FHWA) directive that contains the current policies, regulations, and non-regulatory procedural guidance information related to the FHWA's Federal-aid Highway Program. The FAPG also contains program directives relative to administration of the Federal Lands Highway Program (FLHP). FHWA directives and policy memorandums are available on the Department's website.

1.2.3 NATIONAL INTERAGENCY AND PROJECT AGREEMENTS

Agency agreements are required whenever FHWA performs work for another agency or when work is performed by another agency with funds administered by FHWA. National agreements have been executed between FHWA and principal Federal land management agencies (i.e., National Park Service (NPS), Forest Service (FS), Bureau of Indian Affairs (BIA), Fish and Wildlife Service (FWS). Project agreements are executed between Division offices and another agency to detail project specifics that cannot be covered by a national agreement (e.g., project funding, geometrics, right-of-way acquisition, utility relocation, construction, and maintenance responsibilities). SAFETEA-LU allows tribes to enter into IRR Program agreements directly with FHWA. These are developed and overseen by the Office of Federal Lands Highway. If a tribe requests design work to be conducted by FLH, a project agreement between the Tribe and the FLH Division will be required. Agreements are discussed in Chapter 2.

1.2.4 AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO) POLICY AND GUIDES

AASHTO was organized in 1914 and is composed of representatives from all 50 State highway transportation agencies, the Commonwealth of Puerto Rico and the Northern Mariana Islands, the District of Columbia, six Canadian Provinces and two Territories and the Federal Highway Administration.

The organization brought together Federal, State and other highway engineers for discussion of problems, planning of concerted action and adoption of uniform practices. Its avowed objective is to foster the development, operation and maintenance of a nationwide integrated system of highways to adequately serve the transportation needs of our country.

AASHTO publishes recommended specifications, guides and standards on highway design and construction that generally prescribe good practices or criteria considered adequate to provide safe and cost-effective highway facilities. These approved standards and guides as listed herein may be used in conjunction with this manual. Design standards for highways are listed in 23 CFR Part 625.

AASHTO publications may be purchased online.

1.2.5 FEDERAL LANDS HIGHWAY POLICY REFERENCES

1.	FLHM	*Federal Lands Highway Manual Policy Guide* is a collection of documents developed by the Office of Federal Lands Highway to consolidate all basic policies, directives, standards, and guides pertaining to the Federal Lands Highway operations into a single resource publication for ease of use and reference.
2.	FLH Business Plan	
3.	FLH Safety Philosophy	
4.	FP-XX	Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, DOT, FHWA. Current Edition.
5.	EFLHD LOSS	Eastern Federal Lands Highway Division Library of Supplemental Specifications
6.	CFLHD SCR	Central Federal Lands Highway Division Library of Special Contract Requirements
7.	WFLHD LOSS	Western Federal Lands Highway Division Library of Supplemental Specifications
8.	Standard Drawings	Federal Lands Highway Standard Drawings, current edition.
9.	EFLHD Details	Eastern Federal Lands Highway Division Detail Drawings
10.	CFLHD Details	Central Federal Lands Highway Division Detail Drawings
11.	WFLHD Details	Western Federal Lands Highway Division Detail Drawings
12.	A/E Manual	*A/E Task Order Procedures Manual*
13.	Materials Manual	*Field Materials Manual*, Federal Lands Highway, Publication No. FHWA-FL-91-002, 1994.
14.	*Construction Manual*	
15.	*Park Road Standards*, US Department of the Interior, National Park Service, 1984.	
16.	25 CFR 170	Indian Reservation Roads Program Final Rule

17. SHS *Standard Highway Signs*, DOT, FHWA. Current Edition.

18. MUTCD *Manual on Uniform Traffic Control Devices for Streets and Highways*, DOT, FHWA. Current Edition

19. Green Book *A Policy on Geometric Design of Highways and Streets*, AASHTO. Current Edition.

20. RDG *Roadside Design Guide*, AASHTO. Current Edition.

21. Special Report 214 *Designing Safer Roads, Practices for Resurfacing, Restoration and Rehabilitation*, TRB, 1987.

22. *Materials Manual*, Parts I and II, AASHTO, Current Edition.

23. AASHTO HDG AASHTO Highway Drainage Guidelines, Current Edition.

24. AASHTO MDM AASHTO *Model Drainage Manual*, Current Edition.

25. *Government Printing Office Style Manual*.

1.3 LAND MANAGEMENT AGENCIES

Land management agencies are Federal agencies established under laws and regulations and delegated the authority to administer and manage the vast national resources on federally owned or controlled lands within the United States and its territories. They have the responsibility for constructing and maintaining a public roads system within these lands.

The four principal land management agencies involved with the Federal Lands Highway Programs (FLHP) are as follows:

- National Park Service (NPS),
- Forest Service (FS),
- Bureau of Indian Affairs (BIA), and
- US Fish and Wildlife Service (FWS).

FLH also works, on a smaller scale, with other Federal and State government agencies upon request.

FLH's mission when working with these land management agencies usually entails all phases of project development and design. Authorizing language supporting the Federal Lands Highway Program is contained in:

1. 23 USC 202 Title 23 US Code, Section 202, *Allocations*

2. 23 USC 204 Title 23 US Code, Section 204, *Federal Lands Highways Program*

3. 23 USC 308 Title 23 US Code, Section 308, *Cooperation with Federal and State agencies and foreign countries*

4. SAFETEA-LU See Title I, Section 1119, Federal Lands Highways

1.3.1 NATIONAL PARK SERVICE (NPS)

The NPS is an agency of the US Department of Interior responsible for presiding over all national parklands, recreational areas, monuments, military parks, historical sites, seashores, lakeshores and parkways.

The national park system encompasses more than 21.5 million acres [8.7 million hectares] of Federal lands that are noted for their scenic beauty or historical significance. The system contains some 8100 miles [13,000 km] of park roads and parkways.

Under the authority prescribed in 23 USC 202, 23 USC 204, and 23 USC 308 (see Section 1.3) and in the Memorandum of Agreement between the NPS and the FHWA, the procedures are established defining responsibilities of each organization relative to the project development and construction of park roads and parkways. See *FAPG* G6090.13.

1.3.2 FOREST SERVICE (FS)

The FS is an agency of the US Department of Agriculture whose primary responsibility is the protection and multiple use management of land and resources within the National Forest System as set forth in the 16 USC 1609, *National Forest Management Act* of 1976.

The National Forest system contains approximately 24,000 miles [39,000 km] of Forest Highways and 311,000 miles [500,000 km] of Forest Development Roads (FDR) with some 30,000 miles [48,000 km] of these FDRs maintained for public passenger car use. Under the authority prescribed in 23 CFR 660 and in the Memorandum of Understanding executed between the FS and the FHWA, the procedures are established for coordinating project development applicable to Public Lands Highways.

23 USC 308 establishes the foundation for FHWA's participation in the location, design and/or construction of forest development roads and trails when such activities are requested by the Forest Service.

1.3.3 BUREAU OF INDIAN AFFAIRS (BIA)

The BIA is an agency of the US Department of the Interior with the primary responsibility for constructing and maintaining a system of public roads located within or providing access to an Indian reservation, Indian trust land or restricted Indian land, which is not subject to fee title alienation without the approval of the Federal Government. The Indian Reservation Roads (IRR) system is composed of approximately 86,000 miles [138,000 km] of roads. Of this amount, only 26,000 miles [42,000 km] are owned or maintained by the Tribes or BIA. The remaining mileage is owned or maintained by public agencies such as counties, cities, or States.

Under the authority prescribed in 23 USC 204 and 23 USC 308 and in the Memorandum of Agreement between the BIA and FHWA, the Federal Lands Highway Divisions may perform any or all phases of project development as set forth in individual project agreements executed between BIA and the appropriate division. See *FAPG* G6090.17.

1.3.4 US FISH AND WILDLIFE SERVICE (FWS) REFUGE ROADS

The FWS is an agency in the US Department of Interior. The National Wildlife Refuge System comprises over 95 million acres [38 million hectares], with more than 535 refuges and thousands of small prairie wetlands that serve as waterfowl breeding and nesting areas.

Refuge Roads are public roads that provide access to or within a unit of the National Wildlife Refuge System and ownership and maintenance responsibility belongs to the Federal government. In order to be considered Public Roads, Refuge Roads must be opened to the general public during substantial parts of the year.

Refuge Road funds may only be used for resurfacing, restoration and rehabilitation (RRR) to extend the service life of an existing road and enhance safety. RRR work includes the placement of additional surfacing materials and/or other work necessary to return an existing roadway including shoulders, the roadside and appurtenances, to a condition of structural adequacy. Construction of new roads is not authorized. Refuge Road projects generally will not involve widening beyond the existing road bench or require the construction of new retaining walls or cuts and fills. Exceptions where work could occur off of the road bench include work on drainage structures, existing retaining walls, slope failures, bridges and spot traffic safety improvement work. Eligible structural work includes approach fill rehabilitation, superstructure replacements, abutment and foundation repairs, abutment slope protection, foundation scour repair and protection work and piling replacements. Small bridges or large box culverts may be replaced if the estimated cost for a replacement structure is $500,000 or less.

Because the RRR program improvements are required to stay within the existing roadway prism, design standards for new construction and re-construction are typically not applicable. Since FWS has not developed RRR design criteria, the AASHTO design criterion is the basis for preparation of design exceptions where traffic safety experience does not warrant improvements to full design criteria. Achievement of AASHTO design criteria usually will not be possible without demonstrated and documented safety deficiencies.

1.3.5 OTHER AGENCIES

In addition to the primary land management agencies, FLH, when requested, cooperates and works with other Federal agencies (e.g., Department of Defense, Bureau of Land Management, Federal Aviation Administration, Metropolitan Washington Airports Authority, Federal Railroad Administration, Corps of Engineers, Bonneville Power Administration, Immigration and Naturalization Service).

FLH also provides assistance to State and local agencies as well as to the FHWA-owned Turner Fairbank Highway Research facility in McLean, Virginia on an as-requested basis.

1.4 GLOSSARY

1.4.1 ABBREVIATIONS

Whenever these abbreviations are used, they will have the following meaning:

4R Resurfacing, Restoration, Rehabilitation, and Reconstruction Projects

- A -

A/E Architectural and Engineering Consultant

AA Aluminum Association

AADT Annual Average Daily Traffic

AASHTO American Association of State Highway and Transportation Officials

ACHP Advisory Council on Historic Preservation

ACI American Concrete Institute

ACSM American Congress on Surveying and Mapping

ADA Americans with Disabilities Act

ADAAG Americans with Disabilities Act Accessibility Guidelines

ADT Average Daily Traffic

AISI American Iron and Steel Institute

AMF Accident (or Crash) Modification Factor

ANSI American National Standards Institute

ARTBA American Road and Transportation Builders Association

ASCE American Society of Civil Engineers

ASLA American Society of Landscape Architects

ASPRS American Society of Photogrammetry and Remote Sensing

ASTM American Society for Testing and Materials

AWPA American Wood Preservers' Association

AWS American Welding Society

AWWA American Water Works Association

- B -

BIA Bureau of Indian Affairs

BIP Bridge Inspection Program

BLM Bureau of Land Management

BMP Best Management Practice

- C -

CAA Clean Air Act

CAAA Clean Air Act Amendments

CADD Computer Aided Design and Drafting

CBA Choosing by Advantage

CE Categorical Exclusion

CEQ Council on Environmental Quality

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act

CFLHD Central Federal Lands Highway Division

CFR Code of Federal Regulations

CFT Cross Functional Team

CMF Crash (also Accident) Modification Factor

CNMI Commonwealth of the Northern Mariana Islands

CO Carbon Monoxide

CSD Context Sensitive Design

CSS Context Sensitive Solutions

CWA Clean Water Act

CZMA Coastal Zone Management Act

- D -

DAB Development Advisory Board

DAR Defense Access Road

DHV Design Hourly Volume

DO-12 Director's Order 12 (National Park Service)

DOI Department of the Interior

DOQQ USGS Digital Ortho Quarter Quadrangle maps

DOT United States Department of Transportation

DPG Design Procedures Guide

DSD Decision Sight Distance

DSR Damage Survey Report

DTM Digital Terrain Model

- E -

EA Environmental Assessment

E-CAL Electronic Centralized Agreement Library

EDM Electronic Distance Measuring

EDTS Environmental Document Tracking System

EFH Essential Fish Habitat

EFLHD Eastern Federal Lands Highway Division

EIS Environmental Impact Statement

EO Executive Order

EPA Environmental Protection Agency

ERFO Emergency Relief of Federally Owned Roads Program

ESA Endangered Species Act

- F -

FAA Federal Aviation Administration

FAPG Federal-Aid Policy Guide

FAQ Frequently Asked Questions

FAR Federal Acquisition Regulations

FDR Forest Development Roads

FEMA Federal Emergency Management Agency

FHWA Federal Highway Administration

FLH Federal Lands Highway

FLHM Federal Lands Highway Manual

FLHO Office of Federal Lands Highway

FLHP Federal Lands Highway Program

FLMA Federal Land Management Agency

FONSI Finding of No Significant Impact

FPPA Farmland Protection Policy Act

FP-xx Book of Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (The year of issuance 19xx or 20xx)

FS United States Department of Agriculture Forest Service

FTA Federal Transit Administration

FWS United States Fish and Wildlife Service

- G -

GCDB Geographic Coordinate Data Base

GEOPAK Software program for interactive highway design

GIS Geographic Information System

GPS Global Positioning System

GSA General Services Administration

- H -

HAL High Accident Location

HCM Highway Capacity Manual

HEC Hydraulic Engineering Circular

HES Homestead Entry Survey

HOV High Occupancy Vehicle

HUD Housing and Urban Development

- I -

IDT Interdisciplinary Team

IHSDM Interactive Highway Safety Design Model

IRR Indian Reservation Road

ISD Intersection Sight Distance

ITE Institute of Transportation Engineers

ITS Intelligent Transportation System

- L -

LiDAR Light Detection and Ranging

LHSS Local Highway Safety Study

LOS Level of Service

LWCF Land and Water Conservation Fund

- M -

MOA Memorandum of Agreement

MOU Memorandum of Understanding

MUA Multi-attribute Utility Analysis

MUTCD Manual on Uniform Traffic Control Devices for Streets and Highways

- N -

NAAQS	National Ambient Air Quality Standards
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NGS	National Geodetic Survey
NHPA	National Historic Preservation Act
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute of Standards and Technology
NMFS	National Marine Fishery Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NR	National Register
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NRPP	Natural Resources Preservation Program
NWS	National Weather Service

- O -

OCRM	Office of Ocean and Coastal Resource Management
OSHA	Occupational Safety and Health Administration

- P -

PCA	Portland Cement Association
PCI	Precast Prestressed Concrete Institute
PDDM	Project Development and Design Manual

PDG Office of Real Estate Services Project Development Guide

PE Preliminary Engineering

PIH Plan in Hand

PL Public Law

PLSS Public Land Survey System

PMIS Program Management Information System

PRMS Program and Resource Management System

PRP Park Roads and Parkway Program (may also be PRPP or § PRA)

PRT Perception Reaction Time

PS&E Plans, Specifications and Estimates

PSD Passing Sight Distance

- Q -

QA Quality Assurance

QC Quality Control

- R -

RDG Roadside Design Guide, AASHTO

RGL Regulatory Guidance Letter

RIP Road Inventory Program

ROD Record of Decision

RPM Raised Pavement Marker

RRP Refuge Roads Program

RRR Resurfacing, Restoration and Rehabilitation (3R)

RSA Roadside Safety Audit

RSRAP Roadside Safety Resource Allocation Program

- S -

SADT Seasonal Average Daily Traffic

SARA Superfund Amendments and Reauthorization Act

SCR Special Contract Requirement

SDDC Surface Deployment and Distribution Command

SDWA Safe Drinking Water Act

SEE Social, Economic and Environmental

SHA State Highway Agency

SHPO State Historic Preservation Office

SHS Standard Highway Signs

SI International System of Units (also referred to as Metric)

SIP State Improvement Plan

SSD Stopping Sight Distance

SSPC The Society for Protective Coatings

STARS Service-wide Traffic Crash Reporting System

SUE Subsurface Utility Engineering

SWPPP Stormwater Pollution Prevention Plan

- T -

T&E Threatened and Endangered

TAM Department of Transportation Acquisition Manual

TAR Department of Transportation Acquisition Regulations

TCP Traffic Control Plan

TE Transportation Enhancement

TFHRC Turner Fairbank Highway Research Center

TGM Technical Guidance Manual

THPO Tribal Historic Preservation Officer

TMDL Total Maximum Daily Load

TMP Transportation Management Plan

TNM Traffic Noise Model

TSM Transportation System Management

TRB Transportation Research Board

TTC Temporary Traffic Control

TWLTL Two-Way Left Turn Lane

- U -

USACE United States Army Corps of Engineers

USC United States Code

USCG United States Coast Guard

USDA United States Department of Agriculture

USFS United States Forest Service

USFWS United States Fish and Wildlife Service

USGS United States Geological Survey

- V -

VA Value Analysis

VE Value Engineering

VLVLR Very Low Volume Local Road

VPH Vehicles per Hour

- W -

WFLHD Western Federal Lands Highway Division

1.4.2 DEFINITIONS

Many of the following terms are used throughout the *PDDM*:

- A -

Acceleration Lane – A speed change lane to enable a vehicle entering a roadway to increase its speed to merge with through traffic.

Accuracy – The degree of agreement between a measured value and its established true value.

Aeolian Deposits – Wind-deposited material (e.g., dune sands, loess deposits).

Aesthetics – A branch of philosophy dealing with beauty and the beautiful and judgments of taste concerning them. In highway engineering, aesthetic judgments have to do primarily with the highway as a whole and the roadsides, and includes screening out unpleasant views.

Aggradation – General and progressive raising of the streambed by deposition of sediment.

Alkalinity – The degree of strength of an alkali. A liquid is said to be alkaline if it has a pH factor greater than seven.

Alluvium – Deposits of silts, sands, gravels, cobbles, boulders, and other non-cohesive sediments that have been transported by running water.

Angle of Internal Friction – The angle whose tangent is the ratio between the resistances offered to slide along any plane in the soil and the component of the applied force acting normal to that plane. Values are given in degrees.

Angle of Repose – The angle between the horizontal and the maximum slope that a soil assumes through natural processes.

Anhydrous – Free from water.

Arbitrary Coordinate System – A system of coordinates based upon an arbitrarily chosen origin. Used when established coordinate systems are not available. Sometimes called assumed coordinate system.

Architectural Features – As used in roadside enhancement, these may include stepped retaining walls to minimize the visual impact of massive walls, rock sculpturing to blend disturbed areas into the natural terrain, and special treatment of bridge abutments and culvert headwalls to blend them into the landscape.

Asphalt – A dark brown to black cementitious material in which the predominate constituents are bitumens which occur in nature or are obtained in petroleum processing.

Auxiliary Lane – The portion of the roadway adjoining the traveled way for weaving, truck climbing, speed changing or for other purposes supplementary to through-traffic movement.

Average Daily Traffic (ADT XXXX) – (1) The current or projected average two-way daily traffic for a specified year. (2) (ADT YY) The projected average two-way daily traffic for a specified future period, usually 20 years after the anticipated completion of construction.

Average Highway Speed – The weighted average of the design speeds within a highway section based on each subsection's proportional contribution to total distance, when each subsection has an individual design speed.

Average Initial Horizontal Illuminance – The average level of horizontal illuminance in the pavement area of a traveled way at the time the lighting system is installed, when lamps are new and luminaires are clean. This level is expressed in lux (lumens per square meter of horizontal surface).

Average Running Speed – The average speed of all vehicles over a specified highway section, which is the sum of the distances traveled by vehicles on the highway section during a specified time period divided by the sum of their running times.

- B -

Backfill – Material used to replace, or the act of replacing material removed during construction; also denotes material placed or the act of placing material adjacent to structures.

Backslope – In cuts, the slope from the bottom of the ditch to the top of the cut.

Base Course – The layer, or layers, of specified or selected material of designed thickness placed on a subbase or a subgrade to support a surface course.

Basic Capacity – The maximum number of passenger cars that can pass a given point on a lane or roadway during one hour under the most nearly ideal roadway and traffic conditions that can be attained.

Bedrock – Rock of relatively great thickness and extent in situ.

Bench Mark – A temporary or permanent marker of known elevation with reference to a specific datum plane.

Bitumen – A class of black or dark colored cementitious substances, natural or manufactured composed principally of high molecular weight hydrocarbons, of which asphalts, tars, pitches and asphaltites are typical.

Bituminous – Containing or treated with bitumen (e.g., bituminous pavement, bituminous concrete)

Brake Reaction Distance – The distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied.

Braking Distance – The distance required to stop the vehicle from the instant brake application begins.

Breakaway (Yielding) Supports – A support for a roadside device that yields or collapses readily when struck by a vehicle.

Bridge – A single or multiple span structure, including supports, erected over a depression or an obstruction (e.g., water, highway, railway) and having an opening measured along the center of the roadbed of more than 20 ft [6 m].

Broken Back Curve – An arrangement of curves in which a short tangent separates two curves in the same direction.

Bypass – A highway that permits traffic to avoid part or all of an urban area.

- C -

Cadastral – Pertaining to extent, value and ownership of land. Cadastral maps show property corners and property boundaries.

Cadastral Survey – A survey made to determine the lengths and directions of boundary lines and the area of land bounded by these lines. It may also be a survey made to establish these boundary lines on the ground. Also known as a Property Survey.

Calcareous – Material containing or similar to calcium carbonate or lime.

Calendar Day – Any day shown on the calendar, beginning and ending at midnight.

California Bearing Ratio (CBR) – The ratio of the force required to penetrate a soil mass with a circular piston to the force required to penetrate a mass of high quality crushed stone with the same piston. The rate of penetration in both cases is identical.

Camber – A slight arch designed or built into a structure to compensate for the natural deflection after loading.

Capillary Moisture – Moisture that clings to soil particles by surface tension and reaches the particles by surface tension either when free water passes through the soil or by capillary attraction from a wetter stratum. Within limits, it can move in any direction.

Centerline – For a two-lane highway the centerline is the middle of the traveled way, and for a divided highway the centerline may be the center of the median. For a divided highway with independent roadways, each roadway has its own centerline.

Channel – A course along which water flows. The course can be natural or artificial, open or closed. The flowing water can be confined by soil-based bed and banks, such as those in a natural river or stream or in an artificial ditch or canal; or by an artificial conduit, such as a pipe or flume.

Channelization – The separation of traffic flow into definite paths, by means of traffic markings or islands.

Channelized Intersection – A grade intersection where traffic is directed into definite paths by islands.

Clay – A fine-textured soil, usually plastic and sticky when wet, which usually breaks into hard lumps when dry. When the moist soil is pinched between the thumb and finger, it will form a long, flexible ribbon.

Clear Zone – That area along the side of the traveled way (including the shoulder) that is available for recovery of an errant vehicle.

Climbing Lane – An additional traffic lane provided for slow moving vehicles on the up-grade side of a highway.

Cohesionless Soil – A soil that, when unconfined, has little or no strength when air-dried, and little or no cohesion when submerged. Sand is an example of cohesionless soil.

Cohesive Soil – A soil that when unconfined has considerable strength when air-dried and that has significant cohesion when submerged.

Compressibility – The property of a material that enables it to remain compressed after compaction.

Compressive Stress – The stress produced in a member when the forces acting on it tend to push the particles together.

Construction Limits – The limits on each side of the project that establish the area disturbed by construction operations and beyond which no disturbance is permitted.

Construction Survey – A survey executed to locate or lay out engineering works. In highway construction applications, this survey is used to set grading elevation stakes, reference points, slope stakes and other such controls.

Contour – A line that depicts equal elevation on a land surface. The line representing this on a map.

Contour Grading Plan – A drawing showing an arrangement of contours intended to integrate construction and topography, improve appearance, reduce erosion and improve drainage.

Contour Interval – The elevation difference between adjacent contours.

Contract Document Hierarchy – There are five essential parts to a contract and a requirement occurring in one is as binding as if occurring in all. They are intended to be complementary and to describe and provide for a complete work. In case of discrepancy, numerical dimensions will prevail over scaled dimensions and the parts of the contract will prevail in the following order:

- Contract Clauses, 48 CFR, Chapters 1 and 12;
- Special Contract Requirements;

- Plans;
- Supplemental Specifications; and
- Standard Specifications (FP-XX).

Control Data – The horizontal and vertical values used to define the relative position of a control point.

Control Point – An established point on the ground with known horizontal and vertical positioning. This point is normally used as a basis for gathering field measurements and placing construction stakes.

Control Survey – A survey made to establish the horizontal and vertical positions of a series of control points. In highway applications, a control survey is generally the first survey performed on a project. Other aspects of the surveying process base their measurements on the control points established during the control survey.

Cooperator – A State or local government agency that has jurisdiction over and/or maintenance responsibility for forest highways. See FAPG NS 23 CFR 660A.

Coordinates – A set of numbers used in describing the location of a point on a surface or in space.

Corridor – A strip of land between two termini within which traffic, topography, environment and other characteristics are evaluated for transportation purposes.

Countermeasure – A measure, commonly used in a hydraulic environment, intended to prevent, delay, or reduce the severity of a problem.

Crashworthy – A highway feature is crashworthy if it was successfully crash tested under the NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features* or earlier comparable criteria or if it was accepted through analysis by FHWA, based on similarity to other crashworthy features.

Crash Cushion (Impact Attenuator) – A device placed in front of a fixed roadside object to absorb and dissipate collision energy.

Creep – The slow movement of a material under stress, usually imperceptible except to observations of long duration.

Crest Vertical Curve – A vertical curve having a convex shape in profile.

Critical Length of Grade – That combination of gradient and length of grade that will cause a designated vehicle to operate at some predetermined minimum speed.

Cross Section – A vertical section of the ground, roadway or structure perpendicular to the centerline or baseline of the roadway or other work.

Crosswalk – Any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by signs and by lines or other markings on the surface.

Crossing Sight Distance – A distance along an intersection approach leg such that vehicle operators can see other vehicles on crossroads in time to avoid collision.

Crown – The highest point of the surface of a tangent traveled way in cross section.

Crushed Gravel – The product resulting from the crushing of ordinary gravel with substantially all fragments having one or more faces resulting from fracture.

Crushed Stone – The product resulting from the crushing of fragments of bedrock or large stones with all fragments having all faces resulting from fracture.

Culture or Cultural Features – General term used in mapping to describe manmade features.

Culvert – A structure that provides an opening through an earthen embankment and does not meet the definition of a bridge.

Curb – A structure with a vertical or sloping face placed on roadways to form islands, gutters, etc. and to protect pavement edges.

Curve Widening – The widening of the highway traveled way on sharp curves to compensate for the fact that the rear wheels of a vehicle do not follow exactly in the track of the front wheels.

Curvilinear Alignment – A flowing alignment in which the majority of its length is composed of circular and spiral curves.

- D -

Data Collector – A recording device that electronically records surveying measurements and field notes. The information stored in these collectors is downloaded into a computer for later processing.

Datum Plane – A reference plane to which vertical measurements and elevations are referred. Usually the datum plane (elevation 0.000) used is mean sea level.

Deadman – A buried object serving as an anchor (e.g., a cable-guardrail guy anchors).

Deceleration Lane – A speed-change lane that enables a vehicle to slow to a safe exit speed when making an exit turn.

Decibel (Db) – The unit for measuring the intensity of sound. When A-weighting is used, this unit is abbreviated as dBA.

Deciduous – Having leaves that are shed at the end of the growing season; opposite of evergreen.

Degradation – General and progressive lowering of the longitudinal profile of a channel by erosion.

Delineator – A visual device for defining the alignment of a roadway.

Dense Graded – A well-graded aggregate with sufficient fine material to nearly fill all voids.

Depletion – The progressive withdrawal of water from surface or ground water reservoirs at a rate greater than that of replenishment.

Design Capacity – The practical capacity or lesser value determined for use in designing the highway to accommodate the design volume.

Design Discharge – The volume rate of runoff that a hydraulic structure is designed to safely pass. The rate depends on the characteristics of the watershed and the flood frequency selected for the design, which in turn, depends on the importance of the roadway, and the risk of failure one is willing to accept.

Design Headwater – The elevation of the water surface above a structure inlet, for a given structure type, size and design discharge.

Design Hourly Volume (DHV) – The future two-way hourly traffic volume for use in design, usually the 30^{th} highest hourly volume of the design year (30 HV).

Design Lane – The lane on which the greatest number of equivalent 18,000 lbs [80 kN], single-axle loads is expected. Normally, this will be either lane of a two-lane highway or the outside lane of a multilane highway.

Design Load – The loads that must be supported by a structure.

Design Noise Levels – The noise levels that represent the upper limit of acceptable traffic noise established for various activities or land uses. These levels are used to determine the degree of impact of traffic noise on human activities.

Design Speed – A selected speed used to determine the various geometric features of the roadway.

Design Thickness – The total thickness of the pavement structure determined from the thickness design charts as adequate for a given total 18,000 lbs [80 kN] equivalent single-axle loads soil strength value.

Design Vehicle Turning Radius – The turning radius of a design vehicle used primarily to determine the minimum radius used in the design of turning and intersecting roadways.

Design Year – The future year used to estimate the probable traffic volume for which a highway is designed. A time ten to 20 years from the start of construction is usually used.

Direct Shear Test – A shear test in which soil under an applied normal load is stressed to failure by moving one section of the soil container relative to the other section.

Divided Highway – A highway with separated roadways for traffic in opposite directions.

Divisional Island – A longitudinal island to separate opposing traffic, to provide protection for left turn bays and to channel traffic into the proper approach paths at skewed intersections.

Division Standard Details – Division-specific drawings that are used on a repetitive basis within each FLH Division. These are issued by Division offices for routine use on projects within the Division, and may be used individually or to supplement applicable FLH Standard Drawings.

Division Supplements – Supplements to this manual detailing differences in practice among the Divisions. These are issued by Division offices for use within the Divisions and by their consultants, whenever applicable.

Dormant Stage – The period in plant life when seasonal growth ceases.

Drainage Basin – The area of land contributing surface runoff to a given location. Large basins are commonly referred to as watersheds.

Driveways – Minor roadway connections that fall into three categories:

- Private,
- Commercial, and
- Public.

- E -

Ecology – The branch of science concerned with the relationship of organisms and their environment.

Elastic Limit – The greatest stress that a material is capable of sustaining without any permanent deformation remaining upon complete release of the stress.

Elasticity – That property of a material that permits it to return approximately to its original dimensions upon the removal of an applied load.

Electronic Distance Measuring Instrument (EDM) – A device that transmits and receives a modulated microwave, infrared or visible light signal and, by measuring phase differences between modulations of transmitted and reflected or retransmitted signals, computes the distance between the instrument and the reflector or retransmitter.

Elevation – The vertical distance of a point above mean sea level or above another datum.

Elongation – The increase in gage length of a tension test specimen, usually expressed as a percentage of the original gage length.

Embankment – A raised earth structure on which the roadway pavement structure is placed.

Embankment Foundation – The material below the original ground surface, the physical characteristics of which affect the support of the embankment.

Emergency Vehicle – (1) A vehicle belonging to the armed forces, civil defense, police. (2) Any ambulance rescue unit vehicle. (3) Any designated vehicle used for answering emergency calls for assistance.

Empirical – Developed from experience or observations without regard to science and theory.

Emulsified Asphalt – A mixture of asphalt cement and water mixed with an emulsifying agent.

Emulsified Asphalt Treated Base – A base consisting of a mixture of mineral aggregate and emulsified asphalt spread on a prepared surface to support a surface course.

Energy Dissipator – A structure placed at a drainage outfall to dissipate the energy of flowing water in order to reduce scour and erosion of the receiving channel bed and/or banks.

Environment – The totality of man's surroundings (i.e., social, physical, natural, manmade).

Environmental Design – The location and design of a highway that includes consideration of the impact of the facility on the community or region based on aesthetic, ecological, cultural, sociological, economic, historical, conservation and other factors.

Equivalent Single-Axle Load (EAL) – The effect on pavement performance of any combination of axle loads of varying magnitude, equated to the number of reference single-axle loads required to produce an equivalent number of repetitions of an 18,000 lb [80 kN] single axle.

Erosion – The progressive removal of a surface by the action of wind or water.

Estuary – That portion of a river channel occupied at times or in part by both sea and river flow in appreciable quantities. The water usually has brackish characteristics.

Excavation – (1) The act of taking out material. (2) The materials taken out. (3) The cavity remaining after materials have been removed.

Expressway – A multilane, divided highway designed to move large volumes of traffic at high speeds under free-flow conditions. Expressways have full control of access with grade-separated interchanges.

Expropriation – Acquisition of property for highway purposes by the right of eminent domain.

- F -

Federal Lands Highway Division – A Federal Lands Highway field office, responsible for the administration of the Federal Lands Highway program within a predetermined geographic area. See Exhibit 1.1–A.

- The Eastern Federal Lands Highway Division (EFLHD) office headquartered in Sterling, Virginia.
- The Central Federal Lands Highway Division (CFLHD) office headquartered in Lakewood, Colorado.
- The Western Federal Lands Highway Division (WFLHD) office headquartered in Vancouver, Washington.

Flexible Base – A base with low resistance to bending, enabling it to stay in contact with the underlying structure. This type of base distributes loads to the subbase. Examples are dense-graded aggregate bases and asphalt-treated bases.

Flexible Pavement – A pavement structure that maintains intimate contact with and distributes loads to the subgrade, and depends on aggregate intergranular particle friction and cohesion for stability.

Flood – (1) An overflow or inundation that comes from a river or other body of water and causes or threatens damage. (2) A relatively high streamflow overtopping the natural or artificial banks in any reach of a stream. (3) A relatively high flow as measured by either gage height or discharge quantity.

Flood Frequency – The average interval of time, based on the period of record, between floods equal to or greater than a specified discharge or height. Generally, this frequency is expressed in years.

Flood Plain – Normally dry land areas that are adjacent to a natural stream or watercourse and that are temporarily inundated during floods.

Flow Line – The lowest flow path through a designed channel, culvert, or other engineered conveyance structure.

Footing – Portion of the foundation of a structure that transmits loads directly to the soil or bedrock.

Foreslope – The slope from the edge of the surfaced shoulder to the top of the subgrade or the bottom of the ditch in cuts.

Foundation – Lower part of a structure that transmits loads directly to the soil or bedrock.

Free Water – Water that can move through the soil by force of gravity.

Freeboard – The vertical distance between the level of the water surface at design flow and a specified point (e.g., a bridge beam, levee top, location on a highway grade).

Friable Soil – A soil that can be easily broken and crushed by moderate finger pressure.

Frontage Road – A road contiguous to a controlled access highway, so designed as to (1) intercept, collect and distribute traffic desiring to cross, enter or leave the controlled access highway, and (2) furnish access to adjacent property.

Functional Classification – The grouping of individual roads in a road system according to their purpose and the type of traffic they serve.

- G -

Gaging Station – A location on a stream where measurements of stage or discharge are customarily made.

Geodetic Control – Monument points of known horizontal and/or vertical position established by other agencies and published by NGS.

Geographical Coordinates – a spherical coordinate system for defining geographical locations using latitude, longitude, and an elevation relative to a reference ellipsoid, or a defined geoid surface, or a datum plane.

Geometric Design – The arrangement of the visible elements of a road (e.g., alignment, grades, sight distance, widths, slopes).

Global Positioning System (GPS) – A system of satellites that are used with accurate receiving equipment to determine survey coordinates.

Gradation – A general term used to describe the composition of an aggregate, soil or other granular material. Gradation is usually expressed as the proportions (percents) of the aggregate that will pass each of several sieves of different sizes.

Grade – (1) The profile of the center of the roadway or its rate of ascent or descent. (2) To shape or reshape an earth road by means of cutting or filling. (3) To arrange according to size. (4) Elevation.

Grade Contour – The trace of a predetermined grade plotted on a topographic map or traced on the ground by an Abney Level Line. For example, if the contour interval is 5 ft [2 m] and the gradient five percent, the grade contour intersections with successive contours would be 100 ft [40 m] apart.

Grade-Controlled Location – A section of highway where the highway route is controlled by the maximum allowable gradient and the difference in elevation between termini.

Grade Intersection – An intersection where all roadways join or cross at the same level.

Grade Separation – A structure that provides for highway traffic to pass over or under another highway or the tracks of a railroad.

Gradient – The rate of rise or fall with respect to the horizontal distance.

Grading – (1) Construction of the earthwork portion of the highway; (2) planing or smoothing the surface of various parts of a roadbed.

Gravel – Aggregate composed of hard, durable stones or pebbles, crushed or uncrushed, often intermixed with sand.

Ground Control – An accurate ground survey of targets or other features visible in aerial photographs to ensure the accuracy of photogrammetric mapping.

Ground Cover – Herbaceous vegetation and low-growing woody plants that form an earth cover.

Ground Water – Free water contained in the zone below the water table. The source of water in wells, springs, etc.

Grout – Mortar, composed of sand, cement and water, of a consistency that it can be easily worked.

Guardrail – A protective cable or rail device placed along the roadway edge for the purpose of redirecting vehicles that have left the roadway at a point of hazard.

Gunite – A type of Portland cement mortar blown into place by compressed air. The materials are mixed while being forced through a nozzle.

Gutter – A paved and generally shallow waterway provided for carrying surface drainage.

- H -

Hardpan – A layer of extremely dense soil.

Headwall – A wall or structure constructed at the end of a culvert to prevent earth from spilling into the channel.

Herbaceous – Vegetation that is nonwoody.

Hinge Point – The point where the slope rate changes.

Horizon (Soils) – One of the layers (strata) of the soil profile, distinguished principally by its texture, color, structure and chemical contents.

Horizontal Curve – A circular or transitional curve by means of which a highway can change direction to the right or left.

Hot Mix – A general term used for hot plant mixed asphalt concrete mixtures manufactured and laid at temperatures ranging from 200°F to 320°F [95°C to 160°C].

Humidity (Relative) – The amount of moisture in the air compared with the amount that the air could hold if saturated at that temperature.

Humus – A brown or black material formed by the partial decomposition of vegetable or animal matter; the organic portion of soil.

Hydrated Lime – A dry powder obtained by treating quick-lime with enough water to satisfy its chemical affinity for water under the conditions of its hydration.

Hydraulics – The physical characteristics that describe the movement or flow of water, oil or other liquid, over, through, in, or around any surface.

Hydrograph – A graph showing stage, discharge, velocity or other property of surface water, with respect to time, for a given location.

Hydrology – (1) The science encompassing the behavior of water as it occurs in the atmosphere, on the surface of the ground and underground. (2) The scientific study of the properties, distribution and effects of water on the earth's surface, in the soil and underlying rocks and in the atmosphere.

- I -

Igneous Rock – Those rocks formed by the cooling and consolidation of complex silicious solutions (magma) newly risen from some deeper level.

Impact Attenuator – A device placed in front of a fixed roadside object to absorb and dissipate collision energy.

Impervious – Resistant to the penetration of a liquid or gas.

Independent Alignments – Each roadway of a divided highway is designed and located to take full advantage of the terrain. The median need not be of uniform width, and the two roadways need not be at the same level.

Indigenous – Produced, growing or living naturally in a particular region or environment.

Infiltration – The flow of a fluid into a substance through pores or small openings. It connotes flow into a substance in contradistinction to the word percolation, which connotes flow through a porous substance.

Interchange – A system of interconnecting roadways in conjunction with one or more grade separations, providing for the movement of traffic between two or more roadways on different levels.

Internal Friction – The resistance to sliding within the soil mass.

Intersection – The area common to two or more highways that come together at an angle.

Intersection Angle – The angle between two intersection legs.

Inundate – To cover or fill, as with a flood.

Invert – The lowest point of the internal cross section of a closed conduit or channel.

- K -

Karst Topography – Irregular topography characterized by sink holes, streamless valleys and streams that disappear into the underground, all developed by the action of surface and underground water in soluble rock (e.g., limestone).

- L -

Landscaping – Enhancing the natural features of the land through the design and use of vegetation and other materials.

Lane – A portion of the traveled way providing for a single line of traffic in one direction.

Left-Turn Lane – A traffic lane within the normal surfaced width of a roadway, or an auxiliary lane adjacent to or within a median, reserved for left-turning vehicles at an intersection.

Leveling Course – The layer of material placed on an existing surface to eliminate irregularities prior to placing an overlaying course.

Lime – A general term that includes the various chemical and physical forms of quicklime, hydrated lime and hydraulic lime used for any purpose.

Lithology – A geological term dealing with the physical properties of rocks and their structure.

Loam – A mixture of sand, silt or clay, or a combination of any of these with organic matter. It is sometimes called topsoil in contrast to the subsoils that contain little or no organic matter.

Loess – A uniform windblown deposit of silty material having an open structure and relatively high cohesion due to cementation of clay or calcareous material at grain contacts.

- M -

Matting – Material used as a surface protector in conjunction with seeding that protects the surface until vegetation becomes established.

Median – The portion of a divided highway separating the traveled ways for traffic in opposite directions.

Median Barrier – A longitudinal system used to prevent an errant vehicle from crossing the median of a divided highway.

Median Lane – A speed-change lane within the median to accommodate left-turning vehicles.

Mineral Filler – A fine inert mineral matter (e.g., limestone dust, portland cement) used in asphalt concrete mixtures.

Minimum Turning Path – The path of a designated point on a vehicle making its sharpest turn.

Minimum Turning Radius – The radius of the path of the outer front wheel of a vehicle making its sharpest turn.

Modulus of Elasticity – The ratio of stress to strain for a material under given loading conditions.

Modulus of Rupture – A measure of the strength of concrete when it is broken by bending.

Moisture Content – The percentage, by mass, of water contained in soil or other material, usually based on the dry mass.

Monument or Reference Point – A permanent or semi-permanent reference point set during the survey or construction of a highway so that the survey can be reestablished later.

Mortar – A mixture of cement, sand, lime/fly ash and water.

Muck – An organic soil of very soft consistency.

Mudflow – A well-mixed mass of water and alluvium that, because of its high viscosity and low fluidity as compared with water, moves at a much slower rate, usually piling up and spreading over the fan like a sheet of wet mortar or concrete.

Mulch – Material placed on exposed earth to provide more desirable moisture and temperature relationships for plant growth. It is also used to control the occurrence of unwanted vegetation.

- N -

National Geodetic Vertical Datum of 1929 – The average of the heights of the surface of the sea at all stages of the tides.

Noise Barrier – A barrier of earth, stone, concrete or wood placed adjacent to the highway to reduce the noise level on abutting property.

Noise Level – The sound level obtained through the use of A-weighting according to ANSI Standard 1.4. The unit of measure is the decibel (dB), commonly referred to as DBA when A-weighting is used.

- O -

Office of Federal Lands Highway (FLHO) – A FHWA headquarters office located in Washington, DC with the responsibility for the direct Federal program that is administered through division field offices.

Open-Graded Aggregate – A graded aggregate, containing little or no fines, with a high percentage of aggregate voids.

Operating Speed – The speed at which drivers are observed traveling in fair weather during off-peak, free-flow conditions.

Optimum – The best quantity, number or condition.

Overburden – The mass of soil that overlies a source of rock, gravel or other road material. This material is removed before the materials are quarried to avoid contamination.

Overlaying Course (Overlay) – An asphalt surface course, either plant mixed or road mixed.

Overlook (Scenic Overlook) – A roadside area provided for motorists to stop their vehicles primarily for viewing the scenery.

Overpass – A grade separation where the highway passes over an intersecting highway or railroad.

- P -

Parcel – A tract of private or public land of variable size required for the right-of-way for a highway.

Passing Opportunity – A section of two-lane highway where the clear passing sight distance allows a safe passing maneuver to be performed.

Passing Sight Distance – Minimum sight distance on two-lane highways sufficient to enable the driver of one vehicle to pass another safely and comfortably, without interfering with the speed of an oncoming vehicle traveling at the design speed should it come into view after the overtaking maneuver is started.

Pavement Structure – The combination of subbase, base course and surface course placed on a subgrade to support the traffic load and distribute it to the roadbed.

Peat – A fibrous mass of organic matter in various stages of decomposition.

Pedestrian Crossing (Crosswalk) – An area reserved and clearly marked for the passage of pedestrians at street junctions or other locations where drivers must yield the right-of-way by stopping to enable pedestrians to cross safely.

Pedestrian Overpass (Underpass) – A facility for pedestrian crossings justified by the following:

- Pedestrian crossing volumes,
- Type of highway to be crossed, and
- Location of adjacent crossing facilities and predominating type and age of persons who will utilize the facility.

Perception Reaction Time – The time required by a driver to perceive and react that a speed change or stop is necessary.

Permeability – The properties of a soil that permit the passage of any fluid and depend on grain size, void ratio, shape and arrangement of pores.

Pervious – A layer of material, through which water will move under ordinary hydrostatic pressure.

pH – A scale of numbers from 0 to 14 that indicate the acidity or alkalinity of a solution. Numbers below seven indicate acidity and numbers above seven indicate alkalinity.

Phase – A part of a signal cycle during which a specific traffic movement (and concurrent nonconflicting movements) receives the right-of-way. It includes the change and clearance intervals associated with those movements.

Photoelectric Device – Where detection is accomplished by the vehicle passing between a source of light and a photocell that is capable of distinguishing between light and lack of light.

Photogrammetry – The science and art of obtaining reliable measurements by use of photographs. It produces dimensional data for mapping, cadastral purposes, design and computation of quantities.

Physiographic Region – A geographic area whose patterns of landforms differ significantly from that of adjacent regions.

Pigment – Any substance used to impart color; specifically, an insoluble, dry coloring matter that, when mixed with a suitable medium, forms a paint.

Plane Coordinate System – A cartographic projection that, by accepting small variations of scale, permits describing the position of points on the surface of the earth by their plane coordinates on a cylindrical or conical surface.

Planimetric Map – A map that presents horizontal but not vertical data for the features represented. Drainages, coastlines, cover and culture are usually shown.

Planimetrics – All features both manmade and natural of significant value to the design of a proposed highway.

Plans (Drawings) – The approved plans (drawings), profiles, typical cross sections, working drawings and supplemental drawings, or exact reproductions thereof that show the location, character, dimensions and details of the work.

Pollution – Contamination of any component of the total environment by harmful substances, sounds, smells or sights degrading or injurious to humans and other living organisms.

Pool – A small and rather deep body of quiescent water (e.g., as a pool in a stream).

Porous – Having many small openings, through which liquids may pass.

Portable Traffic Control Signal – A signal that is designed to be moved as a unit to the site and be operated for a limited time. (It normally consists of the necessary signal faces on poles attached to moveable bases, a control unit, the necessary electrical cables and a power supply).

Portland Cement – Hydraulic cement consisting of compounds of silica, lime and alumina; so called from its resemblance in color, when set, to the Portland stone of England.

Precision – The variance of repeated measurements of a characteristic from their average.

Prestressed Concrete (Pretensioned) – Reinforced concrete in which base, wires or cables are held in a stretched condition during placing of the plastic concrete until the concrete has hardened. Then as the tension on the reinforcing steel is released, it compresses the concrete.

Prestressed Concrete (Post-tensioned) – Reinforced concrete in which the prestressing wires or tendons are placed in tubes before the concrete is cast. After the concrete has hardened, the wires or tendons are stretched to a predetermined tension by jacking and are wedged in this position. The tubes may also be pressure-grouted.

Prime Coat – An asphalt material applied to an absorbent surface, preparatory to any subsequent treatment, for the purpose of hardening or toughening the surface and promoting adhesion between it and the superimposed construction.

Profile – A longitudinal section of a highway, drainage course, etc.

Profile Grade – The trace of a vertical plane intersecting a particular surface of the proposed road construction located as shown on the plans; usually along the longitudinal centerline of the roadway at the top of finished pavement. Profile grade means either elevation or gradient of such trace according to the context.

- R -

Radial Survey – A method of ground surveying in which the instrument is placed on a point of known horizontal and vertical position and all required features are located by direction, distance and elevation difference from the instrument point.

Railroad Grade Crossing – The intersection of a highway and a railroad at the same elevation.

Reaction Time – The time required for a driver to apply foot pressure to the brake after perception that a stop must be made.

Reclamation – The restoration of borrow and aggregate pits to a natural form that may include replacement of topsoil and vegetation (seeding).

Recurrence Interval (Return Period) – The average interval of time within which the given flood will be equaled or exceeded once.

Refuge Island – (1) An island in a wide intersection to provide refuge for pedestrians. (2) A place for transit passengers to load and unload from a bus.

Regional Factor – A numerical factor expressed as a summation of the values assigned for precipitation, elevation and drainage. This factor is used to adjust the structural number.

Reinforced Concrete – Concrete where steel reinforcement is embedded so that the steel and concrete act together in resisting stress.

Residential Area – That portion of a municipality or an area within the influence of a municipality in which the dominant land use is residential development, but where small business areas may be included.

Rest Area – A roadside area with parking facilities separated from the roadway providing motorists with opportunities to stop and rest for short periods.

Resurfacing – The placing of one or more new courses on an existing surface.

Reverse Curve – A curve consisting of two arcs of the same or different radii curving in opposite directions and having a common tangent or transition curve at their point of junction.

Right-of-Way (R/W) – (1) Land generally publicly owned, acquired for and devoted to transportation purposes. (2) The privilege of the immediate use of the highway. The right of one vehicle or pedestrian to proceed in a lawful manner in preference to another vehicle or pedestrian.

Right-Turn Lane – An auxiliary lane or designated lane provided at grade intersections for right-turn movements.

Riparian – Pertaining to the banks of a stream.

Ripple – (1) The light fretting or ruffling of the water surface caused by a freeze. (2) Undulating ridges and furrows or crests and troughs formed by action of the flow.

Riprap – A protective covering of graded stones, with or without mortar, to prevent erosion.

Road (Highway) – A general term denoting a public way for purposes of vehicular travel including the entire area within the right-of-way.

Road Approaches – Rural and suburban minor connections to a highway or frontage road from adjoining properties. These approaches can be private, public or commercial.

Roadbed – The graded portion of a road or highway (usually considered as the area between the intersection of top and side slopes) upon which the base course, surface course, shoulders and medians are constructed; the top of the subgrade.

Road Mix – A method of combining surfacing materials (e.g., mineral aggregate combined with liquid asphalt) in which the materials are mixed on the road using discs, harrows, blades or other approved means.

Roadside – That portion of the right-of-way outside the roadway.

Roadside Barrier – A longitudinal system used to shield vehicles from hazards on the roadside.

Roadside Development (Roadside Enhancement) – Treatment of the roadside to (1) conserve, enhance and effectively display the natural beauty of the landscape through which the highway passes; (2) provide safety, utility, economy and highway-related recreation facilities by means of proper location, design, construction and maintenance of highways.

Roadside Hazards – The following are all potential roadside hazards for out-of-control vehicles:

- Embankments;
- Ditches and rock cut slopes;
- Side road intersections; and
- Narrow medians.
- Fixed objects (e.g., trees, boulders, drainage structures, signs, bridge parapets, barrier ends, poles);

Roadway – The portion of a highway, including shoulders, for vehicular use. (A divided highway has two or more roadways.)

Roadway Prism – The volume typically defined by the end areas between the original terrain cross-sections and the design subgrade cross-sections, for successive sections that are averaged and multiplied by the horizontal distance along the centerline of the roadway between the sections.

Rounding – The removal of the angle where cut and fill slopes intersect the natural ground, and the substitution of a gradual transition or rounded surface.

Rumble Strip – A rough textured surface, constructed for the purpose of causing the tires of a motor vehicle driven over it to vibrate audibly as a warning to the drivers.

Runoff – That part of the precipitation that appears in surface streams. It is the same as stream flow unaffected by artificial diversions, storage or other works of man in or on the stream channels.

Running Speed – The speed over a specified section of highway, equal to the length of the highway section divided by the running time, or the time that a vehicle is in motion to travel through the section.

- S -

Sag Vertical Curve – A vertical curve having a concave shape in profile.

Scale – The ratio of the size of the image or representation of an object on a map or photograph to its true size. Scale may be expressed as a representative fraction (1/10,000) or ratio (1:10,000) or as the number of units on the ground represented by the same type of units on the map or photograph (1 in to 100 ft [1 m to 1000 m] or 1:1200 [1:1000]).

Scour – The result of erosive action of running water primarily in streams, excavating and carrying away material from the bed and banks.

Screening – The use of trees, shrubs, fences or other materials to obscure an objectionable view or to reduce an objectionable sound.

Seal Coat – An asphalt coating, sometimes with cover aggregate, applied to the surface of a pavement for the purpose of waterproofing and preserving the surface, altering the surface texture of the pavement or providing resistance to traffic abrasion.

Sediment – Fragmentary material that originates from weathering of rocks and is transported by, suspended in, or deposited by water.

Sedimentation – The action or process of depositing particles of waterborne or windborne soil, rock or other materials.

Sediment Discharge – The rate at which dry mass of sediment passes a section of a stream or is the quantity of sediment, as measured by dry mass or by volume that is discharged in a given time.

Seismic Wave – A gravity wave caused by an earthquake.

Service Road – A road, generally unimproved, used to transport personnel, materials or equipment for the operation or maintenance of utilities located on a highway right-of-way.

Serviceability – A concept where pavements are judged on their ability to serve traffic. Longitudinal smoothness is a primary factor in this judgment.

Shoaling – Deposition of alluvial material resulting in areas with relatively shallow depth.

Shoulder – The portion of the roadway contiguous to the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses.

Shrub – A small, woody multi-stemmed plant.

Side Slopes – Slopes along the side of the roadway identified by their distance from the traveled way, their slope rate and their height.

Sidewalk – That portion of a street or highway between the curb line or edge of the roadway, and the adjacent right-of-way line constructed specifically for pedestrians.

Sight Distance – The length of roadway ahead, visible to the driver.

Signal System – A system of visual signals used to control the movement of traffic, usually on city streets.

Silt – Material passing a 3-in [75-mm] sieve that is non-plastic or very slightly plastic, and exhibits little or no strength when air dried.

Site Map – A large-scale map of a specific small area (e.g., bridge site).

Skew – Oblique, not at right angles.

Skew Angle – The complement of the acute angle between two centerlines that cross.

Sliver Fill – A thin embankment slope that is roughly parallel to the natural slope of the hillside. Sliver fills that are very high in proportion to their thickness, are difficult to compact and should be avoided.

Slope – Any ground whose surface creates an angle with the plane of the horizon.

Slope Rate – The steepness of the slope - usually the ratio of the vertical change divided by the horizontal distance.

Slump – The measure of the consistency of portland cement concrete by consolidating in a slump cone, removing the cone and allowing the concrete to settle under its own mass.

Soil – Sediments or other unconsolidated accumulation of solid particles produced by the natural physical and chemical disintegration of rocks, and which may or may not contain organic matter.

Soil Classification – The arrangement of soils into classes according to their physical properties.

Soil Stabilization – Measures taken to eliminate or minimize the erosion of soil or to improve its supporting capacity.

Spalling – Chipping along the edges, as at joints in concrete pavement and structures.

Special Details – Project-specific special drawings included in the plans to describe items of the work, consistent with the FP-XX. Special Details can be used individually, or to supplement applicable FLH Standard Drawings, or Division Standard Details, or both.

Specifications – The compilation of provisions and requirements for the performance of the prescribed work.

- Standard Specifications. The book of Standard specifications for construction of roads and bridges on Federal Highway projects issued periodically and designated as FP-XX (e.g., FP-03, or simply FP).
- FLH Supplemental Specifications. Additions and revisions to the *Standard Specifications* that have been approved by the Federal Lands Highway Office (FLHO) for use on all FLH projects, or all FLH projects with a particular item or character of work. FLH Supplemental Specifications normally consist of the same standard language in all the Divisions' Libraries of Specifications.

- Division Supplemental Specifications. Additions and revisions to the Standard or FLH Supplemental Specifications that have been approved by a Division. Division Supplemental Specifications consist of standard language that is not to be revised without approval.
- Library of Supplemental Specifications (LOSS). The compilation of all FLH Supplemental Specifications and Division Supplemental Specifications. Each Division maintains its own LOSS.
- Unique Project Specifications. Additions and revisions to the Standard Specifications or Library of Specifications that are developed and used on an individual project basis. Unique Project Specifications are normally written by the project designer to address a unique requirement for a single project.
- Special Contract Requirements (SCRs). All additions and revisions to the *Standard Specifications* and Supplemental Specifications used on an individual project. The SCRs are included in the contract for a project and include all FLH Supplemental Specifications, Division Supplemental Specifications, and Unique Project Specifications applicable to that project.

Spillway – A surface apron or trough for conducting water down a relatively steep slope.

Stabilization – Modification of soils or aggregates by incorporating materials that will increase load-bearing capacity, firmness and resistance to weathering or displacement.

Stage – The height of a water surface above an established datum plane; also gage height.

Stage Construction – The construction of a highway by stages or increments.

Standard Drawings – Drawings issued by the Federal Lands Highway Office and approved for repetitive use.

State Plane Coordinates – A system of plane rectangular coordinate zones, which are defined individually for each state or zone within a state. Within each state plane zone a cartesian (x,y) coordinate system describes geographic locations at a datum plane.

Station – (1) A measure of distance used for highways and railroads. A Metric station is equal to 1000 m. A US Customary station is equal to 100 ft. (2) A precise location along a survey line.

Stereoplotter – A photogrammetric instrument (often simply called a plotter) used for measuring and mapping from aerial photographs. The instrument provides analogical solutions for object point positions from their corresponding image positions on overlapping pairs of photographs. The primary use of stereoplotters is in the compilation of topographic maps and digital terrain models.

Stockpass – A culvert of a size large enough for the passage of domestic and wild animals.

Stone – Rock material produced from a quarry (i.e., nongravel material).

Stop Line – A white line placed transversely on the pavement (at an intersection) to indicate where the vehicle must stop when obeying a traffic signal or stop sign.

Stopping Sight Distance – The distance required by a driver of a vehicle, traveling at a given speed, to bring the vehicle to a stop after an object on the roadway becomes visible. It includes the distance traveled during the perception and reaction times, as well as the vehicle braking distance.

Storm Drain – A system of catch basins and underground conduits for collecting, concentrating and conveying water to a disposal point.

Stratigraphy – The study of rock strata, generally by analyzing rock outcrops or drill cores.

Stress-Strain Diagram – A diagram where corresponding values of the stress and strain are plotted.

Subbase – The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course.

Subgrade – The top surface of a roadbed upon which the pavement structure and shoulders are constructed.

Superelevation – The elevation of the outside edge of a curve to partially offset the centripetal force generated when a vehicle rounds the curve.

Superelevation Runoff – The transition distance between a section with level cross slope on half, or the entire, roadway and the fully superelevated roadway.

Surface Course – One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion and the disintegrating effects of climate. The top layer is sometimes called wearing course.

Surface Treatment – An application of asphalt material and cover aggregate.

Sustained Grade – A continuous highway grade of appreciable length and consistent or nearly consistent gradient.

- T -

Tack Coat – An application of asphalt material to an existing surface to provide bond with a superimposed course.

Target (Aerial) – A contrasting symmetrical pattern centered around a point on the ground to facilitate locating and measuring to the image of the point in a photograph.

Terrain – The topographic and physical features of a tract of land, geographic area or territory.

Toe of Slope – The intersection of a roadway embankment side slope with the original ground surface.

Topographic Map – A planimetric map with an added expression of topography, usually contours.

Topographic Survey – A survey conducted to determine the configuration of the ground.

Topsoil – A surface soil that is predominately a loose, friable, free draining sandy loam, which is free of subsoil, refuse, stamps, roots and rocks larger than 2 in [50 mm] in diameter, but containing some organic matter.

Total Station – A vertical and horizontal angle-measuring theodolite with an electronic distance measuring instrument attached to or integral with the theodolite's telescope. The theodolite generally has the ability to convert angular measurements into a digital form. Such theodolites display the slope and horizontal distance as well as the elevation difference between the instrument point and a remote point. Some models are able to retain horizontal coordinates. Often a data-recording device is offered as optional equipment.

Traffic Actuated Signal – A type of traffic control signal in which the length of most intervals and the cycle and, in some types the sequence of phasing, are varied by the demands of traffic.

Traffic Barriers – Roadside barriers, median barriers, crash cushions and bridge parapets intended to guide or protect traffic from roadside hazards, including collision with other vehicles.

Traffic Control Devices – Signs, signals, markings and devices placed or erected for the purpose of regulating, warning or guiding traffic.

Traffic Island – An island provided in the roadway to separate or direct streams of traffic; includes both divisional and channelizing islands.

Traffic Lane – That portion of the traveled way for the movement of a single line of vehicles.

Traffic Markings – A traffic control device consisting of lines, patterns, words, symbols or colors on the pavement.

Traffic Noise Impacts – Impacts that occur when the predicted traffic noise levels approach or exceed the design noise levels, or when the predicted traffic noise levels substantially exceed the existing noise levels.

Traffic Volume – The number of vehicles passing a given point during a specific period of time.

Transition – A section of variable pavement width required when changing from one width of traveled way to a greater or lesser width; or a section of variable cross slope such as from normal crown to full superelevation.

Transition Curve (Spiral) – A curve of variable radius intended to effect a smooth transition from tangent to curved alignment.

Transverse – At right angle to the longitudinal direction.

Traveled Way – The portion of the roadway for the movement of vehicles, exclusive of shoulders.

Traverse – In surveying, a series of interconnected straight lines. The lengths of the lines and the angles of deviation between them are measured as the traverse develops.

Triaxial Shear Test – A test in which a cylindrical specimen of soil, encased in an impervious membrane, is subject to a confining pressure and then loaded axially to failure.

Trigonometric Leveling – Determining elevation difference by measuring the slope distance, vertical angle and difference in instrument heights between two points.

Turning Track Width – The radial distance between the turning paths of the outside of the outer front tire and the outside of the rear tire that is nearest the center of the turn.

- U -

Underdrain – Porous or perforated pipe or graded aggregate installed under a roadway or shoulder to provide subsurface drainage.

Underpass – A grade separation where the highway passes under an intersecting highway or railroad.

- V -

Vertical Curve – A parabolic curve on the longitudinal profile of a road to provide for change of gradient.

Vista – A distant view seen from a highway. A moving vista is a view observed from a moving vehicle. A stationary vista is a view seen from a fixed place (e.g., rest area, scenic overlook).

- W -

Water-Cement Ratio – The ratio of the mass of water, exclusive only of that absorbed by the aggregates, to the mass of cement in a concrete or mortar mixture.

Water Table – The top of the zone of permanent soil saturation. The water table may rise or fall seasonally, or it may be drawn down by removal of water.

Weathering – The decomposition of rock, shale, etc., resulting from any chemical or mechanical process caused by exposure to weather.

Weephole – A hole through an abutment or retaining wall to relieve hydrostatic pressure.

Working Drawings – Stress sheets, shop drawings, erection plans, falsework plans, framework plans, cofferdam plans, bending diagrams for reinforcing steel or any other supplementary plans or similar data.

Chapter 2 – PLANNING AND PROGRAMMING

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LIST OF EXHIBITS

CHAPTER 2

PLANNING AND PROGRAMMING

2.1 GENERAL

Transportation planning is a process used to:

- Determine goals, policies, and strategies that create a decision-making framework for addressing transportation needs and issues;
- Provide guidance to Federal land management agency offices and units in evaluating programs and projects to address transportation needs and issues;
- Create opportunities for public involvement in transportation decision-making;
- Identify transportation system deficiencies, evaluate transportation needs and issues, and offer solutions;
- Develop performance measures to gauge success in meeting needs; and
- Program and implement transportation system improvements.

The *Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users* (SAFETEA-LU) requires the Federal Lands Highway Program (FLHP) to have transportation planning procedures in place for each of its Federal land management agency programs that are consistent with statewide and metropolitan planning processes.

Statewide and metropolitan planning includes several critical elements that form the foundation of the planning procedures for the FLHP. They are:

- Planning processes that are continuing, cooperative and comprehensive;
- Consideration of planning factors prescribed by law;
- Coverage of all modes;
- Long-range transportation plans that include a financial plan;
- Transportation improvement programs (TIPs);
- Development and use of management systems as a decision-making tool;
- Evaluation of air quality conformity in the development of plans and TIPs, as appropriate;
- Public involvement in the development of plans and TIPs; and
- Defined working relationships among States, Metropolitan Planning Organizations, Rural Planning Organizations, tribes, gateway communities, and other agencies, as appropriate.

Planning with respect to the FLHP includes periodic monitoring of the transportation system to carry out the following:

- Identify current and potential future transportation deficiencies by conducting transportation planning studies;

- Identify functional, structural or safety deficiencies, including an assessment of the condition of pavement, bridges, and traffic congestion;
- Identify the scope of a project and its respective limits; and
- Develop preliminary cost estimates for various improvement alternatives for use by the owner agency to balance capital improvements; Resurfacing, Rehabilitation, and Restoration (3R or RRR) projects; and maintenance programs.

Programming consists of scheduling those identified transportation improvements that provide access to or within Federal or Indian lands both through the FLHP and through the respective programs of the cooperating agencies. Funding requirements, personnel resources and the relative need for the projects are all considered when programming them in a long-range schedule.

Ultimately, this planning and programming process provides the delivery team with the projects and the funds to properly schedule a specific project for design.

The Federal roads associated with the FLHP consist of the following:

- Public Lands Highways (public roads providing access to, within or adjacent to Federal or Indian lands);
- The Park Roads and Parkways (PRP) system administered by the National Park Service (NPS);
- Designated Forest Highways (FH) on roads generally owned and maintained by State or local governments;
- The Refuge Roads (RR) system administered by the US Fish and Wildlife Service (USFWS); and
- The Indian Reservation Roads (IRR) system administered by the Bureau of Indian Affairs (BIA).

Other roads for which the FLH Divisions provide planning, design and construction services include forest roads administered by the USDA Forest Service (FS), public lands development roads administered by the Bureau of Land Management (BLM), various defense access roads off military reservations that are under the jurisdiction of a State or local government, Virgin Islands road and bridge projects administered by the Virgin Islands Government, Washington, DC road and bridge projects administered by the District of Columbia Government and roads and bridges of other Federal agencies, cooperating foreign countries and cooperating State agencies on a reimbursement basis. In addition to the FLHP, funds may also be provided for roads owned by the National Park Service, Fish and Wildlife Service and the Bureau of Indian Affairs through other appropriations.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

2.2 GUIDANCE AND REFERENCES

There are many policy references that apply to the FLHP and the associated transportation systems. (See Chapter 1 for definitions.) These include the following:

1. **Title 23 United States Code (23 USC).** The following sections of Title 23 apply:
   - Section 101 – Definitions and Declarations of Policy,
   - Section 125 – Emergency Relief,
   - Section 134 – Metropolitan Planning,
   - Section 135 – Statewide Planning,
   - Section 201 – Authorizations,
   - Section 202 – Allocations,
   - Section 203 – Availability of Funds,
   - Section 204 – Federal Lands Highway Program,
   - Section 205 – Forest Development Roads and Trails,
   - Section 210 – Defense Access Roads, and
   - Section 214 – Public Land Development Roads and Trails.
2. **Title 23 Code of Federal Regulations (23 CFR).** The following parts of Title 23 apply:
   - Part 450, Subpart B – Statewide Transportation Planning,
   - Part 450, Subpart C – Metropolitan Transportation Planning and Programming,
   - Part 660, Subpart A – Forest Highways,
   - Part 660, Subpart E – Defense Access Roads,
   - Part 661 – Indian Reservation Road Bridge Program,
   - Part 668 – Emergency Relief Program,
   - Part 771 – Environmental Impact and Related Procedures,
   - Part 970 – National Park Service Management Systems,
   - Part 971 – Forest Service Management Systems,
   - Part 972 – Fish and Wildlife Service Management Systems, and
   - Part 973 – Management Systems Pertaining to the Bureau of Indian Affairs and the Indian Reservation Roads Program.
3. **Title 25 Code of Federal Regulations (25 CFR).** The following parts of Title 25 apply:
   - Part 170 – Indian Reservation Roads Program.
4. **Federal-Aid Policy Guide (FAPG).** The following sections of the *FAPG* apply:
   - *FAPG* 23 CFR 660A – FH Administration (includes 23 CFR 660A and non-regulatory supplement),
   - *FAPG* 23 CFR 660E – Defense Access Roads (includes 23 CFR 660E and non-regulatory supplements 1-5),
   - *FAPG* 23 CFR 668B – Emergency Relief Program Procedures for Federal Agencies for Federal Roads (includes 23 CFR 668B),
   - *FAPG* 6090.13 – Preliminary Engineering and Construction for Other Federal Agencies,

- *FAPG* 6090.13A – Preliminary Engineering and Construction for Other Federal Agencies, and
- *FAPG* 6090.17 – Indian Reservation Roads.

5. **Federal Lands Highway Manual (FLHM).** Refer to Chapter 2, "Planning and Programming".

6. **National Interagency Agreements**. The following listed agreements are base agreements covering the standard procedures for coordinating the respective programs. These agreements, associated supplemental agreements and agreements for other programs administered by FLH are accessible through the FHWA's Electronic Centralized Agreement Library (E-CAL):

   - Forest Service, effective May 11, 1981;
   - Bureau of Land Management, Feb. 26, 1982;
   - Bureau of Indian Affairs, May 24, 1983;
   - National Park Service, May 19, 1983; and
   - Fish and Wildlife Service, April 12, 1999.

2.3 PROGRAMS

The Office of Federal Lands Highway (FLHO) administers the FLHP and plays a role in delivering transportation projects for several other Federal agency transportation systems and programs.

2.3.1 FEDERAL LANDS HIGHWAY PROGRAM (FLHP)

The *Surface Transportation Assistance Act* of 1982 established the FLHP. This allowed Federal Highway Trust Funds (HTF) to be spent on Park Roads and Parkways and Indian Reservation Roads that were previously not eligible for HTF financing. Additionally, the Forest Highways and FLH Programs that were previously financed by HTF were brought under the umbrella of the FLHP. The Refuge Roads Program was added to the FLHP in 1998 as part of the *Transportation Equity Act for the 21st Century* (TEA-21). Passage of the SAFETEA-LU in 2005 continued all of these programs under the FLHP.

The programs that come under the FLHP legislation are Public Lands Highways, Park Roads and Parkways, Indian Reservation Roads and Refuge Roads. The Public Lands Highways Program is comprised of both the Forest Highway Program and the Public Lands Highway Discretionary Program.

2.3.1.1 Public Lands Highways

The Public Lands Highways category incorporates two subcategories: (1) Forest Highways and (2) Public Lands Highways Discretionary (PLHD). Title 23 allocates sixty-six percent of Public Lands Highways funding to Forest Highways, and thirty-four percent to PLHD. The following subsections briefly describe each of these highway categories:

2.3.1.1.1 Forest Highways

The Forest Highways (FH) Program provides funding for selected transportation projects providing access to, within, or adjacent to National Forests and Grasslands.

Administration – Forest Highways as described in 23 CFR 660 are roads that are: (1) wholly or partly within or adjacent to and serving the National Forest System, (2) under the jurisdiction of and maintained by a public authority and (3) open to public travel. Forest highways are designated from the eligible roads by FHWA, in consultation with the FS and the appropriate State Department of Transportation (State DOT).

FH route designation is delegated to the FLH Division Engineer. Either the FS or the State can nominate a route, but it must adhere to the following criteria:

- The route is under the jurisdiction of a public authority and open to public travel.

- The route provides a connection between adequate and safe public roads and the resources of the National Forest System that are essential to the local, regional or national economy and/or the communities, shipping points or markets that depend upon those renewable resources.
- The route serves other local needs (e.g. schools, mail delivery, commercial supply, etc.) and access to private property within the National Forest System; serves high-volume traffic, which is generated by use of the National Forest System and its resources; or serves National Forest System-generated traffic volumes that have a substantial impact on roadway design and construction.

Program of Projects – Long-range transportation programs and project schedules are developed at program meetings that are generally held annually. A meeting is held in each State that has an operating tri-agency agreement among the FHWA, FS and State DOT (See Exhibit 2.4–A). At these meetings, potential projects are discussed and a FH program developed. Representatives of the tri-agency partnership and other interested agencies attend the meetings.

FH projects are selected based on the following criteria:

- The development, utilization, protection and administration of the National Forest System and its renewable resources.
- The enhancement of economic development at the local, regional and national level.
- The continuity of the transportation network serving the National Forest System and its dependent communities.
- The mobility of the users of the transportation network and the goods and services provided.
- The improvement of the transportation network for economy of operation and maintenance, and for the safety of its users.
- The protection and enhancement of the rural environment associated with the National Forest System and its renewable resources.
- The results from the pavement, bridge and safety management systems.

The objective of the program meetings is to reach agreement on a minimum five-year FH program that can be accomplished with the available funding and the project delivery capabilities of each agency.

Funding – FH funds are allocated by formula to States having national forest lands. Since the allocations are made for each State, project costs must fit within the available funds. FH funds may be borrowed by one State from another State with unobligated monies provided that these funds are returned by the end of the current highway authorization period. Allocations are managed in the FLH Division offices, but obligation limitation is controlled at Headquarters.

2.3.1.1.2 Public Lands Highways Discretionary

Public Lands Highways Discretionary (PLHD) provides funding for select transportation projects providing access to, within, or adjacent to Federal and Indian lands. Public lands highways are those main highways through unappropriated or unreserved public land, non-taxable Indian lands or other Federal reservations, which are on the Federal-aid system.

The FHWA Office of Infrastructure and FLHO co-administer the funds for PLHD. The States submit applications for the projects, and the FHWA verifies eligibility. Once eligibility has been determined, funding is made available and the customary project development process can proceed.

2.3.1.2 Park Roads and Parkways

The Park Roads and Parkways (PRP) Program provides funding that may be used by the NPS and the FHWA for the planning, design, construction, or reconstruction of designated public roads that provide access to or within national parks, recreation areas, historic areas, and other units of the National Park Service.

Administration – The National Park Service and the Federal Highway Administration through the FLHO jointly administer the program, in accordance with Interagency Agreements. FLHO is tasked with overall stewardship and oversight of the Program. In addition, the FLH Divisions undertake the majority of the design and construction work. They also conduct the inventory and condition assessments for park roads, parkways, bridges and tunnels. The NPS develops the priority program of projects and is responsible for planning, environmental compliance and protection of park values.

Routes on the PRP system are those designated with a functional classification I, II, III, VII and VIII, based on the *Park Road Standards*. There is no formal approval required for roads in this system.

Program of Projects – A priority program of projects developed by the NPS and approved by FHWA is used to allocate funds for PRP. Annually, the NPS issues a call for projects, and each park unit submits to its regional office a list of improvement priorities. The regional office then develops its list of projects based on the budget provided by NPS headquarters (WASO). Each FLH Division meets periodically with appropriate NPS Regions to establish a program of projects to be funded five to ten years into the future. This regional program of projects is then submitted to WASO for coordination and consolidation into a nationwide PRP program that WASO subsequently submits to the FLHO for approval.

Funding – Funding is provided for the planning, design, construction, reconstruction or improvement of park roads and parkways, including bridges, tunnels, and trails located within units of the National Park System. Some of the funds are used for alternative transportation systems including buses, trails, ferries and transit facilities. Title 23 also authorizes funding to be used for other projects such as pedestrian and bicycle facilities, adjacent vehicular parking, interpretive signage, acquisition of scenic easements and scenic or historic sites, and construction or reconstruction of roadside rest areas.

Most funds are allocated to projects in three categories:

1. Rehabilitation (3R) and Reconstruction (4R) Projects
   - Paving
   - Bridge rehabilitation, painting and replacement
   - Safety improvements
   - Drainage
   - Tunnel rehabilitation
2. Congressionally Mandated Parkway Completion Projects:
   - Natchez Trace Parkway – Multi-use Trail
   - Foothills Parkway – Missing Link, 8E Section
3. Transportation Management Program (TMP).

   The TMP, formerly the Alternative Transportation Program (ATP), integrates all modes of travel within a park including transit, ferries, rail, bicycle and pedestrian linkages, and the personal vehicle.

2.3.1.3 Indian Reservation Roads

The Indian Reservation Roads (IRR) Program provides funding that may be used by Indian tribal governments, the Bureau of Indian Affairs, and the FHWA for the planning, design, construction, or reconstruction of designated public roads that provide access to or within an Indian reservation, Indian lands, Indian communities, and Alaska native villages.

Administration – The IRR Program is co-administered by the Bureau of Indian Affairs (BIA) and FLHO. IRR system roads are public roads that are located within or provide access to:

- An Indian reservation or Indian trust land; or
- Restricted Indian land that is not subject to fee title alienation without the approval of the Federal Government; or
- Indian or Alaska Native Villages, groups or communities in which Indians and Alaska Natives reside, whom the Secretary of the Interior has determined are eligible for services generally available to Indians under Federal laws specifically applicable to Indians.

The BIA regional offices designate routes on the IRR system after nomination by the Tribal governing body. BIADOT does the final quality assurance/quality control of a proposed inventory route prior to its being accepted into the inventory. Up to 25 percent of a tribe's IRR Program funds may be used for maintenance.

Program of Projects – The IRR Transportation Improvement Program (IRRTIP) incorporates projects by region as submitted through the BIA region-wide control schedule, with input from the tribes through the tribal priority list or a Tribal Transportation Improvement Program. The IRRTIP is submitted to the BIADOT for review and concurrence. FLHO has final approval of the IRRTIP.

Funding – Funds are distributed according to the Tribal Transportation Allocation Methodology as defined in 25 CFR 170, Indian Reservation Roads Program. A majority of the IRR program funds is distributed either to the 12 BIA regions or directly by the BIA to self-governance tribes based on a relative needs distribution factor defined in the regulation. The factor is derived from a combination of cost-to-construct, vehicle miles traveled and population. After the IRRTIP is reviewed and approved by the FLHO, funds are transferred from the BIA Division of Transportation (BIADOT) to the BIA regions for those projects being administered by the BIA, by the tribes under Public Law 93-638 contracts, or directly to self-governance tribes based on their Annual Funding Agreement with the BIA. Funds may be allocated to the respective Division offices for those projects where the BIA or tribe has requested assistance.

2.3.1.4 Refuge Roads

The Refuge Road Program (RRP) provides funds that may be used by the USFWS and the FHWA for the maintenance and improvement of public roads that provide access to or within a unit of the National Wildlife Refuge System. Construction of new roads is not permitted, except to accommodate spot traffic safety improvements.

Administration – The RRP is co-administered by the FLHO and the USFWS. The program provides a means to pay the cost of maintenance and improvement of public roads that provide access to or within a unit of the National Wildlife Refuge System and for which title and maintenance responsibility is vested in the Federal government.

Program of Projects – Projects are selected taking the following into consideration:

- The Comprehensive Conservation Plan for each refuge,
- Access needs as identified through land use planning,
- Impact of land use planning on existing transportation facilities,
- The National Wildlife Refuge System Act of 1966.

Projects are selected by the USFWS and approved by FLHO. Annually, each refuge submits to its regional office a list of improvement priorities. Regional priorities are developed using the refuge requests. The regional directors then cooperatively develop a list of service-wide priorities. Each FLH Division meets periodically with appropriate USFWS regions to establish a five-year program of projects.

Funding – No legislative formula has been established for allocating funds. Funds are allocated according to the relative needs of the various refuges in the National Wildlife Refuge System. The formula for distributing funds between the USFWS regions is based on four attributes of a region's Refuge Road network:

- Refuge road mileage, and the surface area of parking facilities and bridges,
- Condition of roads and bridges,
- Traffic volumes, and
- Traffic crash rates.

The use of RR funds is restricted to:

- Maintenance and improvement of Refuge Roads;

- Maintenance and improvement of adjacent vehicular parking areas, interpretive signage, provision for pedestrians and bicycles, and construction and reconstruction of roadside rest areas including sanitary and water facilities that are located in or adjacent to wildlife refuges;
- Administrative costs associated with maintenance and improvements;
- The non-Federal share of the cost of any project funded under Title 23 (Highways) or Chapter 53 of Title 49 (Public Transportation), and
- Maintenance and improvement of recreational trails (limited to 5 percent of available funds for each fiscal year).

2.3.2 OTHER FEDERAL AGENCY TRANSPORTATION SYSTEMS

Other Federal agencies have jurisdiction or responsibility over transportation systems. From time-to-time, FHWA will perform work for these agencies. The following subsections describe these systems and activities. The FLH Divisions may provide engineering services for the improvement of highways for other Federal agencies, cooperating foreign countries, US territories and cooperating State agencies on a reimbursement basis.

2.3.2.1 Forest Service

The Forest Service (FS) has jurisdiction over the forest transportation system. The forest transportation system includes roads which are:

- Forest roads under the jurisdiction of the FS such as public forest access roads or forest development roads;
- Wholly or partly within or adjacent to and serving the National Forest System; and
- Necessary for the protection, administration, use and development of FS resources.

When requested by the FS and subject to the appropriate project agreement, FLH Divisions may provide engineering services for projects on the FS system.

2.3.2.2 National Park Service

Some National Park Service (NPS) projects on which FLH Divisions are asked to provide engineering services are funded through agency appropriations with special funding rather than through the FLHP. These include major special interest projects, cyclic maintenance projects and projects with special features. In addition, the NPS also has road programs for roads within their jurisdictional boundaries that are not open to the public (e.g., administrative, maintenance, fire control, and other service roads).

2.3.2.3 Bureau of Indian Affairs

Most Bureau of Indian Affairs (BIA)\ projects on which FLH Divisions are asked to provide engineering services are funded through the FLHP. Others may be specially designated projects funded through agency appropriations or other established programs.

2.3.2.4 Bureau of Land Management

The Bureau of Land Management (BLM) has jurisdiction over public lands development roads and trails that are the public roads determined by the Department of the Interior to be of primary importance for the development, protection, administration and utilization of public lands and resources.

BLM also has jurisdiction over forest access roads on and to the O&C lands (i.e., revested Oregon and California Railroad and reconveyed Coos Bay Wagon Road grant lands) in Oregon.

When requested by BLM and subject to the appropriate project agreement, FLH Divisions may provide engineering services for projects on the BLM system.

2.3.2.5 Department of Defense

Department of Defense (DOD) access roads are roads designated by DOD as important to the military because they access military reservations, defense industry sites and sources of raw materials. These roads are most often owned by State or local governments and are generally not within the boundaries of military reservations. Other roads that also meet the criteria of DOD access roads are highways and highway connections that are shut off from general public use by closures or restrictions at military reservations or defense industry sites. From time-to-time, DOD will request through the appropriate project agreement that an FLH Division provide engineering services for a specific site.

2.3.3 EMERGENCY RELIEF FOR FEDERALLY OWNED ROADS (ERFO) PROGRAM

2.3.3.1 Program Intent

The ERFO Program is intended to help pay the unusually heavy expenses associated with the repair and reconstruction of Federal roads and bridges seriously damaged by a natural disaster over a wide area or catastrophic failure. Restoration in-kind to pre-disaster conditions is expected to be the predominant type of repair. The following definitions apply:

1. **Serious Damage**. Heavy, major or unusual physical damage to the highway that severely impacts the safety, capacity or usefulness of the highway or results in road closure. Serious damage must be beyond the scope of heavy maintenance.

2. **Wide Area**. An area sufficiently large enough to encompass parts of all or several entities (e.g., counties, States, Federal agency management units (individual forests, parks, refuges, regions, districts, etc.)) and can include areas outside of the land administered by a Federal agency applying for emergency relief.
3. **Catastrophic Failure**. A catastrophic failure of a road or bridge is a failure that is sudden and complete due to an external cause. The failure must occur on a major segment or element of the road system and cause a disastrous impact that results in unusually high expenses.
4. **Disastrous Impact**. Denotes severe disruption of access to critical facilities (e.g., schools, hospitals, residences) or severe economic impact to an industry important to the local economy or elimination of access to a major portion of Federal lands.
5. **Federal Roads**. Forest highways, forest development roads and trails, park roads and trails, parkways, refuge roads and trails, public lands highways, public lands development roads and trails, and Indian reservation roads as defined under 23 USC 101(a).

2.3.3.2 Funding Source

The Highway Trust Fund is the source of Emergency Relief funds. Funding for emergency and permanent repairs of Federal-aid and other federally owned roads and bridges is authorized by 23 USC 125. Congress can also authorize additional emergency relief funds through supplemental appropriations.

2.3.3.3 Administrative Procedures

The administrative procedures for this program are outlined in the *Emergency Relief for Federally Owned Roads, Disaster Assistance Manual*, FHWA-FLH-04-007, April 2004.

2.4 PLANNING AND PROGRAM COORDINATION

FLH uses a variety of mechanisms for program planning and coordination, including interagency, State, local and other miscellaneous project agreements. Additionally, there are standing agreements with several agencies, including the FS, BLM, BIA, FWS and NPS, that cover the standard procedures for coordinating the respective programs (see Section 2.2).

2.4.1 INTERAGENCY AGREEMENTS

Whenever FLH performs work for other agencies or other agencies perform work for FLH, an interagency agreement is executed between the organizations. The agreement must spell out the responsibilities and the method of payment for the services rendered. This agreement may cover a continuing program or cover an individual project.

2.4.2 FEDERAL/STATE FOREST HIGHWAY TRI-AGENCY AGREEMENTS

Each State participating in the Forest Highway (FH) program is required to enter into an agreement setting forth the terms by which FH projects will be planned, programmed, designed, constructed and maintained. A sample Forest Highway Tri-Agency Agreement is shown in Exhibit 2.4–A. These agreements are commonly known as tri-agency or tri-party agreements and include the appropriate FLH Division, the FS and the respective State DOT.

2.4.3 FEDERAL/COUNTY FOREST HIGHWAY INTERAGENCY AGREEMENTS

Each county participating in the FH program is asked to enter into an agreement similar to the tri-agency agreements. It is important to insure that roles and responsibilities are clear, since counties are generally not familiar with Federal-aid requirements such as the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. A sample cooperative agreement with a county is shown in Exhibit 2.4–B.

2.4.4 FOREST HIGHWAY PROJECT AGREEMENTS

Every project constructed under the FH program should have a project agreement implementing the terms of the FH tri-agency agreement. Exhibit 2.4–C is a sample project agreement. However, the FH regulations require a project agreement only when the following conditions exist:

- A cooperator's funds are to be made available to FHWA for the project or any portion of the project;
- Federal funds are to be made available to a cooperator for any work;

- Special circumstances exist that make a project agreement necessary for payment purposes, or to clarify any aspect of the project; and
- It is necessary to document jurisdiction and maintenance responsibility.

2.4.5 MISCELLANEOUS INTERAGENCY AGREEMENTS

In addition to the above agreements, the FLH Divisions enter into agreements with utilities, railroads, other Federal agencies, State agencies and local governments to perform specific tasks (e.g., utility removal, railroad crossing protection, signing and markings, materials testing or investigation, special project design, construction management activities).

Exhibit 2.4–A SAMPLE FOREST HIGHWAY TRI-AGENCY AGREEMENT

Parties to Agreement. [*Eastern*][*Central*][*Western*] Federal Lands Highway Division, Federal Highway Administration, U.S. Department of Transportation, hereinafter referred to as the FHWA unless otherwise noted; the U.S. Department of Agriculture (USDA) Forest Service, hereinafter referred to as the FS; and the [*State*] Department of Transportation, hereinafter referred to as the [*State*] DOT.

Purpose: The purpose of this Forest Highway Statewide Agreement (Agreement) is to set forth the general Statewide procedures, mutually acceptable to the parties hereto, for the cooperative planning, programming, survey, design, construction, and maintenance of Forest Highways (FH) in the State of [*State*], pursuant to the provisions of Title 23 United States Code (USC), Sections 202, 203 and 204, and the regulations issued thereunder by the Secretary of Transportation and the Secretary of Agriculture. The Agreement also incorporates the public involvement/public hearing requirements of Title 23 Code of Federal Regulations (CFR) Part 771.111 and 40 CFR Parts 1500 through 1508, other associated environmental review procedures under 23 CFR Part 771, and applicable FS requirements.

Under the Federal Lands Highway Program, Congress has authorized funds for FH that are within, or provide access to the National Forest System (NFS). Recognizing (1) that substantial benefits will accrue to the State and to the Nation from the construction and maintenance of such FH and (2) that the FH are under the jurisdiction of a public road authority, and further (3) that the [*State*] DOT has systems planning, maintenance, right-of-way acquisition, and interdisciplinary facilities available to assist in the accomplishment of the work, as required by 23 CFR Part 660; it is deemed fitting and desirable to the Parties hereto to express by this Agreement the general terms of their cooperation in order to achieve maximum benefits in the public interest.

As stated in 23 CFR Part 660.111, the design and construction of FH projects will be administered by the FHWA unless otherwise provided for in a Federal-Aid Project Agreement (PR-2) approved under that Subpart. Through this Agreement, it is recognized that the [*State*] DOT may administer the design and construction of the FH projects.

In addition, the Parties may enter into a specific project agreement that identifies a different design and construction agency.

Forest Highway Routes. This Agreement shall cover the FH routes, previously approved for inclusion in the designated FH network dated _________, and any approved amendments. The FHWA shall maintain the inventory of the approved designated FH network. The list of such approved routes may be varied from time to time by agreement between the [*State*] DOT and the FS, with the approval of the FHWA, either by adding routes or removing routes or by altering the description of any route to give it proper identity. Each such action shall be indicated by a revised list showing the effective date of the revision.

Exhibit 2.4–A SAMPLE FOREST HIGHWAY TRI-AGENCY AGREEMENT
(Continued)

Transportation Planning/Management Systems. It is recognized that FH are an integral part of the road network in any State. Transportation planning will be performed by the [*State*] DOT. The [*State*] DOT will work with the FS and the FHWA on long-range planning activities of mutual concern. The [*State*] DOT agrees that it will adhere, in performing these functions, to the environmental review/public involvement/public hearing procedures required under the guidelines of 23 CFR Part 771; to the statewide and metropolitan planning requirements of 23 CFR Part 450, and to appropriate agency implementing procedures and policies. The [*State*] DOT, the FHWA, and the FS agree to incorporate the long range FH transportation plan into the State's long range transportation plan. The [*State*] DOT agrees to share information on FH routes in bridge, pavement, and safety management systems.

Program of Projects. A program meeting will be held biennially, or more frequently if deemed necessary, including the [*State*] DOT, the FHWA, and the FS, in accordance with 23 CFR Part 660.109(a). After agreement has been reached on the program of projects, the FHWA will prepare the updated program and forward copies to the [*State*] DOT and the FS.

The FHWA will provide the FH project data to the [S*tate*] DOT prior to the [*State*] DOT's public involvement process on the proposed Statewide Transportation Improvement Program (STIP). After the conclusion of the public involvement process, the [*State*] DOT will incorporate the program of projects into its STIP. The [*State*] DOT will also forward a copy of the program to the appropriate Metropolitan Planning Organization (MPO) for incorporation into its Transportation Improvement Program (TIP) before April 1 of each year.

Development of Projects. As stated previously, either the FHWA or the [*State*] DOT will be the agency administering the design and construction of FH projects. If it is determined to be in the public interest to have an agency other than the FHWA or the [*State*] DOT be responsible for the administration of the FH project, a Memorandum of Agreement specific to the project will be prepared which will establish the responsibilities of each party. Regardless of which agency is administering the project, once projects are included in an approved FH program, the agency administering the project shall proceed promptly, and projects shall be carried forth through completion in accordance with the approved program.

Design standards for the FH projects shall be appropriate to the use of the road, scope of the project and in consideration of the natural and cultural environment. Standards specific to FH or to a particular project will be established by agreement between the [*State*] DOT and the FS, with the approval of the FHWA.

It is the intent of the project development process to keep all agencies informed of progress, to request the [*State*] DOT, FS and FHWA attendance at the scheduled plan reviews, and to obtain written concurrence of the plans, specifications, and estimate (PS&E) and FHWA approval prior to advertisement. If it becomes evident during the development of the project, that the scope of the project or the anticipated construction cost needs to be changed, the agency administering the project will initiate coordination with the other parties to obtain concurrence and approval of the change in the project.

Exhibit 2.4–A SAMPLE FOREST HIGHWAY TRI-AGENCY AGREEMENT
(Continued)

Specifically, if the FHWA is administering the project, the FHWA will coordinate all plan reviews with the [*State*] DOT and the FS and obtain written concurrence in the PS&E prior to advertisement of the project for construction. The FHWA will follow established Federal Lands Highway Program procedures for the development of the project, taking established [*State*] DOT and FS practices into consideration, where appropriate.

If the [*State*] DOT is administering the project, the [*State*] DOT will coordinate with the FS during the development of the project, obtain written concurrence of the PS&E from the FS, and submit the advertisement PS&E package with evidence of the FS concurrence to the FHWA for FHWA project authorization. Upon FHWA approval that the project was developed in accordance with the approved program, FHWA will obligate funds and authorize the [*State*] DOT to proceed with the advertisement and construction of the project. Except as stated previously for coordination with the FS and FHWA approval and funding authorization, the [*State*] DOT will follow approved Federal-aid procedures in the administration of the project.

Compliance with Environmental Review/Public Involvement/Public Hearing Requirements in Project Development. The FHWA and the [*State*] DOT will adhere to the environmental review/public involvement/public hearing procedures required under the guidelines of 23 CFR Part 771 and appropriate agency implementing procedures and policies. These procedures include providing early and continuing opportunities during the project development process for the public to be involved in the identification of social, economic and environmental impacts. When the FHWA is administering the project, consideration will be given to following the [*State*] DOT and FS public involvement procedures. When the [*State*] DOT is administering the project, the FHWA Federal-aid Division office will take all formal approval action on the environmental document in accordance with Federal-aid procedures.

The National Environmental Policy Act (NEPA) requires all Federal agencies and their agents to evaluate and disclose environmental impacts of their actions. This environmental evaluation process often involves several agencies. It is the intent under the Council of Environmental Quality (CEQ) regulations for a project to be evaluated one time comprehensively by a designated lead agency. Because highways are a charged responsibility of the FHWA and its companion State Departments of Transportation, it is reasonable to expect the FHWA to coordinate and complete the environmental process consistent with all State and Federal regulations.

The role and level of involvement of the FS will vary dependent upon the scope of the proposed action. Many projects will be confined within the limits of existing road rights of way and easements. This work will have minimal off-site impact and minor influence on the management program of the FS. Coordination for this type of project will ensure conformance with the approved FH program of projects and require a limited level of environmental resource coordination.

Exhibit 2.4–A SAMPLE FOREST HIGHWAY TRI-AGENCY AGREEMENT
(Continued)

Projects that encroach on National Forest System lands need a greater level of FS review of project area resources and potential project impacts, and more detailed documentation by both the agency administering the project and the FS. Because the highway project is the proposed action triggering the environmental review process, the FS is to be a Cooperating Agency. Because the FS is required to conduct an evaluation of the proposed highway action resulting in the consent to the appropriation and transfer of lands to the [*State*] DOT, it is appropriate to document the review process and conclusions independently and attach these to the environmental document by appendices. When encroachment of National Forest System lands is anticipated, the agency administering the project and the FS should meet and agree upon the specific scope of the resource surveys, the type and frequency of public involvement actions to be used in the development of the project and the time frame for the FS to complete its decision process for the appropriation of the lands. These procedures will allow both the agency administering the project and the FS to fulfill their obligations in their own documentation formats, yet tie the coordinated reviews in a single NEPA document consistent with CEQ guidelines. In coordinating the environmental process and the anticipated Federal land transfer, the intent is to coordinate the issuance with the FS Decision Notice for the pending Federal land transfer and the NEPA public involvement process to achieve one joint public involvement process.

Construction of Projects. Minor changes in grade, alignment, surface course, or structures made necessary by unforeseen contingencies or deemed desirable by conditions that develop during the progress of work may be made by the agency administering the construction project without the prior or separate approval of the other parties to this Agreement. It is incumbent upon the agency administering the project to ensure that any such changes are not in conflict with any of the environmental and/or design parameters agreed to in the development of the project.

All construction is to be performed by contract entered into by competitive bids unless some other method is deemed to be more advantageous and in the public interest.

Following the award of the construction contract, the agency administering the project will notify the other parties in writing of the award of the construction contract, and invite their attendance to a preconstruction conference. Such meetings will provide an opportunity for all interested parties to discuss their mutual concerns regarding project construction. During construction, the FS (and the [*State*] DOT, if FHWA is administering the project) will consult with the Project Engineer on matters pertaining to project construction, environmental and resource coordination required in the stipulation of special use permits for activities such as clean up, borrow pit seeding, or other similar activities.

The FS (and the [*State*] DOT if FHWA is administering the project) will be invited to participate in the final inspection. FS and [*State*] DOT participation is to ensure that the project was constructed in accordance with the approved FH program.

The FHWA will administer projects in accordance with established Federal Lands Highway Program procedures, and in accordance with the applicable Federal acquisition regulations and procedures. The [*State*] DOT will administer projects in accordance with approved Federal-aid procedures.

Exhibit 2.4–A SAMPLE FOREST HIGHWAY TRI-AGENCY AGREEMENT
(Continued)

Funding. When any proposed construction is to be administered by the [*State*] DOT and financed in whole or in part with Federal funds, such circumstances will be set forth in the Project Agreement (PR-2) together with a statement of the amount of Federal funds obligated for the project. The expenditure of Federal funds shall not exceed the amount shown on the PR-2. If it appears that the project cost may exceed the estimate and additional Federal funds may be needed, no obligation on the part of FHWA shall occur until the [*State*] DOT requests and receives an approved Modification of Federal-Aid Project Agreement (PR-2A).

As the work progresses, the [*State*] DOT shall submit Form PR-20 vouchers to the FHWA or shall submit electronic billing claims to the FHWA using the FHWA PR-20 Electronic Billing System for payment of the Government's pro rata share of the cost of the work. The [*State*] DOT shall send Form PR-20 to: [*Eastern*][*Central*][*Western*] Federal Lands Highway Division, Federal Highway Administration, [*fill in address here*]. Upon completion of the work, the [*State*] DOT shall send a final voucher form PR-20 to the FHWA at the above address.

When the FHWA is administering projects funded entirely with FH funding or other funding provided directly to the [*Eastern*][*Central*][*Western*] Federal Lands Highway Division, all project financial transactions will be processed in the Federal Lands Highway Division office.

If State, local, other Federal-aid funds or FS funds are made available on projects, the cost responsibilities and procedures to transfer these funds or to reimburse either the [*State*] DOT or the FHWA for eligible project costs shall be covered by a Memorandum of Agreement specific to the project. Any unused balance of these funds will be returned to the provider after closure of the financial records. The amount of cooperative funds as set forth in the Memorandum of Agreement specific to the project shall be the maximum commitment to the project, unless a modification of the Memorandum of Agreement specific to the project is executed.

When [*State*] DOT and/or FS funds are involved, the agency administering the project shall furnish to the other parties a summary statement of the cost of the project. The FHWA will provide a statement of the FH portion of the project cost as reported in periodic FH financial reports. All financial information will be available at any time to the parties to this Agreement upon request.

Project Agreement. A specific project agreement is to be entered into between the [*State*] DOT and the FHWA for each project for which (1) the survey, construction, acquisition of rights-of-way, or maintenance in connection with a project included in an approved FH program is to be accomplished in a different manner from that set forth in this Agreement, or (2) cooperative funds, including Federal funds from programs other than the Federal Lands Highway Program, are to be made available to the FHWA for the project.

Rights-of-Way. Rights-of-way or other interests in property are to be acquired by and in the name of the [*State*] DOT. The cost of such rights-of-way or other interests in property acquired by the [*State*] DOT is to be at the [*State*] DOT's expense, unless otherwise provided in a Memorandum of Agreement specific to the project. The Agency administering the project will perform the title searches, surveys, write the description, and prepare right-of-way plans. Regardless of whether the FHWA or the [*State*] DOT administers the project, the [*State*] DOT will administer the right-of-way acquisition. The [*State*] DOT shall certify to the FHWA that the right-of-way has been acquired in accordance with Federal-aid procedures.

Exhibit 2.4–A SAMPLE FOREST HIGHWAY TRI-AGENCY AGREEMENT
(Continued)

For Federal land transfers, the agency administering the project will prepare a Highway Easement Deed. All Federal land transfers will be completed in accordance with the Federal-aid procedures that stipulate the coordination process with the Federal agency, the [*State*] DOT, and the FHWA Division office to execute the Federal lands transfer.

Access across National Forest Lands needed for such uses as access to gravel or fill sources and temporary use of lands (such as material source sites, stockpile sites, disposal sites, minor sloping, etc.) outside of the right-of-way required for the construction and maintenance of the highway facility, will be authorized by the FS issuance of an appropriate special use permit.

Claims. The agency administering the project is responsible for resolution of any claim that arises as a result of any project design or construction contract. For [*State*] DOT administered projects, reimbursement of the settlement will be made in accordance with established Federal-aid procedures.

Maintenance. The [*State*] DOT will maintain the FH project, or, by formal agreement with appropriate officials of a county, municipal government, or other public road authority, cause it to be maintained.

The project shall be inspected by the FS, the FHWA, and the [*State*] DOT to identify and resolve any mutual concerns, prior to final construction acceptance by the contracting authority.

Exhibit 2.4–A SAMPLE FOREST HIGHWAY TRI-AGENCY AGREEMENT

(Continued)

Amendments to FH Statewide Agreements. This Agreement together with the environmental review/public involvement/public hearing procedures may be modified by advance notice of 60 days from any of the three parties to the other two.

This Agreement shall be effective as of the __th day of ____, 20__, and shall supersede all prior existing cooperative agreements for the same routes entered into pursuant to 23 USC Sections 202, 203, and 204, "Federal Lands Highway Program" except those involving commitment of funds or arrangement for the performance of construction work on projects underway but not yet completed and final settlement made.

[STATE]
DEPARTMENT OF TRANSPORTATION

By: ____________________________

Title: State Highway Administrator

Date: ____________________________

DEPARTMENT OF AGRICULTURE
FOREST SERVICE
REGION [Number]

By: ____________________________

Title: Regional Forester

Date: ____________________________

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

[*EASTERN*][*CENTRAL*][*WESTERN*] FEDERAL LANDS HIGHWAY DIVISION

By: ____________________________

Title: Division Engineer

Date: ____________________________

Exhibit 2.4–B SAMPLE FOREST HIGHWAY AGREEMENT WITH A COUNTY

FOREST HIGHWAY AGREEMENT
(with *COUNTY)*

Parties to Agreement. Federal Highway Administration, US Department of Transportation, hereinafter called "FHWA," and the County of ______________, State of ______________, hereinafter called the "County."

Purpose. The purpose of this Agreement is to set forth the general terms and conditions, mutually acceptable to the parties hereto, for the project selection, project agreements, survey, design, construction, rights-of-way acquisition and maintenance of Forest Highways in ______________ County, ______________, pursuant to the provisions of Title 23 USC §204 and Title 23 CFR 660 Subpart A.

Project Selection. Projects will be selected by mutual agreement of FHWA, the Forest Service (FS), and the [*State*] Department of Transportation ([*State*] DOT), acting on behalf of the County, in accordance with Title 23 CFR Part 660.109.

Project Agreement. In addition to this Forest Highway Agreement, a project agreement shall be entered into between FHWA and the County for each project prior to the expenditure of Federal funds. The purpose of the project agreement is to spell out the project specifics that cannot be covered in this general agreement, including project length, geometrics, rights-of-way requirements and utility relocation requirements.

The project agreement shall set forth the procedure between FHWA and the County when:

- the survey, construction, acquisition of right-of-way or maintenance in connection with a project included in an approved Forest Highway program is to be accomplished in a different manner from that set forth in this Forest Highway Agreement;
- Federal funds are to be made available to the County for the project; or
- County funds are to be made available to FHWA for the project; project agreements are to be executed in triplicate, one executed copy being for the County, one for the Forest Service and one for FHWA.

Survey, Design and Construction. FHWA will administer the survey, design and construction of each Forest Highway project unless otherwise provided for in a project agreement. The location of the survey and the general design will be accomplished to the mutual satisfaction of the County, FS and FHWA. The County is encouraged to provide input in the project development phase.

The project will be constructed as promptly as possible after funds are made available. Minor changes in grade, alignment, surface course or structures made necessary by unforeseen contingencies or deemed desirable by conditions developing during the progress of the work may be made by FHWA without the prior or separate approval of the County. FHWA will, to the extent practicable, ensure that any such changes are not in conflict with any of the environmental and/or design considerations agreed to in the development of the project.

Exhibit 2.4–B SAMPLE FOREST HIGHWAY AGREEMENT WITH A COUNTY
(Continued)

All work will be performed by contract entered into by competitive bids unless another method is mutually deemed to be in the public interest. No construction shall be undertaken on any Forest Highway project until plans, specifications and estimates have been concurred with by the County and FS, and approved by FHWA.

Compliance with Federal-aid Procedures. Projects or phases of projects administered by the County will be developed in accordance with applicable Federal-aid procedures, including appropriate environmental procedures as set out in Title 23. Projects or phases of projects administered by FHWA will be developed in accordance with 23 CFR Parts 660 and 771.

Rights-of-Way and Utilities. The County or their agent in the name of the County will acquire right-of-way or other interests in property needed for a project. The cost of such right-of-way or other interest in property will be at the County's expense unless otherwise provided in the project agreement. Federal-aid procedures (23 CFR Part 710) shall be used for rights-of-way acquisition.

FHWA will cooperate in the procurement of rights-of-way over or upon Federal lands or other lands under the jurisdiction of the United States government that is required for any project and will furnish the County copies of survey notes, maps and other records unless otherwise provided for in a project agreement.

Pending the execution and recording of deeds or other instruments for the rights-of-way over private lands, the County shall obtain right-of-entry thereon for construction purposes. Utilities that are located within the construction limits of the proposed rights-of-way shall be relocated at the expense of the County prior to awarding the construction contract. Utilities may be accommodated on the rights-of-way when such utilities do not interfere with the free and safe flow of traffic or otherwise impair the highway or its visual quality.

Maintenance. After construction of Forest Highway projects, the County agrees to operate and maintain the highway at the County's expense. Maintenance is the preservation of the entire highway, including surface, shoulders, roadside, structures and such traffic-control devices as are necessary for its safe and efficient utilization.

During construction, the contractor shall bear all expense of maintaining traffic over the project other than during the period of winter suspension. If the facility is to remain open for public use during the winter suspension, the County agrees to provide routine maintenance, including all snow removal, as necessary.

A Forest Highway project shall be accepted by the County for operation and maintenance when all construction work has been completed in substantial conformity with the approved plans and specifications, and the project has been inspected by the County, FS and FHWA.

Exhibit 2.4–B SAMPLE FOREST HIGHWAY AGREEMENT WITH A COUNTY
(Continued)

Amendments to Forest Highway Agreements. This Forest Highway Agreement may be modified by mutual agreement of the parties. Either party may prepare a modification by giving notification at least 60 days in advance of the proposed effective date of the modification.

This agreement shall be effective as of the ______________ day of ______________, and shall supersede all prior existing cooperative agreements for the same routes entered into pursuant to 23 USC §204 and 23 CFR Part 660, Subpart A except those involving a commitment of funds or arrangement for the performance of the construction work on projects underway but not yet completed and final settlement made.

__________ County, ________________

By: ______________________________

Title: ______________________________

By: ______________________________

Title: ______________________________

By: ______________________________

Title: ______________________________

Department of Transportation
Federal Highway Administration
_______ Federal Lands Highway Division

By: ______________________________

Title: Division Engineer

Exhibit 2.4–C SAMPLE PROJECT AGREEMENT

US DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

FOREST HIGHWAY PROJECT AGREEMENT

State: *Colorado* Forest: *Flatland*

County: *Clark* Forest Highway Route No.: *FH Route 75, Glasgow to Opheim*

Project No.: *FH75-2(1)* Project Length (mi [km]): *1.3+ [2.1+]* Terrain: *Mountainous*

This Agreement is entered into between the undersigned parties pursuant to the provision of 23 USC 204, and the Forest Highway regulations issued thereunder jointly by the Secretary of Transportation and the Secretary of Agriculture, and in accordance with the terms of the Forest Highway Agreement dated July 14, 1988.

Project Location. The bridge over Willow Creek located about 5 miles southwest of Opheim, Colorado, on Clark County Route No. 236.

Description of Work. The replacement of Willow Creek Bridge and reconstruction of the approaches.

Funding. The cost of preliminary engineering, construction engineering and physical construction will be the responsibility of the Federal Highway Administration (FHWA). The cost of rights-of-way, utility relocation and maintenance after completion of the project will be the responsibility of Clark County.

Responsibility for the Survey, Design and Construction. FHWA will administer the survey, design and construction as stipulated in the Forest Highway Agreement. Additionally, FHWA will obtain all the necessary environmental clearances, Section 404 fill permits, materials source permits and other Federal or State required permits.

Design Standards. The project will be designed in accordance with the AASHTO *Policy on Geometric Design of Highways and Streets*, 2000 edition.

Structures will be designed in accordance with the AASHTO *Standard Specifications for Highway Bridges*, 15th Edition, 1982, as supplemented.

The following general criteria will be applied for this project:

Design speed: 35 mph [50 km/h] Roadway surface: Asphalt concrete

Design volume: Less than 400 ADT Roadway width: 24 ft [7.3 m]

Design loading: HS-20 [MS-18] Bridge width: 28 ft [8.5 m]

Rights-of-Way. The County or their agent in the name of the County will acquire rights-of-way needed for this project.

Exhibit 2.4–C SAMPLE PROJECT AGREEMENT
(Continued)

FHWA will prepare rights-of-way plans and legal descriptions of the necessary property needed for the project.

Pending the execution and recording of deeds or other instruments for the rights-of-way over private lands, the County shall obtain right-of-entry thereon for construction purposes.

Utility Relocation. Utilities that are located within the construction limits of the proposed rights-of-way shall be relocated at the expense of the County prior to awarding the construction contract. Utilities may be accommodated on the rights-of-way when such utilities do not interfere with the free and safe flow of traffic or otherwise impair the highway or its visual quality.

Construction. As soon as practical after the plans are complete and as soon as funds are available, FHWA will either advertise for or negotiate with a contractor to construct the project in accordance with the *Federal Acquisition Regulations* (48 CFR 1) and the *Transportation Acquisition Regulations* (48 CFR 12). During the construction phase, FHWA will provide a project engineer to oversee and inspect the work to assure a quality product. The construction will be governed by the plans supported by the *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects* (FP-03). The project engineer is the designated FHWA contact for the County and the Forest Service during the construction phase.

Maintenance. After construction, the County shall operate and maintain the highway at the County's expense. Maintenance is the preservation of the entire highway, including surface, shoulders, roadside, structures and such traffic control devices as are necessary for its safe and efficient utilization.

During construction, the contractor shall bear all expense of maintaining traffic over the project other than during the period of winter suspension. If the facility is to remain open for public use during the winter suspension, the County shall provide routine maintenance, including all snow removal, as necessary.

Amendments to the Project Agreement. This Project Agreement may be modified by mutual agreement of the parties. This Agreement shall be effective as of the 30th day of September, 2006.

__Clark____ County, __Colorado______	Department of Transportation Federal Highway Administration _Central__ Federal Lands Highway Division
By: ____________________	By: ____________________
Title: ____________________	Title: ____________________
By: ____________________	DEPARTMENT OF AGRICULTURE FOREST SERVICE
Title: ____________________	ROCKY MOUNTAIN REGION
By: ____________________	By: ____________________
Title: ____________________	Title: __Regional Engineer________

2.5 PLANNING STUDIES AND REPORTS

Complete, concise and accurate data are needed for informed and judicious decisions on needs, priorities and costs of projects. Continuous application of such data during the project life cycle is described as Asset Management.

FLH and owner agencies conduct studies to assist in the transportation planning, programming and project development process. These include corridor studies, project scoping investigation and assessment, special technical studies, road and bridge inventories, unit-wide transportation planning studies, and unit-wide engineering studies. Such studies help to identify needs, costs and alternatives. In addition, they help to establish relative priorities for improvements.

The technical issues evaluated in corridor studies, and project scoping studies are outlined in Section 4.5. Special technical studies are evaluations of specific engineering problems and are usually conducted by the appropriate engineering staff specialist. Examples of these types of studies are referenced in the individual *PDDM* chapters devoted to specific technical disciplines.

The Road Inventory Program (RIP) and Bridge Inspection Program (BIP) consist of periodic rating and assessment of the condition of roads and bridges for the NPS, USFWS and FS. The RIP covers all roads under the jurisdictions of the NPS and USFWS, and is undertaken on a three-year cycle for paved roads in most Parks and Refuges. The Forest Highway system is a more complex system comprised mostly of state and county roads. Only a small portion of the system is owned and maintained by the FS. Therefore, the FLH Divisions use RIP data received from states and local agencies to the extent possible. Generally, the Divisions will supplement this data by collecting additional data, as needed. For example, the Eastern Federal Lands Highway Division collects additional RIP data for the FS in the Eastern United States.

A BIP is required for all bridges open to public traffic, and the inspection program conducted by the FLH Divisions covers all bridges and tunnels on roads under the jurisdiction of the NPS. Bridges are inspected on a two-year cycle. The inspections are used to monitor and identify structural conditions that may lead to bridge failure, as well as identify on-going maintenance requirements.

Unit-wide transportation planning studies are conducted to identify future transportation needs as a result of regional/local growth and transportation activities in the vicinity of the unit under study. Transportation planning studies result in short and long-term recommendations for improvements. They provide valuable information that may be incorporated into NPS Park General Management Plans, USFWS Refuge Comprehensive Conservation Plans, or FS Forest Plans as their transportation component. Transportation planning studies go beyond the scope of work for engineering studies and investigate a wide range of elements involved in shaping the future pattern of transportation activities within the unit under study such as regional/local employment, land use, environmental issues, and socio-economic characteristics of the population. These studies should be carefully coordinated with the local community, including the Metropolitan Planning Organization (MPO) in an urbanized area.

Unit-wide engineering studies are investigations, through data collection and evaluation, to identify and assess various alternative courses of action, and make pre-design recommendations to restore, resurface, rehabilitate or reconstruct roads and bridges with the most reasonable and cost-effective design. In certain cases, these studies may involve the development of alternatives for transit, operational improvements, Intelligent Transportation Systems (ITS) applications, or similar types of projects to address congestion and mobility needs.

These studies provide preliminary information for preparing long-range plans and programs, and for undertaking project design or development activities. They are intended to provide direction and scope for evaluating alternative courses of action for proposed improvements identified in RIP/BIP or transportation planning. The types of engineering studies to be conducted are typically completed at the request of the Federal land management agency when significant road construction or transportation system improvements are anticipated.

Such studies can include, but are not limited to, the following:

- Unit-wide road engineering studies,
- Unit-wide alternative transportation system studies,
- Project planning studies, and
- Travel forecasting and analysis.

Supplemental or special engineering studies may also be needed for traffic engineering, traffic safety, geotechnical evaluations, pavement design and similar activities.

Typically, these studies examine a range of alternatives, identify needs, evaluate costs and set priorities for implementation of a transportation improvement program. The selection process should consider those studies that identify, evaluate and compare impacts of each alternative; address safety issues; establish design flexibility; define commitments to protect and preserve the environment; and provide long-term planning guidance.

There is an ongoing effort to link this phase of the planning process with the NEPA phase of project development to provide an opportunity for the public and other agencies to be involved in the discussion and evaluation of issues earlier in the planning process. Detailed project-level alternatives analysis and decision-making are done later during the NEPA compliance phase of project development. (See Chapter 3 for more information.)

The scope and extent of the data gathering, analysis and reporting will vary for each study. Engineering studies should be in sufficient detail to support alternative engineering solutions, estimates and schedules. A preferred recommended alternative should be identified. These studies may incorporate extensive engineering, economic, traffic and environmental data collection and analysis to support the resulting recommendations

Engineering studies are used for budgeting and programming purposes to form the basis for initial cost estimates. In most instances, further in-depth field investigations and engineering analyses will be required during the design scoping stage.

A diligent effort should be made to complete these types of studies at the earliest possible time to assist in developing a program of projects. Coordination is needed to ensure that decisions and tasks accomplished in the engineering studies will be compatible with owner-agency management plans and transportation system requirements. Proper timing of these studies is critical to the support of further engineering and design activities.

2.5.1 PARK ROADS AND PARKWAYS (PRP) STUDIES

There are a variety of studies performed under the PRP program.

1. **Road Inventory Program (RIP)**. An inventory and condition rating has been completed on all NPS roads and is now being maintained by the EFLHD. During the initial RIP, the entire paved PRP system was photo logged and roadway data collected. Subsequent digital photo logging and data collection are now being done during inventory update cycles. A RIP report is available for each of the National Park Service (NPS) units both in hardcopy and web-based formats.
2. **Bridge Inspection Program (BIP)**. FLH has inventoried and rated all NPS bridges and tunnels. A biannual inspection is conducted as part of the national BIP. A BIP report is available for all NPS bridges and tunnels from the FLH BIP Coordinator.
3. **Parkwide Road Engineering Studies (PRES)**. PRES are complete evaluations of parkwide road systems for individual park units. The studies include evaluations of the condition, safety and signing of a park's road system with a recommended program for upgrading deficiencies.

   The PRES evaluations and recommendations are used by the NPS when considering the overall goals and objectives of a park's General Management Plan (GMP) relative to the park road system.
4. **Road System Evaluation Reports**. These reports are evaluations of the existing roadways conducted by the NPS. The reports make recommendations for needed maintenance, rehabilitation or reconstruction.
5. **Safety and Traffic Crash Studies**. These NPS studies evaluate the safety aspects of a park transportation system and evaluate crash data. Safety improvements are recommended when needed.

   To support these studies, NPS has developed a system-wide traffic counting program and a Service-wide Traffic Accident Reporting System (STARS). This data is collected by the NPS Denver Service Center transportation staff, and is available for input into NPS and FLH Division project planning and development.

2.5.2 FOREST HIGHWAY (FH) STUDIES

Inventories are conducted on all FH routes as directed by FLH Headquarters. The information collected includes average daily traffic, Forest Service (FS) related traffic, physical data and estimated cost of improvements. This data is maintained in various formats and varies among FLH Divisions.

2.5.3 IRR STUDIES

Inventory and condition ratings are continuously being updated by the Tribes and BIA and are kept and maintained by the BIA Division of Transportation.

2.5.4 REFUGE ROAD STUDIES

Inventory and condition rating information has been collected on Refuge Roads and is now being maintained by the Central Federal Lands Highway Division. The data is updated and maintained by FLH based on a RIP cycle agreed upon with the USFWS.

2.5.5 OTHER STUDIES

FLH conducts special engineering studies for other agencies as requested (e.g., the defense access roads studies). Other corridor and engineering studies are discussed in Section 4.10.1.

2.6 PROJECT IDENTIFICATION

Formal fiscal procedures have been developed for allocating funds, establishing accounts and account numbers, recording obligations, producing project cost reports and closing out project accounts. Procedures have also been adopted for using a standardized project numbering system.

2.6.1 PROJECT NUMBERING SYSTEM

The use of a formal numbering system assists in tracking and identifying the type, location and source of funding for a particular project.

A uniform project numbering system has been adopted for projects being administered by FLH. See Exhibit 2.6-A.

Project reports (e.g., the Advertise and Award Schedule) that contain the following information should be submitted in all uppercase letters using the following format to permit FLH-wide compilation of data:

1. **Project Number and Common Name**. For example, PRA BIBE 15(5), ROSS MAXWELL ROAD.
2. **State**. Use uppercase two-letter designation. If multiple States, list the one within which the greatest proportion of the work occurs.
3. **Description**. Begin with work category (see Exhibit 2.6-B for examples), then list length or Number of Bridges if a Bridge project and, finally, list major items of work. For example, REC, 1.2 KM, GR, DR, BS, PAVE.
4. **Engineers Estimate**. Include estimated incentives.
5. **Date Planned/Actually Advertised**. Use actual date, not an estimated quarter.
6. **Set Asides**. Use an X under each category heading, SB, LS, 8a.
7. **Date Planned/Actually Awarded**. Use actual date, not an estimated quarter.
8. **Award Amount**. Include obligated incentives.
9. **Number of Bids Received**. Include only the number of responsive bids.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

Exhibit 2.6-A PROJECT IDENTIFICATION NUMBERS

Source of Funding	Preferred Prefix[10]	Route Number	Section or Sequence Number
FLHP/Highway Trust Funded			
Park Roads and Parkways[1]	PRA	See Note 2	See Note 6
Forest Highway	PFH	See Note 3	
Indian Reservations Roads	IRR	See Note 4	
Refuge Roads	RRP	See Note 4	
Public Lands Highways[7]	PLH	See Note 4	
Emergency Relief for Federally Owned Roads[8]	ERFO	See Note 4	
Allocations/Transfer (Other Federal Agencies)			
National Park Service[1]	NPS	See Note 2	See Note 6
Forest Service	FS	See Note 4	
Bureau of Indian Affairs	BIA	See Note 4	
Fish and Wildlife Service	FWS	See Note 4	
Bureau of Land Management[9]	BLM	See Note 5	
Department of Army	AAD	See Note 5	
Department of Navy	NAD	See Note 5	
Department of Air Force	RAD	See Note 5	
Department of Air Force (O&M)	OMAD	See Note 5	

Notes:

1. On park road projects, use official NPS Park Abbreviations (see Planning and Coordination Unit).
2. Use road inventory route number.
3. Use designated FH route number.
4. Use official system route number.
5. Headquarters, HFPD-8, coordinates route and section number.
6. Section and sequence numbers as agreed upon with appropriate Federal or State agency.
7. State Highway Agency may designate route number.
8. Project number may need coordination with appropriate Federal-aid Division.
9. Bureau of Land Management will generally provide the numbers.
10. Other prefixes may be warranted for special legislative requirements.

Exhibit 2.6-B WORK DESCRIPTIONS

Work Description	**Abbreviation**
Work Category	
New	NEW
Reconstruction	4R
Rehabilitation	3R
Bridge	BR
Major Items of Work	
Grading	GR
Drainage	DR
Base	BS
Graveling	GRVL
Paving	PAVE
Bituminous Surface Treatment	BST
Slide Repair	SLIDE REP
Bridge	BR

2.6.2 ACCOUNTING PROCEDURES

Reserved

Chapter 3 – ENVIRONMENTAL STEWARDSHIP

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CHAPTER 3

ENVIRONMENTAL STEWARDSHIP

3.1 INTRODUCTION

A primary goal of the Federal Lands Highway (FLH) Program is to provide environmental stewardship while designing safe highways and roads to serve our nation's Federal lands. This chapter discusses how to achieve that goal and provides information on the environmental role of the Federal Highway Administration (FHWA), guidance on environmental issues and a description of the environmental compliance process for use in carrying out highway and bridge design responsibilities. Implementing the approaches outlined in this chapter for environmental stewardship and regulatory compliance will promote consistency among the FLH programs and throughout the large geographical area served by these programs.

There is an important link between Chapters 2 and 3. Chapter 2 "Planning and Programming" introduces the various types of roads, programs, agreements, agencies, studies and reports involved in the planning and programming process. During planning, the functional, structural or safety deficiencies of Federal lands roads are identified, the project purpose is developed, cost estimates are prepared and the preliminary delivery schedules are proposed. Then the projects are programmed or approved for development by the FLH and the partner agencies. Planning and programming are parts of a large-scale decision-making process involving multiple agencies, planning studies and reports. Environmental requirements and considerations can affect the feasibility of projects in the planning and programming process by influencing scope, schedule and budget. Similarly, the project purpose and need developed during the planning and programming process defines the range of required environmental activities to be implemented during the project development process to ensure regulatory compliance and timely project construction.

Chapter 3 is also linked to Chapter 4 "Conceptual Studies and Preliminary Design." The environmental process discussed in Chapter 3 is conducted concurrently with the conceptual studies and preliminary design. Given that the information provided in the conceptual studies and preliminary design informs the decisions made in the environmental process, the formal project development process begins with the conceptual studies and preliminary design phase. Close coordination with the resource and regulatory agencies and the public is important to ensure that the range of improvement alternatives is established in recognition of overall environmental factors. This allows for an orderly and complete evaluation when determining the preferred alternative. A preferred alternative is selected after the range of improvement alternatives have been evaluated in the environmental documents, and by the resource and regulatory agencies and the public. At the conclusion of the conceptual studies and preliminary design phase, a decision should be made identifying the alternative selected for advancement into the design phase.

The sections below present the purpose and objectives of this chapter, its applicability to FLH projects and the organization of the remainder of the chapter.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

3.1.1 PURPOSE

The purpose of this chapter is threefold:

1. To provide guidance on FHWA's environmental role in delivery of FLH projects and to explain how FHWA's role is different for each program, and may even vary among projects within the same program.
2. To provide guidance on identifying and addressing environmental issues. The chapter discusses FHWA responsibilities under the *National Environmental Policy Act* (NEPA) and other environmental requirements that may be applicable to FLH projects.
3. To describe the environmental compliance process for those projects where the FHWA is designated as the lead agency.

3.1.2 APPLICABILITY TO FEDERAL LANDS HIGHWAY PROJECTS

This chapter applies to actions or projects carried out under programs administered by the FLH Divisions (i.e., Central, Eastern, Western), including the Forest Highway Program, the Park Roads and Parkways Program and the Refuge Road Program, among others. These programs are administered in accordance with agreements established between the FHWA and the appropriate partner agencies (e.g., the U.S. Forest Service (FS), the National Park Service (NPS), and the US Fish and Wildlife Service (FWS)).

The respective agreements are listed and accessible for viewing on the Electronic Centralized Agreement Library (E-CAL). E-CAL also provides a summary of each agreement's purpose, the FHWA offices and non-FHWA parties involved, and financial requirements.

3.1.3 ORGANIZATION

The remainder of this chapter is organized as follows:

- **Section 3.2 – Responsibilities by Program** summarizes the roles of lead agencies, cooperating agencies and interagency/interdisciplinary teams; describes the agency's environmental responsibilities under existing program agreements; and identifies other agreements with Federal agencies in which the FLH has an environmental responsibility.
- **Section 3.3 – Laws, Regulations, Policies, Guidance and Permits** summarizes the major laws and implementing regulations that govern agency projects and actions. Resource-specific environmental issues that should be considered in the NEPA process are also discussed. The FHWA policies and a summary of available guidance covering a broad range of issues are included. Finally, the permits typically required for FLH projects are identified.

- Section 3.4 – **Environmental Process** describes the elements depicted in the environmental process flowchart:
  - ◊ Planning and Programming,
  - ◊ Project Development,
  - ◊ Advertising and Award,
  - ◊ Construction, and
  - ◊ Evaluation.

  This section also defines the goal of environmental streamlining and the methods used to accomplish this goal.

- Section 3.5 – **NEPA Documentation** describes the NEPA class of action system and provides NEPA document standards, guidance on preparation of each type of NEPA document, including sample outlines, checklists and timelines and a table showing the steps for obtaining internal document approvals (and delegation of authority).
- Section 3.6 – **Tracking and Reporting** describes the *environmental document tracking system* (EDTS) and associated requirements, including the FHWA Headquarters requirement for annual reporting of wetland impacts and mitigation ratios, and provides guidance for using the tracking system.
- Appendix 3A.1 – **Law, Regulations, Policies, Guidance and Permits** provides links to guidance material on State departments of transportation and other agency websites.
- Appendix 3A.2 – **NEPA Documentation** provides links to guidance material related to NEPA documentation.

3.1.4 REVISIONS

This chapter is a working document that will be revised in response to changes in laws, regulations, policies or guidance on an as-needed basis. Chapter 3 is maintained and updated by the FLH Environment Team, which includes the environment team leader and environment senior technical specialist from each division, as well as the FLH environment discipline leader.

The revision process for updating information in this manual is described in Section 1.1.5.

3.2 RESPONSIBILITIES BY PROGRAM

The FLH Divisions coordinate numerous programs with Federal Land Management Agencies (FLMAs), also referred to as the partner agencies. The FLH environmental role varies for each program. The FLH Division may serve as the NEPA lead agency, a NEPA joint lead agency, a NEPA cooperating agency and/or a member of a NEPA interagency/interdisciplinary team.

These environmental roles of the FLH Divisions are described in the first part of this section. Next, the specific programs administered by the FLH Divisions are identified and the NEPA compliance procedures and environmental role for each of those programs are described. Finally, agreements with other Federal agencies where FLH has a NEPA or environmental role are identified and described.

3.2.1 GENERAL ENVIRONMENTAL COMPLIANCE RESPONSIBILITIES

This section provides general definitions of the lead agency, joint lead agency, cooperating agency and interagency/interdisciplinary team and their roles. The responsibilities assigned under these different roles are intended to help streamline the environmental process by fostering close coordination among the partner, resource and regulatory agencies; encouraging the integration of NEPA requirements with other Federal environmental review and consultation processes; eliminating duplication in Federal, State and local procedures; and ultimately arriving at environmentally responsible transportation decisions.

The Council on Environmental Quality (CEQ) regulations (40 CFR 1500 -1508) introduce the concepts of *lead agency* (Section 1501.5) and *cooperating agency* (Section 1501.6). The *lead agency* determines the project's purpose and need, prepares the environmental documentation and is responsible for ensuring that NEPA requirements and other environmental requirements are met. Under NEPA, a *cooperating agency* has a jurisdictional authority or special expertise related to the project, although the agency's level of involvement varies with the project. *The Forty Most Asked Questions Concerning CEQ's NEPA Regulations* also provides guidance on the roles of lead and cooperating agencies. The roles of lead, joint lead and cooperating agencies are further discussed below.

3.2.1.1 Lead Agency

In accordance with CEQ and FHWA regulations and guidance, the lead agency determines the NEPA class of action and the purpose and need for the project, and is responsible for ensuring that NEPA requirements and other environmental requirements are met. Generally, the lead agency is the agency providing the primary funding for the project, the agency with project approval or disapproval authority, or the agency with the most expertise concerning the project and its environmental effects.

The lead agency is typically determined through the program agreements that cover the standard procedures for coordinating FLH programs, described in Section 3.2.2. If a program agreement does not specify lead agency roles, the lead agency is identified during development of the project-specific agreement, described in Section 3.2.3.1.

When acting as lead Federal agency in the NEPA process, the FLH Division is responsible for establishing the scope of the environmental review, inviting cooperating agencies to participate, seeking consensus among stakeholders with diverse interests, resolving conflicts and ensuring that high-quality transportation decisions are fully explained in the environmental document. The environmental process in which FLH serves as the lead agency is outlined in Section 3.4.2.

Section 6002 of the Safe, Accountable, Flexible, & Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) strengthens the management role of the FHWA during the environmental review process for projects, asserting that the FHWA is responsible for the overall direction of the process and for expediting the delivery of transportation projects. The statute also requires the FHWA to assume a lead agency or joint lead agency role for all EIS projects funded by the Highway Trust Fund and requiring U.S. Department of Transportation (USDOT) approval. Section 6002 also asserts that lead agencies must proactively identify and involve participating agencies; must provide opportunities for the involvement of participating agencies and the public; must consider input provided by these groups in developing the project purpose and need and in determining the range of alternatives; must collaborate with participating agencies in determining the level of detail and methods for the analysis of alternatives; and must also provide increased oversight in managing the process and resolving issues. Additional information is provided in the SAFETEA-LU Environmental Review Process Final Guidance.

The FHWA implementing regulations provide guidance on the lead agency role in developing the NEPA documentation. Guidance on the appropriate exercise of authority by lead, joint lead and cooperating agencies in determining the project's purpose and need is provided by the CEQ. Additional sources of information are provided in the FHWA *Environmental Guidebook*.

3.2.1.2 Joint Lead Agency

In accordance with Section 1501.5(b) of the CEQ regulations, Federal, State or local agencies, including at least one Federal agency, may act as joint lead agencies to prepare an EIS. The responsibilities of a joint lead agency are the same as those for the single lead agency, although a joint lead agency needs to exercise more sensitivity by following a process and producing a NEPA document that meets the requirements of all lead Federal agencies.

3.2.1.3 Cooperating Agency

Under NEPA, a cooperating agency is an agency with jurisdiction by law or special expertise associated with a proposed project. The agency might own needed property, issue required permits or have special expertise or interest in an affected element of the environment. The cooperating agency's level of involvement varies with the project.

Cooperating agencies are typically identified when an EIS is prepared, although they can also contribute to the preparation of environmental assessments (EAs) as well. The primary purpose of identifying cooperating agencies is to begin agency coordination early in the NEPA process. Therefore, cooperating agencies should be invited as early in the process as feasible, which is typically during the environmental scoping activity of the project development phase. See Exhibit 3.4–A.

The participation of cooperating agencies should begin early in the project development process and continue throughout development of environmental documentation. The intent of this participation is to assist in identifying potential environmental impacts, alternatives, mitigating measures and required permits. Cooperating agencies review and comment formally or informally on EAs and EISs. They may also prepare special studies or share in the cost of the environmental documentation. Cooperating agencies may include Federal and State resource agencies and local and tribal governments.

The CEQ regulations provide guidance on selecting the cooperating agencies for a project and determining their respective roles. The policy on cooperating agency involvement is described in *Guidance on Cooperating Agencies*, FHWA Memorandum, March 19, 1992.

The *CEQ Memorandum for the Heads of Federal Agencies Regarding Cooperating Agencies in Implementing the Procedural Requirements of NEPA*, January 30, 2002 provides guidance on the importance of involvement by cooperating agencies.

The *CEQ Memorandum for Heads of Federal Agencies: Designation of Non-Federal Agencies to Be Cooperating Agencies in Implementing the Procedural Requirements of NEPA*, 28 July 1999, urges agencies to more actively solicit the participation of State, Tribal and local governments as cooperating agencies in implementing the EIS process under NEPA.

In some instances, FLH may serve as a cooperating agency rather than as lead agency, as defined in specific program agreements. For example, in the Park Roads and Parkways Program (one of the major FLH programs), FLH will typically serves the role of cooperating agency. For EIS projects, FLH is required to serve as lead agency. See Section 3.2.1.1.

No specific guidance is available regarding the roles and responsibilities of FLH as a cooperating agency. Typically, the expectations of the cooperating agency are stated in the project-specific agreements as described in Section 3.2.3.1 or in the invitation letter sent by the lead agency.

Cooperating agencies may adopt the EA or EIS to satisfy their NEPA responsibilities. The CEQ regulations provide guidance on adopting NEPA documents. The FHWA implementing regulations (23 CFR 771.121) also provide guidance on adopting NEPA documents.

3.2.1.4 Interagency/Interdisciplinary Team

For all projects that require the FLH Division to serve as the lead agency, an interagency/interdisciplinary team (referred to here as the project team) is established to guide project development activities and ensure that all environmental resources and concerns are identified and addressed. The project team is also a decision-making body that acts on behalf of the agencies to coordinate and share project-level activities and reach consensus on major project decisions. This team is composed of representatives of the partner agencies, which are:

- The affected FLMA,
- The State departments of transportation,
- The county (if any portion of the road is under county jurisdiction), and
- A representative of the FLH Division (with support from other agencies as needed).

To establish the team, the partnering agencies are requested to designate a member who can address the primary issues that the project will encounter and participate in project level decisions concerning transportation issues, alternative development and environmental impacts. The ideal team includes representation from multiple disciplines so all environmental and engineering elements receive balanced consideration.

The project team performs the following activities:

- Assists environmental planning and engineering offices in coordinating major proposals during conceptual studies and preliminary design;
- Acts as a steering team for project development activities (e.g., public involvement events, field and office reviews, interagency meeting);
- Correlates the expected project impacts and engineering needs; and
- Represents and advises its agency of any consequences of alternative highway locations and designs.

The project team members have authority to do the following:

- Make commitments concerning alternatives, and
- Call on needed and available disciplines within their respective agencies.

3.2.2 PROGRAM-SPECIFIC ENVIRONMENTAL COMPLIANCE RESPONSIBILITIES

FLH administers a number of programs through which it designs and constructs roads for other Federal agencies. See a brief description of these programs and partner agencies.

The primary programs administered by the FLH Divisions include:

- The Forest Highway Program,
- The Park Roads and Parkways Program, and
- The Refuge Road Program.

Interagency agreements have been developed between the FHWA and the partner agencies for these programs. These agreements cover the standard procedures for coordinating the respective programs. Agreements for these and other FLH programs are accessible through the Electronic Centralized Agreement Library (E-CAL).

3.2.2.1 Forest Highway Program

3.2.2.1.1 Participating Agencies

The Forest Highway Program is delivered in partnership with the Forest Service (FS).

3.2.2.1.2 Existing Agreements

The *Memorandum of Understanding Related to Forest Highways over National Forest Lands*, May 11, 1981, established procedures between the FHWA and the FS for coordinating the planning, reconnaissance, location, design, construction and signing as well as consideration of social, economic and environmental effects related to forest highway use and occupancy of national forest lands.

The May 11, 1981 memorandum of understanding (MOU) was supplemented by the *Memorandum of Understanding between United States Department of Agriculture, Forest Service and United States Department of Transportation, Federal Highway Administration, Regarding the Appropriation and Transfer of National Forest System Lands for Highway Purposes*, August 20, 1998. This MOU describes the procedures for appropriating and transferring national forest lands to the public road agency for highway rights-of-way, and addresses the issue of NEPA document consistency with forest plans.

3.2.2.1.3 NEPA Roles and Responsibilities

The May 11, 1981 MOU does not directly specify the roles of the FHWA and the FS relative to NEPA documentation. However, FLH typically serves as lead agency with the FS serving as a cooperating agency.

The August 20, 1998 MOU assigns the FLH responsibility for compliance with NEPA and other legal requirements in arriving at its determination that use of FS land is necessary for the project; and the FS acts as a cooperating agency (or in some situations as a joint lead agency) in development of the NEPA document. FLH coordinates with the FS in determining the appropriate environmental analysis.

The August 20, 1998 MOU also discusses the need for consistency with the forest plan, both for projects affecting FS land and for projects requiring a consent to easement. The NEPA document should clearly state this. In rare cases, it may not be possible to satisfy the project purpose and need while maintaining consistency with the forest plan. In this situation, an amendment to the forest plan may be considered.

3.2.2.2 Park Roads and Parkways Program

3.2.2.2.1 Participating Agencies

The Park Roads and Parkways Program is delivered in partnership with the NPS.

3.2.2.2.2 Existing Agreements

The *Interagency Agreement between the National Park Service and the Federal Highway Administration, Relating to Park Roads and Parkways*, May 19, 1983 outlines general responsibilities for each agency in delivery of the Park Roads and Parkways Program. FLH has responsibility for program oversight and provides engineering, planning, design, and construction services. The NPS is responsible for the environmental review process, including protection of park resources.

There are three supplements to the May 19, 1983, interagency agreement:

- The *Memorandum of Understanding between Secretary of Transportation and Secretary of the Interior for Integrated Transportation Planning*, November 25, 1997.
- The *Program Agreement between the National Park Service and the Federal Highway Administration for Highway Safety*, July 7, 1999.
- The *Memorandum of Agreement between Department of Interior, National Park Service and the Department of Transportation, Federal Highway Administration for the President's National Park Service Deferred Maintenance Roads Initiative*, January 2003.

None of these supplements amend the roles or responsibilities of the agencies outlined in the May 19, 1983 interagency agreement. However, the deferred maintenance roads initiative states the following:

> *"NPS will work with the Parks to ensure that the environmental process is completed in a timely manner and that the Parks have identified opportunities to streamline the environmental process."*

3.2.2.2.3 NEPA Roles and Responsibilities

Under this agreement, NPS has primary responsibility for NEPA compliance, including the public involvement process. In most cases, the NPS serves as lead agency and FLH serves as a cooperating agency. For EIS projects, FLH is required to serve as a lead agency. See Section 3.2.1.1.

NEPA roles and other environmental roles of the agencies may be modified in accordance with project-specific agreements described in Section 3.2.3.1.

3.2.2.3 Refuge Road Program

3.2.2.3.1 Participating Agencies

The Refuge Road Program is delivered in partnership with the FWS.

3.2.2.3.2 Existing Agreements

The *Interagency Agreement between the US Fish and Wildlife Service and the Federal Highway Administration Relating to Public Roads on the National Wildlife Refuge System*, April 12, 1999, outlines general responsibilities for each agency in delivery of the Refuge Road Program. FLH has responsibility for program oversight and provides engineering, planning, design, and construction services. The FWS is responsible for the environmental review process, including protection of refuge resources.

3.2.2.3.3 NEPA Roles and Responsibilities

Under this agreement, the FWS has primary responsibility for NEPA compliance, including the public involvement process. In most cases, the FWS serves as the lead agency and the FLH serves as a cooperating agency.

3.2.3 OTHER AGREEMENTS AND PROGRAMS

The FLH may provide project delivery services funded through programs other than those identified above. The most common programs are briefly described in this section. Other agreements that direct the work performed by FLH are also described.

3.2.3.1 Project-Specific Agreements

In addition to the program agreements, any project proposed under the various programs requires a project-specific agreement. These project-specific agreements set forth the roles and responsibilities of each agency in the project and may assign roles differently from the program agreements. The project-specific agreements may also further detail cost-sharing responsibilities, data collection and reporting responsibilities, coordination and correspondence procedures and expectations of the lead and cooperating agencies.

3.2.3.2 United States Coast Guard

The *U.S. Coast Guard (USCG)/FHWA Memorandum of Understanding on Implementing NEPA* (N 6640.22), July 17, 1981, outlines the procedures for strengthening early coordination between the two agencies for environmental review, planning and development of the affected highway section. The memorandum states that when a highway section requires an action by both the FHWA and the USCG, the FHWA normally serves as lead agency for preparing and processing of environmental documents. The primary purpose of the agreement is to facilitate the permitting process for bridges over navigable waters.

3.2.3.3 Emergency Relief for Federally Owned Roads Program

FLH may be asked to provide project delivery services for projects funded through the Emergency Relief of Federally Owned (ERFO) Roads Program. Thorough guidance on the

ERFO program, including general agency roles and responsibilities, is provided in the *Emergency Relief for Federally Owned Roads Disaster Relief Manual*. Project-specific agreements will further define roles and responsibilities.

3.2.3.4 Defense Access Roads Program

FLH may be asked to provide project delivery services for projects funded under the Defense Access Roads (DAR) Program. FLH typically serves as the lead agency. Project-specific agreements will further define roles and responsibilities.

3.2.3.5 Indian Reservation Roads Program

The *Memorandum of Agreement between the Bureau of Indian Affairs and the Federal Highway Administration Relating to Indian Reservation Roads*, May 24, 1983, provides guidance on the Indian Reservation Roads (IRR) Program that is administered by the FLH Headquarters in partnership with the Bureau of Indian Affairs (BIA).

Under the IRR program, the FLH Headquarters reviews and approves a program of projects proposed by the BIA. Based on that program of projects, funds are transferred to the BIA for delivery of projects. All project development work is typically performed by the BIA.

3.3 LAWS, REGULATIONS, POLICIES, GUIDANCE AND PERMITS

This section summarizes the environmental laws and implementing regulations applicable to the development of roadway projects, along with policies and guidance to ensure compliance. Commonly required permits, the issuing agency and the permit process are discussed at the end of this section.

NEPA and its implementing regulations and the associated FHWA policies and guidance are addressed first. Then, the individual environmental resources and associated laws and regulations to be considered during NEPA environmental review are discussed. For each environmental resource, the FHWA policies and guidance are identified.

Sources of additional guidance materials available online from State departments of transportation and resource agencies are provided in Appendix 3A.1.

3.3.1 *NATIONAL ENVIRONMENTAL POLICY ACT* OF 1969 (42 USC 4321; PL 91 90)

The purpose of NEPA is to ensure better decision-making with regard to the implementation of projects that affect the environment by ensuring that agencies consider the potential environmental consequences of their proposals, document their analyses and make this information available to the public for comment prior to project implementation. Section 2 of the statute states that its purposes are to:

> *"Declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality"* (NEPA of 1969, as amended).

For information from States with NEPA-equivalent laws see the CEQ website

3.3.1.1 NEPA Implementing Regulations

Regulations for implementing NEPA in FLH projects are found in the CEQ regulations (40 CFR 1500) and the FHWA implementing regulations (23 CFR 771.109(c)(2)).

3.3.1.1.1 Council on Environmental Quality Regulations

The CEQ regulations (40 CFR 1500 [1978 amended]) set forth the NEPA compliance requirements for all Federal agencies. These requirements address NEPA and agency planning (with sections on lead agency and cooperating agency roles and scoping), the purpose of an EIS, a recommended format, details on the purpose and need statement, development of alternatives, analysis of environmental impacts, and circulation of the document. See the CEQ regulations for an easy-to-use index.

3.3.1.1.2 Environmental Impact and Related Procedures

23 CFR 771 prescribes the FHWA policies and procedures for implementing NEPA and the CEQ regulations for highway and mass transit projects. See the FHWA implementing regulations for an easy-to-use index format.

3.3.1.2 FHWA Environmental Policies

A number of policies have been established to implement the requirements and intent of NEPA, as summarized below.

3.3.1.2.1 FHWA Environmental Policy Statement (FHWA 1990, 1994)

The first Environmental Policy Statement in 1990 affirmed the FHWA commitment to environmental protection and enhancement. These principles, reiterated in the 1994 Environmental Policy Statement, are summarized in the list below:

- Full involvement of our partners;
- Complete integration of environmental concerns;
- Active protection and enhancement of our environment;
- Vigorous research, technology transfer and training; and
- Effective development and promotion of environmental expertise.

3.3.1.2.2 FHWA/Federal Transit Administration Interim Policy Guidance on Public Involvement (FHWA and FTA 1994)

This guidance declares that it is the policy of the FHWA and the Federal Transit Administration (FTA) to aggressively support proactive public involvement at all stages of planning and project development.

3.3.1.2.3 FHWA Vital Few Goals

The FHWA's three vital few goals are safety, environmental streamlining and stewardship, and congestion mitigation. Additional emphasis on environmental streamlining and stewardship is outlined in *Environmental Stewardship and Transportation Infrastructure Project Reviews,* Executive Order 13274 (EO 13274), issued on September 18, 2002.

The environmental streamlining and stewardship goal and EO 13274 set expectations, measures and methods for advancing an improved and efficient environmental review process and for demonstrating environmental stewardship. The success of this goal is focused on improving processes that influence outcomes. The performance objectives for the environmental vital few goal measures process improvements and documents the results of significant stewardship activities.

3.3.1.2.4 Environmental Impact and Related Procedures

Both the FHWA implementing regulations for NEPA (23 CFR 771.105).and the CEQ regulations (Section 1500.2) for highway and urban mass transportation projects include sections titled *Policy*.

3.3.1.2.5 Procedures for Considering Environmental Impacts

DOT Order 5610.ID, dated July 5, 2000, provides instructions for implementing NEPA Section 102(2) and CEQ regulations 40 CFR 1500–1508.

3.3.1.2.6 Other FHWA Guidance

Other FHWA guidance includes:

1. **Technical Advisory T6640.8A, Guidance for Preparing and Processing Environmental and Section 4(f) Documents (FHWA, 1987)**. The stated purpose of Technical Advisory T6640.8A is to provide guidance to field offices and project applicants (i.e., States) on the preparation and processing of Section 4(f) evaluations and other NEPA documents. This technical advisory is one of the primary sources of guidance for agency staff to ensure compliance with NEPA and other environmental regulations.
2. **SAFETEA-LU Environmental Review Process Final Guidance (FHWA 2006)**. The purpose of this guidance is to provide explanations of new and changed aspects of the environmental review process for FHWA practitioners. The guidance informs the reader about what, and how, things need to be done differently for EIS projects as a result of SAFETEA-LU.
3. **Summary of Environmental Legislation Affecting Transportation (FHWA 1998)**. This source provides a matrix of laws, legislative and regulatory references, purpose of each statute, applicability to transportation projects, general procedures and agencies for coordination and consultation. This summary also is useful in identifying the resource surveys required for a proposed action, as discussed in Section 3.4.2.2.1.
4. **The FHWA *Environmental Guidebook***. The FHWA *Environmental Guidebook* provides information on environmental documentation, public involvement, Section 404 permitting under the *Clean Water Act*, and other relevant topics. The guidebook can be searched by subject.
5. **Communities of Practice**. Re: NEPA is the FHWA online "community of practice" supporting an open exchange of experience and information about NEPA, related environmental issues and transportation decision-making. The goal of Re: NEPA is to provide additional opportunities to explore the transportation decision-making process through discussion, research, assistance and education directed toward a streamlined

solution oriented process for balancing transportation needs with the social, economic, cultural and natural environments.

3.3.1.2.7 Program-Specific Guidance

This section provides links to the primary guidance documents used by the partner agencies in complying with the NEPA process. The following information is useful to ensure that the compliance needs of our partners can be addressed concurrently:

1. **Forest Highway Program**. The FS policies and procedures for implementing NEPA are contained in the FS *Environmental Policy and Procedures Manual* (FSM 1950). Detailed procedures for environmental analysis and documentation needed are set forth in the *Environmental Policy and Procedures Handbook* (FSH 1909.15).
2. **Park Roads and Parkways Program**. The policies and procedures by which NPS meets its NEPA requirements are set forth in *Director's Order 12 (DO-12)*, *Handbook for Environmental Impact Analysis*. The DO-12 *Handbook* provides the NPS procedures and requirements for complying with NEPA.
3. **Refuge Road Program**. The FWS and Department of the Interior NEPA guidance and procedures are contained in the *FWS NEPA Reference Handbook*. The *Handbook* provides the full text of various NEPA authorities, selected NEPA-related authorities and NEPA-related checklists. The Handbook includes documents cited in the FWS NEPA guidance, departmental procedures and memorandums.

3.3.2 RESOURCE-SPECIFIC ENVIRONMENTAL CONSIDERATIONS

NEPA serves as the encompassing law under which all other environmental compliance should be performed. The FHWA policy as stated in 23 CFR 771.105(a) is that:

> *(a) To the fullest extent possible, all environmental investigations, reviews and consultations be coordinated as a single process, and compliance with all applicable environmental requirements be reflected in the environmental document required by this regulation.*

NEPA requires that all Federal actions undergo planning to ensure that environmental considerations (e.g., impacts on geology and soils, threatened and endangered species, wetlands) are given due weight in project decision-making (42 USC 4321). In addition to the action itself, all interrelated and interdependent actions should be analyzed, including development of material source sites, use of disposal sites, development of construction staging areas, etc.

For many environmental resources, there are specific laws and processes for compliance. This section lists the environmental resources and associated laws, regulations, policies and guidance that are commonly considered during the NEPA process. After laws, regulations and guidance are briefly addressed for each resource, there is a discussion of requirements for NEPA documentation. A project's potential for impacts on a resource and the potential significance of those impacts determine the NEPA class of action (discussed in Section 3.5.1), and the scope of investigations and documentation for each affected resources. For example, a project that has substantial impacts on various resources may require an EIS supported by technical reports addressing specific environmental resources. Results of the technical studies are summarized in the EIS. In contrast, a project classified as a categorical exclusion (CE), with very limited potential for impacts, is unlikely to require detailed investigations or extensive documentation.

When there are specific NEPA requirements for documentation for a particular environmental resource, the text below includes a summary of the requirements. Links to additional helpful information are located in Appendix 3A.2. Various specific environmental resource technical report requirements are addressed in Section 4.6. Requirements for other technical reports related to engineering that may be consulted during the environmental review process (e.g., hydraulic, geotechnical studies) are found in Chapter 6 and Chapter 7.

Generally, the regulations identified in the *Summary of Environmental Legislation Affecting Transportation* are the basis for the list of laws identified for the environmental resources below. The laws on the list that are not directly applicable to FLH projects are not included.

3.3.2.1 Air Quality

Laws, regulations and policies, as well as relevant guidance and required NEPA documentation pertaining to air quality are summarized below. The primary laws governing activities affecting air quality are the *Clean Air Act* (CAA) of 1970, and the *Clean Air Act Amendments* (CAAA) of 1990. Because these laws are cumbersome, a brief summary is provided in this section explaining how the laws work, important terms and their applicability to transportation projects.

A few common air pollutants are found throughout the United States. These pollutants can impair health, harm the environment and cause property damage. The U.S. Environmental Protection Agency (EPA) calls these pollutants *criteria air pollutants* because the agency has regulated them by first developing health-based criteria (science-based guidelines) as the basis for setting permissible levels. Under the CAA, the EPA sets limits on allowable concentrations of a pollutant in the air anywhere in the United States. One set of limits (primary standard) protects health; another set of limits (secondary standard) is intended to prevent environmental and property damage. A geographic area that meets the primary standard is called an *attainment area*; areas that do not meet the primary standard are called *nonattainment areas*.

Although the CAA is a Federal law covering the entire country, the States do much of the work to carry out this law. The law recognizes that it makes sense for States to take the lead in carrying out the CAA because pollution control problems often require special understanding of local industries, geography, housing patterns and other factors. Therefore, States are required to develop State Implementation Plans (SIPs) that explain how each State will meet its responsibilities under the CAA. A SIP is a collection of the regulations the State uses to clean up air pollution in a nonattainment area.

Transportation conformity, as required by the CAA, ensures that Federally funded or approved transportation plans, programs and projects conform to the air quality objectives established in the SIP. Transportation conformity regulations are developed by the EPA with USDOT input and concurrence. The USDOT (through the FHWA and the FTA) is responsible for implementing the conformity regulation in nonattainment and maintenance areas. The EPA has a consulting role in the analysis and finds that are required. An air quality conformity determination is required for all transportation plans and transportation improvement programs.

3.3.2.1.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the following laws, regulations and policies govern activities affecting air quality.

The CAA was enacted to protect and enhance air quality and to assist State and local governments with air pollution prevention programs (42 USC 7401 et seq.).

The CAAA, the *Intermodal Surface Transportation Efficiency Act* of 1991 (ISTEA) and the *Transportation Equity Act* for the 21st Century (TEA-21) reinforce the close linkage between clean air goals and transportation investments. These statutes also specify requirements that apply to transportation and air quality agencies throughout the United States. A key section of this law relating to conformity is Title I, *Provisions for the Attainment and Maintenance of National Ambient Air Quality Standards (NAAQS)*.

3.3.2.1.2 Guidance

The following guidance is available:

- The *Transportation Conformity Reference Guide* describes the air quality conformity process in a question-and-answer format.
- Multiple sources of guidance on compliance with the CAA for transportation projects are compiled in the FHWA *Environmental Guidebook* and the FHWA Air Quality Program.
- See the FHWA Transportation Conformity Guidance for Qualitative Hot-spot Analysis in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas.
- The EPA provides links to extensive background information on a wide range of air quality topics, including an explanation of how EPA implements the requirements of the CAA in the *Plain English Guide to the Clean Air Act.*
- An air quality issue of rising importance is mobile source air toxics. See FHWA information on Transportation and Toxic Air Pollutants.

Appendix 3A.1.1.1 contains additional links to relevant guidance materials.

For projects sponsored through the Park Roads and Parkways Program, the project must also comply with *Director's Order 77*, *Natural Resource Protection*.

3.3.2.1.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides guidance on the contents of the air quality section in an EIS. Additional guidance is available from the FHWA *Environmental Guidebook* and the guidance document titled *Discussion Paper on the Appropriate Level of Highway Air Quality Analysis for the CE, EA/FONSI, and EIS* (April 7, 1986). Both of these guidance documents are geared toward projects in urban areas; therefore, discretion should be used to determine if the required documentation is necessary for a given project. For projects involving earthwork, the construction impacts section of the NEPA document should identify appropriate best management practices (BMPs) for dust control.

The level of consideration, including analysis and documentation, appropriate for a given project will depend on a number of factors but particularly whether the area is within a designated nonattainment or maintenance area, the nature of the project and the projected traffic growth and characteristics. Exempt projects are considered to have a neutral impact on air quality; these are listed in 40 CFR 93.126.

As stated above, all transportation plans and transportation improvement programs are subject to air quality conformity determinations. The FHWA/FTA joint conformity determination is based on a quantitative demonstration that projected motor vehicle emissions from the planned transportation system do not exceed the motor vehicle emissions budget established in the SIP. If the NEPA process results in a project whose design concept and scope are significantly different from those in the transportation improvement program, then before NEPA process completion, the project should meet the criteria in 40 CFR 93.109–93.119 for projects not from a transportation improvement program.

In carbon monoxide and particulate matter non-attainment and maintenance areas, additional localized or microscale analysis may be necessary to determine project-level conformity for federally funded or approved highway and transit projects. These projects must come from a currently conforming transportation plan and transportation improvement program. This analysis is sometimes called *Hotspot Analysis*. Given the rural locations of most FLH projects, hotspot analysis is rarely required.

3.3.2.2 Coastal Areas and Shorelines

3.3.2.2.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the following laws and regulations govern activities in coastal areas, including coastal zones and coastal barriers:

1. **Coastal Zones**. See the *Coastal Zone Management Act* (CZMA) of 1972 (16 USC 1451). Also, see the implementing regulations, 15 CFR 923-930.

   The CZMA is intended to:

   - Preserve, protect, develop and, where possible, restore or enhance the resources of the nation’s coastal zone for this and succeeding generations.

- Encourage and assist the States to develop coastal zone management programs that provide for the protection of natural resources and the management of coastal development.
- Encourage the preparation of special area management plans, which provide for increased specificity in protecting significant natural resources, reasonable coastal dependent economic growth and improved protection of life and property in hazardous areas.

2. **Coastal Barriers**. See the *Coastal Barrier Resources Act* of 1982 (16 USC 3501).

   Also, see the amendment to the *Coastal Barrier Resources Act*, the *Coastal Barrier Improvement Act* of 1990 (PL 101-591).

   These laws limit Federal subsidies for development within the coastal barrier resources system and currently apply to the Atlantic Coast, Gulf Coast and Great Lakes.

3.3.2.2.2 Guidance

For further information on coastal areas and shorelines, see the following:

1. **Coastal Zones**. The FHWA *Environmental Guidebook* provides links to all of the laws, regulations and policies on coastal zones.
2. **Coastal Barriers**. The FHWA *Environmental Guidebook* provides links to all of the laws, regulations and policies on coastal barriers. The *Guidebook* includes links to FWS guidance to Federal agencies for complying with the *Coastal Barrier Resources Act*, dated October 6, 1983.

Appendix 3A.1.1.2 contains web links to State coastal programs and relevant guidance materials.

3.3.2.2.3 NEPA Documentation Requirements

1. **Coastal Zones**. Generally, regulations associated with coastal zones are implemented at the State level and each State has its own procedures for determining whether a project requires a coastal zone consistency review. Therefore, each State has its own process for complying with the regulations. Therefore, it is important to check with the State in which the specific project is located and follow the appropriate process.

   The NEPA document should identify the required permits and approvals, including permits or determinations needed from State or local jurisdictions. The document should also summarize the coordination efforts with the coastal resource agencies. The FHWA Technical Advisory T6640.8A provides additional guidance on documentation requirements for an EIS relative to coastal zone issues.

2. **Coastal Barriers**. The FHWA Technical Advisory T6640.8A contains guidance on the content requirements for an EIS relative to coastal barriers. If the project is in a coastal barrier unit, the NEPA document (i.e., CE, EA, EIS) should include the results of the consultation process and should summarize the results and findings of the consultation.

3.3.2.3 Earth (Geology and Soils)

3.3.2.3.1 Applicable Laws, Regulations and Policies

Aside from the requirements of NEPA, there are no major laws or regulations that directly govern activities affecting geology and soils.

Soils are often considered a source of pollutants in stormwater runoff at a construction site and are, therefore, regulated through the National Pollutant Discharge Elimination System (NPDES) administered by the EPA as authorized in Section 402 of the *Clean Water Act* (CWA). This program is described in Section 3.3.3.3.

3.3.2.3.2 Guidance

The following guidance is available:

- Description of the EPA stormwater program and permit requirements.
- Permit requirements are described in Section 3.3.3.3.

Appendix 3A.1.1.3 presents additional guidance materials.

For projects sponsored through the Park Roads and Parkways Program, the project must also comply with the *Director's Order 77*, Natural Resource Protection.

3.3.2.3.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides no guidance on addressing geology and soils issues in an EIS. NEPA reporting requirements are a function of the project's NEPA class of action (described in Section 3.5.1) and the potential for significant impacts on geology and soils. Issues related to geology include potential of landslides, erosion/accretion and settlement. In marine areas, marine sediments, shoreline erosion/accretion and geology are primary concerns. The major issue related to soils is erosion. Requirements for geotechnical reports are defined in Chapter 6, and Chapter 4 includes technical report requirements at the conceptual phase. These technical reports provide an excellent starting point for obtaining relevant information to include in the NEPA document.

If a categorical exclusion (CE) is prepared, the project file should note whether any issues of concern relative to geology and soils have been identified for the project area and how these issues are addressed in the roadway design. If an EA or EIS is prepared and the project area is located in a landslide area, the NEPA document should identify if construction activities will affect slope stability. If settlement or slides are an issue for the road surface, the document should identify how the project will address these issues. If the project is in an area where geologic hazards are a concern (e.g., faulting, earthquakes), the document should state that current standard seismic designs would be used for all proposed structures.

The NEPA document should also identify the permits that will be acquired for the project and a list of best management practices to be incorporated during construction to control erosion and contain sediment runoff from the construction site.

The construction impacts section of the EA or EIS should also identify where borrow materials or waste sites will be located in relation to the project and the associated impacts as well as measures to minimize the impacts.

3.3.2.4 Energy

3.3.2.4.1 Applicable Laws, Regulations and Policies

Aside from the requirements of NEPA, there are no specific laws, regulations or policies related to energy.

3.3.2.4.2 Guidance

Appendix 3A.1.1.4 contains additional links to relevant guidance materials.

3.3.2.4.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides limited guidance on analysis of energy issues and gives guidelines for preparing NEPA documents addressing energy.

Documentation related to energy is generally not required for a CE. Typically, energy can be adequately addressed with one or two lines in an EA or EIS as described in the technical advisory. Energy is more likely to be included in an EIS for projects in more urban areas.

3.3.2.5 Farmland

3.3.2.5.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the principal law governing impacts on farmlands is the *Farmland Protection Policy Act* (FPPA) of 1981 (7 USC 4201–4209).

The 1994 amendment to the statute identifies the Natural Resources Conservation Service (NRCS) regulations under the FPPA (7 CFR 658.4), including a scoring system for determining the potential impacts of a project that could hasten the conversion of farmland.

The NRCS responsibilities relative to prime and unique farmlands are described in 7 CFR 657.4.

3.3.2.5.2 Guidance

The following list provides links to guidance on farmlands as well as the NRCS guidance and forms.

- The FHWA *Environmental Guidebook* provides links to the FPPA as well as guidance on implementing the FPPA on highway projects.
- A summary of the Farmland Protection Policy Act and activities subject to the law, as well as the full text of the law and forms and instructions for completing the farmland documentation.

Appendix 3A.1.1.5 contains additional links to relevant guidance materials.

3.3.2.5.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides limited guidance on analysis of farmland resources in an EIS.

For any project using Federal funding, a determination should be made whether Federal farmland will be converted by the project. A farmlands technical report is typically not necessary for a project. Rather, it is more important to document compliance with the FPPA by completing the farmland conversion rating forms and coordinating with the local NRCS office. The NEPA document should identify and take into account adverse effects of the project on the preservation of farmland; consider alternative actions that could lessen adverse effects; and ensure that programs, to the maximum extent practical, are compatible with other local or private policies or programs protecting farmland.

3.3.2.6 Floodplains

3.3.2.6.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, 42 USC 4321, the following laws and regulations govern activities in floodplains.

Floodplain Management (Presidential Executive Order 11988, May 24, 1977) directs Federal agencies to avoid to the extent possible adverse impacts associated with floodplains and to avoid direct or indirect support of floodplain development.

Current FHWA policy, regulations and nonregulatory procedural guidance for floodplains are provided in 23 CFR 650A, titled *Location and Hydraulic Design of Encroachment on Floodplains*.

3.3.2.6.2 Guidance

The following additional guidance is available:

- The FHWA *Environmental Guidebook* provides links to all of the laws, regulations and policies on floodplains.
- For projects sponsored through the Park Roads and Parkways Program, the project must also comply with *Director's Order 77-2*, *Floodplain Management*.

Appendix 3A.1.1.6 contains additional links to relevant guidance materials.

3.3.2.6.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides guidance on the content requirements for an EIS relative to floodplains.

Local, State and Federal water resources and floodplain management agencies should be consulted to determine if the proposed highway action is consistent with existing management programs and to obtain current information on development and proposed actions in the affected watershed. Generally, the information contained in the preliminary hydraulic report (Section 3.3.2.6.4) should be summarized in the NEPA document commensurate with the expected impacts of the project.

If there is regulatory floodway involvement for a CE, then the CE project file should document the project's consistency with EO 11988, and the regulatory floodway and demonstrate coordination with the Federal Emergency Management Agency (FEMA) and local floodway management agencies.

For an EA or EIS, a more detailed summary should be developed and incorporated into the document. The summary should address the following topics as required by EO 11988 and 23 CFR 650A:

- Alternatives to encroachment,
- Risk assessment,
- Impacts (on the floodplain and floodplain values associated with the project), and
- Measures to avoid or minimize floodplain impacts.

If the preferred alternative includes a floodplain encroachment resulting in a significant impact, the final EIS should include an *only practicable alternative finding* required by 23 CFR 650.113. It should be included in a separate subsection titled Only Practicable Alternative Finding and should be supported by the following information:

- The reasons why the proposed action must be located in the floodplain,
- The alternatives considered and why they are not practicable, and
- A statement indicating whether the action conforms to applicable State or local floodplain protection standards.

This finding should also be provided in a *finding of no significant impact* (FONSI) when the preferred alternative includes substantial encroachments on floodplains but overall the natural environment is not significantly affected. The FONSI should also include cost estimates for mitigation measures.

3.3.2.6.4 Hydraulic Report

Title 23 CFR 650A states that a location hydraulic report is required when floodplain encroachments are anticipated. The majority of the information required in this report is likely to be found in the preliminary hydraulic report as described in Chapter 7 Hydrology/Hydraulics. The preliminary hydraulic report should provide sufficient information to make a finding in regard to floodplain encroachment impacts. The terminology of findings varies by State.

3.3.2.7 Hazardous Substances

3.3.2.7.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the following laws, regulations and policies govern hazardous substances.

- The *Resource Conservation and Recovery Act* of 1976 (RCRA) is administered by the EPA. This law requires the treatment, storage and disposal of hazardous waste. The 1984 amendment, Hazardous and Solid Waste Amendments, expanded the initial scope, prohibiting land disposal of certain wastes and creating treatment standards for these wastes.

- The *Comprehensive Environmental Response, Compensation, and Liability Act* of 1980, as amended (CERCLA), also known as the Superfund law, created the legal framework for identifying parties liable for hazardous waste contamination and requiring them to take responsibility for cleanup operations. Under this statute, a person or agency is required to provide notification of releases or potential releases of hazardous materials. This law created the EPA hazard ranking system and the National Priorities List (NPL).

Hazardous substance issues should also be addressed in the context of documentation prepared to comply with the following additional laws:

- *Clean Water Act* (33 USC 1251);
- *Safe Drinking Water Act* (42 USC 300f);
- *Toxic Substances Control Act* (15 USC 2601–2629);
- *Occupational Safety and Health Act* (OSHA); and
- *Clean Air Act* (42 USC 7901).

3.3.2.7.2 Guidance

The following guidance is available on hazardous waste:

- FLH follows the American Society for Testing and Materials (ASTM) standard for environmental site assessments. Practitioners should obtain the ASTM standards.

- Links to numerous guidance documents are available through the FHWA *Environmental Guidebook.*

Appendix 3A.1.1.7 contains additional links to relevant guidance materials.

3.3.2.7.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides limited guidance on analysis of hazardous waste issues.

Documentation requirements for hazardous substance issues are clearly defined in the FHWA *Environmental Guidebook*. This guidance mostly applies to internal recordkeeping but also describes the EA, FONSI and EIS documentation requirements.

At a minimum, the NEPA documentation should state whether the project is near a site on the National Priorities List. In addition, the NEPA document should identify all sites in the project corridor that are listed on the EPA inventory or that have the potential to harbor hazardous substances. When a project will affect lands with the potential to harbor hazardous substances, an appropriate survey should be conducted to confirm the presence or absence of hazardous substances, and the appropriate coordination with resource agency officials should be performed. The results of the survey and resource agency coordination should be summarized in the NEPA document. Assessment of the project corridor for the presence of hazardous sites is also required for CEs, and the results of the survey reports should be stored in the project file.

3.3.2.8 Historic, Cultural and Archaeological Resources (Section 106 Resources)

Although both Section 106 and Section 4(f) provide protection for sites listed on or eligible for the National Register of Historic Places (NRHP), the requirements of each are different and are described separately in this document.

3.3.2.8.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, numerous laws, regulations and policies govern activities affecting cultural, archaeological and historic properties.

The *National Historic Preservation Act* (NHPA) of 1966, as amended (16 USC 470 et seq.), requires Federal agencies to take into account the effects of a project on properties included in or eligible for inclusion in the NRHP. The law also requires Federal agencies to provide the Advisory Council on Historic Preservation (ACHP), a reasonable opportunity to comment on proposed projects. Section 110(f) of the law states that the agency shall, to the maximum extent possible, undertake planning and actions necessary to minimize harm to any national historic landmark.

The implementing regulations of the ACHP, Protection of Historic Properties (36 CFR 800), focus on the process of identifying historic properties and considering options to avoid or minimize adverse effects, including avoidance, rehabilitation, modified use, marketing and relocation.

Cultural, historic and archaeological issues should also be addressed in the context of documentation prepared to comply with the following additional laws:

- *Archaeological Resources Protection Act* of 1979,
- *American Indian Religious Freedom Act* (1978),
- *American Antiquities Act* (1906),
- *Economic Recovery Tax Act* (1981),
- *Native American Graves Protection and Repatriation Act* (1990),
- *Surface Transportation and Uniform Relocation Assistance Act* (1987), and
- Tax Reform Act (1986).

See Appendix 3A.1.1.8 for more information on these laws.

3.3.2.8.2 Guidance

The following guidance on compliance with the requirements of Section 106 is available:

- The FHWA *Environmental Guidebook* includes a section with multiple links to policies and processes.
- The FHWA Historic Preservation Program website has links to laws and additional guidance documents.
- The ACHP website has training materials, guidance for Federal agencies, questions and answers and other documents. The ACHP also provides a flowchart on compliance with Section 106.

Appendix 3A.1.1.8 provides additional guidance materials.

Projects sponsored through the Park Roads and Parkways Program must also comply with the following orders:

- Director's Order 28, *Cultural Resources Management*.
- Director's Order 28A, *Archeology*.

3.3.2.8.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides guidance on analysis of historic and archaeological resources in an EIS document. This guidance is also applicable to EAs. In order to disclose potential impacts related to Section 106, in most instances, it is necessary to prepare a technical report and resource surveys during the conceptual studies and preliminary design phase of the environmental process, so that the Section 106 process and coordination efforts are fully disclosed in the NEPA document.

The Section 106 documents that are required under the *National Historic Preservation Act* also provide the basis for the required assessment of cultural resources, project alternatives and historic property impacts in the NEPA document. For the CE, this documentation should be retained in the project files. For an EA or EIS, the Section 106 concurrence documents, including letters of concurrence and any memorandums of agreement, are often appended to the NEPA document and the results of the coordination with the State Historic Preservation Officer and/or Tribal Historic Preservation Officer are summarized in the document. However, the locations of sites considered eligible for listing should not be revealed if disclosure may cause a significant invasion of privacy, may risk harm to the historic resources or may impede the use of a traditional religious site by practitioners.

3.3.2.9 Land Use

3.3.2.9.1 Applicable Laws, Regulations and Policies

Aside from the requirements of NEPA there are no major laws that govern activities affecting land use. However, 23 USC 109(h), states that disruption of desirable community and regional growth is a major consideration in project decisions.

3.3.2.9.2 Guidance

It is important to review FLMA land use guidelines, forest plans, national park management plans, zoning information, local land use plans and transportation plans. These documents may contain pertinent information about the current and future proposed land use in a project area, and reviewing these plans will help ensure that the proposed project is in compliance with those plans.

Appendix 3A.1.1.9 contains additional links to relevant guidance materials.

3.3.2.9.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides limited guidance on analysis of land use issues in an EIS document.

The guidance contained in the technical advisory is applicable for both EA and EIS projects. Most important, the CE project file, the EA or EIS should state whether or not the alternatives are consistent with the applicable land use and transportation plans for the area. If the project is not consistent with the applicable land use plan, the plan should be amended or the project should be modified. If a community impact assessment report is prepared, the contents should be summarized in the NEPA document.

3.3.2.9.4 Community Impact Assessment

If a transportation project would result in substantial effects on a community and its quality of life, a community impact assessment should be prepared. To address the community's concerns in transportation decision-making, the assessment should include all items of importance to people (e.g., impacts on mobility, safety, employment, relocation, isolation and other community issues).

Community Impact Assessment: A Quick Reference for Transportation, Publication No. FHWA-PD-96-036 (September 1996) is useful guidance for transportation professionals. It identifies basic tools and information sources in parallel with the FHWA/NEPA project development process.

The FHWA and University of Southern Florida Community Impact Assessment website provides a wide range of topics, guidance and case studies.

Appendix 3A.1.1.10 presents links to additional relevant guidance materials.

3.3.2.10 Noise

3.3.2.10.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the following laws, regulations and policies govern activities generating noise.

The *Federal-Aid Highway Act* of 1970 set forth the requirement for highway noise standards.

The *Noise Control Act* of 1972 (42 USC 4901 et seq.) authorizes the establishment of Federal noise emission standards.

The FHWA provides noise standards, policies and procedures that apply to projects within the Federal-aid program.

The need for a noise study should be evaluated on a case-by-case basis. Generally, a noise study is required for a project constructing a roadway in a new location, for a project that significantly changes either the horizontal or vertical alignment of an existing highway or for a project that is expected to generate substantial noise impacts.

3.3.2.10.2 Guidance

Noise issues have received more attention in recent years spurning the development of the following guidance. While these documents provide valuable background on noise issues and the human environment, it should be noted that this guidance typically applies to Federal-aid highway projects in urban settings:

- The FHWA/Department of Transportation – *Highway Traffic Noise in the United States, Problem and Response*.
- Numerous guidance materials are available in the noise section of the FHWA *Environmental Guidebook*.

The updated Traffic Noise Model (TNM) released in April 2004 is an entirely new, state-of-the-art computer program used for predicting noise impacts in the vicinity of highways. It uses advances in personal computer hardware and software to improve upon the accuracy and ease of modeling highway noise, including the design of effective, cost-efficient highway noise barriers.

For projects with low-traffic volumes, the TNM look-up tables may be the only data needed to comply with noise requirements in the NEPA document.

Projects sponsored through the Park Roads and Parkways Program must also comply with Director's Order 47, *Sound Preservation and Noise Management*.

Appendix 3A.1.1.11 provides additional sources for relevant guidance materials.

3.3.2.10.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides guidance on the content requirements of an EIS relative to noise issues.

Noise can be an issue for new roadway projects and for projects in urban areas. FLH projects rarely result in permanent noise impacts; therefore, noise is seldom addressed in the NEPA documentation. A discussion of noise may be pertinent in the construction impacts section of the EA or EIS if the project area includes in-holdings of private lands with permanent residences. Public concerns and comments determine whether to address construction noise issues and mitigation measures in the NEPA document.

3.3.2.11 Property Acquisition and Relocation of Individuals, Farms and Businesses

3.3.2.11.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the following laws, regulations and policies govern activities requiring relocations.

The *Uniform Relocation Assistance and Real Property Acquisition Act* of 1970, amended in 1987, establishes a uniform policy for the fair and equitable treatment of individuals and businesses displaced as a direct result of programs or projects undertaken by a Federal agency or with Federal financial assistance. The primary purpose of this *Act* is to ensure that such persons shall not suffer disproportionate adverse impact as a result of programs and projects designed for the benefit of the public as a whole and to minimize the hardship of displacement.

The FHWA implementing regulations for the *Uniform Relocation Assistance and Real Property Acquisition Act* are contained in 49 CFR 24.

23 USC 109(h) states that injurious displacement of people, businesses or farms is a major consideration in project decisions.

3.3.2.11.2 Guidance

Appendix 3A.1.1.13 provides additional sources of relevant guidance materials.

3.3.2.11.3 NEPA Documentation Requirements

The public services and utilities discussion generally focuses on changes in demand for services and utilities resulting from the proposed project and impacts on the ability of purveyors to provide services or utilities. There may be some overlap in topics covered by pubic services and utilities and the social, economic and relocation portion of the environmental document.

The FHWA Technical Advisory T6640.8A provides guidance on analysis of relocation issues in an EIS. The information identified in this guidance should also be provided for an EA if relocations are an anticipated impact. The level of information in the EA and EIS should be commensurate with the scope of the project and the severity of the impact expected. If relocations are required, the NEPA document should include a statement that acquisition and relocation will be conducted in accordance with the *Uniform Relocation Assistance and Real Property Acquisition Policies Act* of 1970 and that relocation resources are available to all residential and business relocates without discrimination.

Most FLH projects do not result in relocations. Acquisition of lands for highway right-of-way easements should be coordinated with the appropriate land management agency. Coordination efforts should be documented in the CE project file, EA or EIS.

For projects at the EIS level, relocation issues can be addressed in a community impact assessment report. See Section 3.3.2.9.4 for more information.

3.3.2.12 Public Services and Utilities

3.3.2.12.1 Applicable Laws, Regulations and Policies

Aside from the requirements of NEPA, there are no major laws governing activities affecting public services and utilities.

23 CFR 645 describes the implementing regulations for adjustment and relocation of utility facilities on Federal-aid and FLH projects.

23 USC 109(h) states that public services are a major consideration in project decisions.

3.3.2.12.2 Guidance

Appendix 3A.1.1.12 presents additional sources of relevant guidance materials.

3.3.2.12.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides limited guidance on analysis of impacts on public services and utilities in its discussion of social impacts. Public services usually include police, fire, emergency response, etc. Utilities include sewer, water supply and electricity. Within an EA or EIS, the public services and utilities discussion generally focuses on changes in demand for services and utilities resulting from the proposed project and impacts on the ability of purveyors to provide services or utilities. There may be some overlap in topics covered by public services and utilities and the social, economic and relocation portion of the NEPA document. The social analysis in a NEPA document may also address services, but from the perspective of community cohesion (i.e., how the construction of a road would split a community in two, or would affect senior citizen access to an essential facility).

Transportation projects affect public services and utilities primarily during the construction period. Service interruptions (e.g., delays in police, fire, emergency services) and relocation of utility facilities should be disclosed in the CE project file, EA or EIS, along with measures to minimize these impacts, if necessary.

For projects at the EIS level, public service and utility issues can be addressed in a community impact assessment report. See Section 3.3.2.9.4 for more information.

3.3.2.13 Recreation

3.3.2.13.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA (42 USC 4321), the laws and regulations discussed in the following sections govern activities affecting recreational resources.

For many projects, the most significant laws with direct application to FLH projects and recreational resources are Section 4(f) of the *USDOT Act* of 1966 and Section 6(f) of the *Land and Water Conservation Fund Act* of 1965. These laws and associated guidance and NEPA documentation requirements are discussed in Section 3.3.2.14.

The following provides brief descriptions of the recreational programs regulated by NEPA:

1. **Bicycle and Pedestrian Program**. 23 USC 217 authorizes the integration of bicycling and walking into the transportation mainstream. More importantly, it enhances the ability of communities to invest in projects that can improve the safety and practicality of bicycling and walking for everyday travel.
2. **Recreational Trails Program**. The FHWA Recreational Trails Program makes Federal transportation funds available to the States to develop and maintain trail facilities for both nonmotorized and motorized recreational uses.
3. **National Scenic Byways Program**. The National Scenic Byways Program was established through 23 USC 162. Under the program, certain roads are recognized as “national scenic byways” or “all-American roads” based on their archaeological, cultural, historic, natural, recreational and scenic qualities.

   The FHWA interim policy for the National Scenic Byways Program sets forth the criteria for the designation of roads as national scenic byways or all-American roads based upon their scenic, historic, recreational, cultural, archeological or natural intrinsic qualities.
4. **Transportation Enhancement Activities**. Transportation Enhancement (TE) activities offer communities funding opportunities to help expand transportation choices (e.g., safe bicycle and pedestrian facilities, scenic routes, beautification, other investments) that increase recreational opportunity and access. Communities may also use TE funds to contribute toward the revitalization of local and regional economies by restoring historic buildings, renovating streetscapes or providing transportation museums and visitor

centers. TE activities have been eligible for funding under the Surface Transportation Program since its inception under the *Intermodal Transportation Efficiency Act* of 1991.

3.3.2.13.2 Guidance

There is no FHWA guidance on the topic of recreation. FHWA guidance on Section 4(f) and Section 6(f) is provided in Section 3.3.2.14.2. While the FHWA *Environmental Guidebook* does not contain a specific section addressing recreation, it does provide the following resources:

- Bicycle and Pedestrian Issues,
- Scenic Byways, and
- Transportation Enhancements.

FHWA Programs include:

- FHWA partnerships with other Federal agencies;
- Access and the *Americans with Disabilities Act* (ADA);
- Pedestrian accommodations and safety;
- Physical activity, heritage and trail programs; and
- Recreational interests.

Projects sponsored through the Park Roads and Parkways Program also must comply with Director's Order 77, Natural Resource Protection.

3.3.2.13.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A has no specific guidance on the contents of a recreation section in a NEPA document and provides only brief references to recreation in the sections on social impacts, water body modification and wildlife impacts, wild and scenic rivers and Section 4(f) evaluations. Most recreational resources and issues are addressed through Section 4(f), Section 6(f), or in the discussion of bicycles and pedestrians in the transportation section. However, a separate discussion of these resources may be warranted in the NEPA document if the project area provides access to (or is adjacent to) dispersed recreation areas (e.g., hiking, fishing), is located on a scenic byway or supports high levels of bicycle and pedestrian use.

Relevant information to be provided in the NEPA document includes proximity of dispersed recreation resources to the project area, access points to these resources in and outside the project area, the level of recreational use in these areas and the season of use for these areas. If the level of recreational use in an area is high, it may also be considered in the context of social and economic impacts.

The NEPA document should consider the potential for disturbance of dispersed recreation users during project construction and should identify expected interruptions in access to those recreational areas. If feasible, alternative access points or modifications to the construction schedule to accommodate recreational access should be considered to mitigate potential impacts.

3.3.2.14 Section 4(f) and Section 6(f)

Section 4(f) has been part of Federal law since the *Department of Transportation Act* of 1966, and applies only to agencies within the USDOT. The law pre-dates NEPA. Section 4(f) protects publicly-owned public parks, recreation areas, wildlife and waterfowl refuges and historic, cultural and archeological sites listed on or eligible for the National Register of Historic Places (NRHP). Although both Section 106 and Section 4(f) provide protection for sites listed on or eligible for the NRHP, the requirements of each are different.

While Section 4(f) and Section 6(f) have similar names, they are not at all related, originating from completely different laws. However, because Section 6(f) money can be used only in parks, recreation areas and wildlife refuges, Section 6(f) applies only to properties that also are protected under Section 4(f). Therefore, the Section 6(f) discussion is usually combined with the Section 4(f) evaluation. The manager of all Section 4(f) park, recreation area and wildlife refuge properties should be interviewed to determine if Section 6(f) money has been used on the property.

3.3.2.14.1 Laws, Regulations and Policies

The following laws, regulations and policies apply:

1. **Section 4(f)**. Section 4(f) was created when the USDOT was formed in 1966. It was initially codified at 49 USC 1653(f) (Section 4(f) of the *USDOT Act* of 1966) and applies only to USDOT agencies. Later that year, 23 USC 138 was added with somewhat different language, which applied only to the highway program. In 1983, Section 1653(f) was reworded without substantive change and recodified at 49 USC 303. In their final forms, these statutes have no real practical distinction and are still commonly referred to as Section 4(f).

   Section 4(f) states:

   > *"The Secretary shall not approve any program or project which requires the use of any publicly owned land from a public park, recreation area, or wildlife and waterfowl refuge of national, States, or local significance as determined by the Federal, State, or local officials having Jurisdiction thereof, or any land from an historic site of national, State, or local significance as so determined by such officials unless (1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreation areas, wildlife and waterfowl refuge or historic sites resulting from such use. In carrying out the national policy declared in this section, the Secretary, in cooperation with the Secretary of the Interior and appropriate State and local officials, is authorized to conduct studies as to the most feasible Federal-aid routes for the movement of motor vehicular traffic through or around national parks so as to best serve the needs of the traveling public while preserving the natural beauty of these areas."*

2. **Section 6(f) of the Land and Water Conservation Fund Act**. Section 6(f) of the *Land and Water Conservation Fund Act* of 1965 (16 USC Chapter 1, Subchapter LXIX) applies to all projects that affect recreational lands purchased or improved with land and water conservation State grant funds.

   Section 6(f) prohibits the conversion of property acquired or developed with State grants to a nonrecreational purpose without NPS approval. NPS is required to ensure that replacement lands of equal value, location and usefulness are provided as a condition of such conversions, also known as *in-kind* replacement. Consequently, where conversions of Section 6(f) lands are proposed for highway projects, replacement lands are required.

   The *Land and Water Conservation Fund Act* has specific requirements for Federal-aid and Federal lands projects. The Federal lands portion of the law (e.g., used to purchase land for national wildlife refuges) does not include the in-kind replacement provision.

3.3.2.14.2 Guidance

1. **Section 4(f)**. The FHWA *Environmental Guidebook* includes a section with multiple policies and programmatic and nationwide evaluations.

   The *FHWA Section 4(f) Policy Paper* provides an overview of the law, FHWA interpretation of its requirements, applicability to various types of resources and guidance on the key areas of the Section 4(f) evaluation.

2. **Section 6(f)**. The following guidance is available:

   - NPS provides an overview of the Land and Water Conservation Fund Program.
   - Title 36 CFR 59.3 describes the conversion requirements when a project sponsor affects Land and Water Conservation Fund lands.

Appendix 3A.1.1.14 provides additional sources of relevant guidance materials.

According to 49 USC 303(c) and 23 USC 138, Section 4(f) does not apply to “any project for a park road or parkway under Section 204” of Title 23. This exempts almost all NPS projects from compliance with Section 4(f).

The FWS NEPA Reference Handbook contains a checklist for Section 4(f) compliance as well as the *Handbook on Departmental Review of Section 4(f) Evaluations* (February 2002).

3.3.2.14.3 NEPA Documentation Requirements

According to NEPA, documentation is required for projects determined to be governed by Section 4(f) and Section 6(f). The following applies:

1. **Section 4(f)**. The primary guidance for addressing Section 4(f) issues in a NEPA document is the FHWA implementing regulations. The purpose of these procedures is to establish an administrative record of the basis for determining that there is no feasible

and prudent alternative, and to obtain informed input from knowledgeable sources on feasible and prudent alternatives and on measures to minimize harm.

Specifically, the evaluation of alternatives to avoid the use of Section 4(f) land and possible measures to minimize harm to these lands must be developed and presented in the EA or draft EIS, or as a separate document for projects classified for a CE. Uses of Section 4(f) land covered by a programmatic Section 4(f) evaluation (see Section 3.3.2.14.5) should be documented by the requirements for the specific programmatic Section 4(f) evaluation. The discussion in the final EIS, FONSI or separate Section 4(f) evaluation should specifically address the following:

- The reasons why the alternatives to avoid a Section 4(f) property are not feasible and prudent
- How the preferred alternative results in the least harm to the 4(f) property compared to all feasible and prudent alternatives, and
- All measures that will be taken to minimize harm to the Section 4(f) property.

2. **Section 6(f)**. Approval of Section 6(f) conversion/replacement property should be documented in a Section 4(f) evaluation and the NEPA document. Appendix 3A.2 presents additional useful information on Section 6(f) documentation.

3.3.2.14.4 Section 4(f) Evaluation

When a project proposes to use resources protected by Section 4(f), a Section 4(f) evaluation must be prepared. While the law does not require preparation of any written document, the FHWA has developed procedures for preparation, circulation and coordination of Section 4(f) evaluation documents. The Section 4(f) evaluation must also undergo legal sufficiency review; soliciting this review early in the process is advised to avoid potential issues later. Typically, the Section 4(f) evaluation is contained in a separate section of EAs and EISs. For CEs (and occasionally for EAs and EISs), the Section 4(f) evaluation is a separate document.

The FHWA Technical Advisory T6640.8A provides guidance on preparing and processing Section 4(f) evaluations, including format and content. The FHWA *Section 4(f) Policy Paper* provides guidance on the key areas of a Section 4(f) evaluation, including alternative analysis, measures to minimize harm and mitigation, among others.

Section 6009(a) of SAFETEA-LU amended existing Section 4(f) legislation in 23 USC 138 and 49 USC 303 to simplify the processing and approval of projects that have only *de minimis* impacts on lands protected by Section 4(f). This is the first substantive revision of Section 4(f) legislation since passage of the U.S. Department of Transportation Act of 1966. This revision provides that when USDOT determines that a transportation use of Section 4(f) property (after consideration of any impact avoidance, minimization, and mitigation or enhancement measures) results in a *de minimis* impact on that property, an analysis of avoidance alternatives is not required, and the Section 4(f) evaluation process is complete. The impact criteria and associated determination requirements are explained in *Guidance for Determining De Minimis Impacts to Section 4(f) Resources*.

3.3.2.14.5 Programmatic Section 4(f) Evaluation

For EAs and CEs, programmatic Section 4(f) evaluations provide a standardized way to make key determinations on projects having minor impacts on areas protected by Section 4(f). Programmatic evaluations cannot be used for an EIS. In order to qualify for the programmatic evaluations, the impacts on the Section 4(f) property should meet several requirements that are outlined in each evaluation. Programmatic evaluations are not required to be circulated to the Department of Interior for review. The five programmatic Section 4(f) evaluations are listed below:

- Independent walkway and bikeways construction projects (negative declaration);
- Historic bridges;
- Minor involvements with historic sites;
- Minor involvements with parks, recreation areas and waterfowl and wildlife refuges; and
- Net benefits 4(f) programmatic.

3.3.2.15 Socioeconomics and Environmental Justice

3.3.2.15.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the following laws, regulations and policies govern activities affecting the social, economic and demographic characteristics of a community.

Environmental justice is codified in Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority and Low-Income Populations*, requires Federal agencies to include environmental justice in their mission.

Title VI of the *Civil Rights Act* of 1964 is a Federal law that prohibits discrimination. The principles of environmental justice are an extension of Title VI of the *Civil Rights Act* of 1964 and the Civil Rights Restoration Act of 1984. Federal agencies are responsible for oversight of environmental justice compliance when a Federal action is involved for transportation projects.

23 USC 109(h) states that adverse employment impacts and tax and property value losses are a major consideration in project decisions.

3.3.2.15.2 Guidance

The following guidance materials are available:

- *FHWA Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* is the order that provides specific policies and procedures addressing environmental justice.
- The FHWA *Environmental Guidebook* on Title VI and environmental justice presents sources for FHWA orders, memorandums, strategies (in the Code of Federal Regulations) and notices.

- The FHWA Environmental Justice website provides an overview of environmental justice, case studies and effective practices. The FHWA's effective practices CD-ROM provides guidance on addressing environmental justice in the NEPA process, along with practical examples of how environmental justice has been integrated into transportation programs, policies, plans and activities.

The FS guidance on social and economic issues is contained in the FS *Economic and Social Analysis Handbook* (FSH 1909.17).

The FWS NEPA Reference Handbook contains a checklist of social and economic impacts to be considered in the environmental document.

Appendix 3A.1.1.15 contains additional links to relevant guidance materials.

3.3.2.15.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides limited guidance on analysis of social and economic impacts in an EIS.

Environmental justice should be considered and addressed in the NEPA document. The FHWA California Division has developed interim guidance for addressing environmental justice in EAs and EISs. In addition, see the checklist that clearly outlines requirements for addressing environmental justice issues in NEPA documents.

For projects requiring an EIS, social, economic, environmental justice, relocation and public service issues can be addressed in a community impact assessment report. Additional information on the content of a community impact assessment report is described in Section 3.3.2.9.4.

3.3.2.16 Threatened and Endangered Species

3.3.2.16.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the *Endangered Species Act* (ESA) governs activities affecting Federally protected species.

Section 7 of the *Endangered Species Act* of 1973 (7 CFR 355 and 50 CFR 17-453) requires Federal agencies to ensure that their actions do not jeopardize the continued existence of any threatened or endangered species, and describes the consultation procedures and conservation obligations of Federal agencies. The National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) regulates marine species, including anadromous fishes, listed under the ESA. The FWS regulates nonmarine plant and animal species, including inland fishes, listed under the ESA.

3.3.2.16.2 Guidance

The following guidance is available:

- The FHWA *Environmental Guidebook* also provides links to numerous guidance documents, including *Guidelines for the Fulfillment of Interagency Cooperation Under Section 7 of the Endangered Species Act* (July 1987).
- On February 18, 2005, the FHWA and the FWS issued a Joint Agency Agreement on the ESA formal consultation process, focusing on responsibilities of the agencies and timing and information requirements. The agreement also describes the processes for elevating a project under tight time constraints.
- *The Management of the Endangered Species Act (ESA) Environmental Analysis and Consultation Process* includes a description of the interaction of the NEPA process and ESA consultation.
- See the ESA streamlining guidance pertaining to Programmatic Consultations to help with implementation of TEA-21.
- The American Association of State Highway & Transportation Officials' AASHTO Center for Environmental Excellence provides numerous guidance documents.
- Procedures for conducting Section 7 consultations and conferences are described in the *Endangered Species Act Consultation Handbook.* An overview of the formal and informal consultation processes is provided in Chapters 3 and 4 of the *Handbook*.

Appendix 3A.1.1.16 presents additional links to relevant guidance materials.

Projects sponsored through the Park Roads and Parkways Program must also comply with Director's Order 77-8, *Endangered Species*.

3.3.2.16.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides guidelines for addressing threatened or endangered species in an EIS. A potential impact on species or habitat protected by the ESA does not automatically require elevation of the NEPA documentation (CE, EA, EIS), which depends on the importance of the resources and the scope of the impacts. In general, if a biological assessment is prepared for a project, the NEPA document should include a summary of the biological assessment findings (see Section 3.3.2.16.4). Specifically, the following information should be provided:

- The species distribution, habitat needs and other biological requirements,
- The affected areas of the proposed project,
- Possible impacts on the species, including opinions of recognized experts on the species at issue,
- Measures to avoid or minimize adverse impacts, and
- Results of consultation with the FWS and/or the NOAA Fisheries.

If additional detail is needed in the environmental document, the biological assessment can be included as an appendix.

A discussion of noise impacts on protected species may be pertinent in the construction impacts section of the EA or EIS if endangered species are present in the project area.

3.3.2.16.4 *Endangered Species Act* Documentation Requirements

Biological assessments are written specifically to address potential impacts on species listed under the ESA. These reports differ from the biological evaluation reports developed for other species including FS sensitive species and State-listed species.

If a project will have no effect on Federally listed threatened, endangered, proposed or candidate species and designated or proposed critical habitats, consultation with the FWS or the NOAA Fisheries is not required. However, a *no-effect letter* can be written for the project. A *no-effect letter* is an abbreviated assessment documenting the absence of any impacts on species or habitats and is usually provided to the FWS or the NOAA Fisheries as a courtesy. (Unless specifically requested, a no concurrence letter may not be distributed by these agencies for projects that have submitted ESA documentation in the form of a no-effect letter.)

If a project may result in effects on listed species or habitats, a biological assessment is prepared. This document is submitted to the FWS or the NOAA Fisheries when consultation is initiated, whether informal or formal. Informal consultation occurs when the effect determination in the biological assessment *may affect, not likely to adversely affect*. If the FWS or the NOAA Fisheries agrees, the agency issue, a *concurrence letter* and consultation is complete. If the effect determination in the biological assessment *may affect, likely to adversely affect*, then formal consultation is needed. If the FWS or the NOAA Fisheries agrees with the conclusions of the biological assessment and the proposed conservation measures, the agency issues a *biological opinion*, and consultation is complete.

The organization of biological assessments can vary. In general, the report should include these elements:

- Cover page, table of contents, executive summary;
- Project description – describe proposed action, project location and action area;
- Identification of all Federally listed and proposed species and critical habitat that may be affected;
- Description of each species, species status and habitat;
- Description of environmental baseline within action area – include information from resource agency databases, agency or local experts and site survey;
- Analysis and quantification of effects of the action – consider direct and indirect effects (associated with project construction and operation, as well as with interrelated or interdependent activities);
- Assessment of cumulative effects for projects that require formal consultation;

- Description of avoidance, minimization and mitigation agreements, if any;
- Summary of effect determinations; and
- References (include studies, species lists and agency correspondence).

3.3.2.17 Transportation and Traffic Impacts

3.3.2.17.1 Applicable Laws, Regulations and Policies

Aside from the requirements of NEPA, there are no laws directly governing transportation and traffic as an environmental resource.

There are numerous policies and procedures relating to the provision of pedestrian and bicycle accommodations as described in 23 USC 217 and 23 CFR 652. See 23 CFR 652.11 for planning considerations and 23 CFR 652.13 for design and construction criteria.

Federal Aviation Administration regulations, 14 CFR 77 (January 1975), include guidance relevant to design of road projects affecting navigable air space.

3.3.2.17.2 Guidance

The following guidance materials are available:

- The FHWA *Environmental Guidebook* (several guidance and policy documents on bicycle and pedestrian issues)
- The FHWA Bicycle and Pedestrian Program (additional publications and resources)
- The Federal Aviation Administration Notice – *Requirement Related to Highways*.

Appendix 3A.1.1.17 contains additional links to relevant guidance materials.

3.3.2.17.3 NEPA Documentation Requirements

It is assumed that the transportation analysis conducted for an environmental document conforms to standard transportation engineering standards such as those contained in the *Highway Capacity Manual*.

The FHWA Technical Advisory T6640.8A does not address transportation as an environmental resource to be analyzed in the environmental document. Guidance on defining the project's purpose and need suggests that traffic issues should be discussed as part of the purpose and need statement. A useful source of information for evaluating transportation effects of project alternatives is the results of the traffic characteristics data gathered during the information-gathering phase described in Section 4.3. These are the data to support the purpose and need of the project.

Considerations relating to pedestrians and bicyclists are discussed in the FHWA Technical Advisory T6640.8A. If a project has substantive bicycle and pedestrian issues, those may be addressed in this section or a separate section may be appropriate.

The construction impacts section of the EA or EIS should describe anticipated traffic delays, road closures and/or detour routes. Mitigation measures to minimize impacts on the traveling public during construction should be identified.

3.3.2.18 Visual Quality

3.3.2.18.1 Applicable Laws, Regulations and Policies

Aside from NEPA, there are no laws directly governing activities affecting visual quality. Although some regulations and policies (e.g., Scenic Byways Program (23 USC 162), *Highway Beautification Act* of 1965 (23 CFR 750) influence transportation activities relative to visual quality, these regulations and policies are not particularly applicable to FLH programs, and they do not provide explicit information or guidance pertaining to visual quality.

Visual quality concerns should be addressed in the context of documentation prepared to comply with the *National Historic Preservation Act* of 1966 and the *Wild and Scenic Rivers Act*. For guidance on compliance with these laws, see Sections 3.3.2.8 and 3.3.2.21, respectively.

Visual impacts can be considered an adverse effect on a historic resource. See the implementing regulations for the *National Historic Preservation Act* (36 CFR 800).

The *Wild and Scenic Rivers Act* requires protection and enhancement of the values that qualify the river to be designated for protection.

Each FLMA has requirements related to its own defined visual quality objectives, which can be more restrictive than the Federal regulations cited above.

3.3.2.18.2 Guidance

The following additional guidance is available:

- *Visual Prioritization Process—Users Manual*, Report No. FHWA-FLP-93-007, is a guide to conducting visual quality assessments.
- The FHWA outlines recommended methods in *Visual Impact Assessment for Highway Projects*.
- Each FLMA has established visual quality standards, typically contained in the land management plan.

Appendix 3A.1.1.18 provides additional links to relevant guidance materials.

3.3.2.18.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides limited guidance on analysis of visual elements in an EIS. The guidance provided in the technical advisory is applicable to both an EA and an EIS and should be commensurate with the scope of the project. *Environmental Impact Statement: Visual Impact Assessment* is useful for defining the types of issues that should be addressed in both an EA and an EIS.

However, if the project uses the *Visual Prioritization Process Users Manual* to guide the analysis of visual impacts in the project corridor, the NEPA document should summarize the results of this analysis.

The most important NEPA requirement pertaining to visual quality is consistency with the visual standards identified in the FLMA land management plan. The CE project file should document compliance with the visual standards of the land management plan and any design features or mitigation measures required. This statement should also be provided in the EA or EIS.

3.3.2.19 Water Resources

3.3.2.19.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the following laws, regulations and policies govern activities affecting water resources (e.g., water quality, surface waters, ground water).

The *Clean Water Act* (CWA) of 1972 (33 USC 1251) regulates all sources of water pollution and prohibits the discharge of pollutants to waters from non-permitted sources. The CWA covers surface waters, wetlands and ground water. Several sections of the CWA (303(d), 305(b), 401, 402 and 404) have implications for permitting activities in surface waters.

The *Safe Drinking Water Act* (SDWA) of 1974 (42 USC Chapter 6A), sets national primary drinking water standards, regulates underground injection of fluids and designates sole source aquifers. Amendments in 1986 and 1996 provide for water operator training, public information and source water protection as components of the SDWA.

Section 9 of the *Rivers and Harbors Act* of 1899 (33 USC 401) prohibits the construction of any bridge, dam, dike or causeway over or in navigable waterways of the United States without congressional approval. Administration of Section 9 has been delegated to the US Coast Guard. Section 10 prohibits work in navigable waters without a permit from the U.S. Army Corps of Engineers (USACE).

The *Fish and Wildlife Coordination Act* (16 USC 661-667(e)) authorizes the FWS, NOAA Fisheries and State agencies to investigate all proposed Federal and non-Federal actions (needing a Federal permit or license) that would impound, divert, deepen or otherwise control or modify a stream or other body of water, and to make mitigation or enhancement recommendations. The primary goal of this statute is to incorporate wildlife conservation with water resource development programs. The requirements of the law are addressed in Section 3.3.2.22.1.

3.3.2.19.2 Guidance

The following guidance materials are available:

- The FHWA *Environmental Guidebook* section on the Safe Drinking Water Act provides links to the laws, regulations and policies governing surface waters. The *Guidebook* section on the SDWA provides online sources to the laws, regulations, policies and the EPA guidance on compliance.
- The FHWA *Environmental Guidebook* section on stormwater and the CWA provides links to the laws, regulations and policies governing surface waters. The *Guidebook* section on stormwater provides online guidance on stormwater analysis.
- AASHTO provides additional guidance on NPDES permitting requirements under CWA Section 402 and the establishment of *total maximum daily loads* (TMDLs) under CWA Section 303.
- The EPA maintains a list of designated sole-source aquifers along with guidance for analysis and reporting.
- For additional information on required water resource permits, see Section 3.3.3.1 through 3.3.3.5.

Appendix 3A.1.1.19 provides additional sources to relevant guidance materials.

Projects sponsored through the Park Roads and Parkways Program must also comply with Director's Order 77, *Natural Resource Protection*.

3.3.2.19.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides guidance on the analysis of water quality issues in an EIS. Generally, the NEPA document should characterize water resources in a watershed context that includes surface water, ground water, wellhead protection areas, source water protection areas, soils, topographic features affecting basin hydrology, existing water quality conditions and land use patterns affecting runoff conditions. The NEPA document should identify roadway runoff or other nonpoint source pollution that may have an adverse impact on sensitive water resources (e.g., water supply reservoirs, ground water recharge areas, high-quality streams).

When a proposed project is located in a sole source aquifer, early coordination with the EPA is required to identify potential impacts. If the project will affect the aquifer, then the design should be developed to the satisfaction of the EPA that it will not contaminate the aquifer. The NEPA document should record coordination activities with the EPA and identify their position on the impacts of the various alternatives. The CE project file should include documentation of the coordination efforts with the EPA and the results of the coordination. The NEPA decision documents (i.e., the EA/FONSI or final EIS/record of decision [ROD]) should demonstrate that any concerns identified by the EPA related to the preferred alternative have been addressed.

When a proposed project encroaches on a wellhead protection area (as identified by a State under approval by the EPA), the NEPA document should identify the area, the potential impacts and proposed mitigation measures. The CE project file should document that the project complies with the approved State wellhead protection plan. The NEPA decision document (the EA/FONSI or final EIS/ROD) should document that the project complies with the approved State wellhead protection plan.

3.3.2.20 Wetlands

3.3.2.20.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA (42 USC 4321), the following laws and regulations govern activities in wetlands.

Protection of Wetlands, Executive Order 11990 of 1977 (EO 11990) requires Federal agencies to minimize the loss or degradation of wetlands and enhance their natural value.

The Clean Water Act (Sections 401 – 404) regulates the discharge, dredging or placing of fill material in waters of the United States, including wetlands. Section 401 requires applicants for permits for activities resulting in a discharge to seek certification for compliance with State water quality standards and other aquatic protection laws.

Section 404(b)(1) (40 CFR 230) provides guidelines for a permit review process that requires a sequencing of analysis of alternatives to avoid and minimize wetlands impacts as much as practical. Established by the EPA, these guidelines are the substantive criteria used in evaluating discharges of dredged and fill material into wetland and non-wetland waters of the United States under the CWA, Section 404, and are applicable to all Section 404 permit decisions.

The USACE is required to conduct a 404(b)(1) review when considering Section 404 permit applications in order to determine the least environmentally damaging practicable alternative.

3.3.2.20.2 Guidance

The following guidance materials are available:

- See the FHWA Environmental Guidebook and FHWA policies and guidance on wetlands and mitigation.
- AASHTO provides additional guidance on wetland issues, including FHWA guidance on recent court decisions related to wetlands.
- For additional information on required wetland permits, see Section 3.3.3.1.

Appendix 3A.1.1.20 presents additional sources to relevant guidance materials.

Projects sponsored through the Park Roads and Parkways Program must also comply with Director's Order 77-1, *Wetland Protection*.

3.3.2.20.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A gives guidelines for addressing wetland impacts in an EIS. This guidance is also applicable to CEs and EAs.

The NEPA document in general should include a summary of the relevant wetland information and evaluations. This information is often derived from the resource surveys or wetland delineation report prepared during the activities comprising the conceptual studies and preliminary design phase. The level of detail should be in proportion to the magnitude of the anticipated impacts and the type of NEPA document produced (i.e., CE, EA, EIS). In addition, the NEPA document should identify measures taken to avoid and minimize impacts; summarize the mitigation commitments that were made with the resource agencies; and, if necessary, identify plans to compensate for unavoidable wetland impacts.

If the preferred alternative is located in wetlands, the CE, FONSI, final EIS and ROD must contain the wetland finding required by EO 11990. This is usually contained in a separate section titled Only Practicable Alternative Finding or Wetland Finding, which should be supported by the following information:

- A reference to EO 11990,
- Justification for concluding that there are no practical alternatives to the proposed action,
- An explanation of how the proposed action includes all practicable measures to minimize harm to wetlands, and
- A concluding statement expressing the following:

  Based upon the above considerations, it is determined that there is no practicable alternative to the proposed construction in wetlands and that the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use.

3.3.2.20.4 Wetland Delineation Report

For all projects that might affect wetlands, a Wetland Delineation Report is prepared in accordance with the USACE *Wetlands Delineation Manual* (1987).

A wetland delineation identifies and demarcates wetlands that may be under USACE jurisdiction for purposes of the CWA, Section 404. The wetland delineation should be performed by a qualified biologist. State or local wetland delineation procedures may differ from the USACE procedures required for Federal projects.

A wetland delineation report includes the results of the wetland delineation and an analysis of impacts in terms of the expected loss of wetland functions and values. Proposed mitigation measures or compensation actions are also included in the report. There is no required format for the technical report, although the wetland delineation must be performed in accordance with the USACE *1987 Manual*.

3.3.2.20.5 Conceptual Wetland Mitigation Plan

When impacts on wetlands cannot be avoided or sufficiently minimized, compensatory mitigation is required. Wetland compensation may involve the creation of a wetland where one does not currently exist, or wetland restoration at a site where wetland functions have been degraded. The proposed compensatory mitigation measures are detailed in a conceptual wetland mitigation plan, which is commonly appended to the NEPA document.

On December 24, 2002, the EPA and the USACE released the *National Wetlands Mitigation Action Plan*. Concurrently, the USACE published the Regulatory Guidance Letter (RGL) 02-2, *Guidance on Compensatory Mitigation Projects for Aquatic Resources Under the USACE Regulatory Program Pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899*, which supersedes RGL 01-1 of the same title. This source provides guidance on identifying suitable sites for mitigation and identifies the following required elements of the wetland mitigation plan:

- Baseline information,
- Goals and objectives,
- Financial assurances,
- Site selection criteria,
- Work plan,
- Performance standards,
- Contingency plan,
- Monitoring, and
- A long-term management program.

3.3.2.20.6 Section 404(b)(1) Showing (Evaluation)

Projects requiring an individual Section 404 permit typically require preparation of a 404(b)(1) (also called a 404(b)(1) evaluation), which generally follows the format of the EPA guidelines. See the additional EPA guidance on the level of analysis required.

3.3.2.21 Wild and Scenic Rivers

3.3.2.21.1 Applicable Laws, Regulations and Policies

Wild and scenic rivers should be addressed in the context of documentation prepared to comply with the *USDOT Act* of 1966, Section 4(f), described in Section 3.3.2.14.

Often, regulatory agencies require documentation of compliance with the *Wild and Scenic Rivers Act* (16 USC 1271) before issuing a permit or finalizing the consultation process for Federally listed species.

3.3.2.21.2 Guidance

The FHWA *Environmental Guidebook* includes the laws, regulations and policies pertaining to wild and scenic rivers. Of particular interest is the FHWA's *Policy Guidance for Wild and Scenic Rivers*, which describes how to integrate agency responsibilities under the Wild and Scenic Rivers Act within the NEPA process.

Appendix 3A.1.1.21 presents additional sources to relevant guidance materials.

Projects sponsored through the Park Roads and Parkways Program must also comply with Director's Order 46A, *Wild and Scenic Rivers Within the National Park System*.

3.3.2.21.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides guidance on contents of the NEPA document regarding wild and scenic rivers.

For a CE, keep a record of coordination activities with the river managing agencies and consultation results in the project file. For an EA/FONSI or EIS, report coordination activities with the river managing agencies and consultation results in the NEPA document.

3.3.2.22 Wildlife, Fish and Vegetation

3.3.2.22.1 Applicable Laws, Regulations and Policies

In addition to the requirements of NEPA, the following laws, regulations and policies govern activities affecting wildlife, fish, vegetation and essential fish habitat as defined under the *Magnuson-Stevens Act*. Threatened and endangered species are addressed in Section 3.3.2.16:

1. **Wildlife and Fish**. The *Fish and Wildlife Coordination Act* of 1958 (16 USC 661) authorizes the FWS, NOAA Fisheries and State agencies to investigate all proposed Federal and non-Federal actions (needing a Federal permit or license) that would impound, divert, deepen or otherwise control or modify a stream or other body of water, and to make mitigation or enhancement recommendations. The primary goal of this law is to incorporate wildlife conservation with water resource development programs.

   The *Migratory Bird Treaty Act* of 1918 (16 USC 703–712), administered by the FWS, regulates activities affecting migratory birds, with the exception of game birds during established hunting seasons. This law is particularly applicable if birds are actively nesting on bridges, culverts or signs in the project area.

   Responsibilities of Federal Agencies to Protect Migratory Birds, EO 13186, January 10, 2001, requires the FHWA to enter into a MOU with the FWS on protecting a wide range of migratory bird species. The MOU is not yet finalized.

The primary goal of the *National Forest Management Act* of 1976 (16 USC 1600–1614) is to maintain multiple use and species diversity on Federal forest lands. The statute applies directly to lands administered by the FS, but also provides direction for Bureau of Land Management (BLM) land management plans. The BLM and the FS have integrated NEPA requirements within their land management regulations.

The *Magnuson-Stevens Act* is the 1996 amendment to the Fishery Conservation and Management Act of 1976 (i.e., the Magnuson Act). The law, administered by the NOAA Fisheries, emphasizes sustainability of the nation's fisheries and creates a new habitat conservation approach. The protected habitat is called essential fish habitat. Federal agencies should consult with the NOAA Fisheries on all activities or proposed activities authorized, funded or undertaken by the agency that may adversely affect essential fish habitat.

Other laws requiring the consideration of wildlife and fish issues include the following:

- Tribal laws (vary by tribe);
- The *Bald and Golden Eagle Protection Act* (16 USC 668–668d).
- The *Marine Mammal Protection Act* of 1972 (16 USC 1361–1407).
- The *Anadromous Fish Conservation Act* of 1965 (16 USC 757a–757g).

2. **Vegetation**. The *Noxious Weed Act* of 1975 (PL 93-629) established a Federal program to control the spread of invasive plant species. Amendments to the law in 1990 (PL 101-624) identify additional requirements for Federal land management agencies to develop and fund a plant management program, implement cooperative agreements with States regarding undesirable plants on agency lands and establish integrated management systems to control undesirable plants targeted by the cooperative agreements.

   Invasive Species (EO 13112) requires Federal agencies to work to prevent and control the introduction and spread of invasive species.

3.3.2.22.2 Guidance

The FHWA *Environmental Guidebook* includes the laws, regulations and policies pertaining to wildlife, habitat, and ecosystems.

The FHWA roadside vegetation management program provides policy and guidance information. Of particular interest is FHWA's guidance on compliance with EO 13112 and Section 6006 of SAFETEA–LU guidance on control of noxious weeds.

Appendix 3A.1.1.22 presents additional sources to relevant guidance materials.

Projects sponsored through the Park Roads and Parkways Program also must comply with Director's Order 77, *Natural Resource Protection*.

Practitioners need to consider many issues that are rising in importance relative to transportation and traffic impacts on wildlife. For example, wildlife mortality and habitat connectivity are related to traffic volumes, speeds, road width and road-related barriers. The FHWA provides information on wildlife and highways.

3.3.2.22.3 NEPA Documentation Requirements

The FHWA Technical Advisory T6640.8A provides guidelines for documenting fish and wildlife impacts in an EIS.

The EA or EIS should contain exhibits and discussions identifying the location and extent of wildlife or fish habitat and vegetation. Impacts on fish and wildlife resulting from the loss, degradation or modification of aquatic or terrestrial habitat should also be discussed. The results of coordination with appropriate Federal, State and local agencies should be documented in the EA or EIS; for example, coordination with the FWS under the *Fish and Wildlife Coordination Act* of 1958.

A discussion of noise may be pertinent in the construction impacts section of the EA or EIS if the project would affect species of special concern (especially those protected under the *Endangered Species Act* or those designated in the Federal Land Management Agency (FLMA) land management plan as sensitive).

The NEPA document should also document project compliance with the goals and standards of the FLMA land management plan for managing populations of wildlife and fish, and controlling the spread of noxious weeds. In addition, the results of the biological evaluation should be summarized in the NEPA document.

The essential fish habitat assessment, which may be prepared as a separate document, provides sufficient information pertaining to Federally managed fisheries and their associated habitats and should be included or summarized in the NEPA document. If the determination of effect for essential fish habitat is *adverse effect*, the NEPA document should summarize any conservation commitments made with the regulatory agency.

The required information on invasive species to be provided in the NEPA document is outlined in the FHWA *Environmental Guidebook* for roadside vegetation. This guidance states that until the national vegetation management plan specified in the executive order is completed, NEPA analyses should rely on each State's noxious weed list to identify the invasive plants to address and the measures to be implemented to minimize their harm. The guidance also States that the NEPA document should include identification of any invasive terrestrial or aquatic animal or plant species that could do harm to native habitats within the project study area and identify the potential impact of the disturbances caused by construction on the spread of invasive species. Finally, the analysis should describe any preventive or eradication measures to be taken.

3.3.2.22.4 *Magnuson-Stevens Act* Documentation Requirements

Federal agencies consult with the NOAA Fisheries to ensure compliance with the *Magnuson-Stevens Act* and its requirements regarding essential fish habitat. The analysis of essential fish habitat should include:

- A brief introductory paragraph describing why addressing essential fish habitat is required;
- A definition of the essential fish habitat designation for the fisheries potentially affected by the project;
- An identification of the fish species likely to occur in the project area and a brief description of fish use of the project action area; significant prey species should also be considered;
- A brief statement of potential impacts on essential fish habitat; and
- A determination of effect for essential fish habitat (either *no effect* or *adverse effect*).

If the determination is *adverse effect*, NOAA Fisheries will provide essential fish habitat conservation recommendations to the Federal agency that submitted the environmental documentation. The Federal action agency should then provide a detailed written response within 30 days after receiving them or at least ten days prior to final approval of the action.

3.3.2.22.5 Evaluation for Sensitive Species on Federal Lands

Any ground-disturbing activities on Federal lands may need to consider potential impacts on various sensitive species, including FS sensitive species, FS management indicator species or BLM sensitive species, as designated in the land management plan of that Federal agency (e.g., the FS, the BLM), and State-listed species whose populations are rare or in decline in the State in which the Federal lands are located. Impacts on these species are addressed in a biological evaluation report. This report can be combined with the biological assessment report generated to assess potential project impacts on threatened and endangered species or it can be combined with the general wildlife and fish technical report. The main objectives of the biological evaluation are to identify and reduce adverse impacts, increase mitigation opportunities for sensitive species, to ensure that the FS/BLM actions do not decrease the viability of native or desired non-native plant or animal species and to ensure that actions will not lead to the Federal listing of species. For States maintaining a list of State-sensitive species, the biological evaluation should also include a discussion of these species.

A biological evaluation should include the following:

- Identification of all FS, BLM and State-listed sensitive species and Federally listed and proposed species and their habitat potentially affected by the proposed activity,
- Identification and description of habitat within the area needed to meet FS/BLM objectives for sensitive species,
- Analysis of the direct, indirect and cumulative effects of the proposed action, including mitigation, on species or habitat essential to meet FS/BLM objectives,
- Determination for each sensitive species of either “no impact,” “beneficial impact,” “may have impact on individuals but not likely to cause a trend toward Federal listing or loss of viability” or “likely to result in a trend toward Federal listing or loss of viability,”

- Discussion of the process and rationale for the impact determination, including documentation of any contacts with other agencies or data sources whose information was used in the determination, and
- Recommendations for reducing adverse impacts and beneficial mitigation measures.

No FS or BLM guidance is available for FS/BLM biological evaluation requirements. Therefore, the land management agency should be consulted to determine how best to meet its requirements.

3.3.3 COMMONLY REQUIRED PERMITS

This section identifies the major permits required for Federal transportation projects, describes the permit process and provides links to guidance. The checklist provided in the FHWA *Summary of Environmental Legislation Affecting Transportation* gives a good overview of potential permit requirements.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

3.3.3.1 Section 404 Permit

3.3.3.1.1 *Clean Water Act* (CWA)

Section 404 of the CWA regulates the discharge of dredged and fill material into waters of the United States, including wetlands. The Section 404 permit is required for work in streams, tidal waters, wetlands or lakes.

3.3.3.1.2 Issuing Agency

The USACE has the authority to issue permits for activities involving the discharge of dredge and fill materials into waters of the United States, including wetlands.

3.3.3.1.3 Permit Process

The USACE is organized into eight divisions supported by numerous districts. Each division or district may use a different permit application or have its own process for filing permits and should be consulted for additional information. Generally, a standard form ENG 4345 is used to apply for Section 404 permits. The form includes guidance for completing the application and preparing project drawings. Some States have combined permit application forms for securing local, State and Federal permits that can be substituted for the standard form ENG 4345. Therefore, the permits required should be identified prior to determining which permit application is appropriate for the project.

FLH projects are likely to require a nationwide permit or an individual permit from the USACE. The nationwide permit program authorizes specific activities in areas under USACE jurisdiction, usually through an expedited review process.

An individual Section 404 permit is usually required when a project cannot meet the conditions of a nationwide permit (e.g., with substantial impacts on wetlands). Projects requiring an individual permit typically require the preparation of a Section 404(b)(1) as described in Section 3.3.2.20.6.

For all Section 404 permits, additional coordination may be required for projects on tribal reservation lands and during the application review process, the USACE may request comment from other Federal and State agencies.

Compliance with several major laws is required prior to issuance of a Section 404 permit. These laws include the following:

- Section 307 of the *Coastal Zone Management Act* of 1972 (see Section 3.3.2.2),
- Section 106 of the *National Historic Preservation Act* of 1966 (see Section 3.3.2.8),
- *Endangered Species Act* of 1973 (see Section 3.3.2.16), and
- *Wild and Scenic Rivers Act* (see Section 3.3.2.21).

The USACE district office covering the project area should be contacted to determine its preferred process for securing the required permits.

3.3.3.1.4 Additional Guidance

Information pertaining specifically to Section 404 of the *Clean Water Act* and Federal-aid highway projects is available in *Applying the 404 Permit Process to Federal-Aid Highway Projects*, also known as the Red Book.

3.3.3.2 Section 401 Certification

3.3.3.2.1 *Clean Water Act* (CWA)

Section 401 of the CWA, which requires certification that discharges of dredged or fill material into waters of the United States comply with water quality standards.

3.3.3.2.2 Issuing Agency

Under Section 401, the USACE, the EPA or designated States and Tribes can review and approve, condition, or deny all Federal permits or licenses that might result in a discharge to State or Tribal waters, including wetlands.

3.3.3.2.3 Permit Process

Certification procedures vary by State based on local water quality standards and are usually integrated into a combined permit review process. General water quality standards and contact information are available by state.

3.3.3.2.4 Additional Guidance

No additional guidance is identified at this time.

3.3.3.3 National Pollutant Discharge Elimination System (NPDES) Permits

3.3.3.3.1 *Clean Water Act* (CWA)

Section 402 of the CWA requires that an NPDES permit be obtained for all discharges to waters of the United States from construction sites and water management facilities. Although highways have not been classified as industrial sites, highway construction has been classified as an industrial activity. An NPDES construction permit is required for all construction activities identified in the NPDES general permit for stormwater discharges from construction activities. Construction activities, including other land-disturbing activities that disturb one acre or more, are regulated under the NPDES stormwater program.

3.3.3.3.2 Issuing Agency

The EPA administers the NPDES program. This is often done by delegating stormwater permitting responsibilities to State agencies. State requirements for NPDES permits vary by State. Several States have authority to issue NPDES permits. In States where the EPA retains permitting responsibilities, NPDES permit applications are submitted directly to the EPA. In general, NPDES permits on tribal lands remain the responsibility of the EPA, although in some cases the Tribes have authority.

3.3.3.3.3 Permit Process

For the construction general permit, the EPA has established an electronic application process (*eNOI*).

To complete this electronic application form, the following activities should be completed. After each activity, navigate to the website noted for a description of the procedures for that activity:

- Read the construction General Permit.
- Develop a Stormwater Pollution Prevention Plan (SWPPP).
- Complete an Endangered Species Certification for the project site.
- Determine whether stormwater from the site will reach a water body with an established TMDL for any listed pollutant. If the water body has an established pollutant TMDL, ensure the project site is in compliance with that TMDL.
- Know the site's latitude and longitude.

In addition, permit applications and forms are available for download.

For State-issued NPDES permits, authorized State agencies should be contacted directly to determine permit application requirements. See the interactive online map.

In an emergency situation, contact the EPA or the authorized State agency to determine its preferred process for securing the required permits.

3.3.3.3.4 Additional Guidance

The EPA provides an overview of the stormwater program for a construction general permit.

3.3.3.4 Section 10 Permit

3.3.3.4.1 *Rivers and Harbors Act*

Section 10 of the *Rivers and Harbors Act* of 1899 regulates activities in navigable waters of the United States. Activities subject to this regulation include obstruction, dredging, alteration or improvement of any navigable water, and building or installing structures within these waters. Navigable waters of the United States are defined in 33 CFR 329.

3.3.3.4.2 Issuing Agency

The USACE issues permits for activities in navigable waters.

3.3.3.4.3 Permit Process

Typically, a standard form ENG 4345 is used to apply for USACE *Rivers and Harbors Act* Section 10 permits. This same form can be used to apply for a CWA Section 404 permit. Some States have combined permit application forms for securing local, State and Federal permits that can be substituted for the standard form ENG 4345. Therefore, the permits required should be identified prior to determining which permit application is appropriate for the project.

The USACE may request comment from other Federal and State agencies.

In an emergency situation, contact the USACE division office covering the project area to determine its preferred process for securing the required permits.

3.3.3.4.4 Additional Guidance

The USACE district offices issuing this permit offer additional permit information.

3.3.3.5 Section 9 Permit

3.3.3.5.1 *Rivers and Harbors Act*

Under Section 9 of the *Rivers and Harbors Act* of 1899, the *General Bridge Act* of 1946 and other statutes, a permit is required for bridges or causeways in or over navigable waters of the United States, and for causeway construction in all tidal waters of the United States. Lighted structures in water that are used for navigational purposes also require this permit.

3.3.3.5.2 Issuing Agency

The US Coast Guard (USCG) is responsible for administering the *Rivers and Harbors Act* Section 9 permit.

3.3.3.5.3 Permit Process

The US Coast Guard provides permit applications and general information on bridge permits.

In an emergency situation, contact the US Coast Guard to determine its preferred process for securing the required permits.

3.3.3.5.4 Additional Guidance

The USCG/FHWA *Memorandum of Understanding on Implementing NEPA*, N 6640.22, July 17, 1981, provides additional guidance on coordinating permits for highway projects over navigable waters.

3.3.3.6 Federal Land Management Agency Permits

The FS provides the most detailed guidance for permits among all FLMAs. The FS requirements are described below. Other FLMAs may also have permit requirements and the project team member should be consulted to determine whether any permits are required for the FLH activities on their lands.

3.3.3.6.1 Trigger

A special use permit may be issued to the FLH by the FS for preliminary engineering activities (e.g., geotechnical investigations, resource surveys) that are performed prior to completion of the project's NEPA documentation. A special use permit may also be issued for the use of gravel pits, borrow pits, waste sites, stone quarries or other areas or facilities used to support construction activities, if such sites are not identified and evaluated as part of the project's NEPA documentation. All project-related uses and impacts should be identified and disclosed in the project's NEPA document to the fullest extent possible. If it is later determined that a site on FS land is required for use that was not originally disclosed in the NEPA document, a special use permit may be issued prior to advertisement to address the impacts and associated mitigation for use of the site.

All issues regarding special use permits should be coordinated through the FS SEE team representative.

3.3.3.6.2 Issuing Agency

These permits are issued by the FS.

3.3.3.6.3 Permit Process

The FS provides general information on the FS permit process. For transportation and utility systems on Federal lands in Alaska, Standard Form 299 can be used to apply for special use permits. This form may also be accepted for transportation projects in other regions; however, local or regional offices should be contacted first to see if they have specific application requirements.

3.3.3.6.4 Additional Guidance

The FS regional offices provide contact information and a directory of National forests.

3.3.3.7 Threatened and Endangered Species Permits

Personnel who survey, handle or collect listed species may require permits from the FWS or NOAA Fisheries. *Take* permits may also be issued through a biological opinion from the FWS or NOAA Fisheries if a project is expected to result in the *take* of a listed species.

State and Tribal fish and wildlife agencies may also require permits for handling or collecting plants, animals or fish. The respective agencies should be contacted prior to initiating any activities that may require the handling or collection of plants, animals or fish.

3.3.3.8 Tribal Permits

Many Tribes require permits for work in tribal reservation areas that could affect cultural, historic or archeological resources, as well as water, fish, wildlife, habitat, air quality, etc. Occasionally, a Tribe is also authorized to administer Federal permits (e.g., NPDES permits, CWA Section 401 certification). Therefore, tribal agency websites and personnel should be contacted to identify the tribal permits that apply to FLH projects.

3.3.3.9 State Permits

Coordination with State permitting agencies is required when the State is authorized to administer Federal permits (e.g., NPDES permits, CWA Section 401 certification). Otherwise, the Federal government cannot be regulated by State or local agencies. However, this does not preclude the need to coordinate with State regulatory agencies on proposed activities.

Also, some States have combined permit application forms for securing local, State and Federal permits. Therefore, State agencies should be contacted to identify the State permits that apply to FLH projects.

3.4 ENVIRONMENTAL PROCESS

NEPA directs Federal agencies to conduct environmental reviews to consider the potential impacts on the environment that could result from their proposed actions. Because NEPA requires the agency to consider impacts on all aspects of the environment, NEPA review serves as the overarching process under which all other environmental reviews required by other environmental laws take place. Consequently, the NEPA process is intended to be a comprehensive and a coordinated project review conducted by an interagency and interdisciplinary team, and the public to ensure that all environmental concerns and issues have been identified and are adequately addressed.

This section introduces the role of environmental streamlining in the environmental process and describes the FLH environmental process for projects in which FLH is the lead agency.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

3.4.1 ROLE OF ENVIRONMENTAL STREAMLINING IN THE ENVIRONMENTAL PROCESS

Efficient and effective coordination of multiple environmental reviews, analyses, and permitting actions under the over-arching law of NEPA is essential in meeting the environmental streamlining mandate for highway and transit projects. The FHWA's strategic approach to environmental streamlining is the environmental stewardship and streamlining FHWA's *vital few goal*. See detailed discussion in Section 3.3.1.2.3.

The FHWA's streamlining/stewardship program demonstrates the agency's commitment to streamlining. The agency is continually setting and revising expectations, measures and methods for advancing an improved and efficient environmental review process and for demonstrating environmental stewardship. The program also provides information on streamlining initiatives from various State departments of transportation.

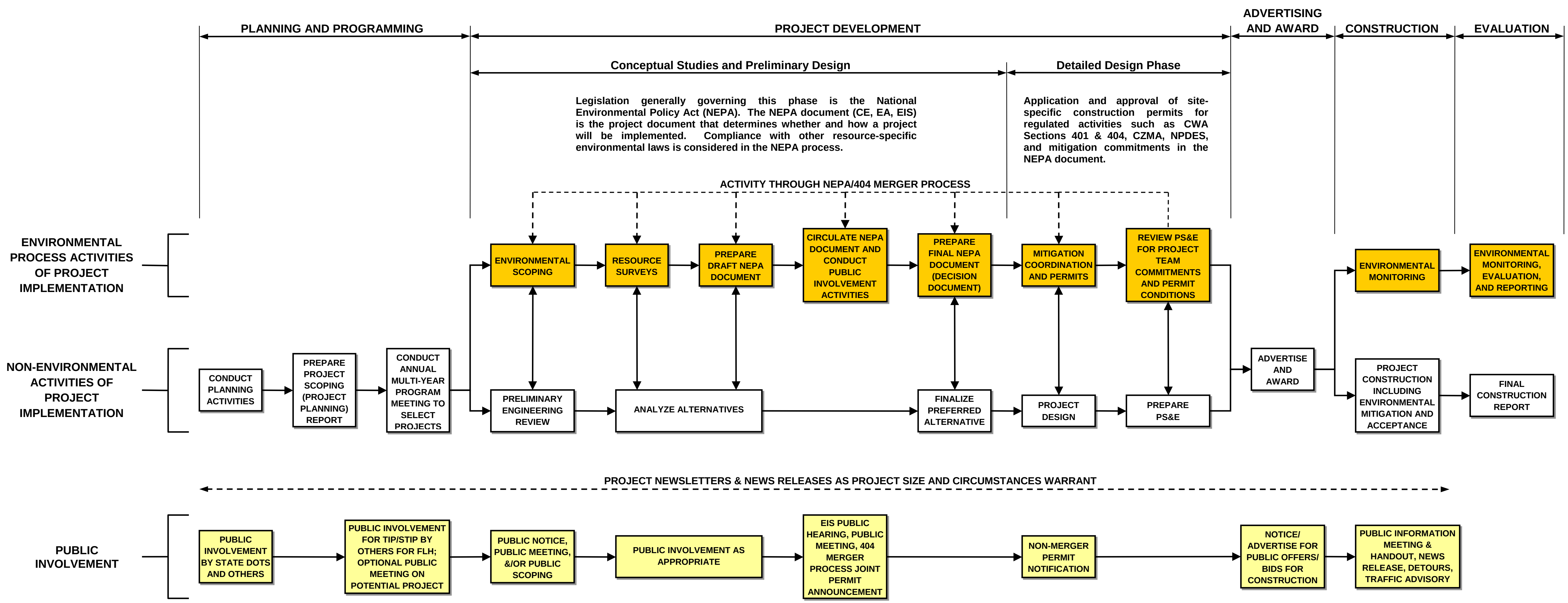
3.4.2 FEDERAL LANDS HIGHWAY ENVIRONMENTAL PROCESS

When the FLH serves as the lead agency, projects are developed and delivered through a sequence of activities as shown in Exhibit 3.4–A. The flowchart identifies five distinct processes, which are explained in the subsections indicated:

- Planning and Programming (Section 3.4.2.1),
- Project Development (Section 3.4.2.2),
- Advertising and Award (Section 3.4.2.3),
- Construction (Section 3.4.2.4), and
- Evaluation (Section 3.4.2.5).

Although environmental tasks occur in each of these five processes, the majority of FLH responsibilities arise during the project development process. Environmental tasks are discussed in the subsections below. The elements of each environmental task vary according

Exhibit 3.4–A FLH ENVIRONMENTAL PROCESS



ABBREVIATIONS:

CE	Categorical Exclusion
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DOTs	Departments of Transportation
EA	Environmental Assessment
EIS	Environmental Impact Statement
FLH	Federal Lands Highway
FONSI	Finding of No Significant Impact
NPDES	National Pollutant Discharge Elimination System
PS&E	Plans, Specifications, and Estimates
ROD	Record of Decision
STIP	State Transportation Improvement Program
TIP	Transportation Improvement Program

LEGEND

Activity	Environmental Process Activities of Project Implementation
Activity	Non-Environmental Activities of Project Implementation
Activity	Public Involvement

TASKS

Task 1: Review the project scoping (project planning) report
Task 2: Establish project team and conduct initial meeting
Task 3: Develop mailing list
Task 4: Send project notice to public agencies
Task 5: Conduct public scoping meetings
Task 6: Publish Notice of Intent in Federal Register (EIS only)
Task 7: Develop and refine the Purpose and Need and the alternatives, and identify major concerns

TASKS

Task 1: Determine resource survey needs
Task 2: Send introductory letters to resource agencies
Task 3: Obtain access permission onto public and private property
Task 4: Initiate and complete surveys
Task 5: Review survey data and finalize survey
Task 6: Coordinate survey results with analysis of alternatives

TASKS

Task 1: Complete resource analysis
Task 2: Analyze and refine alternatives
Task 3: Develop conceptual mitigation
Task 4: Write draft NEPA document
Task 5: Coordinate document with project team

TASKS

Task 1: Public notice
Task 2: Copy and distribute NEPA document
Task 3: Conduct public involvement

TASKS

Task 1: Review and respond to public comments
Task 2: Finalize preferred alternative(s)
Task 3: Prepare and approve the CE
Task 4: Prepare EA or final EIS
Task 5: Prepare, review and approve FONSI or ROD
Task 6: Copy and circulate public notice and NEPA document(s)

TASKS

Task 1: Develop final mitigation plans or measures
Task 2: Coordinate and collaborate with internal and external customers/ partners
Task 3: Develop, submit and coordinate permit package

TASKS

Task 1: Prepare final mitigation

TASKS

Task 1: Monitor construction mitigation
Task 2: Document and report (if short-term)

TASKS

Task 1: Monitor after completion of construction (extended monitoring)
Task 2: Arrange or contract for extended monitoring
Task 3: Document and report monitoring to regulatory agency
Task 4: Evaluate for future projects
Task 5: Post-construction collaborative review

to the type and magnitude of the proposed project and its anticipated social, economic and environmental effects and issues.

All of the activities outlined in the following sections are intended to streamline the environmental review process by involving resource agencies early in project planning and development. In addition, public involvement activities are conducted during each process to further ensure that stakeholder concerns are identified and adequately addressed.

3.4.2.1 Planning and Programming Process

As depicted in Exhibit 3.4–B, the planning and programming process consists of three major non-environmental activities:

- Conduct planning activities (Section 3.4.2.1.1),
- Prepare project scoping report (Section 3.4.2.1.2), and
- Conduct annual multi-year program meeting to select projects (Section 3.4.2.1.3).

Chapter 2 describes the planning and programming process in detail. The environmental tasks that may be required during these activities are described in the following subsections.

3.4.2.1.1 Conduct Planning Activities

Typically, no environmental tasks occur during this activity, except for environmental staff occasionally providing input on issues as needed. Chapter 2 describes the activities encompassed in the transportation planning process.

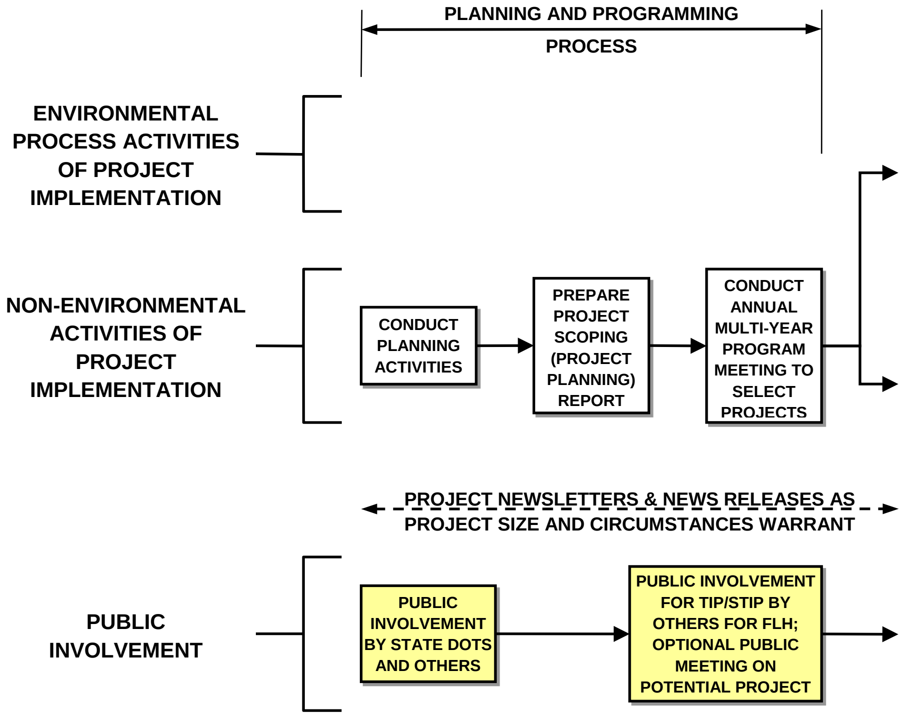
3.4.2.1.2 Prepare Project Scoping (Project Planning) Report

Preliminary environmental information should be gathered for inclusion in the project scoping report. See Section 4.5.2. This type of information may be gathered through record searches, contacting environmental agencies and conducting interagency meetings or field reviews. The preliminary environmental information may consist of the following:

- Initial project NEPA class of action (i.e., Class I—EIS, Class II—CE, Class III—EA). Section 3.5.1 describes the NEPA environmental class of action system in greater detail. Additional information is also included in the 23 CFR 771.115 of the FHWA implementing regulations.
- Tentative schedule for completing the environment compliance requirements;
- Tentative project costs for environmental compliance and mitigation activities;
- Draft purpose and need statement (see *The Importance of Purpose and Need in Environmental Documents*);
- Preliminary list of readily identifiable alternatives (see *Development and Evaluation of Alternatives*);
- Potential environmental concerns or benefits associated with the project;

- Existing survey data; and
- Consistency with local, State or Federal land management plans.

Exhibit 3.4–B PLANNING AND PROGRAMMING PROCESS



3.4.2.1.3 Conduct Annual Multi-Year Program Meeting to Select Projects

The environmental staff may attend these meetings to provide information regarding the status of programmed projects and the feasibility, from an environmental standpoint, of programming other projects.

3.4.2.2 Project Development Process

The majority of the environmental review and compliance activities occur during the project development process. During this process, additional engineering and environmental data are developed through engineering analyses, environmental resource surveys and impact studies. In addition, interagency coordination and public involvement activities are conducted to obtain input on project development and the environmental processes. The appropriate NEPA documents and supporting information are prepared during this process, and project decisions are recorded, including selection of the alternative to be implemented. The project team oversees and guides these environmental activities.

Early in the project development process, the roles, expectations and schedules for involvement by those agencies, particularly cooperating agencies, participating in the project development, should be agreed upon and recorded in a project agreement as described in Section 3.2.3.1.

The project development process consists of two phases:

- The conceptual studies and preliminary design phase, and
- The detailed design phase.

3.4.2.2.1 Conceptual Studies and Preliminary Design Phase

The conceptual studies and preliminary design phase consists of five environmental activities:

- Determine the scope of the environmental review (scoping process),
- Conduct resource surveys,
- Prepare draft environmental document,
- Circulate draft environmental document and conduct public involvement activities, and
- Prepare final environmental document.

Each of these activities is described briefly in the following sections and is graphically illustrated in Exhibit 3.4–C.

1. **Environmental Scoping**

   Prior to initiating the tasks comprising this activity, it is important to review the project agreement to develop a clear understanding of the agency roles, points of contact and other procedures and agreements. A preliminary engineering review is conducted concurrently with the environmental scoping activity as a part of the project development process. This engineering review should be consulted throughout the environmental scoping activity and the other activities in the conceptual studies and preliminary design phase.

   Environmental scoping activities are formally undertaken in this phase, building on the information and input obtained during the planning and programming process. The environmental scoping activity consists of the following seven major tasks as graphically illustrated in Exhibit 3.4–D.

   a. ***Task 1: Review the project scoping (project planning) report***

      The environmental staff reviews all pertinent information on the environmental issues and concerns of the proposed project and project area as identified during the earlier planning and programming process, including project scoping reports.

   b. ***Task 2: Establish project team and conduct initial meeting***

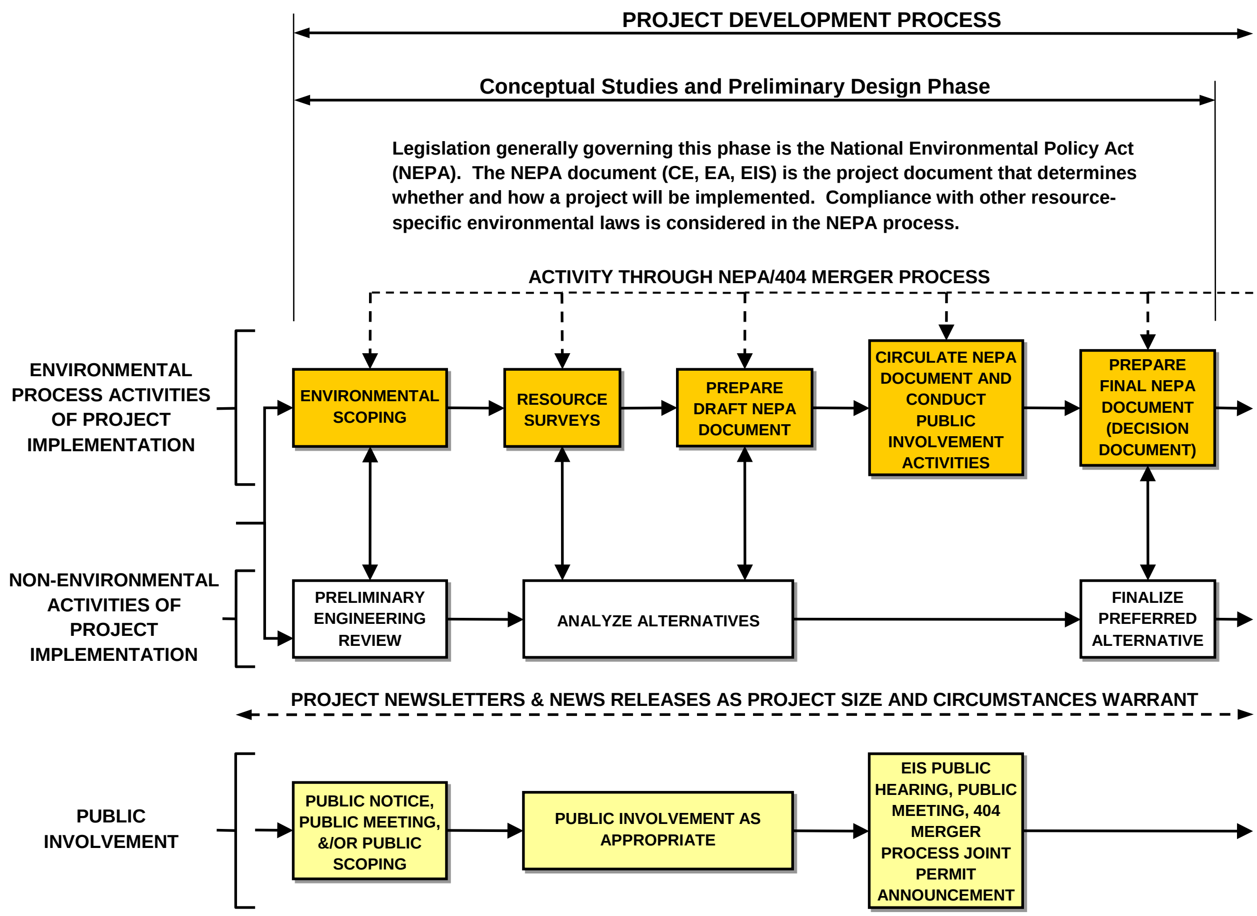
      Depending on the scope of the project, the interagency/interdisciplinary team (the project team) may consist of representatives just from the program agencies or membership may be extended to representatives from resource and regulatory agencies, NEPA cooperating agencies and local governments. Only the program agencies are required to have members on this team. The project team is the decision-making body that acts on behalf of the member agencies to coordinate and share project activities and reach a consensus on major project decisions.

      The first meeting should be conducted as early as possible during the conceptual studies and preliminary design phase to ensure that agency concerns and suggestions are taken into account before the project design progresses too far.

The initial team meeting should be conducted in conjunction with a field review of the project site. The following tasks should be accomplished at the first meeting:

- Review and discuss, as needed, the project agreement and each agency's roles and responsibilities,
- Discuss any project changes and developments since completion of the planning and programming process,

Exhibit 3.4–C PROJECT DEVELOPMENT PROCESS, CONCEPTUAL STUDIES AND PRELIMINARY DESIGN PHASE



TASKS

Task 1: Review the project scoping (project planning) report
Task 2: Establish project team and conduct initial meeting
Task 3: Develop mailing list
Task 4: Send project notice to public agencies
Task 5: Conduct public scoping meetings
Task 6: Publish Notice of Intent in Federal Register (EIS only)
Task 7: Develop and refine the Purpose and Need and the alternatives, and identify major concerns

TASKS

Task 1: Determine resource survey needs
Task 2: Send introductory letters to resource agencies
Task 3: Obtain access permission onto public and private property
Task 4: Initiate and complete surveys
Task 5: Review survey data and finalize survey
Task 6: Coordinate survey results with analysis of alternatives

TASKS

Task 1: Complete resource analysis
Task 2: Analyze and refine alternatives
Task 3: Develop conceptual mitigation
Task 4: Write draft NEPA document
Task 5: Coordinate document with project team

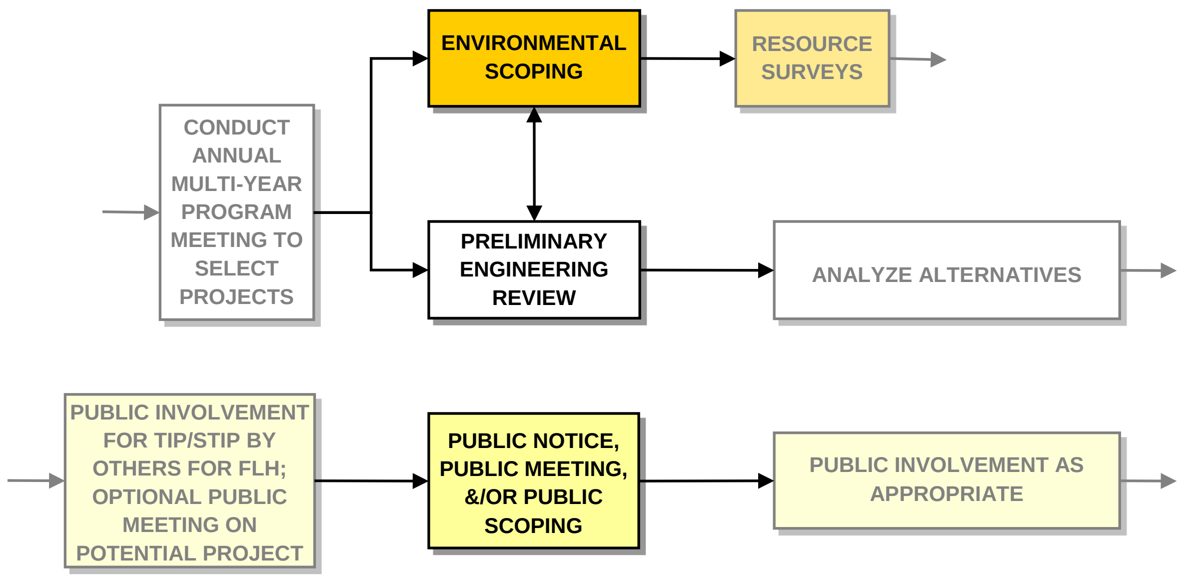
TASKS

Task 1: Public notice
Task 2: Copy and distribute NEPA document
Task 3: Conduct public involvement

TASKS

Task 1: Review and respond to public comments
Task 2: Finalize preferred alternative(s)
Task 3: Prepare and approve the CE
Task 4: Prepare EA or final EIS
Task 5: Prepare, review and approve FONSI or ROD
Task 6: Copy and circulate public notice and NEPA document(s)

Exhibit 3.4–D ENVIRONMENTAL SCOPING



TASKS

Task 1: Review the project scoping (project planning) report
Task 2: Establish project team and conduct initial meeting
Task 3: Develop mailing list
Task 4: Send project notice to public agencies
Task 5: Conduct public scoping meetings
Task 6: Publish Notice of Intent in Federal Register (EIS only)
Task 7: Develop and refine the Purpose and Need and the alternatives, and identify major concerns

- Develop a tentative project schedule,
- Draft a project purpose and need statement to be included in the environmental document,
- Review the preliminary list of alternatives in the project scoping report, and revise as needed, and
- Set a tentative time for the next team meeting.

In the event that the project team consists only of the program agencies, then the team should arrange to meet with other Federal, State and local resources and regulatory agencies as early as possible to inspect the project area onsite and obtain feedback to guide further environmental surveys, studies, analyses and project development activities.

c. ***Task 3: Develop mailing list***

The environmental staff should obtain existing mailing lists from the FLMA and amend them to include the parties associated with the project, including local property owners. The project mailing list should be updated as the public involvement process progresses and additional interested parties are identified. The mailing list is used to send project notices, newsletters and other communications to the interested public and agencies.

d. ***Task 4: Send project notice to public agencies***

Generally, a project notice is sent to the resource and regulatory agencies describing the proposed project and soliciting their input on the project. The primary purpose at this stage is to notify the agencies that project development work is beginning and that this process will include identifying a range of alternatives to be considered and the issues to be addressed, as well as the type of environmental document to be developed, among other tasks. For an EIS, the resource and regulatory agencies may also be asked to provide input on the project purpose and need. The notice may also alert the agencies to upcoming project team meetings to discuss the project.

e. ***Task 5: Conduct public scoping meetings***

A public scoping meeting is usually held in or near the project area. The key objectives of the scoping meeting are the following:

- Provide an agency contact person or website for the public to obtain further information on the project;
- Describe the expected future project development activities;
- Outline the project schedule;
- Identify future opportunities for the public to obtain more information and provide comments (e.g., public meetings or hearings);
- Obtain public comments;
- Gather information from the public that will assist the FLH staff in analyzing and addressing the social, economic and environmental impacts of the project;
- Describe the purpose and need for the project; and
- Present preliminary alternatives identified in the project scoping report.

As this phase proceeds, it is important to keep the local public and other interested parties apprised of project development and to solicit and address the public's concerns. Effective public involvement is a key to successful project development. A public involvement plan may be prepared to guide these public involvement activities, which should be consistent with and build on the efforts made during the earlier planning and programming process. Public involvement can be accomplished with a variety of techniques, depending on the type and magnitude of the project, the issues involved and the interest and background of the public.

Additional guidance on public involvement and the scoping process is available from both the FHWA and the CEQ:

- *Public Involvement Techniques for Transportation Decision-Making*.
- *Public Involvement and its Role in Project Development*.
- CEQ Scoping Guidance.

Guidance from State transportation agencies on public involvement is also provided in Appendices 3A.1 and 3A.2.

f. ***Task 6: Publish Notice of Intent in Federal Register (EIS only)***

For Class I actions, an EIS is prepared, requiring the publication of a Notice of Intent (NOI) in the *Federal Register* to alert other agencies, interest groups and the public of proposed scoping activities, and the plan to prepare an EIS. The NOI is prepared by the FLH environmental staff and is published and distributed as directed in 23 CFR 771.123 and in the FHWA Technical Advisory T6640.8A. The content and format of the notice is provided in explicit detail in the FHWA Technical Advisory T6640.8A, along with examples. Shortly after the NOI is published in the *Federal Register*, appropriate agencies should be formally invited to participate as cooperating agencies or participating agencies. Section 6002 of SAFETEA-LU supplements the existing FHWA and CEQ implementing regulations for NEPA and describes the roles and responsibilities of the lead, participating and cooperating agencies. The *SAFETEA-LU Environmental Review Process Final Guidance* is available and provides guidance on the environmental review process required by Section 6002 of SAFETEA-LU.

g. ***Task 7: Develop and refine the Purpose and Need and the alternatives, and identify major concerns***

Based on the preliminary environmental information gathered during the scoping process, the environmental staff, in coordination with the project team, develops and refines the purpose and need statement for the project. For EIS projects, cooperating and participating agencies and the public must also be given an opportunity to provide input on the purpose and need. For these larger, more complex projects, it is recommended that the environmental staff obtain written approval of the project purpose and need from each member of the project team. The purpose and need statement may continue to undergo minor refinements as the NEPA process continues. If any major changes are made to the project scope, thereby affecting the purpose and need, written approval should be obtained from the project team members.

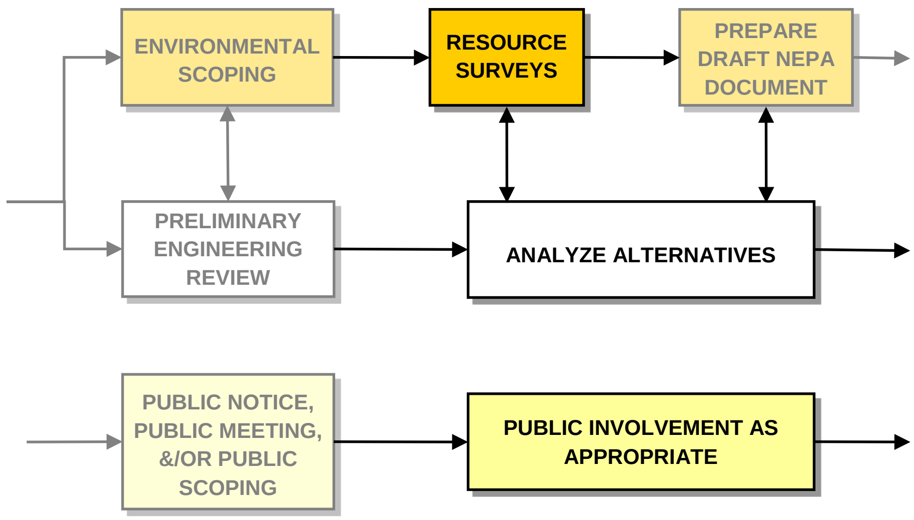
Using the information gathered during the scoping process, the project team should review the alternatives identified in the project scoping report and determine whether these alternatives are still feasible. A range of reasonable alternatives addressing the project purpose and need should be identified. Alternatives found to be unreasonable should be recorded, along with the reasons for that finding. For EIS projects, cooperating and participating agencies and the public must be given an opportunity to provide input on the range of alternatives and in determining the methods and level of detail for the analysis of alternatives. For larger, more complex projects, it is recommended that the environmental staff obtain written approval from each project team member for the range of alternatives to be considered.

Using the information in the project scoping report and the information gathered during the scoping process, the project team identifies the social, economic and environmental issues and concerns associated with the project. For EIS projects, participating agencies and the public must also be given an opportunity to identify issues of concern regarding the project's potential environmental or socioeconomic impacts.

2. **Resource Surveys**

A list of environmental resources to be considered during this activity is provided in Section 3.3.2. The resource surveys activity consists of the following six tasks as illustrated in Exhibit 3.4–E:

Exhibit 3.4–E RESOURCE SURVEYS



TASKS

Task 1: Determine resource survey needs
Task 2: Send introductory letters to resource agencies
Task 3: Obtain access permission onto public and private property
Task 4: Initiate and complete surveys
Task 5: Review survey data and finalize survey
Task 6: Coordinate survey results with analysis of alternatives

a. ***Task 1: Determine resource survey needs***

The tasks performed under the environment scoping activity aid in identifying the social, economic and environmental issues and concerns that should be addressed in the environmental documents and help determine which environmental resource surveys need to be conducted in order to comply with all applicable Federal, State and local requirements. The project area and preliminary design alternatives should be thoroughly reviewed to identify the potentially affected resources and the scope of the required surveys.

b. ***Task 2: Send introductory letters to resource agencies***

By the time this activity is initiated, the resource and regulatory agencies should already be aware of the project. If a project notice was not sent during the environmental scoping phase, it should be sent now. The resource and regulatory agencies and other interested agencies and groups should be aware of and involved in the development of the proposed project, the alternatives under consideration, the environmental resource surveys, environmental analysis and environmental documentation.

Resource and regulatory agency involvement in the resource surveys may include providing comments and advice on the area of potential effects, the survey data required to be collected, conducting these surveys and analyses or portions of them, or providing data in support of the resource surveys. Experience has shown that proactive interagency involvement is critical to secure the various agencies' trust and ensure successful project development.

c. ***Task 3: Obtain access permission onto public and private property***

In order to conduct the resource surveys, coordination with property owners and tenants on or adjacent to the proposed project right-of-way is necessary to obtain access permission onto public and private property. Prior to initiating resources surveys, property owners and tenants should be made aware of when field staff will be in the area collecting data. Notification may be provided through a bulk mailing or telephone calls to property owners.

d. ***Task 4: Initiate and complete surveys***

Resource surveys may be conducted by staff specialists or experts engaged by the partner agencies to assess existing environmental conditions; estimate the effects of the proposed project on the resources; and identify mitigation measures suitable to avoid or minimize the impacts. Base maps of the preliminary alternatives should be made available to ensure adequate data collection in the field and accurate estimates of project impacts. Existing literature and data provided by resource and regulatory agencies should be reviewed, preferably before the resource surveys are conducted and incorporated into the resource survey results. Resource or partner agencies should also provide input on the appropriate methods of data collection.

Section 3.3.2 identifies the environmental resources considered in the NEPA analysis and describes the information required to support NEPA documentation.

e. ***Task 5: Review survey data and finalize survey***

The project team should review the resource survey results to become familiar with the type and location of resources in the project area. Previously undocumented resources or potential issues should be reviewed to determine if additional data collection is required.

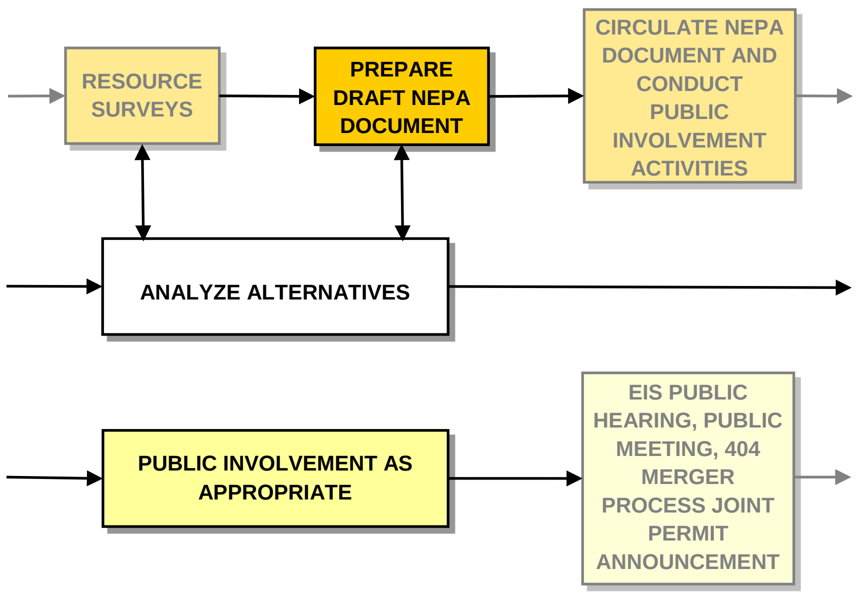
f. ***Task 6: Coordinate survey results with analysis of alternatives***

The project team should review the results of the resource studies and determine the significance of environmental impacts resulting from the proposed alternatives. This analysis should be based on the results of the resource surveys and input from the resource and regulatory agencies and the public. If data gaps are identified or additional information is needed to draw a firm conclusion about significance, additional data should be collected.

3. **Prepare Draft NEPA Document**

As the scoping process and environmental studies proceed, the preliminary NEPA class of action of the project made earlier in this phase should be confirmed (or updated) and implemented. Section 3.5.1 describes the NEPA class of action system. Preparation of the draft NEPA document consists of the following five tasks illustrated in Exhibit 3.4–F:

Exhibit 3.4–F PREPARE DRAFT NEPA DOCUMENT



TASKS

Task 1: Complete resource analysis
Task 2: Analyze and refine alternatives
Task 3: Develop conceptual mitigation
Task 4: Write draft NEPA document
Task 5: Coordinate document with project team

a. ***Task 1: Complete resource analysis***

If data gaps have been identified or additional information is needed to draw a firm conclusion about significance, additional data should be collected so that firm conclusions about significance can be made.

b. ***Task 2: Analyze and refine alternatives***

The results of the resource surveys should be coordinated with the ongoing project engineering and environmental analyses to refine the project alternatives. If the required NEPA document is an EA, it may discuss the preferred alternative and any other alternatives considered; or if a preferred alternative has not been identified, it may present alternatives under consideration. An EA may address only one action alternative (or "build alternative") and is not required to evaluate in detail all reasonable alternatives for the project.

If the required NEPA document is an EIS, the draft EIS should discuss all reasonable alternatives and also should summarize those alternatives eliminated from detailed study. If, based on early coordination and environmental studies, a preferred alternative has been identified, it should be so stated in the draft EIS.

c. ***Task 3: Develop conceptual mitigation***

Once the alternatives are refined and the analysis of impacts has begun, compensatory mitigation requirements can be better defined. Mitigation is defined in Section 1508.20 of the CEQ regulations. Development of the mitigation concepts should be coordinated with the program agencies and the appropriate resource and regulatory agencies. Mitigation for unavoidable adverse impacts should be identified in the NEPA document and incorporated into the project action [23 CFR 771.105(d)]. An EIS should consider mitigation of impacts whether or not the impacts are significant (see Forty Most Asked Questions Concerning CEQ's NEPA Regulations). The conditions for funding mitigation measures are identified in the FHWA implementing regulations, 23 CFR 771.105(d).

Preliminary design work for some types of proposed mitigation should be performed at this time to ensure that the mitigation plan is feasible, has a reasonable chance for long-term success, and is acceptable to the regulatory agencies.

It is FHWA Policy to seek opportunities to go beyond traditional mitigation efforts and to implement enhancement measures into transportation projects.

Enhancement measures should be considered and incorporated into the project at this stage. These types of enhancements can help to build strong relationships with affected communities. They should be coordinated with the program agencies and the public to determine their suitability for projects in the planning stage.

d. ***Task 4: Write draft NEPA document***

The results of the scoping process, the resource surveys and the engineering and environmental analyses are summarized and documented in the appropriate NEPA document for the project (i.e., CE, EA, draft EIS), which is prepared during this activity. Additional supporting documents are also prepared as needed to comply with all applicable environmental requirements. These may include a Section 4(f) evaluation, an ESA biological assessment, a CWA Section 404(b)(1) analysis, and others.

Guidance on the content of these documents is provided in Section 3.3.2.

At a minimum, the CE (i.e., Class II actions) describes the proposed action, the surrounding area and any specific areas of concern (e.g., wetlands, Section 4(f), relocations), and any other Federal actions required for the project. Once a project has been approved as a CE, final design activities may begin (23 CFR 771.113). Additional guidance on the contents and format of the CE are provided in Section 3.5.2.1.

The EA (i.e., Class III actions) addresses the purpose and need for the project; the preferred alternative under consideration and those dismissed from further consideration; and the social, economic and environmental impacts of the project. Additional guidance on the contents and organization of the EA are provided in Section 3.5.2.2.

The draft EIS (Class I actions) addresses the purpose and need for the project; all reasonable alternatives under consideration and those dismissed from further consideration, the preferred alternative if one has been selected; and the social, economic and environmental impacts of each alternative. The NEPA document should demonstrate the project's compliance with all applicable regulatory requirements, and should balance the benefits gained in meeting the purpose and need against the adverse impacts and costs of each alternative, taking into account the proposed mitigation measures. Guidance on the format and content of the EIS is provided in Section 3.4.2.2.

e. ***Task 5: Coordinate document with project team***

Once the environmental staff is satisfied with the preliminary NEPA document, it should be distributed to the project team members for a thorough review. Team members' comments on the document are often best resolved in a full team meeting with open communication.

If the document is a draft EIS, it should be reviewed and approved by the cooperating agencies after the project team comments are incorporated.

4. **Circulate NEPA Document and Conduct Public Involvement Activities**

Once the draft NEPA document is approved by the project team, it is distributed to other agencies and the public, as identified on the mailing list and in accordance with the CEQ and FHWA implementing regulations. Circulation of the draft NEPA document is accomplished through the following three tasks as illustrated in Exhibit 3.4–G:

a. ***Task 1: Public notice***

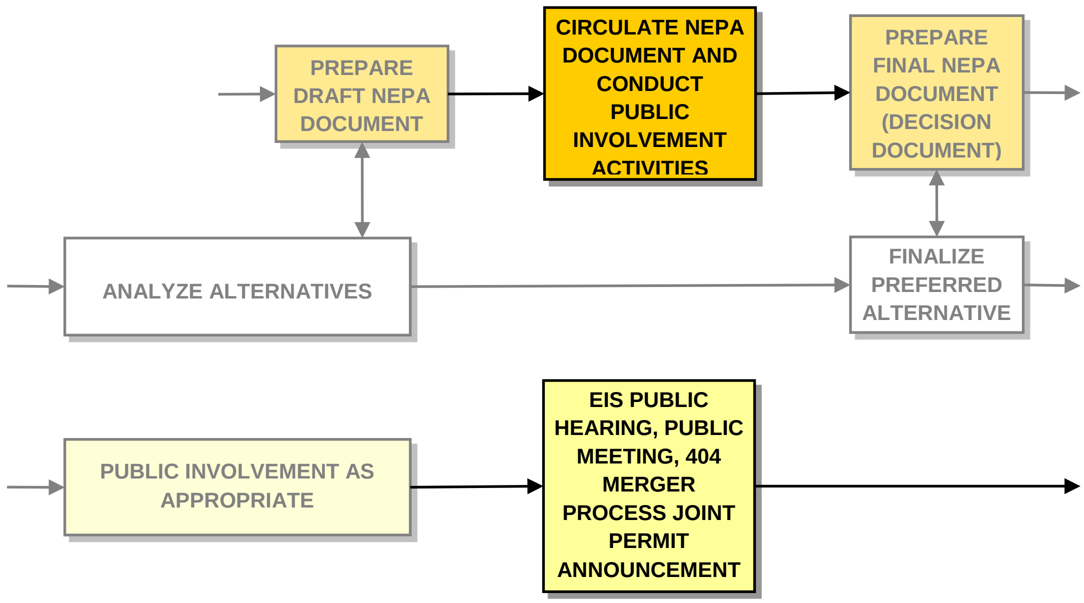
If the document is a CE, it is typically circulated and reviewed only within the FLH and the other partner agencies, although it may be announced and circulated to others if desired or requested.

The publication of an EA or draft EIS and any scheduled public meetings or hearings are usually announced with a public notice in the local general-circulation newspaper(s). In addition, notices are sent to the mailing list of interested citizens, agencies and stakeholder groups.

The EA or draft EIS public notice should contain the name of the project (and road), the project number, names of the lead and cooperating agencies, the project termini, a brief statement of the project purpose and need, a description of the planned activities and a map of the project area. The notice should explain the status of the project in the environmental review process and should invite public comments regarding the environmental analysis, permits and approvals.

Contact information should be included for those who wish to comment or request further information.

Exhibit 3.4–G CIRCULATE NEPA DOCUMENT



TASKS

Task 1: Public notice

Task 2: Copy and distribute NEPA document

Task 3: Conduct public involvement

A copy of the draft EIS is filed with the EPA. The EPA publishes a notice of availability in the *Federal Register*. The draft EIS should be distributed no later than the time the document is filed with the EPA for *Federal Register* publication and should allow for a minimum 45-day review period.

b. ***Task 2: Copy and distribute NEPA document***

By the time the public notice is published, the EA or draft EIS should have been distributed to the parties on the mailing list. Copies of the document are also made available for review at convenient locations. The extent of distribution is determined by the NEPA class of action, size and scope of the project, public interest and the number of parties on the mailing list.

The distribution requirements for an EA or draft EIS are described in the FHWA Technical Advisory T6640.8A. The FHWA *Environmental Guidebook*, environmental documentation section, provides guidance on filing an EIS.

c. ***Task 3: Conduct public involvement***

Although not required, after an EA is circulated, a public meeting is typically scheduled in conjunction with a 30-day public comment period on the document.

After a draft EIS is circulated, a minimum 45-day public comment period is required. Within this time period, a public hearing is required to obtain additional comments on the project and the document. Public meetings may be scheduled in addition to a public hearing.

Procedures for conducting public meetings and hearings are explained in the FHWA guidance, *Public Involvement Techniques for Transportation Decision-Making*. In addition, the FHWA implementing regulations provide procedures for conducting public meetings and hearings.

The interagency agreements discussed in Section 3.2.2 may include provisions for conducting jointly sponsored public meetings and hearings when appropriate.

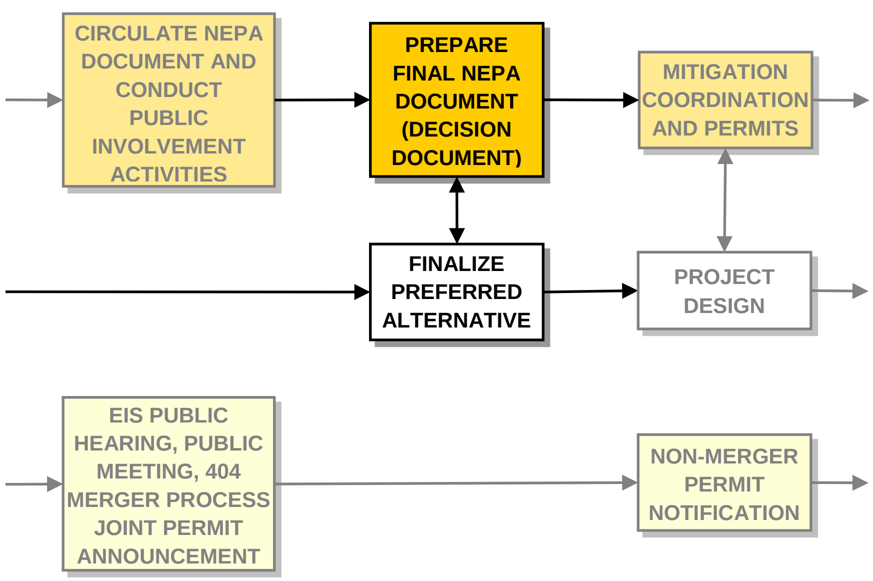
5. **Prepare Final NEPA Document (Decision Document)**

Preparation of a decision document (i.e., EA/FONSI, final EIS/ROD) consists of six tasks as illustrated in Exhibit 3.4–H:

a. ***Task 1: Review and respond to public comments***

Based on the circulation of the initial NEPA document and the oral or written comments received from the agencies and the public, the environmental staff reviews and responds to the comments, incorporates any necessary changes in the project and the document and prepares the decision document.

Exhibit 3.4–H PREPARE FINAL NEPA DOCUMENT



TASKS

Task 1: Review and respond to public comments
Task 2: Finalize preferred alternative(s)
Task 3: Prepare and approve the CE
Task 4: Prepare EA or final EIS
Task 5: Prepare, review and approve FONSI or ROD
Task 6: Copy and circulate public notice and NEPA document(s)

For EAs and EISs, the environmental staff coordinates with the other program agencies and the project's cooperating agencies to address the comments received. The comments should be included in the final environmental document along with the responses. There is no prescribed method for responding to comments or presenting changes in the decision document.

b. ***Task 2: Finalize preferred alternative(s)***

Typically, the EA or draft EIS identifies the preferred alternative for the project. Once the comments on the EA or draft EIS are addressed, the environmental staff coordinates with the project team and the cooperating agencies to identify any additional changes to the preferred alternative, or to determine whether selection of a new preferred alternative is warranted.

If the draft EIS does not identify a preferred alternative, then the preferred alternative should be identified as the alternative that best meets the project purpose and need while taking into account and balancing all of the social, economic, and environmental impacts and costs. The preferred alternative should be one that was fully studied in the draft EIS, or a combination of alternatives that were fully studied. If an alternative that was not fully studied is selected based on comments or new information, then preparation and circulation of a supplemental draft EIS may be required before the project can proceed to the decision document stage.

c. ***Task 3: Prepare and approve the CE***

Approved CEs are usually distributed only within the FLH and the partner agencies, although they may be announced and distributed to others if desired or requested. A notice of the CE approval and project status should be provided to interested parties. If a Section 4(f) approval is required for a project processed as a CE, the project may not proceed until notice of the approval has been issued (23 CFR 771.135(l)). The approval process for the CE is identified in Section 3.5.3.

d. ***Task 4: Prepare EA or final EIS***

For an EA or a final EIS, once the preferred alternative is selected, the final document is approved by the FLH and published. The content and format of the EA and the final EIS are described in Sections 3.5.2.2 and 3.5.2.3.2, respectively.

Once the environmental staff is satisfied with the EA or final EIS, copies of the document are distributed to the project team for a thorough review. If the document is a final EIS, it is also reviewed and approved by the project cooperating agencies after the project team is satisfied with the document.

e. ***Task 5: Prepare, review and approve FONSI or ROD***

For EAs (i.e., Class III actions), the decision document is a FONSI. Prior to preparing the FONSI and following the public availability period and receipt of comments on the EA, the action should be reviewed to determine the significance of impacts. If, after completing the process, it is evident that there are no significant impacts associated with the project, a FONSI may be prepared. If, at any point in the process of preparing or processing an EA, it is discovered that the project would result in any significant impacts to the environment, then a draft EIS should be prepared.

The FONSI describes the action to be implemented, including the preliminary design features, environmental commitments and mitigation measures. The FONSI also explains why the action will not result in significant impacts. The FONSI should summarize the factors considered in the determination and may include responses to public comments on the EA.

For an EIS (i.e., Class I action), the decision document is a final EIS and ROD, which can be issued no sooner than the later of the following two dates:

- 90 days after publication of the notice of availability of the draft EIS, or
- 30 days after the final EIS is published.

The ROD identifies the alternative to be implemented, provides the rationale for this decision and summarizes the measures incorporated into the project to avoid or minimize environmental harm.

Once the FLH staff is satisfied with the FONSI or ROD, the document is circulated to the project team for review and approval. Subsequently, it is circulated to the cooperating agencies for review.

The FLH approval of the FONSI or ROD also constitutes approval to begin the detailed design phase of the project. The FHWA regulations require that the final environmental document for the project be approved before final design or other major project activities (e.g., property acquisition) can advance (23 CFR 771.113). If a Section 4(f) approval is required for a project processed as a FONSI, the project may not proceed until notice of the approval has been issued (23 CFR 771.135(l)).

Information on the content and format of FONSIs and RODs is available in Sections 3.5.2.2.2 and 3.5.2.3.3, respectively. The approval process for the FONSI and the ROD is outlined in Section 3.5.3.

f. ***Task 6: Copy and circulate public notice and NEPA document(s)***

Formal distribution of a FONSI is not required, but the notice of availability of the FONSI should be sent to Federal, State and local government agencies likely to have an interest in the project. The notice of availability should include all relevant project details, with contact information for requesting a copy of the FONSI. Alternatively, availability of a FONSI may be announced by public notice to the local newspaper(s) and the mailing list, and copies are made available at convenient locations for public review. The distribution requirements for the EA and FONSI are described in the FHWA Technical Advisory T6640.8A.

Availability of a final EIS is announced by public notice to the local newspaper(s) and the mailing list. Copies are circulated and made available at convenient locations for public review. A notice of availability of the final EIS is published by the EPA in the *Federal Register*.

For a final EIS, the notice should announce the project decision and the availability of the ROD. The ROD can be issued no sooner than 30 days after the approved final EIS is made available.

The distribution requirements for the final EIS and ROD are described in the FHWA Technical Advisory T6640.8A. Guidance for filing EISs is also available in the FHWA *Environmental Guidebook*, environmental documentation section.

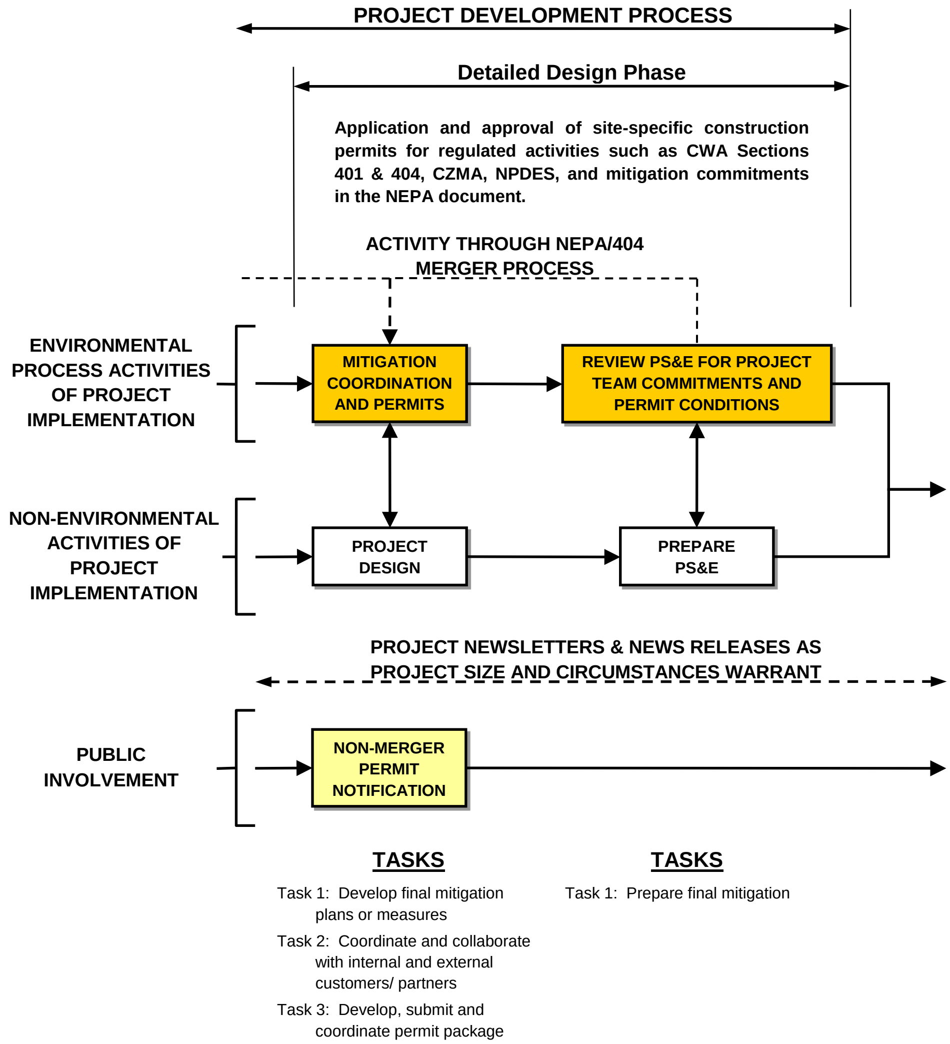
Section 6002(a) of SAFETEA-LU (also referred to as 23 USC 139(l) Limitation on Claims Notices) includes a new provision creating a maximum statute of limitations period of 180 days after publication of a notice in the Federal Register announcing that the permit, license or approval is final pursuant to the law under which the agency action is taken. If a notice is not filed in the Federal Register, then the applicable limitation on claims is a period of 6 years (28 USC 2401). This new provision may be used for any highway project, regardless of the class of action. However, it is likely justified only for EIS and EA projects. *FHWA Guidance on the Limitation of Claims Notices* gives additional information on its application in the NEPA process, including suggested language for inclusion in the NEPA documents.

3.4.2.2.2 Detailed Design Phase

This phase, illustrated in Exhibit 3.4–I, involves the refinement of the project design (e.g., specific structural features, right-of-way plans, construction permit conditions, construction materials, methods and scheduling, and the plans, specifications, and estimates [PS&E]). The final environmental mitigation measures are also coordinated and incorporated, as appropriate, into the final design and PS&E. During the detailed design phase, the project team continues to seek to avoid, minimize and mitigate the adverse impacts of the selected alternative. The project team continues to oversee and guide the environmental process through this phase.

The detailed design measures, mitigation measures and permit requirements are expected to be consistent with the surveys, analyses and coordination conducted in the earlier phases and to build on them. Barring any substantial changes to the project, the project's final environmental document (i.e., CE, FONSI, final EIS/ROD) and its environmental commitments are expected to be valid and to be reflected in the project final design and PS&E. The environmental staff should confirm the validity of the environmental document before proceeding with each major project approval (i.e., final design, right-of-way, PS&E approval, construction). If a change occurs in the project that may substantially change the associated project impacts, or if considerable time has elapsed since the environmental document was approved or reviewed for validity, the environmental staff should conduct a written reevaluation of the document and supplement it if necessary.

Exhibit 3.4–I PROJECT DEVELOPMENT PROCESS, DETAILED DESIGN PHASE



The FHWA implementing regulations identify when a reevaluation or supplement is required. The format and content of a reevaluation and supplemental EIS are described in Sections 3.5.2.4 and 3.5.2.5, respectively.

The two activities and related tasks encompassed in the detailed design phase are described as follows:

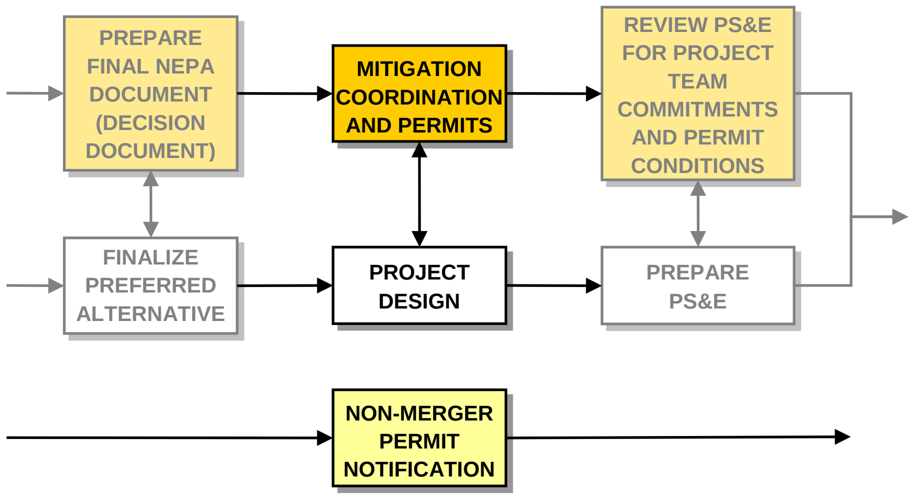
1. **Mitigation Coordination and Permits**

   The mitigation coordination and permit activity consists of three tasks as illustrated in Exhibit 3.4–J and described below.

   a. ***Task 1: Develop final mitigation plans or measures***

      Refinement of the project final mitigation measures is conducted in close coordination with partner agencies and the resource and regulatory agencies. Wetlands, streams, vegetation and cultural resources are common areas for which project-level mitigation measures are prepared. These measures may include design documents, contractor specifications and/or permit conditions and other commitments. Design documents are often reviewed with the partner, resource and regulatory agencies and the environmental staff to obtain input on design features, mitigation requirements and permit conditions. The standard operating procedures for interagency agreements and cooperating agencies emphasize the full coordination and involvement of these agencies in development of the mitigation measures and permit application.

Exhibit 3.4–J MITIGATION



TASKS

Task 1: Develop final mitigation plans or measures
Task 2: Coordinate and collaborate with internal and external customers/ partners
Task 3: Develop, submit and coordinate permit package

b. ***Task 2: Coordinate and collaborate with internal and external customers/ partners***

As the detailed design phase proceeds, the local public and other interested parties should be advised of the project status and any important changes or developments. This may be accomplished through a project notice to the local newspaper(s) and the mailing list, or other appropriate techniques (e.g., a project newsletter, website). For some large, complex or sensitive projects, a public meeting may be held to inform the public on the design process, present the project design and solicit comments. Also during this phase, development of plans for the project right-of-way and property acquisition requires close coordination with property owners and tenants within, adjacent to, and near the project right-of-way. Finally, the mitigation commitments identified in the NEPA document and permits need to be communicated and incorporated into the PS&E package.

c. ***Task 3: Develop, submit and coordinate permit package***

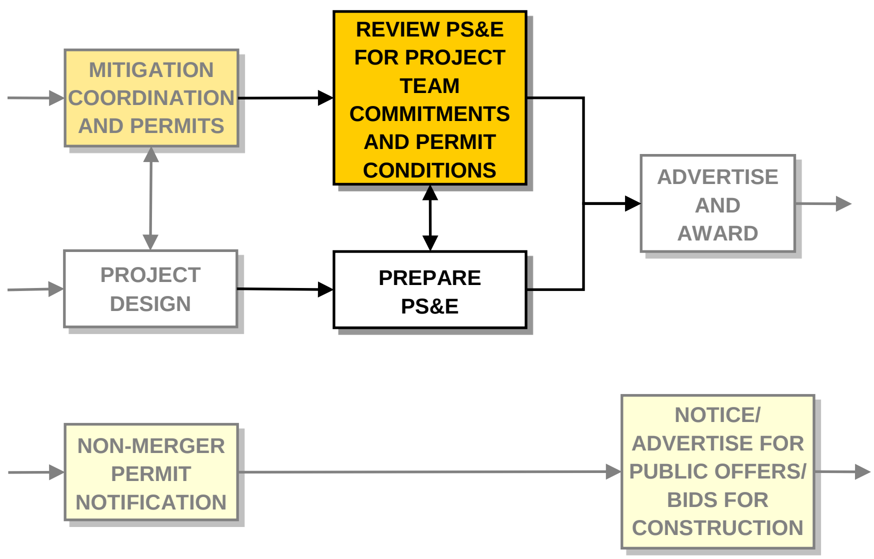
The environmental staff gathers data from all sources (e.g., design documents, program agencies, NEPA documents, resource surveys) to complete the required permit applications. It is wise to verify with each agency the correct permit application forms and instructions. Incorrect or missing information will delay the permit process. Each permit application is signed, and applicable application fees should be paid when the permit is submitted.

Permits have variable life spans. Ideally, the permits are valid for the duration of the project. If this is not feasible, the issuing agency should be contacted to ensure a clear understanding and process for extending the permit, if necessary.

2. **Review PS&E for Project Team Commitments and Permit Conditions**

During this activity illustrated in Exhibit 3.4–K, the environmental staff, project team and others review the PS&E package to ensure that the proposed action has not changed since the NEPA approval stage, and that the environmental mitigation measures, commitments and permit conditions are incorporated into the PS&E package as addressed in the environmental document and as coordinated with the regulatory agencies. Any items that are lacking or deficient are identified by these reviewers, who specify the conditions that need to be addressed or completed. The final, complete PS&E package is reviewed by the responsible environmental official to verify that the project is ready for advertisement. This activity consists of one task:

Exhibit 3.4–K REVIEW PS&E



TASKS

Task 1: Prepare final mitigation

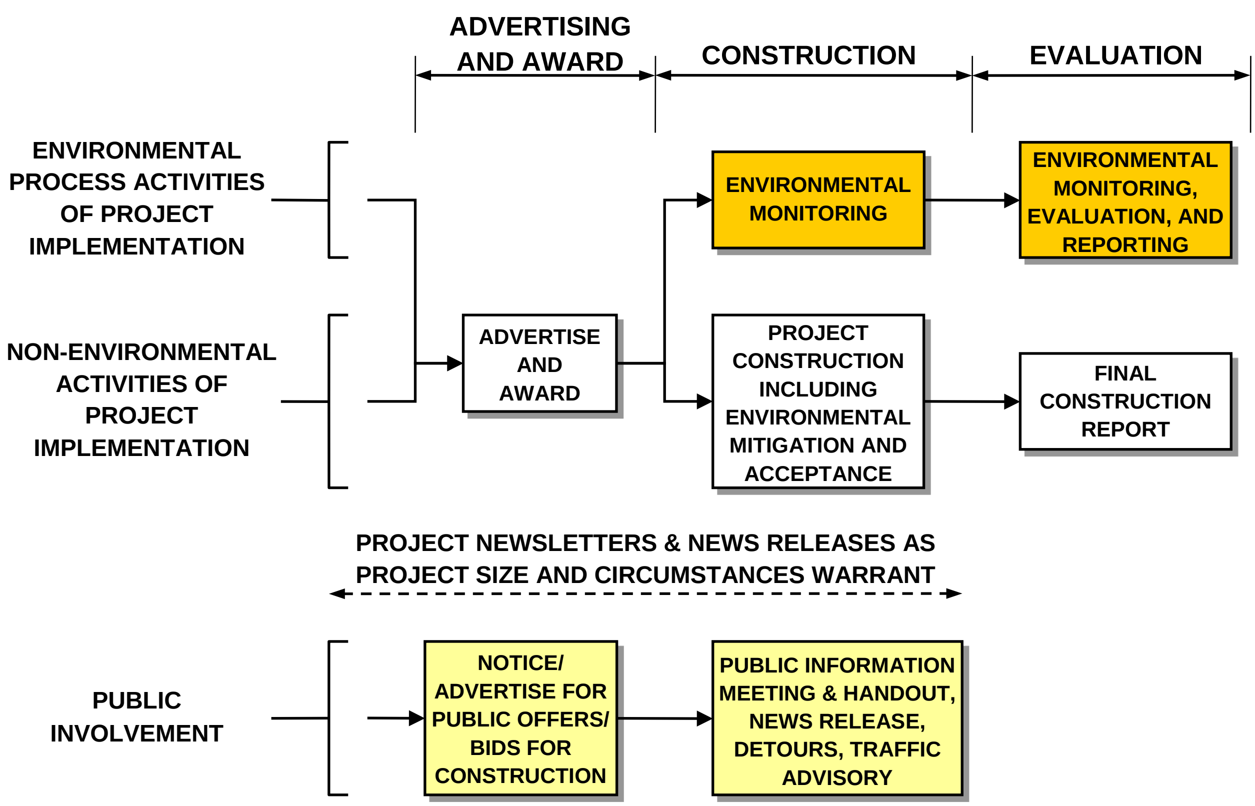
a. ***Task 1: Prepare final mitigation***

The final mitigation plan should be completed under this activity and should be ready prior to advertising and award. The plan may be included in the highway contract or developed as a separate contract, or implemented by a program agency.

3.4.2.3 Advertising and Award Process

The advertising and award process is generally not affected by environmental procedures. All environmental documents and other information that would be useful to the contract management staff should be compiled during this process. In addition, if a project faces complex environmental issues, a meeting with the construction staff may be scheduled to communicate those complexities and the commitments that have been made. The advertising and award process is shown in Exhibit 3.4–L.

Exhibit 3.4–L ADVERTISING AND AWARD, CONSTRUCTION AND EVALUATION PROCESSES



TASKS

Task 1: Monitor construction mitigation

Task 2: Document and report (if short-term)

TASKS

Task 1: Monitor after completion of construction (extended monitoring)

Task 2: Arrange or contract for extended monitoring

Task 3: Document and report monitoring to regulatory agency

Task 4: Evaluate for future projects

Task 5: Post-construction collaborative review

3.4.2.4 Construction Process

During this process, the project is constructed according to the final design in the PS&E including the environmental commitments, mitigation measures and permit conditions. Construction is expected to be consistent with the determinations and commitments of the environmental document and earlier environmental coordination. If project changes occur during construction that affect earlier environmental coordination, determinations or commitments, these changes are to be coordinated with the environmental staff, the partner agencies and the resource and regulatory agencies, as appropriate. The construction staff is expected to use all practical means to minimize adverse social, economic and environmental impacts during construction.

The construction process consists of one primary activity, environmental monitoring as shown in Exhibit 3.4–L. The project mitigation plan and environmental permits may specify that environmental monitoring and reporting be carried out during construction activities. The environmental staff may also selectively monitor project construction for environmental compliance. The environmental monitoring activity consists of the two tasks:

1. ***Task 1: Monitor construction mitigation***

   The purpose of monitoring during construction may vary with the project. Resources that are commonly monitored during construction include wetlands, erosion control, water quality and revegetation. Most often, monitoring is required to ensure that environmental mitigation measures and commitments are implemented as intended. For example, the contractor is required to ensure that the best management practices (BMPs) and measures identified in the stormwater pollution and prevention plan (required under the NPDES permit, described in Section 3.3.3.3) are properly installed and functioning. Sometimes monitoring is required to ensure that construction follows the appropriate sequence or achieves the design requirements (e.g., topographic elevation, slope position, skew). Monitoring is arranged by the environmental staff and is conducted by FLH, other agencies or their consultants.

2. ***Task 2: Document and report (if short-term)***

   Reporting in some form (i.e., reports, forms, memos) may be required during construction, depending on commitments with the regulatory agencies. Documentation during the construction period is most likely to be required when construction involves important or sensitive environmental features or conditions, or when new or innovative design or mitigation measures are used. Reporting is often provided by those conducting the monitoring. The report is then forwarded to the environmental staff, who circulates it to the construction engineer, engineering staff, partner agencies, resource and regulatory agencies, project team and others as appropriate.

3.4.2.5 Evaluation Process

The completed construction project is evaluated for proper implementation of environmental measures and assessment of the effectiveness of these measures. The evaluation process consists of environmental monitoring, evaluation and reporting as shown in Exhibit 3.4–L.

Once construction is complete, the construction engineer formally accepts the completed project from the contractor and verifies that environmental mitigation measures and commitments have been constructed and are operating as intended. The construction personnel also summarize the implementation and effectiveness of these measures in the final project construction report.

The purposes and processes for carrying out post-construction monitoring, evaluation and reporting are similar to those discussed above for the construction process. The environmental staff arranges for monitoring, evaluation and reporting in coordination with the resource and regulatory agencies, the interagency/interdisciplinary team, the maintaining agency and others as appropriate. The environmental monitoring, evaluation and reporting activity consists of five tasks:

1. ***Task 1: Monitor after completion of construction (extended monitoring)***

   The project mitigation plan and environmental permits may specify that environmental monitoring and evaluation be carried out after construction activities are complete. Long-term monitoring is likely to be required when compensatory wetland mitigation is required or when the project includes a new or innovative design or mitigation measures (e.g., wildlife crossing structures, slope stabilization, stormwater treatment or control). Revegetated areas or exposed slopes may also be monitored after construction is complete.

   The purpose of monitoring varies with the project. Most often monitoring is conducted to ensure that environmental mitigation measures and commitments adequately offset the impacts of the project.

2. ***Task 2: Arrange or contract for extended monitoring***

   Long-term monitoring is arranged by the environmental staff and may be conducted by FLH, other agencies or their consultants.

3. ***Task 3: Document and report monitoring to regulatory agency***

   The results of long-term monitoring are documented in a report to the regulatory agency, often prepared by those conducting the monitoring. The report is then forwarded to the environmental staff, who circulates it to the construction engineer, engineering staff, program agencies, resource and regulatory agencies, the project team and others as appropriate. If the mitigation efforts are unsuccessful, additional mitigation measures may be required.

4. ***Task 4: Evaluate for future projects***

   The results of the post-construction monitoring should be evaluated to inform future projects. Monitoring and evaluation serve a further purpose when the lessons learned are applied to future projects.

5. ***Task 5: Post-construction collaborative review***

   A post-construction review should be performed with the design team, construction staff and other technical personnel to gain an understanding of the successes and failures of the mitigation efforts. It is important to evaluate the performance of both the construction-process mitigation measures and the permanent mitigation measures. The follow-up review may include an onsite visit by FLH staff, program agencies and resource and regulatory agencies.

3.5 NEPA DOCUMENTATION

This section describes the FHWA NEPA class of action system and identifies the required NEPA documentation for each class of action. In addition, guidance is provided on contents of the documentation. The process for producing NEPA documents when FLH is the lead agency is discussed in Section 3.4.2. If FLH is not designated as the lead agency for NEPA compliance, the division engineer determines when FLH incurs a NEPA responsibility and identifies the appropriate documentation to address that responsibility.

The most useful resource for specific information on the contents of NEPA documents is the FHWA Technical Advisory T6640.8A.

Appendix 3A.2 lists additional online sources from State transportation agencies that provide information on each NEPA document type and the required contents.

3.5.1 NEPA CLASS OF ACTION

There are three classes of actions that prescribe the level of NEPA documentation required:

- Class I Action—Requires an EIS.
- Class II Action—Requires a CE.
- Class III Action—Requires an EA.

An action is defined as “a highway or transit project proposed for FHWA or FTA funding. It also includes activities such as joint and multiple use permits, changes in access control, etc., which may or may not involve a commitment of Federal funds [23 CFR 771.107(b)]”. The FHWA implementing regulations describing the classes of actions and providing examples are discussed in the following sections.

3.5.1.1 Class I Action (EIS)

A Class I action is an action that significantly affects the environment and requires an EIS (23 CFR 771.115(a)). The following are examples of actions that normally require an EIS:

- A new controlled access freeway;
- A highway project of four or more lanes on a new location;
- New construction or extension of fixed rail transit facilities (e.g., rapid rail, light rail, commuter rail, automated guideway transit); and/or
- New construction or extension of a separate roadway for buses or high occupancy vehicles not located within an existing highway facility.

An EIS is required for any action that has a significant environmental impact. “Significantly” as used in NEPA requires considerations of both context and intensity and is defined in the

CEQ regulations. An EIS may also be prepared for other reasons, including significant public controversy with widespread and/or conflicting opinions by recognized experts.

3.5.1.2 Class II Action (CE)

Categorical exclusion refers to actions that do not individually and cumulatively have a significant effect on the human environment (23 CFR 771.115(b)). These actions are excluded from the requirement to prepare an EA or EIS. The FHWA Technical Advisory T6640.8A provides additional guidance for determining whether a project qualifies for a CE.

The FHWA implementing regulations include a list of projects that generally meet the criteria for a CE.

CEs are divided into two groups based on a proposed action's potential for impacts. The first group of actions, known as the C list (23 CFR 771.117(c)), includes 20 types of actions that normally do not cause significant environmental impacts. The second group, known as the D list (23 CFR 771.117(d)), consists of actions having a higher potential for impacts than the first group but still meeting the criteria for a CE.

All projects considered for a CE must undergo an "unusual circumstances" review as defined in 23 CFR 771.117(b). If a project involves one or more of these unusual circumstances, resource studies should be conducted to determine whether the CE classification is appropriate. As defined in 23 CFR 771.117(b), unusual circumstances include the following:

- Significant environmental impacts;
- Substantial controversy on environmental grounds;
- Significant impact on properties protected by Section 4(f) of the *USDOT Act* or Section 106 of the *National Historic Preservation Act*; and
- Inconsistencies with any Federal, State or local law, requirement or administrative determination relating to the environmental aspects of the action.

3.5.1.3 Class III Action (EA)

A Class III action is an action in which the significance of the environmental impact is not clearly established. All actions that are not Class I or II are Class III. All actions in this class require the preparation of an EA to determine the appropriate environmental document required (23 CFR 771.115 (c)).

3.5.2 NEPA DOCUMENT CONTENTS

This section describes the content requirements for each NEPA document type. NEPA documents should be logical, thorough and concise, with all impact conclusions self-evident based on the contents of the document itself and associated appendices, if any. Although there is a general list of items that each document should contain, each document should be customized to the conditions and circumstances of the project. Therefore, only the important issues (as identified by the project team in consultation with resource agencies and the public, and based on the results of resource surveys) should be thoroughly analyzed, with less attention given to issues that the project team and the public determine to be of less concern.

The primary reference for the content and format of all NEPA document types is the FHWA Technical Advisory T6640.8A.

Another useful guidance document on NEPA document contents and the NEPA process is the Forty Most Asked Questions Concerning CEQ's NEPA Regulations.

See Section 3.3.1 for more information on States with NEPA-equivalent laws.

When the FLH serves as a joint lead agency, the NEPA document may have additional content requirements to meet the needs of the other Federal lead agencies. See Section 3.3.1.2.7 for more information on partner agency guidance on preparing NEPA documents.

3.5.2.1 Categorical Exclusion (Class II Action)

If an action is on the C list, the action is automatically classified for a CE, and except where unusual circumstances exist, the project does not require further approvals or documentation to comply with NEPA. However, other environmental laws (e.g., NHPA, ESA, CWA) may still apply and documentation necessary to comply with those laws is not nullified by classifying a project as a CE.

If an action is on the D list, or is not on either list but might qualify for a CE, additional information and documentation is needed to determine whether the CE classification is appropriate. Typically, D list projects have a higher potential for impacts than C list projects but still meet the criteria for a CE.

It is standard procedure to prepare a CE document for all CE projects, regardless of their status on the C list or D list. The FHWA Technical Advisory T6640.8A provides guidance on the level of documentation appropriate for the type of action and extent of impacts, and emphasizes that different levels of information and environmental studies may be required to approve the CE. The CE project files should include justification for classifying the project as a CE as well as records of coordination and compliance with the various environmental regulations described in Section 3.3.2.

There is no standard format or outline for CE content and format.

3.5.2.2 Environmental Assessment (Class III Action)

The documentation for Class III actions includes the EA and the FONSI. The contents of each document are discussed in the following sections. The process and timing for preparation and submittal of each of these documents are discussed in Section 3.4.2.

3.5.2.2.1 Environmental Assessment

See the FHWA implementing regulations on EAs. The EA should briefly address all relevant environmental resources or features but should fully address those environmental resources that would be potentially affected by the project. The EA should also be a concise document and should not contain long descriptions of detailed information which may have been gathered or analyses which may have been conducted for the proposed action. See *NEPA Documentation: Environmental Assessment* for the definition of and purpose for an EA, as well as a brief overview of the content and process.

The FHWA Technical Advisory T6640.8A suggests an outline for the EA and describes the information to be included for each item in the outline. The technical advisory States that the discussion of impacts should include enough analysis to adequately identify the expected impacts and appropriate mitigation measures. In addition, it is appropriate to include a summary of mitigation commitments in a separate section of the EA.

In addition to the guidance on the purpose and need for the action and project alternatives provided in the FHWA Technical Advisory T6640.8A, see *The Importance of Purpose and Need in Environmental Documents* and *Development and Evaluation of Alternatives*.

See question 36a in the Forty Most Asked Questions Concerning CEQ's NEPA Regulations, which asks "How long and detailed must an EA be?"

If a Section 4(f) evaluation is required for the project, it is typically included as part of the EA. Pertinent information in the EA may be summarized in the Section 4(f) evaluation to avoid repetition. Additional guidance on documentation requirements for the Section 4(f) evaluation in the EA is contained in the FHWA implementing regulations.

The FHWA *Environmental Guidebook*, *Indirect and Cumulative Impacts* contains several links to useful guidance on the consideration of indirect and cumulative impacts in the NEPA document.

The EA appendix materials may include a Section 404(b)(1) evaluation, a biological assessment, a biological opinion, a conceptual wetland mitigation plan, or documentation of compliance with Section 106 or other executive orders. The format and content of these documents are discussed in Section 3.3.2.

The FHWA Technical Advisory T6640.8A also provides guidance on the contents of a revised EA, issued after the public availability period. The key elements of EA revisions include:

- Documentation of changes in the proposed action or mitigation measures resulting from comments received during the public availability period.
- Statements of findings, agreements, or determinations for the project.
- Summary of pertinent comments on the EA and appropriate responses to the comments.

3.5.2.2.2 Finding of No Significant Impact

See the FHWA implementing regulations on FONSIs.

After reviewing the public comments on the EA, responses to the comments are prepared and, if appropriate, a finding is made that the project would have no significant impacts. The responses to comments, the amending of the EA as needed and the FONSI all require approval and concurrence from the appropriate project team members.

The FONSI is a separate, brief document attached to the EA. The FONSI is a decision document that sets forth and supports the FHWA's conclusions that the proposed action has no significant impacts. For further information, see the CEQ regulations definition of FONSI. Section 6002(a) of SAFETEA-LU (also referred to as 23 USC 139(l) Limitation on Claims Notices) includes a provision creating a maximum statute of limitations period of 180 days, versus 6 years as identified in 28 USC 2401. Refer to FHWA Guidance on the Limitation of Claims Notices for application of this new provision in the NEPA process.

In addition to documenting compliance with NEPA, the EA and FONSI should also document compliance with other applicable environmental laws, executive orders and related requirements. If full compliance with these other requirements is not possible at the time the FONSI is prepared and signed, the EA and FONSI should summarize the consultation that has occurred thus far, and describe when and how the requirements will be met. If use of a Section 4(f) evaluation is required for a project, the FONSI must specifically address the reasons why the alternatives to avoid a Section 4(f) property are not feasible and prudent, and all measures to be taken to minimize harm to the Section 4(f) property. Additional guidance on the documentation requirements for the Section 4(f) evaluation in the FONSI is contained in the FHWA implementing regulations.

If it is determined that based on the information contained in the EA, the project may have significant impacts, then the project is upgraded to a Class I action requiring the preparation of an EIS.

3.5.2.3 Environmental Impact Statement (Class I Action)

See Section 3.5.1.1 for guidance on determining whether a project meets the criteria for an EIS.

Documentation for Class I actions are the draft EIS, final EIS and ROD. The contents of each of these documents are discussed below. The process and timing for their preparation and submittal are discussed in Section 3.4.2.

3.5.2.3.1 Draft Environmental Impact Statement (Draft EIS)

The primary reference for draft EIS organization and content is the FHWA Technical Advisory T6640.8A. Also, see the FHWA implementing regulations on the draft EIS. The implementing regulations describe the draft EIS process and the FHWA responsibilities in preparing and circulating the document. A concise overview of the content and process for an EIS is available at *NEPA Documentation: Environmental Impact Statement*.

The CEQ regulations provide only general guidance on the recommended format for EISs. The regulations state that the agency shall use an EIS format that encourages good analysis and clear presentation of the alternatives, including the proposed action. The regulations contain a standard EIS format that should be followed unless the agency determines that there is a compelling reason to do otherwise.

The California Division of the FHWA developed a checklist for draft NEPA documents. The checklist is based on FHWA Technical Advisory T6640.8A, but provides a useful and concise list of the information that should be provided in a draft EIS. Some FLH Divisions have developed their own checklists.

The FHWA Technical Advisory T6640.8A provides a suggested outline for the draft EIS. The advisory contains considerable detail regarding the content for each item and therefore is not repeated here. The technical advisory suggests that the draft EIS should provide a single description of the project area and should document all socially, economically and environmentally sensitive features in the proposed impact area. The summary of existing conditions should be limited to information which will have a bearing on possible impacts, mitigation measures and selection of an alternative. The discussion should be commensurate with the importance of the impact and less important information should be summarized or referenced. The technical advisory also suggests impacts and mitigation measures should be discussed in the environmental consequences section of the draft EIS. It is appropriate to include a summary of mitigation commitments in a separate section of the EIS.

Section 3.3.2 provides additional guidance on the required NEPA documentation for the environmental resources addressed in the draft EIS.

If a Section 4(f) evaluation is required for the project, it is typically included as part of the draft EIS. Pertinent information in the EIS may be summarized in the Section 4(f) evaluation to avoid repetition. Additional guidance on the documentation requirements for the Section 4(f) evaluation in the final EIS is contained in the FHWA implementing regulations and the Technical Advisory T6640.8A.

The appendix materials to the draft EIS may include a Section 404(b)(1) evaluation, a Section 106 Memorandum of Agreement, a biological assessment, a biological opinion, a conceptual wetland mitigation plan or documentation of compliance with Section 106 or other executive orders. The format and content of these documents are discussed in Section 3.3.2.

3.5.2.3.2 Final Environmental Impact Statement (Final EIS)

See the FHWA implementing regulations for information on the final EIS. The regulations describe the final EIS approval and circulation process.

The California Division of the FHWA also developed a checklist for final NEPA documents.

The FHWA Technical Advisory T6640.8A provides guidance on content for each of the three options for preparing a final EIS (i.e., traditional approach, condensed final EIS, abbreviated version of a final EIS).

The final EIS, particularly the discussion of the preferred alternative, may warrant additional information and more detail on expected impacts as well as firm mitigation commitments. The final EIS must address public comments received on the draft EIS. The Forty Most Asked Questions Concerning CEQ's NEPA Regulations provides guidance on how the comments should be addressed in the final EIS.

If a Section 4(f) evaluation is required for a project, the final EIS must specifically address the reasons why the alternatives that avoid use of a Section 4(f) property are not feasible and prudent, and all measures that will be taken to minimize harm to the Section 4(f) property. Additional guidance on requirements for the Section 4(f) evaluation in the final EIS is contained in the FHWA implementing regulations.

Procedures for Considering Environmental Impacts, DOT Order 5610.ID, provides additional guidance on the content, approval and circulation of the final EIS.

3.5.2.3.3 Record of Decision (ROD)

See the FHWA implementing regulations for information on RODs. The regulations describe the timing and purpose of the ROD and identify the conditions requiring a revised ROD.

The ROD identifies the selected project alternative, explains the reasons for the decision, summarizes any mitigation measures incorporated into the project, and documents any required Section 4(f) approval. The ROD must explain the basis for the project decision as completely as possible, based on the information contained in the EIS (40 CFR 1505.2).

The FHWA Technical Advisory T6640.8A identifies the following key items that must be addressed in the ROD:

- Decision;
- Alternatives;
- Section 4(f) evaluation;
- Measures to minimize harm;
- Monitoring or enforcement program; and
- Comments on final EIS.

The Forty Most Asked Questions Concerning CEQ's NEPA Regulations provides guidance on the content of the ROD as well as required provisions pertaining to mitigation and monitoring.

The ROD should also include a statement of concurrence from the partner agencies.

Section 6002(a) of SAFETEA-LU (also referred to as 23 USC 139(l) Limitation on Claims Notices) includes a provision creating a maximum statute of limitations period of 180 days, versus 6 years as identified in 28 USC 2401. Refer to FHWA Guidance on the Limitation of Claims Notices for application of this new provision in the NEPA process.

3.5.2.4 Reevaluations

Prior to finalizing the decision document, letting a contract, or approving a project that has been shelved for a period of time, the NEPA document should be reviewed to ensure that the scope of the project is still covered by the document, the resource surveys are still current, and that the identified impacts and related mitigation are still accurate.

The FHWA implementing regulations pertaining to reevaluations (23 CFR 771.129) describe the conditions under which a reevaluation is conducted. These conditions are:

1. **Draft EIS Evaluation**. A written evaluation of the draft EIS shall be prepared if an acceptable final EIS is not submitted to the FHWA within three years after the date of the draft EIS circulation. The purpose of this evaluation is to determine whether a supplement to the draft EIS or a new draft EIS is needed.
2. **Final EIS Evaluation**. A written evaluation of the final EIS will be required before further approvals may be granted if major steps to advance the action (e.g., authority to undertake final design, authority to acquire a significant portion of the right-of-way, approval of the plans, specifications and estimates) have not occurred within three years after the approval of the final EIS, final EIS supplement or the last major FHWA approval or grant.
3. **Approval**. After approval of the EIS, FONSI, or CE designation, the applicant shall consult with the FHWA prior to requesting any major approvals or grants, in order to establish whether the approved environmental document or CE designation remains valid for the requested FHWA action. These consultations will be documented when determined necessary by the FHWA.

No additional guidance is provided on the reevaluation of CEs or EAs.

The FHWA Technical Advisory T6640.8A identifies the criteria requiring a reevaluation and discusses the contents of reevaluations for draft and final EISs.

3.5.2.5 Supplemental Environmental Impact Statement

The CEQ regulations describe the conditions for preparing a supplemental EIS. *Procedures for Considering Environmental Impacts*, DOT Order 5610.ID provides additional guidance on when a supplemental EIS is required. Generally, the supplemental EIS is required whenever there are changes, new information, or further developments on a project that result in significant environmental impacts not identified in the most recently distributed draft or final EIS.

When there are changes, new information or further developments on a project, these new data must first be reviewed to determine if they would result in significant environmental impacts not previously identified. If it is determined that the changes would not result in significant environmental impacts, that determination should be documented. For a draft EIS, this documentation could be a discussion in the final EIS. After final EIS approval, this documentation would take the form of notation to the files describing any appropriate environmental studies and analyses.

The FHWA implementing regulations on supplemental EISs are contained in 23 CFR 771.130. The regulations describe the circumstances for preparing a supplemental EIS and its format and content.

The FHWA Technical Advisory T6640.8A discusses the format and content of supplemental draft and final EISs.

3.5.2.6 Use of Consultant Logo

Consultant logos are not displayed on FHWA-approved NEPA documents. Consultant identification is allowed only in the list of contributors and preparers.

3.5.3 INTERNAL DOCUMENT APPROVALS

Part I, Delegations of Authority, Chapter 6 Federal Lands of the *FHWA Delegations and Organization Manual*, FHWA Order M1100.1A provides detailed guidance on internal document approvals. The appendix at the end of Part I, Delegations, Chapter 6, Federal Lands provides a clear summary of delegations for NEPA documents and Section 4(f) approvals.

3.6 TRACKING AND REPORTING

3.6.1 ENVIRONMENTAL DOCUMENT TRACKING SYSTEM

An environmental document tracking system (EDTS) is used to track time required to complete EA and EIS documents and track reasons for delays.

The tracking system database itself is accessible only through the FHWA StaffNet site and only by staff registered to use the system. The program provides a help menu to assist with navigating the system. See a description of the tracking system and a contact source for more information about the database.

Each FLH Division is expected to record and periodically update key information on the progress of every active EA and EIS project. The environment team leader in each FLH Division is responsible to ensure that information in the system is complete and current.

3.6.2 WETLAND IMPACT AND MITIGATION REPORTING

A goal of the FHWA 1998 National Strategic Plan is to protect and enhance the environment and communities affected by highway transportation. The strategic objectives of this goal are to reduce highway-related pollution and to protect and enhance ecosystems. To assess annual progress toward these objectives, the FHWA staff measures performance on indicators of air quality improvement and wetland mitigation based on data collected each year through the division offices. These data should be compiled for each project at the division level and retained in a central location so that they can be easily and accurately reported when requested.

This subsection addresses the wetland impact and mitigation reporting requirements only. The performance data gathered on wetland mitigation are used to judge agency performance against a strategic objective of achieving a 50 percent increase in wetland acreage within ten years.

Each FLH Division reports its wetland information to the environmental discipline leader, who compiles it and submits a single FLH response to the FHWA Headquarters.

3.6.3 *ENDANGERED SPECIES ACT* COMPLIANCE COSTS

Each year the FWS, through the FHWA Headquarters, asks for a report of the total annual costs associated with ESA compliance for FHWA projects. Therefore, each FLH Division is responsible for tracking these compliance costs (including formal and informal consultation) for its projects. These data should be compiled for each project at the division level and retained in a central location so that they can be easily and accurately reported when requested.

3.6.4 SECTION 4(F) *DE MINIMIS* FINDINGS

Section 6009(c) of SAFETEA-LU requires the USDOT to conduct a study and issue a report on the implementation of the new Section 4(f) *de minimis* provisions. The study will include evaluation of 1) the implementation processes developed and the resulting efficiencies; 2) the post-construction effectiveness of any impact mitigation and avoidance commitments adopted as part of the projects; and 3) the number of projects determined to have *de minimis* impacts, including information on the location, size, and cost of the projects. The initial study and report will address the first three years of implementation. The FHWA Division offices are required to maintain a record of the projects for which *de minimis* findings are made and track the progress of those projects in order to facilitate the future evaluation of the post-construction effectiveness of any commitments of mitigation made as part of the *de minimis* finding. Additional guidance and information regarding the required study and report will be provided in the future.

3.6.5 ENVIRONMENTAL COMMITMENTS

A key component of environmental stewardship is follow-through on project-level environmental commitments. Each FLH Division is responsible for developing procedures for documenting, communicating and tracking implementation of environmental commitments. Ideally, this documentation should also include information on the success of these commitments in achieving their ultimate goals (i.e., whether the commitment adequately mitigated the anticipated impact).

3.6.6 OTHER TRACKING

Division Supplements may include information on division-specific tracking requirements.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

Chapter 3 – ENVIRONMENTAL STEWARDSHIP

LIST OF APPENDICES

3A.1 LAWS, REGULATIONS, POLICIES, GUIDANCE AND PERMITS

This appendix provides links to guidance material on state transportation departments and other agency websites.

3A.1.1 RESOURCE-SPECIFIC ENVIRONMENTAL CONSIDERATIONS

3A.1.1.1 Air Quality

Additional links to relevant guidance materials include:

- The Florida Department of Transportation (FDOT) *Project Development and Environment (PD&E) Manual, Part 2, Chapter 16* provides the most detailed guidance on the air quality analysis process and reporting requirements. Although the guidance is specific to that agency, much of the information is applicable to projects in other locations.
- The New York State Department of Transportation (NYSDOT) *Environmental Procedures Manual (EPM*), Attachment 1.1-F provides an Example Air Quality Report.
- The Washington State Department of Transportation (WSDOT) *EPM, Section 425* provides detailed information on conformity, a checklist for an air quality technical report (called a discipline report) and guidance for NEPA documentation of air quality issues.

3A.1.1.2 Coastal Areas and Shorelines

Additional links to relevant guidance materials include:

- More information on the *Coastal Barrier Resources Act* from the FWS.
- Programs are often fairly consistent from State to State. Both the FDOT *PD&E Manual, Part 2, Chapter 25* and the California Department of Transportation (Caltrans) *Environmental Handbook, Volume 1, Chapter 18* provide overviews that can be helpful in understanding the process and procedures for compliance with Federal and State laws that protect coastal resources as well as required documentation.
- The FDOT *PD&E Manual, Part 2, Chapter 26* provides an excellent overview of the *Coastal Resources Barrier Act* and how it is implemented.

3A.1.1.3 Earth (Geology and Soils)

Additional links to relevant guidance materials include:

- The WSDOT *EPM, Section 420* provides general guidance on the content of various sections in technical reports, temporary erosion and sedimentation control plans, soil surveys, and erosion control plans. The discipline report checklist serves as guidance to help authors determine necessary information for inclusion in the NEPA document.

3A.1.1.4 Energy

Additional links to relevant guidance materials include:

- The Caltrans *Environmental Handbook, Volume 1, Chapter 13* provides a flowchart and a complete list of the information to include in the energy discipline report as well as the NEPA document.
- The Idaho Transportation Department (ITD) *Environmental Process Manual, Section 1200* provides a more concise list of information to include in an energy discipline report.

3A.1.1.5 Farmland

Additional links to relevant guidance materials include:

- The NYSDOT *EPM, Chapter 2.5* (see Section IV, Steps 5 and 6) has a succinct but thorough process for compliance with the FPPA.
- The WSDOT *EPM, Section 450* contains a summary of the required contents for a NEPA document to comply with the FPPA. A farmlands discipline report checklist serves as useful guidance for preparing an EIS section to ensure compliance with the FPPA.
- The Caltrans *Environmental Handbook, Volume 4* (see Section 3-3) provides a discussion of the analysis required in an environmental document in order to comply with the FPPA. This document also identifies sources of information and provides guidance on defining a significant impact.

3A.1.1.6 Floodplains

Additional links to relevant guidance materials include:

- The Caltrans *Environmental Handbook, Volume 1, Chapter 17* and the FDOT *PD&E Manual, Part 2, Chapter 24* provide detailed guidance on floodplain-related documentation.
- The WSDOT *EPM, Section 432* provides a useful flowchart (see Figure 432-1) summarizing the documentation process for floodplains.

3A.1.1.7 Hazardous Substances

Additional links to relevant guidance materials include:

- The FDOT *PD&E Manual, Part 2, Chapter 22* provides the best guidance and step-by-step requirements on research, reporting and documentation for potential hazardous substances.

- The NYSDOT *EPM, Chapter 5.1* (see Section X) has a useful flowchart that describes the steps to screen for hazardous wastes and contaminated materials and performing more detailed assessments.

3A.1.1.8 Historic, Cultural and Archaeological Resources (Section 106)

Other laws that may be considered in conjunction with Section 106 issues include:

- *Historic Sites Act* of 1935 (16 USC 461-467)
- *Archeological and Historic Preservation Act* (16 USC 469–469c-2)
- *Preservation of American Antiquities Act* (16 USC 431–433)
- *Archeological Resources Protection Act* (16 USC 470aa–470mm)
- *American Indian Religious Freedom Act* (42 USC 1996)
- *Native American Graves Protection and Repatriation Act* of 1990 (25 USC 3001 et seq.)
- Executive Order 11593 May 6, 1971.

Additional links to relevant guidance materials include:

- The *AASHTO Center for Environmental Excellence* provides a useful link to recent developments related to Section 4(f) and Section 106.
- The Maryland Department of Transportation provides excellent Section 4(f) interactive training that can also be used as a resource when planning and writing 4(f) documents. It includes information on NEPA and Section 106 of the *National Historic Preservation Act*.
- The WSDOT *EPM, Section 456* provides guidance on the Section 106 Regulations, Users Guide, and National Register Evaluation Criteria. It also provides a glossary of terms related to historical, cultural and archeological resources.
- The FDOT *PD&E Manual, Part 2, Chapter 12* describes the documentation and procedures of the Section 106 process and includes a flowchart of the process. Florida also outlines the steps required for a cultural resources survey and a determination of eligibility for the properties identified.
- The Caltrans *Environmental Handbook, Volume 1, Chapter 28* outlines the reporting requirements for Section 106 compliance and requirements for the NEPA documentation.
- The NPS provides guidelines for evaluating and documenting traditional cultural resources.

3A.1.1.9 Land Use

Additional links to relevant guidance materials include:

- The Caltrans *Environmental Handbook, Volume 4* (see Section 3-2, 4-2, and 4-4) provides thorough guidance on the technical report format and contents, and an overview of land use issues to be considered in the NEPA document. It also provides comprehensive guidance on the analysis of induced growth in the context of cumulative effects.

- The WSDOT *EPM, Section 450* provides the most concise and thorough checklist of issues that should be considered relative to land use, regardless of the project classification. This checklist is particularly useful for categorical exclusions and environmental assessments when a technical report has not been produced.

3A.1.1.10 Community Impact Assessment

Additional links to relevant guidance materials include:

- The best guidance for large-scale EIS projects with numerous implications for the community is the Caltrans *Environmental Handbook, Volume 4* "Community Impact Assessment." The *Handbook* describes the methodological approaches and the sources available for obtaining the information needed for community impact assessment.

- Guidance on community impact topics to discuss (see Discussion Points) and reporting requirements (see Report Content and Required/Recommended Format) are available in the Caltrans *Environmental Handbook, Volume 1, Chapter 24*.

- The WSDOT *EPM, Section 458* provides information on social, economic and environmental justice impact regulations, policy and guidance. Checklists outlining the topics that should be covered in preparing the social, economic and relocation impacts sections of environmental documents (see Exhibits).

- The FDOT *PD&E Manual, Part 2, Chapter 9* provides guidance on community impact assessment and the type of information that should be included in an environmental document. This web link includes information on the appropriate level of documentation and the method of determining whether there is a significant effect.

- *The Community Impact Assessment and Environmental Justice for Transit Agencies: A Reference*, January 2002.

3A.1.1.11 Noise

Additional links to relevant guidance materials include:

- The NYSDOT *EPM, Chapter 3* provides a detailed and well-organized overview of procedures for noise analysis and abatement and documentation of these impacts.
- The FDOT *PD&E Manual, Part 2, Chapter 17* provides a good overview of methods, procedures, abatement considerations, noise study report contents and required noise content for NEPA documents.
- The WSDOT *EPM, Section 446* provides a checklist of noise issues to be addressed in technical reports and NEPA documents.

3A.1.1.12 Public Services and Utilities

Additional links to relevant guidance materials include:

- The WSDOT *EPM, Section 470* provides information on the required analysis for NEPA documents relative to public services and utilities.

3A.1.1.13 Relocations

Additional links to relevant guidance materials include:

- The WSDOT *EPM, Section 458* contains checklist outlining the topics that should be covered in preparing the relocation impacts sections of NEPA documents.

3A.1.1.14 Section 4(f) and Section 6(f)

Additional links to relevant guidance materials include:

- The Maryland Department of Transportation provides excellent Section 4(f) interactive training that can also be used as a resource for planning and writing 4(f) documents. It includes information on NEPA and Section 106 of the *National Historic Preservation Act (NHPA)*.
- The Caltrans *Environmental Handbook, Volume 1, Chapter 20* provides an overall checklist for preparing Section 4(f) evaluations. It includes information on appropriate documentation in an EIS or environmental assessment when there is no Section 4(f) use. Chapter 20 of the *Handbook* also provides detailed guidance on 4(f) application and requirements.
- The WSDOT *EPM, Section 450* provides discipline report checklists and an outline of a Section 4(f) evaluation. This section also provides a discipline report checklist as well as detailed guidance on the 6(f) process and documentation. Exact procedures vary by State.
- The FDOT *PD&E Manual, Part 2, Chapter 13* provides examples of transmittal letters to FHWA in its overall guidance on 4(f) documentation.
- Caltrans has merged its Section 6(f) documentation information and guidance into the Section 4(f) guidance. The decision tree is helpful for sorting out the relationship between 4(f) and 6(f).

3A.1.1.15 Socioeconomics and Environmental Justice

Additional links to relevant guidance materials include:

- The WSDOT *EPM, Section 458* provides thorough information on the following topics:
    - ◊ When an environmental justice analysis should be performed,
    - ◊ Whether the environmental justice analysis must be a separate technical study,
    - ◊ How environmental justice should be addressed in the NEPA process,
    - ◊ How to perform a technical analysis, and

◊ An outline for an environmental justice report.

This section also contains checklists outlining the topics that should be covered in preparing the social, economic and relocation impacts sections of NEPA documents (see Exhibits 458-1 to 3).

- The Caltrans *Environmental Handbook, Volume 1, Chapter 25* provides detailed information on environmental justice documentation and regulatory compliance, including a subject matter decision tree, timing of studies with the environmental process and report content and format.

3A.1.1.16 Threatened and Endangered Species

Additional links to relevant guidance materials include:

- Threatened and endangered species information by State is available from the FWS.
- The Caltrans *Environmental Handbook, Volume 1, Chapter 14* (see discussion under Reporting) provides the most detailed discussion of Section 7 documentation procedures and has developed a template for biological assessments.
- The NYSDOT *EPM, Chapter 4.1* provides a thorough overview of the Endangered Species Act Section 7 documentation process, including a step-by-step description of procedures and a flowchart to determine whether a project will affect listed species.
- The WSDOT *EPM, Section 436* provides a general overview of policies and procedures related to wildlife, fish and vegetation, including the ESA analysis and documentation process.

3A.1.1.17 Transportation and Traffic Impacts

The FDOT pioneered a method for evaluating the quality of service a corridor provides for pedestrians and bicyclists. This method is described in the *2009 Quality/Level of Service Handbook*. This method has gained widespread acceptance and may provide a suitable approach to analyzing existing conditions and expected impacts on pedestrians and bicyclists at the EIS level.

3A.1.1.18 Visual

Additional links to relevant guidance materials include:

- The Caltrans *Environmental Handbook, Volume 1, Chapter 27* provides an excellent annotated outline of a technical report for complex projects based on the FHWA method for Visual Impact Assessment for Highway Projects.
- The WSDOT *EPM, Section 459* provides a discipline report checklist for addressing visual assessments. The checklist may serve as a guide to the contents of a technical report or an EIS section.

3A.1.1.19 Water Resources

Additional links to relevant guidance materials include:

- The WSDOT *EPM, Section 430* provides detailed technical guidance on water quality technical reports as well as checklists.
- The NYSDOT *EPM, Attachment 4.4.B* has detailed guidance pertaining to the contents of the ground water report when a project is located in a designated sole-source aquifer.

3A.1.1.20 Wetlands

Additional links to relevant guidance materials include:

- The FDOT *PD&E Manual, Part 2, Chapter 18* has detailed guidance regarding environmental documentation content including the wetland report, conceptual mitigation report and a NEPA document.
- The Caltrans *Environmental Handbook, Volume 3, Chapter 3, Section 3.7* , Volume 3, provides an overview of delineation considerations and the wetland delineation report contents.
- The WSDOT *EPM, Section 431* has detailed guidance on wetland mitigation plans and reports.

3A.1.1.21 Wild and Scenic Rivers

Additional links to relevant guidance materials include:

- The NYSDOT *EPM, Chapter 4.6* provides step-by-step procedures for compliance with the *Wild and Scenic Rivers Act* (see Section IV).
- The FDOT *PD&E Manual, Part 2, Chapter 23* provides a brief summary of the information required on Wild and Scenic Rivers depending on the type of NEPA document being prepared.
- The Caltrans *Environmental Handbook, Volume 1, Chapter 19* provides guidance on the contents of environmental documents relative to Wild and Scenic Rivers.

3A.1.1.22 Wildlife, Fish and Vegetation

Additional links to relevant guidance materials include:

- The WSDOT *EPM, Section 431* provides a detailed checklist for a combined wetland/biology discipline report.
- The Caltrans *Environmental Handbook, Volume 1, Chapter 14* provides excellent guidance on technical reports, cumulative impact analysis and permits.

3A.2 NEPA DOCUMENTATION

3A.2.1 CATEGORICAL EXCLUSION

Additional links to relevant guidance materials include:

- The Caltrans *Environmental Handbook, Volume 1, Chapter 30* provides guidance on categorical exclusions including the preparation and processing of documentation.
- The FDOT *PD&E Manual, Part 1, Chapter 2* provides a categorical exclusion checklist.

3A.2.2 ENVIRONMENTAL ASSESSMENT

Additional links to relevant guidance materials include:

- The Caltrans *Environmental Handbook, Volume 1, Chapter 31* provides guidance on environmental assessments including the preparation and processing of documentation.
- The FDOT *PD&E Manual, Part 1, Chapter 6* contains a table of contents for environmental assessments as well as general guidance on environmental assessments.
- The EPA provides extensive information on the public involvement process.

3A.2.3 FINDING OF NO SIGNIFICANT IMPACT

The FDOT *PD&E Manual, Part 2, Chapter 3* provides the most comprehensive guidance on FONSI content and organization and provides example language.

3A.2.4 DRAFT ENVIRONMENTAL IMPACT STATEMENT

Additional links to relevant guidance materials include:

- The FDOT *PD&E Manual, Part 2, Chapter 3* provides comprehensive guidance on EIS content and organization and example language for dealing with several environmental issues.
- The Caltrans *Environmental Handbook, Volume 1, Chapter 32* provides guidance on the key elements of the draft EIS including:
  - ◊ Purpose and Need section,
  - ◊ Alternatives,
  - ◊ Affected Environment contents,
  - ◊ Environmental Consequences contents,

- ◊ Cumulative Impacts, and
- ◊ Mitigation.

3A.2.5 REEVALUATIONS

Additional links to relevant guidance materials include the following:

- The Caltrans *Environmental Handbook, Volume 1, Chapter 33* provides detailed guidance on reevaluations for all NEPA documents, including decision flowcharts.
- The FDOT *PD&E Manual, Part 1, Chapter 13* provides detailed guidance on reevaluations including a suggested format and a process flowchart.

Chapter 4 – CONCEPTUAL STUDIES AND PRELIMINARY DESIGN

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CHAPTER 4

CONCEPTUAL STUDIES AND PRELIMINARY DESIGN

4.1 GENERAL

This chapter provides policies, standards, practices, guidance, and references for developing and documenting the first two phases of the project development engineering process: the conceptual studies phase and the preliminary design phase. Subsequent steps in the project development engineering process are described in Section 9.6.3. Refer to Section 1.1.1 for definitions of policy, standards, and guidance. Statements of FLH Policy are shown in **bold type**. Statements regarding FLH Standard Practice are so indicated. Information on how to perform basic design procedures and fundamental steps for performing the design work are typically incorporated by references to other documents.

The overall objectives of the conceptual studies and preliminary design phases are to:

- Fully clarify and quantify the transportation needs and deficiencies identified during the planning and programming phase,
- Develop a general course of proposed action,
- Identify and evaluate with engineering analyses the feasible and reasonable solutions (alternatives) to these needs and deficiencies, and
- Document the engineering analyses, preliminary design, and the project delivery plan, to guide implementation of the project.

Conceptual studies are typically initiated as needed to support the planning and programming process (see Section 2.5). After projects are placed in the multi-year FLH program for preliminary engineering the conceptual studies phase further identifies, defines and considers sufficient courses of action (i.e., engineering concepts) to address the transportation needs and deficiencies initially identified during the planning and programming process. This phase advances a project proposed in the multi-year program to a point where it is sufficiently described, defined and scoped to enable the preliminary design and technical engineering activities to begin. Conceptual studies are typically based on analysis of existing available information, on-site interdisciplinary reviews and meetings with stakeholders. The conceptual studies phase is typically documented in the form of a project scoping report and in a project agreement.

The preliminary design phase involves developing the engineering design and evaluation in collaboration with the various functional disciplines including right-of-way, surveys and mapping, environment, safety, highway design, pavements, hydraulics, geotechnical, structural design, and construction, to support the identification of a preferred alternative and the decision-making process as described in Section 3.4. This phase may include developing multiple alignment configurations, roadway templates, pavement structures, roadside features or other alternatives for evaluation. The preliminary design is typically developed to approximately the 30 percent level of design detail using substantial additional engineering data, information and input to supplement the information gathered during the conceptual studies phase. This phase typically includes identification of a detailed scope of engineering activities, estimated costs, and a project delivery plan for implementing the proposed project and achieving the project objectives on schedule and within budget.

For small-scale improvements such as resurfacing, restoration and rehabilitation (RRR) type projects, isolated bridge replacements and other projects constrained by a limited or well defined scope, the preliminary design and technical engineering activities are often readily identifiable without the need to fully perform all of the activities described for the conceptual studies phase. A typical process for the preliminary design phase includes:

- Develop survey and mapping for preliminary engineering and environmental activities,
- Develop design criteria for each alternative being considered,
- Develop initial alignments, typical sections and roadway design for each alternative,
- Determine proposed pavement structure options,
- Develop preliminary technical discipline recommendations, as applicable (e.g., cut/fill slopes, walls, major culverts, bridge foundations),
- Develop resource mapping and identify potential impacts of each alternative;
- Provide design information for the environmental analysis, such as: areas of impact, preliminary earthwork quantities, waste and staging areas, material source plans, preliminary drainage designs, bridge layout, right-of-way exhibits, construction phasing and closure schedules and cost estimates; and
- Provide design information for other analyses, such as for Park Roads projects a Value Analysis may be performed by the NPS.

Deliverables or outputs from the preliminary design process may include:

- Corridor study report, if applicable,
- Preliminary engineering study report,
- 30 percent preliminary plans of the design alternatives (i.e., plan/profile sheets, typical sections, major work items identified and located), and
- Preliminary construction cost estimates for the design alternatives.

The conceptual studies and preliminary design phases are performed in conjunction and concurrently with the environmental process outlined in Section 3.4. The environmental process evaluates environmental impacts of the engineering proposals resulting from the conceptual studies and preliminary design phases.

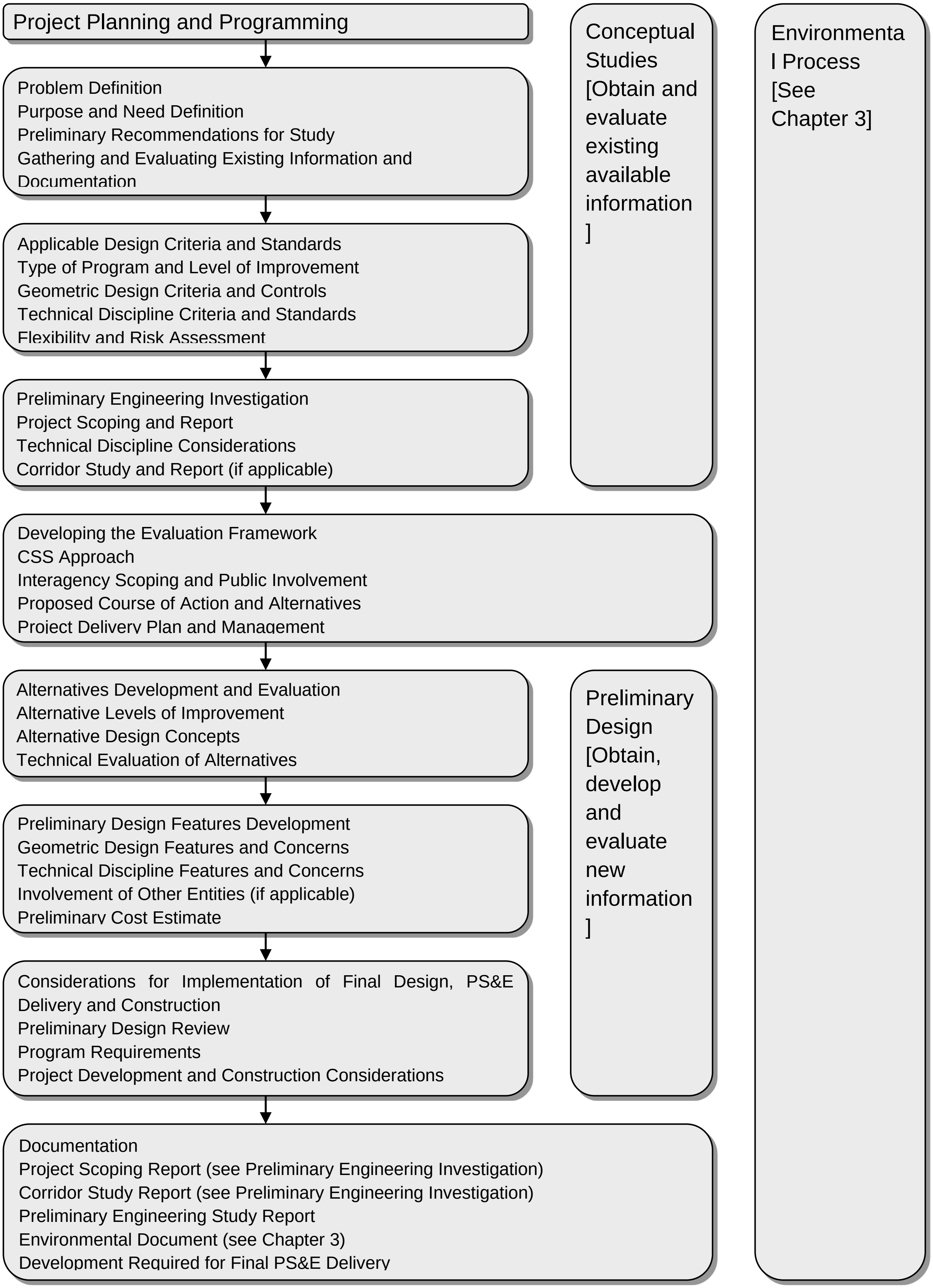
A preferred alternative is identified after the environmental effects of the proposed actions are evaluated in the environmental process. The selected action is recorded in the final approved environmental decision document (e.g., Categorical Exclusion (CE), Finding of No Significant Impact (FONSI), Record of Decision (ROD)). Assuming the selected action is a build alternative it will be carried forward into final design (see Chapter 9). The conceptual studies and preliminary design phases conclude with the documentation of the engineering aspects of the selected action, defined by a category of improvement, geographical corridor, preliminary highway design standards and clear design concepts. Exhibit 1.1-B depicts the general, overall project development process. Specific interdisciplinary activities that are involved in the project development process are not shown, but are addressed in detail in this and other *PDDM* chapters. Exhibit 4.1–A depicts the conceptual studies and preliminary design process that are described in this chapter.

Guidance and references for performing the conceptual studies and preliminary design are described in Section 4.2. The basis for the preliminary engineering investigation is the problem definition and evaluation of existing information that is gathered as described in Section 4.3, together with consideration of the applicable design standards and controls as described in Section 4.4. The result of the preliminary engineering investigation (see Section 4.5) is an initial recommended course of action that is carried forward for development during the preliminary design phase as described in Section 4.6, including any alternatives that will be developed as described in Section 4.7. The results of the preliminary design and alternatives analysis are determined and established as described in Section 4.8. Considerations for implementation of preferred action are described in Section 4.9, and the final results of the conceptual study and preliminary design process are documented as described in Section 4.10. Supplemental requirements, guidance and procedures specific to the FLH Division offices are listed throughout the chapter.

The development of the final design is covered in Chapter 9. Additional information on the overall project development process is provided in Chapter 1 of *A Guide for Achieving Flexibility in Highway Design*, AASHTO, 2004.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

Exhibit 4.1–A CONCEPTUAL STUDIES AND PRELIMINARY DESIGN PROCESS



4.2 GUIDANCE AND REFERENCES

The regulations, policies, guides and references that provide the background for implementing conceptual studies and preliminary design are listed in the various chapters of this manual relating to the interdisciplinary development of the conceptual studies and preliminary design.

For references on specific subjects, refer to the guidance and references in the appropriate *PDDM* chapter. The primary references that are most frequently cited in this chapter are provided below. The guidance and references are not all inclusive and other documents may contain useful information in special situations.

Abbreviations and definitions are described in Section 1.4.

4.2.1 STANDARDS OF PRACTICE

1.	Green Book	A Policy on Geometric Design of Highways and Streets, AASHTO, current edition (specific references in this chapter are to the 2011 edition).
2.	Park Road Standards	*Park Road Standards*, US Department of the Interior, National Park Service, 1984.
3.	RDG	Roadside Design Guide, AASHTO, 2006.
4.	VLVLR	Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤400), AASHTO, 2001
5.	23 CFR 625	Title 23 of the Code of Federal Regulations, Part 625, *Design Standards for Highways*.
6.	NS 23 CFR 625	Federal-Aid Policy Guide (FAPG), Non-regulatory Supplement to 23 CFR 625.

4.2.2 GUIDANCE

1.	FHWA-PD-97-062	*Flexibility in Highway Design*, FHWA, 1997
2.	AASHTO Flexibility Guide	*A Guide for Achieving Flexibility in Highway Design*, AASHTO, 2004.
3.	NCHRP Report 480	NCHRP Report 480, *A Guide to Best Practices for Achieving Context Sensitive Solutions*, TRB, 2004.

4.	T 5040.28	Technical Advisory T 5040.28, *Developing Geometric Design Criteria and Processes for NonFreeway RRR Projects*, FHWA, October 17, 1988.
5.	ERFO Manual	*Emergency Relief for Federally Owned Roads Disaster Assistance Manual*, FHWA, April 2011
6.	Special Report 214	TRB Special Report 214, *Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation*, TRB, 1987
7.	IHSDM	Interactive Highway Safety Design Model

4.3 PROBLEM DEFINITION

This section provides guidance to define the transportation problem, the context, and the related issues addressed by the project. This includes clarifying the purpose and need for action, determining the type and extent of information gathering, and investigating the project site.

4.3.1 IDENTIFY PURPOSE AND NEED

Identification of the purpose and need for action begins with an evaluation of the facility's operational, physical, and performance characteristics for determination of deficiencies. This includes a comprehensive assessment of its physical condition, safety performance, traffic operational performance, capacity, efficiency, convenience, sustainability, environmental compatibility and maintenance aspects. For new roads, the purpose and need will be established as part of a comprehensive planning study. Refer to Section 2.5.

A goal or general objective will typically be identified during the planning and programming process. Refer to Section 2.3 for a description of this activity. Development of the purpose and need is an essential activity that is performed as part of the environmental analysis and documentation. Refer to Section 3.4.2.2.1, item (1)(g), Task 7 for additional guidance on development of purpose and need for improvements.

A listing of the road's current deficiencies, both physical and operational, and the relative importance of each should be prepared to indicate where the performance of the road is currently substandard and not functioning properly. Exercise care when determining the major contributing factors of a poorly functioning road facility. Many factors influence and contribute to the performance characteristics of a facility; an existing substandard road feature is not necessarily the problem.

The long-term transportation performance needs of the users, the facility infrastructure condition, and the surrounding context must also be determined. This is based on projections of how land use activities in an area are going to change along with their associated transportation requirements. A forecasted 20-year average daily traffic (ADT) from the anticipated completion date of the project, and percentage of vehicle types (e.g., trucks, buses, recreational vehicles) that will use the facility is commonly used to describe the future level of use that an improvement is intended to accommodate. Other factors such as development of the roadside or of destinations along the route, and functional classification changes also characterize future transportation requirements. The intended lifetime of the improvement and future serviceability must also be determined in order to identify the purpose and need, and to evaluate the level of investment warranted and resulting benefits of various alternative solutions that may be proposed.

4.3.1.1 Interdisciplinary/Interagency Approach

The gathering of existing information and other activities for development of the purpose and need, conceptual studies and preliminary design is performed with an interdisciplinary team (IDT), lead by the project manager. For an interagency IDT, identify the respective agency roles and responsibilities. Close coordination among the various technical disciplines, especially with the environmental specialist preparing the environmental analysis and documentation, is essential. Various members of an interdisciplinary project team may perform the activities and requirements described in this chapter, so it is essential that the project team be properly organized with clearly assigned responsibilities to perform each of the various activities that are necessary. It is also essential to maintain close and continuous coordination with the land management agency, and other stakeholders in the facility, during the conceptual studies and preliminary design phases, as well as throughout the project delivery process.

Since the FLH Program is delivered entirely through partnerships with other agencies, a collaborative approach is used during all phases of the project delivery, with involvement of all stakeholders. The interagency/interdisciplinary approach to conceptual studies and preliminary design is fundamental to obtaining an end product that will serve the public and be consistent with Federal, State and local goals, objectives and standards. Early contact and coordination with partner agencies helps to alleviate or minimize conflict and controversy. As early as possible in the project development process, a project agreement should be prepared that addresses the principle contacts, roles and responsibilities for interagency coordination of project delivery activities, as described in Section 4.6.4.

Coordinate with the land management agency contacts and other stakeholders throughout the preliminary and final design process, to achieve a smooth transition between the design and construction phases. The interdisciplinary/interagency study team includes the principle agency contacts for projects that require an environmental assessment or environmental impact study, as described in Section 3.4.2.2.1, item (1)(b), Task 2. Coordinate with contacts of regulatory, resource and other agencies regarding permit requirements and clearances. The interagency contacts should be identified and included in the Project Scoping Report described in Section 4.5.2.

On Park Road and Parkway projects, the coordinator in the NPS Denver Service Center, or if appropriate, the National Park Service Support Office or the local park representative is the principal contact for input and review of the design alternatives. The NPS will sometimes take the lead for coordination with other agencies and outside disciplines, when applicable.

On Forest Highway projects, the road-owning agency (typically either a County or State DOT) engineering staff, together with engineering staff and resource staff in the Forest Supervisor’s Office and/or the District Ranger’s Office are typically the principal contacts for project input. These agencies will normally have technical specialists with local expertise and are familiar with the transportation needs and resource issues of the facility, its users and its local context.

On Refuge Road projects, the FWS regional program coordinator and the refuge facility manager are typically the principal contacts for engineering and technical input. The FWS will sometimes take the lead for coordination with other agencies and outside disciplines for environmental and permit compliance, when applicable.

On some projects, the FHWA Federal-aid Division office may participate in the development of the project. The extent of the involvement varies from office-to-office, but using the expertise available in the FHWA Federal-aid Division offices can provide an independent review of the preliminary design and environmental analysis.

4.3.1.2 Transportation Planning Reports and Inventories

Data collection is an integral step in the conceptual study process. The following sections describe the most common sources and areas where comprehensive information must be gathered for highway location analysis. Also, general traffic data and operational characteristics including seasonal variations, peak use, vehicle types and their volume percentages should be obtained. Travel information like running speeds, congestion periods or any irregularities should be determined. Typically, the maintenance forces have many observations to offer. The needs and quantity of other road users (e.g., bicyclists, pedestrians) must also be established.

Refer to Section 2.5 for transportation planning reports and inventories that are prepared. FLH maintains a road inventory program (RIP) data and reports, bridge inventory program (BIP) data and reports, and other system information for National Park roads and other Federal land management agencies. For National Park roads an interactive video and condition database is maintained in VisiData format, and this information should be readily available.

Planning reports and inventories are sometimes available from the land management agency or agency with jurisdiction of the highway, in the form of a Needs Study. These documents provide system-wide highway information on the physical condition, current deficiencies and future needs of routes on a system. General types of needed improvements and approximate construction cost estimates may also be documented and can be used to develop a priority list of projects.

While this information is primarily used to show funding needs or assists the priority setting/programming process, it can provide good starting data for conceptual studies. Usually, needs studies are general in nature and must be expanded and refined into specific project data, issues and details. Comparing the current highway facility with the geometric standards of a road that is sized to accommodate its future traffic volumes and travel conditions can provide an initial indication of the extent of upgrading that may be warranted to address the long-range transportation needs.

4.3.1.3 Information from Land Management Agencies

The land management agencies through their planning offices and area-wide comprehensive planning documents (e.g., NPS General Management Plan, NPS Development Concept Plans, FS National Forest and Resources Management Plans) can provide some information and assistance in determining future travel demands on highways. General management plans and other documents are used to document the land management agency’s need to expand facilities or services to other areas, and support the purpose and need for new or improved roads.

4.3.1.4 Response to Emergencies/Site Conditions

Occasionally, a project is developed to repair a damaged road or highway due to an act of nature or a major vehicle incident that made the roadway impassible. These projects cannot be programmed or planned in advance, but are necessary to keep the roadway open and operational to local and regional traffic. The Emergency Relief of Federally Owned Roads (ERFO) program provides funding for repairing disaster damaged Federal highway facilities and returning them to their pre-disaster condition. The Program of Projects (POP) Letter authorizes ERFO Projects and the scope of the repair is specified in the Damage Survey Report (DSR). The purpose of this type of project is to restore the facility to pre-disaster conditions as quickly as possible, and will likely not have the benefit of advance planning and coordination to implement all of the desirable improvements, or the available funds to complete any more than restoration in-kind to the pre-disaster condition. For approval of upgrades or additional features to protect the facility from future disaster damage it must be shown that the added expenditure is cost-effective for reducing future ERFO program costs. Within the program eligibility guidelines, the repair must not only restore the facility, but also it should ensure that an inordinate risk of subsequent failure is not perpetuated in the reconstruction. Therefore, every effort should be made by the response team to evaluate repairs that will make efficient and effective use of the limited funds for the roadway system, and to identify appropriate betterments and safety enhancements as recommended improvements that may be funded by the land managing agency.

4.3.1.5 Programming Information

Refer to Section 2.3 for programming information that is developed for the project development activities. The following sections describe programming information that should be obtained early in the conceptual design phase.

4.3.1.5.1 Pre-Programming Studies

Obtain relevant project pre-programming reconnaissance studies and scoping documents, if available (e.g., Project Agreement, Project Identification Report (specific to WFLHD)), and relevant scoping reports, conceptual studies and data that may have been prepared for planning or programming purposes. Obtain information about the scope of project as established by FLH and partnering agencies and roles and responsibilities of FLH and partnering agencies.

4.3.1.5.2 Project Delivery Schedule

Obtain the proposed project delivery schedule, including the environmental and design schedule milestones, from the Division’s project delivery and resource scheduling program (e.g., Program Resource Management System (PRMS), Primavera P3e/c, Open Plan).

4.3.1.5.3 Preliminary Engineering Budget

Obtain existing information on programmed funding available for preliminary engineering (PE).

4.3.1.5.4 Preliminary Construction Cost Estimate

Obtain any construction estimate information previously developed for the project from any prior conceptual studies and scoping documents (e.g., Project Identification Report, Project Agreement).

4.3.1.5.5 Interdisciplinary Team (IDT) and Social, Environmental, Economic (SEE) Team Members

Obtain a listing of interdisciplinary (IDT) team members and Social, Environmental, Economic (SEE) team members that are assigned as resources for the project. The SEE team is formed to guide the NEPA environmental process. The interdisciplinary team may also be referred to within FLH as the cross-functional team (CFT).

4.3.1.6 Preliminary Recommendations for Study

Based on the prior planning and programming activities, and initial contacts made at the beginning of project development activities, assess information needs and determine how extensive the reconnaissance and preliminary engineering investigation effort needs to be. Before proceeding with subsequent activities covered in this chapter, develop preliminary recommendations that describe the level of study to be performed during the conceptual and preliminary design. For smaller scale projects, a less comprehensive effort that only requires a limited level of information gathering and reporting may be appropriate for conceptual studies and preliminary design. It may not be necessary to gather all of the existing information listed in the following sections if the scale of planned improvements is very limited.

4.3.2 GATHERING EXISTING INFORMATION

The information on the existing facility provides the historical background and gives an insight as to why the facility was designed the way it exists today. This effort also includes some initial assessments of existing deficiencies. The following subjects are the most common areas where comprehensive information must be gathered before evaluation or analysis can begin for the conceptual studies and preliminary design. These sources supplement information available from planning studies and inventories described in Section 4.3.1.2.

4.3.2.1 As-Built Plans and Previous Studies

Gather relevant information regarding the facility's history, including prior engineering work and previous construction projects, construction reports, etc.

A primary source of information for reconstruction and RRR projects is as-constructed plans. Each Federal Lands Highway Division office has access to a set of as-constructed plans for its completed projects. They contain information on alignments, drainage, bridges, right-of-way, pavement structure and other engineering features.

Local governments, State DOTs and other Federal land management agencies can also provide as-constructed plans and a variety of information relating to a specific section of highway.

The NPS Denver Service Center maintains microfilm files on as-constructed plans on park road projects. The NPS Regional Offices and individual park units may also have as-built plans, previous engineering studies, or may maintain other information systems that can provide relevant information about the existing facility.

While information from as-constructed plans and from other agencies has significant value, the data should not be blindly accepted as fact. Field verification is necessary.

4.3.2.2 Roadway Geometry

The existing geometric elements of a roadway are used to describe in conventional engineering terms the physical, structural, safety and operational characteristics of a facility. While many elements of design (e.g., stopping sight distance, grades, horizontal/vertical alignment, superelevation) must be established to develop a highway design, only a few controlling elements are essential to evaluate it at the conceptual stage. Roadway width (i.e., lanes, shoulders), design speed, surfacing type and alignment location, or new corridor location, if applicable, are the main criteria for studying highway alternatives.

Other than for new roads entirely on new location, this information consists of an inventory of the physical features and operational characteristics of the existing highway. Most of this information is available from the highway owning agencies (e.g., highway departments, Federal land management agencies), through their road monitoring reports and planning/inventory studies. In addition to as-constructed plans and these reports, the engineer should determine and verify through field inspections the road's length, width, surfacing type, traffic control devices and roadside features along with their current condition. Evaluate the available sight distance along the roadway and at intersections, and identify any discernible sight distance restrictions. Refer to Section 8.4.3 for guidance on gathering this information and preparing an Existing Geometric Controlling Features Analysis.

After gathering the data, compare the existing road and its current functional classification, geometric standards, physical condition and present and future travel demand with the highway agency's road standards. If the highway agency has separate RRR geometric standards and design procedures, determine if they apply to the project. The AASHTO *Green Book* geometric standards are broad enough to address most types of roads if there are no other standards that apply.

For RRR projects where the roadway geometry is not changed, completing the Existing Geometric Controlling Features Analysis, described in Section 8.4.3, is still necessary to verify the design criteria that will be incorporated into the project.

Applicable geometric design standards and criteria that are developed are discussed in Section 4.4.

Exhibit 4.3–A provides an illustration of typical rural cross section elements, Exhibit 4.3–B shows a recoverable roadside including clear zone and Exhibit 4.3–C shows a typical urban cross section elements.

Exhibit 4.3–A TYPICAL RURAL CROSS SECTION ELEMENTS

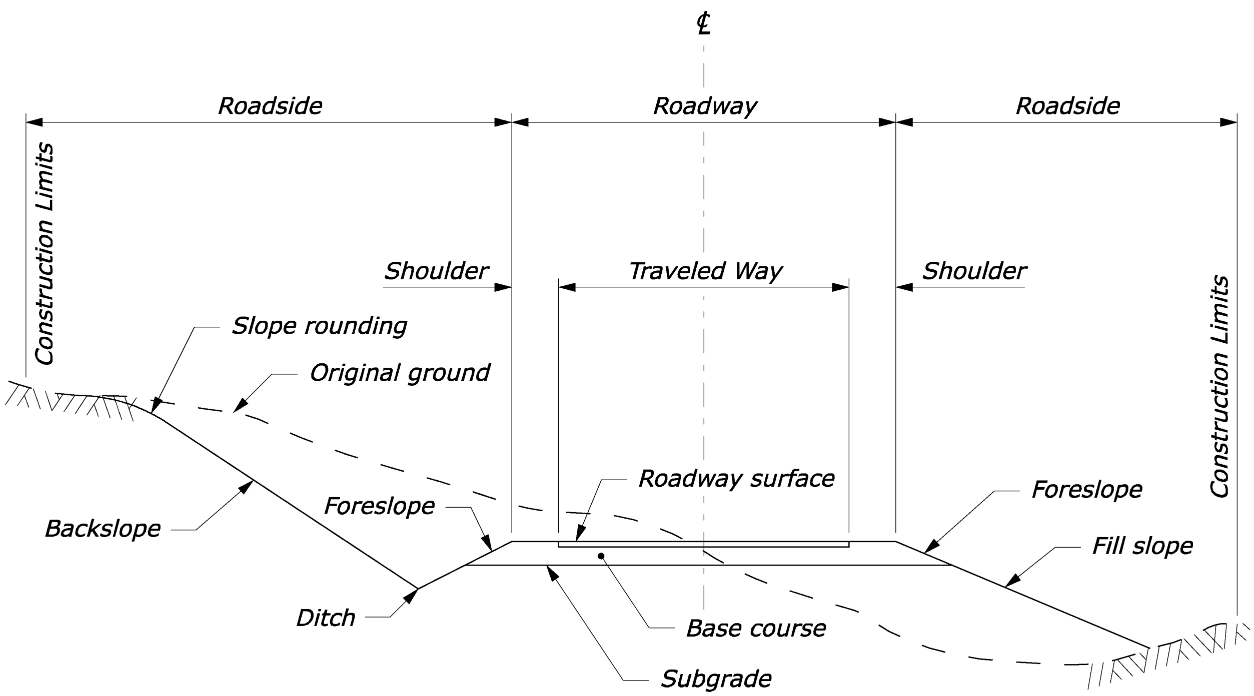


Exhibit 4.3–B RECOVERABLE FORESLOPE

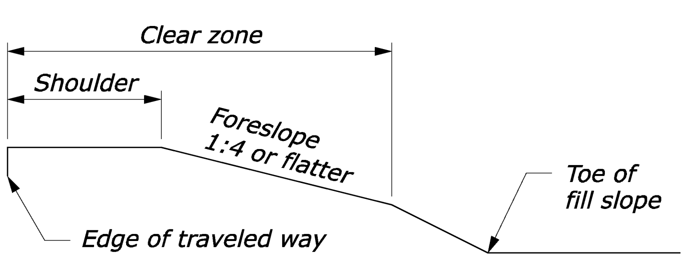
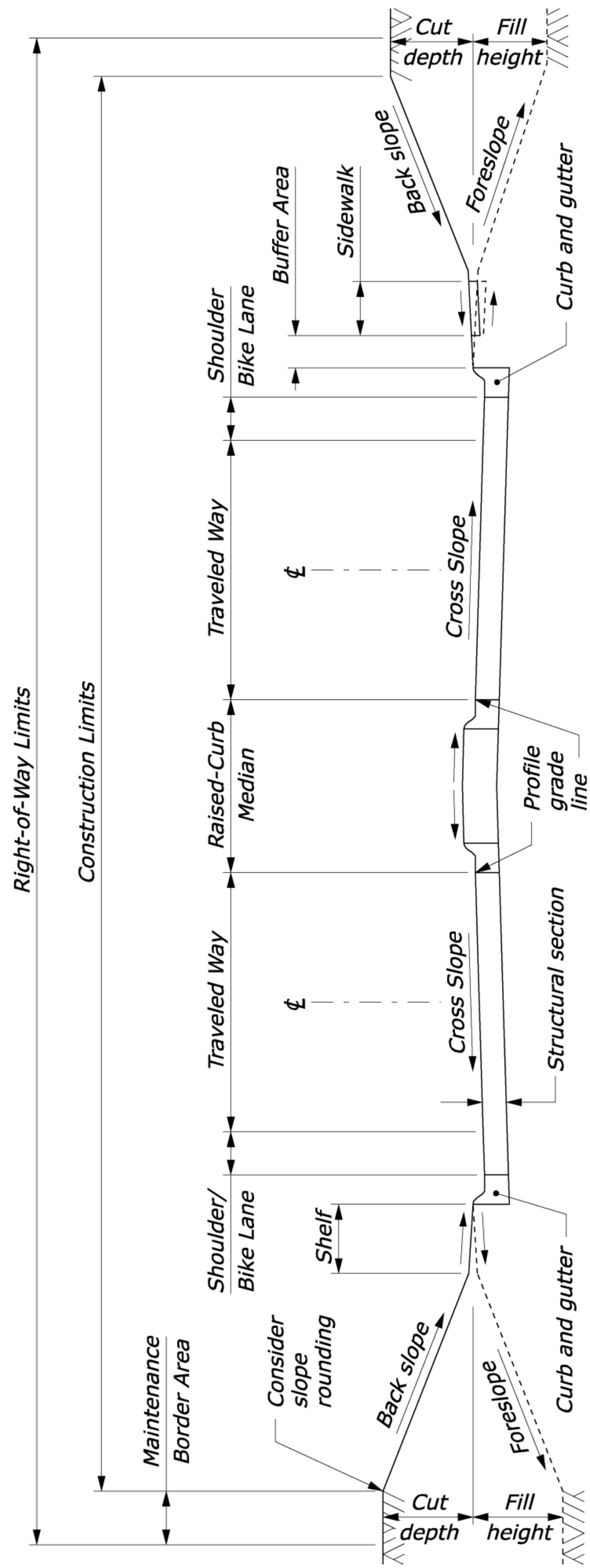


Exhibit 4.3–C TYPICAL URBAN CROSS SECTION ELEMENTS



4.3.2.3 Traffic Characteristics

Traffic characteristics play a major role in establishing the concept and design of a highway. Traffic indicates the type of service for which the improvement is being made and directly affects the criteria for geometric design features (e.g., widths, alignment, grades).

Basic traffic data (e.g., average daily traffic, vehicle classification) is collected on almost a continuous basis by most highway departments and some land management agencies, including the National Park Service. This information can be readily obtained and provides a benchmark for traffic data in the study area. When traffic data is not present, it must be developed by special counts or by calculating the number of vehicles from related information (e.g., National Park visitations, board feet [cubic meters] of timber hauled, recreational visitor days). The FLH Division offices have traffic counter equipment that can be used to collect current traffic data for development of individual projects. When needed to verify the functional classification or other design controls, obtain information on the various users' origin and destination patterns and their functional use of the highway.

Some of the common traffic data elements are listed below, and are described in more depth in Section 8.6.1. Note that not all items listed are required for every project and can vary depending on specific project requirements:

1. **Average Annual Daily Traffic (AADT).** The total yearly volume of motor vehicles divided by the number of days in the year.
2. **Average Daily Traffic (ADT).** The calculation of average traffic volumes in a time period within the year, greater than a single day and less than one year. If for a specific season within the year, it is designated Seasonal Average Daily Traffic (SADT).
3. **Peak-Hour Traffic (PH).** The highest number of vehicles passing over a section of highway during 60 consecutive minutes. Non peak-hour traffic is representative of other times.
4. **Peak-Hour Factor (PHF).** A ratio of the total volume occurring during the peak hour to the maximum rate of flow during a given time period with the peak hour (typically 15 minutes).
5. **Design Hourly Volume (DHV).** The one-hour volume in the design year selected for determining the highway design.
6. **K-factor (K).** The K-factor is the percent of daily traffic that occurs during the peak hour. A rule of thumb for rural highways is approximately 15% of the ADT.
7. **Traffic Growth Rate.** The trends and growth rates, past and projected.
8. **Classification of Vehicles.** Percent passenger vehicles, single-unit and single-trailer and multi-trailer trucks, buses, and recreational vehicles (motor home, camper trailer, boat trailer).
9. **Directional Split.** Percentage of the design volumes in either direction.
10. **Turning movements.** Traffic volumes of vehicles making allowable turns at major intersections. Typically expressed as a portion of the DHV.

11. **Congestion data.** Speed, density, volume, headway, percent of time following, and level of service data at identified traffic congestion areas.
12. **Speed and delay data.** Measurements of operating speeds, running speeds, and amount of delay to vehicles at intersections.
13. **Conflict study data.** The identification of potential conflict points at intersections, and the associated numbers of vehicles exposed to the potential conflicts.

Identify any areas that are being considered for new traffic patterns, directional signing, revised pavement markings and other change to traffic control devices that benefit traffic operations.

The AASHTO *Green Book* Section 2.3 provides a description of traffic characteristics (e.g., volume, directional distribution, composition of traffic projections, speeds). While much of this information has a more direct bearing on design details, conceptual studies and associated alternative analyses are also dependent on overall traffic data. Sometimes traffic data (e.g., operating speeds, travel time and delay, occupancy rates) are needed to address a special issue (e.g., determining the design speed or the need for passing lanes). If this data is unavailable, conduct the traffic studies as described in the ITE *Transportation and Traffic Engineering Handbook* to provide this information.

4.3.2.4 Crash Data

Obtain the current traffic crash data for the route. Vehicular crash data can provide excellent guidance in determining a road's past safety performance problems. These data and statistics are usually maintained and readily available at the highway department, land management agency and/or the law enforcement office responsible for that highway facility. When this type of data is not immediately available, conduct a short-term traffic safety study or an assessment of crash potential. If a formal traffic study is not available, anecdotal information from responsible sources can provide insight as well, and it is recommended to contact law enforcement agencies responsible for the area to supplement the information from their records.

Figures for crash rates are shown in crashes per million vehicle miles [kilometers] traveled. Figures for fatality rates are shown in fatalities per one hundred million vehicle miles [kilometers] traveled.

See Section 8.4 for guidance on the safety analyses of highways.

4.3.2.5 Roadside Safety Features

Identify existing information on roadside features (e.g., clear zone, side slopes, ditch widths, clearing limits, barriers, barrier terminals and transitions, fixed objects) even if the width of project disturbance will not affect them, as these existing features contribute to the roadside safety as incorporated within the project. (See Exhibit 4.3–A.)

4.3.2.6 Controlling Site Features

Identify and obtain information regarding the existing features that may control the location, design or scope of improvements. These may be topographic features, environmental features, roadside development, intersections, approach roads, utilities, railroads, etc.

4.3.2.7 Construction Considerations

Obtain available information on considerations that will control construction activities (e.g., work limitations, access limitations, construction staging, environmental commitments and stockpile area limitations and hauling limitations) and limitations on sources of construction materials.

4.3.2.8 Environmental Considerations

A highway has wide-ranging effects beyond that of providing traffic service to its users. It is essential that the highway be considered as an element of the total environment. The highway can and should be located and designed to complement its environment and serve as a catalyst to environmental improvement. Obtain relevant information on the context of the facility and the needs of non-highway users that are affected by the facility, as well as the users. Obtain available information about the project community both in terms of its physical attributes (e.g. land use, landscape, demographics, economic conditions and trends, and natural and man-made resources), as well as relevant information that describe the intrinsic characteristics that are valued by its members, define its sense of place, and which make the community unique. Obtain relevant information on travel destinations and access needs served by the facility (e.g., schools, commercial, and recreation access within the corridor) and the relationship of the facility within the overall environment.

Determine requirements for wildlife crossings and fish passage within the highway corridor. Refer to Section 9.5.10 for information regarding design of wildlife crossings and design of drainage structures for fish passage.

Obtain resource mapping (e.g., wetland delineation, historic and archeological sites, wildlife habitat areas mapping and restrictions). Obtain resource information from stakeholder, partner and cooperating agencies and incorporate with the engineering mapping information described below.

Obtain relevant environmental documentation from the environmental process. Data for conceptual studies and preliminary design are collected concurrently with the environmental process and each has a major effect on the other. As outlined in Chapter 3, close coordination is important to ensure the range of improvement alternatives is established in recognition of overall environmental factors. This allows for an orderly, complete evaluation when determining the preferred improvement alternative. Also, the design of the selected alternative must reflect the limitations and mitigation commitments identified in the environmental phase.

4.3.2.9 Survey and Mapping

Obtain existing information on survey control points, benchmarks and control data (e.g. datum, coordinate system basis, etc.), as described in Chapter 5.

If available, obtain existing aerial photography and mapping for study and illustration of the existing highway, roadside features and proposed improvements. Obtain available maps and mosaic photo composites, USGS digital ortho quarter quadrangle maps (DOQQ's), satellite imagery or aerial photographs from other agencies to assist in the conceptual studies, even when minor improvements are being investigated.

As applicable, obtain photogrammetric maps, topographic maps (paper copies or digital files) and aerial photographs of the area from the following sources:

- Previous route surveys and reports,
- Previous highway corridor mapping,
- Maps by Federal, State, county and municipal agencies,
- Topographic maps by US Geological Survey (USGS) and National Geodetic Survey,
- Hydrographic surveys of rivers and river and harbor surveys by the US Army Corps of Engineers (USACE),
- Tideland maps by the State land department,
- Surveys by the Bureau of Reclamation, NPS and Bureau of Indian Affairs (BIA),
- Highway right-of-way maps by FHWA, State and county agencies,
- Public Land Survey System (PLSS) plats and Master Title Plats from the Bureau of Land Management (BLM),
- Maps by Forest Service (e.g., transportation maps, firemen's maps, topographic maps),
- Stereo-photographs from private sources and government agencies, particularly the USGS and the Department of Agriculture,
- Railway maps and profiles,
- Maps made by the State planning divisions (i.e., county maps showing county road systems and roadside culture and city maps, which include the immediate surrounding area),
- FLMA, State and local GIS mapping,
- County tax maps,
- Geotechnical maps, and
- Mapping services such as Google Earth, Virtual Earth, and NASA World Wind.

4.3.2.10 Right-of-Way

Collect existing right-of-way documents, plats and exhibits. Obtain existing information regarding railroad property, if applicable. See Chapter 5 and Chapter 12 for right-of-way information gathering.

4.3.2.11 Existing Access Management

Collect existing access management plans and documents, travel management maps, corridor travel management plans, etc., if available.

4.3.2.12 Utilities

Collect existing utility maps, plans and agreements. See Chapter 5 and Chapter 12 for utilities information gathering. Contact the utility company to determine the type and location of existing utilities. Utilities may be located within easements.

4.3.2.13 Permits

Obtain existing use permits for activities within the corridor. Refer to Section 3.3.3 for information on common environmental related permits. See Chapter 12 for Special Use Permits. Utilities typically are within the right of way by permission from the highway owner or operating agency. Permits differ from easements or fee title in that permits are revocable.

4.3.2.14 Geotechnical

Obtain existing geotechnical and materials reports, if available. Obtain geological maps, references and reports for the area. Refer to Section 6.3 for geotechnical information gathering.

4.3.2.15 Pavements

Obtain existing information on surfacing conditions, if available. Refer to Section 11.1.5 for pavement information gathering.

As applicable, obtain pavement condition data for National Park Service (NPS) roads and parkways from the Road Inventory Program (RIP). The VisiData software application is available to view and query RIP data. VisiData displays forward-view and pavement-view digital imagery, as well as surface condition data and an asset inventory of each paved NPS road.

4.3.2.16 Hydrology and Hydraulics

Obtain available hydrology and hydraulic information where water resources are an issue affecting the road project (e.g., flood plains, erosion, drainage, water quality). This data aids in determining the cause of some road problems and, more importantly, provides guidance to determine feasibility, location or size of hydraulic structures for the alternatives under consideration. This data is needed to establish baseline conditions, address environmental concerns and to resolve engineering design problems, in the preliminary and final design phase. See Section 7.1.3 for scoping and gathering information about hydrology and hydraulic conditions.

4.3.2.17 Structures

Obtain bridge inventory and condition inspection reports. Obtain existing reports regarding pier, abutment or channel scour. Obtain as-constructed plans of existing bridge structures.

4.3.2.18 Pedestrian and Bicycle Use

Obtain information on pedestrian and bicycle use. Also obtain information on any other motorized and non-motorized use of the facility (e.g., equestrian, snowmobile, all terrain vehicles). This may also include Statewide, regional or local bicycle and pedestrian planning documents.

4.3.2.19 Alternative Transportation Elements

Obtain existing information (not performance of new planning or design) pertaining to alternative transportation elements (e.g., transit systems, school busing, tour busing).

4.3.2.20 Intelligent Transportation System (ITS) Elements

Obtain existing information on any ITS elements or systems that are present. See Section 8.7.5 for more information.

4.3.3 SITE INSPECTION

Perform a site inspection to view the existing conditions and verify the existing information that has been gathered. Conduct a collaborative walk-through with the project stakeholders, technical specialists, and local project constituents familiar with the features or concerns related to the project. Key items to investigate or information to verify during the site inspection include:

- Context resources (environmental, cultural, historic, and man-made), constraints and controls that have been, or will need to be, inventoried and mapped for the project area;
- Traffic data, travel demands (for all modes), and crash data which identify operational, capacity, and roadway safety problems, and/or potential problems with future conditions. See Section 8.4.1;
- Roadside safety conditions, barriers, signs and markings. See Section 8.4.2;
- Roadway geometry, cross section dimensions, sight distances, roadside and ditches. See Section 8.4.3;
- Pavement conditions, local materials and geotechnical conditions. See Section 11.3.1;
- Road approach and access conditions, traffic conflicts, intersection sight distances;

- Hydraulic conditions, adequacy and sufficiency of existing structures, bridge inventory information and floodplain effects;
- Geotechnical conditions. See Section 6.3;
- Right-of-way information, identification of property lines and property owners; and
- Existing utilities, location and potential conflicts.

An essential result of reviewing the existing information and evaluating the on-site conditions in the field is so the interdisciplinary team understands the overall context, land uses, and intrinsic character of the project location, the natural environment, and surrounding community. Local knowledge and on-site interaction is critical to form an understanding of the environment, surrounding land use, and community character and values.

4.4 DESIGN STANDARDS

Design standards include the geometric design standards and other technical standards. Geometric design standards relate to the functional classification of highways, types of users, traffic density and character, design speed, capacity, safety, terrain, and land use.

Design of the overall highway should be done to a consistent standard. Evaluate the route between major termini to maintain a uniform approach to the major design features of an overall route that may be improved in stages on a project-by-project basis. Identify contextual features and qualitative aspects of each project early in the design process, before design standards are selected, and consider them throughout the design process.

Proposed highway improvement alternatives are principally described by the preliminary design standards. The design standards listed in *FLHM* 3-C-1 (see Exhibit 4.4–A) can be supplemented or substituted with approved highway design standards from owner agencies. Any substitutions of design standards must be consistent with the highway program legislation, regulations and interagency agreements discussed in Section 2.3 and Section 2.4. Refer to interagency memorandums of agreement for information regarding applicable design standards.

Some Federal agencies, most States and many local highway agencies have established standards that adopt AASHTO policy supplemented with additional and clarifying criteria. The practitioner should be familiar with the sources of information on the design policies, standards, guidelines and procedures that are applicable to the State in which the project is located. See the list of State DOT design manuals.

Current FHWA and AASHTO guidelines for geometric design and technical activities emphasize balancing the needs of the transportation user with the context of the facility. This requires a comprehensive understanding of social, economic, and environmental concerns and effects, as well as the concerns and effects for capacity, speed, safety, quality, and efficiency. Achieving an appropriate balance of the needs of the transportation facility users with values of the environment and communities that are affected involves seeking *Context Sensitive Solutions* (CSS) and applying innovative decision-making approaches to the project development, design and delivery process. Refer to NCHRP Report 480, *A Guide to Best Practices for Achieving Context Sensitive Solutions* for additional information on CSS. Also, refer to Section 4.4.5 and Section 4.7.2 for guidance on CSS.

FHWA has adopted policies and standards for Federal-aid highway design that recognize these concepts and which are also applicable to Federal Lands Highway design. The policies and standards are listed in Title 23 of the Code of Federal Regulations, Part 625 (23 CFR 625) and supplemented in the *Federal-aid Policy Guide* (*FAPG*) NS 23 CFR 625. These standards basically adopt AASHTO policy for projects on the National Highway System (NHS) and refer to the approved State or local design guidelines, standards and procedures for non-NHS projects.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

4.4.1 APPLICABLE DESIGN STANDARDS

It is FLH policy to use approved standards for the design of projects funded from the highway trust fund. Refer to 23 CFR 625. For non-NHS projects funded through owner-agency appropriations, the owner-agency's standards apply, provided they are consistent with professional engineering practice and FHWA and FLH policies, and the FLH standard practices outlined in this manual including guidelines for providing context sensitive solutions. For all new construction and reconstruction projects on the NHS, the 23 CFR 625 listed standards apply, in particular the criteria in the *Green Book* pertaining to arterials. For non-Interstate RRR projects on the NHS, FHWA approved State standards may be used. Exhibit 4.4–A lists the principle FLH Programs and corresponding design standards.

Exhibit 4.4–A DESIGN STANDARDS

Type of Roadway	Applicable Standards
Forest Highway and Public Lands Highways	23 CFR 625 listed standards and FHWA approved State or local standards
National Park Roads and Parkways	*Park Road Standards* (1984) and 23 CFR 625 listed standards *(See Note 2)*
Indian Reservation Roads	25 CFR 170, *BIA Design Manual* and 23 CFR 625 listed standards
FAA Roads	23 CFR 625 listed standards
BLM Access Roads	*FAPG G6090.13* and *BLM Manual*, Section 9113 – Roads
Defense Access Roads	23 CFR 625 listed standards or FHWA-approved State or local standards
FS Roads and Trails	*FS Handbook FSH 7709.56*
ERFO	Standards determined by classification of highway to be repaired or reconstructed. (See *ERFO Manual*)
Refuge Roads	23 CFR 625 listed standards as applicable to RRR projects
US Virgin Islands	23 CFR 625 listed standards and FHWA approved standards (AASHTO Green Book)

Notes: *1. Where there is a conflict between agency standards and 23 CFR 625, mutually resolve the design criteria with the client agency.*

2. For all references in the Park Road Standards to criteria compiled from the 1984 AASHTO Green Book tables, substitute corresponding values in the current Green Book.

The appropriate standards are normally identified from the source of program funding for the project and the associated MOU as described in Chapter 2. Occasionally the practitioner will need to determine which standards are approved for use on a specific project. When it is uncertain which standards apply, consult with the appropriate Branch Chief.

When it is determined that specific design criteria are applicable to the particular project type and conditions, then the applicable design criteria is established as the standard for the project. Use of design criteria less than the applicable minimum standards must be approved and documented as a design exception. In addition to meeting the minimum design standards, each project should be evaluated on the basis of desirable design criteria to provide the safest overall design. The AASHTO publication, *A Policy on Geometric Design of Highways and Streets*, (also known as the *Green Book*) is specifically referenced in 23 CFR Part 625 and is the principle source for highway design standards and criteria. Use the 2011 edition of the Green Book as the basis for design standards for FLH projects; however the 2004 edition may be used for projects already begun with that edition. Supplements to the *Green Book* include other AASHTO and technical publications adopted by FHWA as acceptable criteria and other approved Federal, State and local specifications for use on their roads. These acceptable supplements are referenced throughout the *PDDM*. The AASHTO *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)*, 2001 may be used in lieu of the current *Green Book* when designing local roads that fit the criteria; however, first consult with the Branch Chief responsible for Highway Design.

While, in many cases, the minimum AASHTO or Park Road geometric standards will provide the most appropriate level of safety, convenience and operational efficiency, alternatives with different standards must also be considered to address special factors (e.g., economic, environmental, operational) that affect the road, its users and context. Gathering and evaluating diverse land use, transportation, environmental and economic data, together with applied engineering judgment and analysis, will aid in formulating practical improvement alternatives that may fall above and/or below the minimum geometric standards.

Consider higher than minimum values for the geometric design standard if analyses of design traffic volumes, percent of truck traffic, level of pedestrian, bicycle or transit use, safety performance, level of service, future transportation needs, or other factors indicate such values are appropriate.

Environmental impacts and concerns, social impacts, extraordinary costs, or costs prohibitive of the limited available funds occasionally justify the need for design elements that are less than the minimum design standard. This is often the case for RRR projects. Analysis should include consideration of adjacent highway sections and the relationship to future improvements, as well as existing conditions, and operational and safety conditions that will result from completion of the project. When the analysis concludes that achieving full standards is not practical, evaluate the consequences and document each decision for exception to the standards as outlined in Section 9.1.3. The design exception analysis and documentation process shall also include and discuss the incorporation in the design any existing substandard conditions or elements that are not reconstructed to approved, current standards as part of the project.

The preliminary design standards, applicable to describe the alternatives being considered, establish more detailed criteria to be used in the final design process. Many of these other elements are functions of the ADT, design speed or roadway width and are developed during the final design phase. The design criteria is typically represented by a range of acceptable values from which a selection is based on the discretion and engineering judgment of the design team to best fit the conditions and a variety of competing objectives. The preliminary design standards, as well as the other design standards and criteria, become the adopted project standards when an alternative is selected in the final approved environmental document (see Section 3.4.2.2.1).

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

4.4.2 RESURFACING, RESTORATION AND REHABILITATION (RRR) PROJECTS

The primary purpose of a RRR project is to preserve and extend the pavement service life, provide additional pavement strength, restore or improve the original roadway cross section, improve the ride of the roadway, and enhance highway safety and traffic operations. The scope of such projects exceeds routine maintenance, but is less than new construction or reconstruction. This may include placement of additional base and surface material and/or other work necessary to return an existing roadway to a condition of structural or functional adequacy.

The improvements, whether only at spot locations or continuous, should acceptably meet existing and preferably future (i.e., 10 to 20 years) traffic needs and conditions in a manner conducive to safety, durability and economy of maintenance. Usually, the RRR project only addresses the most critical deficiencies of the highway so the resultant condition will still retain some potential problem areas or substandard features that would normally be addressed as part of a future reconstruction.

RRR projects may consist of the following limited types of improvements:

- Pavement preservation other than routine maintenance,
- Resurfacing,
- Pavement structural and joint repair, other than isolated segments and patching,
- Minor lane and shoulder widening,
- Minor selected alterations to vertical and horizontal alignment,
- Superelevation correction as practical,
- Intersection improvements,
- Traffic control improvements,
- Bridge repair, and
- Safety improvements, such as sight distances and removal or protection of roadside obstacles.

The design policy applicable for RRR projects is the same as for new construction and reconstruction, unless a separate FHWA approved State or local RRR design policy is applicable to the project. See Section 4.4.1. However, designing RRR programmed projects to full standards is usually not intended and may not be practical. Funding limitations and other factors often prevent designing RRR projects to meet approved standards. The RRR design process often includes incorporation into the design many existing substandard conditions or elements that are not necessary or practical to reconstruct to approved, current standards as part of the project. As stated in the Foreword to the *Green Book*, existing roads that do not meet the guidelines for geometric design are not necessarily unsafe and do not necessarily have to be upgraded to meet the design criteria. However, all substandard elements must be identified and evaluated. Identify all such substandard features and document each exception to the standards as outlined in Section 9.1.3.

The agency with jurisdiction of the road may have separate design standards and procedures that apply to RRR projects. Most of the State DOT's have established separate RRR design standards and procedures, which have received FHWA approval for use on their Federal-aid projects. The State's approved RRR design standards and procedures may be used for specific programs or projects where appropriate, such as for Forest Highway and Public Lands Highways, and Defense Access Roads. Before using approved State or local RRR design standards and procedures for a project, consult the Branch Chief responsible for Highway Design.

FHWA has issued guidance to the States for developing specific RRR design standards and procedures, and this guidance is appropriate for use in developing FLH RRR projects, as an exception to the listed standards. FHWA T 5040.28 provides guidance for developing safety conscious design procedures for the design of RRR projects. For RRR projects, any deviations from the established design standards (e.g., design criteria associated with the posted speed) are treated as design exceptions. This requirement also pertains to the roadside design, and while not included in the 13 principal design elements classified as controlling criteria requiring a formal design exception (see Section 9.1.3), it must be fully documented if approved roadside design criteria are not possible to achieve. Although deviations from the 13 controlling criteria require approval and documentation as a formal design exception, all deviations from FLH standard practices need to receive endorsement and be documented in some manner regardless if for a RRR or a reconstruction project.

When the pavement condition reaches minimal service level, there is a need for cost-effective pavement and roadway improvement projects. RRR projects reflect and emphasize economic management of the highway system. Therefore, economic considerations will largely determine the scope of work. The following are factors that may influence the scope of a RRR project:

- Pavement conditions,
- Roadside conditions,
- Funding constraints,
- Environmental concerns,
- Changing traffic and land use patterns,
- Traffic data, and
- Crash data.

The limits of construction for RRR projects are generally limited to the existing roadbed bench, consisting of the roadway surface and subsurface, adjacent foreslope, and ditch. Acquisition of additional right-of-way to construct RRR improvements is sometimes necessary. Horizontal and vertical alignment modifications, if any, should be minor and should be consistent with the geometry of adjoining roadway segments. However, the proposed work on the roadway will typically affect the foreslopes from the edge of pavement to the hinge point of the fill slope and to the bottom of ditch slopes.

A RRR project must not decrease the existing geometrics of the roadway section. For RRR projects, the original roadway template is, at best, restored or slightly enhanced and the geometry (alignment, width, profile) of the facility remains essentially as it was originally constructed. If the surface condition has greatly deteriorated, improvements to the roadway surface may result in slightly increased operating speeds. At some locations the roadway may have deteriorated to a point that the original design template cannot be easily restored. In some locations the existing geometry, and its inferred theoretical design speed as categorized by current geometric standards, will often be less than the current design standards for the posted speed limit. Although the original geometry and its associated design criteria is perpetuated by the RRR project, the project should assume a new overall design speed that is consistent with the regulatory speed or the posted speed limit that will be established after the project is completed (or a higher speed if justified). Refer to Section 9.3.1.13 for guidance on establishing an appropriate design speed for RRR projects. Although a facility's as-constructed plans may indicate or theoretically infer an original design speed, it should not ordinarily be perpetuated as the design standard for the new project if it is less than the regulatory or posted speed limit. There may be certain instances (such as where the theoretical design speeds of curves are consistently 10 mph [16 km/h] lower than the posted speed) where the posted speed should be re-evaluated.

If the RRR project cannot be surveyed cost effectively in enough detail to identify the deficiencies to the controlling criteria (e.g., superelevation, grades), visually evaluate the roadway for any discernable geometric deficiencies. Perform an on-site study or field review of the RRR project and document any identified geometric design deficiencies and exceptions to standards and design policy.

Improvements to the roadway surface may result in increased operating speeds. To maintain an acceptable level of operational safety, examine the geometrics and roadside conditions with respect to anticipated operating speeds after construction and consider modifying them, if necessary.

Carefully establish project limits, particularly where widening occurs. Avoid ending the project at potentially hazardous locations (e.g., a narrow structure, a severe vertical or horizontal curvature). Provide the appropriate safety measures where these conditions are unavoidable.

Section 8.4 describes techniques to evaluate safety conditions and deficiencies applicable to RRR projects. Additional considerations for the evaluation of lesser design conditions are provided in Chapter 3 (pages 49-80) of AASHTO *A Guide for Achieving Flexibility in Highway Design*, May 2004; and on pages 190-206 of Special Report 214, *Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation*, TRB, 1987. Refer to FHWA policy memorandum dated September 12, 2005 regarding pavement preservation definitions.

Refer to Section 9.4 for additional design guidance specific to RRR projects.

4.4.3 GEOMETRIC DESIGN CRITERIA

Geometric design is the development of the surface dimensions of a highway such that its form will meet the functional and operational characteristics of drivers, vehicles, pedestrians and other users. The geometric design includes the facility's location, alignment, profile, cross section, intersections and shape of the roadside. The geometric form and dimensions should reflect the user's desires and expectations for safety, mobility, comfort, convenience and aesthetic quality. It should do so with compatibility and sensitivity to the terrain, land use, roadside and community development, natural and cultural environment, and with consideration for cost and economic efficiency. A consistent approach to geometric design matches and reinforces expectations of the user, which is important to guide the full range of drivers and conditions including drivers that are unfamiliar, older, inexperienced, distracted, inattentive, tired or impaired. A consistent approach also addresses the safety and other needs of pedestrians and bicyclists, and their interactions with motor vehicles. Refer to Section 9.3 for standards, criteria, guidance, and philosophy for development of the geometric design.

4.4.4 DESIGN CONTROLS

Basic design controls serve as the foundation for establishing the physical form, safety and functionality of the facility. Some design controls are inherent characteristics of the facility (e.g. its context and the transportation demands placed upon it). Other basic design controls are selected or determined in order to address a project's purpose and need. Selecting appropriate values or characteristics for these basic design controls is essential to achieve a safe, effective, context sensitive solution. Evaluate the following design controls to understand the factors influencing the design and to determine the applicable criteria for establishing the standards for the project:

- Contextual factors and environmental constraints,
- Functional classification,
- Topography within the corridor,
- Location (i.e. rural or urban),
- Existing and expected traffic volumes and composition (e.g. ADT),
- Level of service and mobility,
- Level of access and management,
- Cross section type and level of multi-modal accommodation,
- Existing and expected users and their characteristics,
- Superelevation rate,
- Existing and expected speed characteristics,
- Appropriate design speed,
- Existing and expected safety performance, and
- Other technical factors (geotechnical, hydraulic, pavement, structural, etc.).

Refer to Section 9.3.1 for guidance on evaluating the geometric design controls. Refer to the respective chapters in this manual for applicable guidance on other design controls.

4.4.5 FLEXIBILITY IN HIGHWAY DESIGN

The design standards shown in Exhibit 4.4–A provide considerable flexibility in the determination of specific design criteria applicable to particular highway types and conditions. Flexibility in the design standards is associated with the purpose and function of the highway and other design parameters (e.g., traffic volume and type of vehicles).

The determination of applicable highway standards is intended to cover broad classifications of highway facilities. However, each project is unique. The setting and character of the area, the values of the community, the needs of the highway users, and the challenges and opportunities of the site are unique factors that must be considered with determination of design criteria for each highway project. The applicable standards provide flexibility in the selection of highway design criteria, which requires decisions on the part of the project design team and stakeholders. The standards allow designs to be tailored to the particular situations encountered in each highway project. Often, the flexibility within the range of criteria provides enough flexibility to achieve a balanced design that meets both the objectives of the project and is sensitive to the surrounding environment and context. In some instances, the criteria may not provide sufficient flexibility to adequately protect essential resources or values. For these cases a design exception process is provided to recognize the need for an exception to the standard, evaluate the consequences and risks, and develop mitigation.

The interdisciplinary project development team is expected to use their respective expertise and judgment to develop the conceptual and preliminary design of each road to fit into the natural and human environments, while functioning efficiently and operating safely. Each highway situation must be evaluated to determine the possibilities that are appropriate for that particular project, using an interdisciplinary approach to explore various concepts, options, constraints and flexibilities.

Refer to *Flexibility in Highway Design*, (FHWA-PD-97-062), 1997 and *A Guide for Achieving Flexibility in Highway Design*, AASHTO, 2004 for additional guidance in using flexibility in the selection of applicable design standards and criteria.

4.4.6 RISK ASSESSMENT

See Section 1.1.3 for general guidance on risk assessment and risk tolerance. Also refer to the other chapters in this manual for guidance on risk assessment applicable to the specific engineering disciplines.

Exhibit 4.4–B describes generalized categories of risk level, the type of endorsement that is anticipated, and the form of guidance for evaluation and approval.

The safety effects (predicted crash risks), if any, of providing geometric design features that are less than the standard for a particular design speed are not well established, although new methods for estimating safety effects of geometric designs are available (e.g., the IHSDM and its library of references). The safety risks may be lowered by providing mitigating features (e.g., additional traffic control devices, enhanced warning signs with advisory speed plaques, delineation, markings) and by modifying the roadway and roadside (e.g., shoulder widening, enhanced recovery area, improved barrier) to reduce the severity of crashes. However, the degree to which the safety risks may be reduced by this type of mitigation is difficult to quantify.

Exhibit 4.4–B RISK ASSESSMENT AND ENDORSEMENT LEVELS

Risk Level	Endorsement	Guidance
Expected/Typical	Interdisciplinary Team Representative	PDDM acknowledges risk tolerance and provides policy, FLH standard practices, criteria, and guidelines that allow flexibility.
Elevated	Project Manager and Division Discipline Functional Managers	PDDM discusses technical considerations and mitigation applicable for various engineering disciplines, when deviation from FLH standards is necessary.
High	Branch Chiefs or Directors	Procedures for design exceptions and exceptions to critical FLH standard practices applicable for various engineering disciplines.
Very High	Division Engineer	Project-specific design standards and criteria may be approved if necessary, as applicable for various engineering disciplines.

Refer to Section 8.4 for guidance on assessment of the safety and operational risks associated with existing roadway conditions, and refer to Section 9.3 or Section 9.4 for guidance on assessment of the geometric design and operational effects, risks and mitigation for specific geometric design elements and features. Also refer to Chapter 4 of *A Guide for Achieving Flexibility in Highway Design*, AASHTO, 2004 for guidance on evaluating and documenting risks associated with the geometric design.

Refer to the Division Supplements for guidance specifically applicable to each FLH Division regarding procedures for evaluating and documenting risk assessments.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

4.5 PRELIMINARY ENGINEERING INVESTIGATION

The purpose of the preliminary engineering investigation is to compile, evaluate and document all the preceding conceptual studies in order to plan the various interdisciplinary activities for performing the preliminary design and related engineering activities considered in the environmental process, and to plan the interdisciplinary activities for the comprehensive project development and delivery process. The following sections provide guidelines for performing the:

- Project scoping study,
- Preparation of the project scoping report, and
- Corridor studies and report (if applicable).

The basis for this preliminary engineering investigation is the problem definition and evaluation of existing information that is gathered as described in Section 4.3, together with consideration of the applicable design standards and controls as described in Section 4.4.

The result of this preliminary engineering investigation is an initial recommended course of action that will be carried forward for development during the preliminary design phase as described in Section 4.6, including any alternatives that will be developed as described in Section 4.7. The results of the preliminary design and alternatives analysis are subsequently established as described in Section 4.8.

4.5.1 PROJECT SCOPING STUDY

The project scoping study evaluates the existing data and context information, project needs, goals and objectives, initial environmental coordination and public outreach, and applicable design standards and controls, which is all performed in advance of preliminary design. The project scoping study collectively includes:

- Interdisciplinary field inspections and engineering investigations involved with identifying and quantifying a highway's deficiencies and needs,
- Evaluating the feasibility and identifying a proposed course of action with improvement alternatives, and
- Conducting engineering analyses that result in a report identifying feasible proposed improvements.

Project planning study, route study, feasibility study, reconnaissance study and preliminary engineering study are all terms used by different agencies and offices to mean some form of project scoping activity that falls within the conceptual study phase. Within FLH, the Project Scoping Report may also be known as a design scoping report, project identification report or reconnaissance report. For evaluation of road corridors on new alignment, a Corridor Study may also be needed (see Section 4.5.3).

The project scoping study initially organizes and documents the major needs, issues, constraints, scope and feasibility of proposed improvements from which the more comprehensive, interdisciplinary preliminary engineering activities, surveys, investigations, environmental studies and analyses for the project can be effectively planned, budgeted, and scheduled.

A project scoping study should be initiated as part of the pre-programming activity to help prioritize or screen projects being considered for inclusion in the multi-year program (refer to Section 2.5), and to help streamline the project development activities. The pre-programming scoping study may not be as detailed as described in this chapter. If a project scoping study was not completed earlier, the remaining project scoping study activities are performed directly after the project is programmed for funding.

The project scoping study is performed using an interdisciplinary, interagency approach with close coordination of the land management agency and principal stakeholders of the facility. For reconstruction projects, the interdisciplinary team should thoroughly explore the existing corridor for opportunities to improve safety, traffic operations and efficiency including realignment and reconstruction of the existing roadway within the existing corridor.

For purposes of defining the series of investigations during the conceptual studies phase for Federal lands, the project scoping study is a combination of the field inspections and existing engineering data used to identify and quantify a highway's deficiencies and needs. The data are gathered and summarized in the Project Scoping Report. As part of this study, recommendations for further study will also be made in order to develop a course of action with suggestions for investigating improvement alternatives and conducting engineering analyses that ultimately result in a preferred alternative are collectively called a project scoping study.

4.5.2 PROJECT SCOPING REPORT

The results of the field inspections and compilation of existing engineering data used to identify and quantify a highway's deficiencies; user needs and context are gathered and summarized in the Project Scoping Report. Also refer to Division Supplements for specific information requirements, report format or checklists that are applicable to each Division. As applicable to each individual project scope of work, include information described in the following sections.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

4.5.2.1 Introduction

Describe the authority, purpose and need for the study. It should include the relevant project history, a general project description and describe the nature of the work. It should also describe the major issues, concerns and opportunities that will be addressed by the study.

4.5.2.2 Resources Used

Identify all sources of information, maps and available data obtained for the study. This is not merely a listing of the agencies that provided data, but a summary of all of the existing reports, as-constructed plans and previous studies reviewed as well as any site investigations performed.

4.5.2.3 Route Description/Termini

The study termini should be established to be comprehensive and logical, although the overall route may include portions that already conform to standards or meet the purpose and need. Identify any segments along the route where significant changes occur in traffic use, speed, roadway width, terrain or overall condition. If this project is one of several on a corridor, also provide a brief summary of the other projects, their limits and how they relate to this study. Refer to Section 3.4.2.2.1 for more information to determine logical termini for analysis.

4.5.2.4 Preliminary Programming and Funding Information

Based on preliminary program budgets for the project, or expectations of the land management agency, a budget and target fiscal year is established for the proposed work. This information should document those initial assumptions so the project team is aware of the anticipated scope of improvements and the funding constraints that may exist. This includes the funding type(s), program fiscal year(s), construction cost, engineering and other project delivery costs. This information should also describe any inter-agency agreements that have been made that will help fund the project. Also document the assumptions and risks identified and agreed upon when creating the budget. This may include risks associated with unknown subsurface conditions, environmental, social or political uncertainties, and other factors that may greatly affect project scope and budget.

4.5.2.5 Project Contacts

A conceptual study is a discovery process. The time required to complete these discoveries can frequently result in new participants being assigned to the study from the various contributing agencies. To keep all of the agencies informed, and to provide contact information to those that are added to the team, the contact information of all participants should be included in the Project Scoping Report. In addition to their respective phone, mail and e-mail addresses, it should include their title and what discipline/subject area they are responsible.

4.5.2.6 Description of Purpose and Need

A preliminary purpose and need is initially described in the planning and programming phase. The purpose and need description should be refined by the interdisciplinary/interagency team in collaboration with the environmental process. Refer to Section 3.4.2.2.1 for additional information on this process.

This purpose and need description is more detailed than the general purpose and need described in Section 4.3.1. Some examples of points that could be addressed include:

- Describe the primary highway related needs for improvement of this route (e.g., safety, operational, capacity, structural deficiency, travel corridor demand, system continuity). Also, describe the secondary needs for improvement of this route (e.g., water quality).
- How would improvement of this route aid in the development, use, protection and administration of the land and its renewable resources by the land management agency?
- How would improvement of this route aid in the enhancement of economic development at the local, regional and national level?
- How would improvement of this route aid in the continuity of the transportation network serving its dependent communities and the land management agency?
- How would improvement of this route aid in the mobility of the transportation network and the goods and services provided?
- How would improvement of this route aid in the protection and enhancement of the surrounding environment associated with the land managing agency and its renewable and nonrenewable resources?
- Have there been public requests for improvement of the route?

The purpose and need for improvement of the facility should be related as closely as possible to the intent, authority and eligibility of the enabling program that is funding the project.

The purpose and need should include a summary of the available traffic data and crash data.

4.5.2.6.1 Summary of Traffic Data

Based on the evaluation of existing traffic data and other related information that is collected, summarize the average daily traffic and the projected traffic level for the future design period.

4.5.2.6.2 Summary of Crash Data

Based on evaluation of the current traffic crash statistics for the route, summarize the crash information. Categorize data according to route segments and spot high-frequency locations. This must be supplemented with field identification of potential crash sites that may not be discernible from the past data.

4.5.2.7 Climate, Physiography and Geology

Provide a general description of the climate, significant geographic features, land uses and geology of the area.

4.5.2.8 Controlling Factors

Describe all controlling features involved found during reconnaissance of the route. The following provides some examples:

- Major intersecting roads;
- Railroad crossings;
- Bridges and other structures;
- High-voltage power line crossings (i.e., elevation of low point in power line cable and air temperature at time of measurement);
- Major utilities and/or special services (e.g., gas and oil pipelines, water distribution lines, telecommunications trunk lines);
- Roadside developments (e.g., private commercial and residential development, visitor centers, lodgings);
- Historic structures and features, special architectural, decorative or aesthetic features and aspects;
- Designated critical habitat for protected species, or other areas that have special designation by law, regulation or policy;
- Floodplains, wetlands, major natural features, major rock outcrops, etc.;
- Existing, unique features outside the limits of the pavement that define the context of the roadway corridor that should be preserved or avoided (e.g., take photos of any vistas or vegetation to preserve, unique outcroppings);
- Especially difficult terrain; and
- Restrictions on, or difficult construction access, staging, etc.

4.5.2.9 Criteria to Be Applied

Describe the primary design standards and criteria to be followed for the development of the various alternatives for all disciplines. Describe the source and range of proposed preliminary roadway design standards, especially alignment and grades, roadway cross sections, type and cost of structures and other preliminary design elements being considered. Describe all the proposed controlling geometric design criteria and any proposed design exceptions as outlined in Section 9.1.3.

4.5.2.10 Preliminary Recommendations for Study

During the project scoping efforts, the project interdisciplinary team will have insights as to what is anticipated to address the purpose and need. These recommendations will form the scope of work for the preliminary engineering stage. All of the alternatives to be considered and the breadth of effort needed to investigate these alternatives should be described to properly convey the vision of the interdisciplinary team to those performing the preliminary engineering efforts.

4.5.2.11 Environmental Features and Concerns

Briefly describe the overall level of environmental sensitivity of the facility and the action, key features and concerns, and the anticipated type of NEPA document that is recommended by the environmental discipline specialists. Describe the proposed lead agency and cooperating agencies for the NEPA document and associated responsibilities. Identify any State-specific documentation requirements (e.g. CEQA in California, SEPA in Washington, etc.) that must be coordinated. Briefly describe the anticipated level of applicability of the following key issues, which are addressed as part of the environmental process (see Section 3.4.2.2):

- Wildlife resources (e.g., T&E species, State-listed species, species of local concern, critical habitat, conservation areas);
- Aquatic resources (e.g., wild/scenic/recreational rivers, lakes, shorelines, fish passage, spawning restrictions, NOAA fisheries);
- Wetlands or water quality resources, water supplies, groundwater protections;
- Historic, cultural or archeological resources (e.g., National Register eligible sites, SHPO – Section 106 involvement);
- Tribal or traditional cultural properties (TCP);
- Recreation areas, parks, Section 4(f) and 6(f) requirements (see Section 3.3.2.14);
- Scenic Byway or aesthetic resources;
- Public concern or controversy; and/or
- Other key environmental issues.

4.5.2.12 Summary of Functional Discipline Considerations

This section provides guidance for each engineering functional discipline to consider for planning the development of the preliminary engineering (30 percent plans). For each discipline, provide a description of technical considerations, and the anticipated scope of services to be performed during the preliminary engineering stage.

4.5.2.12.1 Roadway Design

Describe the overall existing horizontal and vertical alignment characteristics, cross section elements, intersections, public access approach roads and other major geometric features. Describe the existing and proposed traffic operations and user characteristics. Provide a listing of roadside features that will control or have a major influence on the design. Describe major roadway features (e.g., parking areas, walls, curbs, barriers, sidewalks, fencing) that may be left in place or rehabilitated. Describe the general roadside conditions, slopes, drainage, vegetation, aesthetic features and other factors that will heavily influence the design criteria and development of the preliminary design that are not addressed in Section 4.5.2.8. Describe the overall level of roadway improvements that are proposed, and level of design development that is anticipated during the preliminary design phase.

Based on the evaluation of the existing geometry, describe any horizontal and vertical alignment problems that must be specifically addressed or studied further. If there are alternatives to be considered, describe potential realignment options that should be considered, provide the general scope and the reasons for the investigation. Describe the major maintenance issues that the road owner is dealing with that should be addressed in the roadway design.

Perform a design assessment of driver information needs and describe locations with potential for either insufficient positive guidance information, or information overload, including sight distance needs for these conditions. Refer to *Green Book* Section 2.2.9 for guidance on these considerations.

Identify any intersection problems that must be improved or problems with approaching roadways that tie into the roadway that must be studied further. Associated with this, identify any private driveways or access points that require special improvement or investigation within the project limits.

Describe other roadway features to be rehabilitated or rebuilt (i.e., parking areas, pullouts, picnic areas, entrance gates, concession areas, rest areas, bus shelters). Identify who will provide the design plans if they are not part of this study.

In addition to the roadway, identify any other facilities that must be realigned (e.g., bicycle, pedestrian, equestrian, snowmobile trails).

4.5.2.12.2 Traffic/Safety Investigations

Traffic and crash data are described in Section 4.5.2.6. Investigate the crash history data and describe any identifiable problems with sight distance, clear zone, roadside hazards (e.g., trees, headwalls, utility poles, and utility boxes), pedestrian crossings, unusual traffic conditions or poor operations. Identify constraints for obtaining clear zone and forgiving, recoverable roadside conditions at completion of the construction. Describe locations where needed improvement of the roadside is difficult, and where barriers may be warranted. Describe any identifiable deficiencies in the roadside safety hardware (e.g., sign supports, barriers and terminals, bridge rails and terminals) for compliance with current standards for crashworthiness. Describe the condition of traffic control devices (e.g., signs, markings, delineation, retro-reflectivity, messages) and the scope of needed improvements. Describe the overall level of safety and traffic operations improvements that are proposed.

In order to develop and evaluate the recommended alternatives, identify any site-specific traffic counts that are required to help determine the future traffic needs of the facility. These could include general counts, turning movements at busy intersections or projected growth information due to proposed developments in the area.

4.5.2.12.3 Survey and Mapping

Describe the level of existing survey, mapping or GIS information that is available. If existing survey data is not adequate to design the project, describe additional survey data needed. Describe the type(s) of survey that is recommended or that should be considered. Describe the factors affecting the survey work (e.g., as availability of control, monuments, sky exposure for GPS, photogrammetric mapping or LiDAR data collection, terrain and ground cover, traffic). Describe the extent of special features that will require precise location (e.g., walls, fences, utilities, bridges). Describe the extent of coordination that may needed for survey and mapping with environmental resource surveys of wetlands, critical habitats, nest sites, etc.

The type and scale of surveys and mapping required are dictated by the terrain and land use intensity of the route corridor area, type of project and the level of preliminary design analysis to be conducted. The maps must be complete, current and provide full details of topography and physical features.

Mosaic reproductions or photographic prints may be used in conjunction with USGS quadrangle maps or satellite imagery to show overall existing routes. Development of new photogrammetric mapping or other imagery for scoping studies may be used where feasible and cost-effective.

Topographic mapping for areas of moderate to intensive land use should preferably be to a scale of 1:1200 [1:1000] or 1:2400 [1:2000] with a 5 ft or 10 ft [1 m or 2 m] contour interval. In areas of limited or homogeneous land use and in mountainous or heavily forested areas, a map scale of 1:4800 [1:5000] with a 10 ft or 20 ft [3 m or 5 m], contour interval will suffice. If only broad reconnaissance is to be done, existing USGS quadrangle maps with 1:24,000 scale and 20 ft or 40 ft [5 m or 10 m] contour intervals may be adequate.

Further survey and mapping guidance is contained in Section 5.4.

4.5.2.12.4 Right-of-Way

Describe existing right-of-way in terms of existing widths, types of ownership and types of property improvements adjacent the roadway. Describe the overall extent of the route that is private and public property and the approximate number of landowners that may be affected. Identify the agency and contacts that have responsibility to coordinate and pay for any additional right-of-way. Describe the level of existing right-of-way documents that are available. If right-of-way plans need to be prepared for acquisition, describe the agency responsible for preparing documents and any unusual requirements for preparation. For public land, describe any special use permits for the roadway or related uses. Describe the approximate area of private and public right-of-way that may be affected or acquired for purposes of estimating the level of right-of-way activities. Describe any special fencing requirements or access management features that are anticipated.

4.5.2.12.5 Utilities

Describe the type and location of existing utilities. Identify if any known utilities will likely need to be relocated or avoided. Describe any special considerations regarding utilities that are unusually sensitive or difficult to address for clearance prior to construction. Identify the agency responsible for utility issue coordination and costs for relocation. Develop a contact list of utility representatives. Describe any existing utility agreements or easements between the roadway owner and the utilities. Describe entities (e.g., water and irrigation districts, transmission lines, railroad facilities).

Most existing utilities can be easily identified in the field or summarized by utility section maps. If there are specific utility issues that must be addressed during the evaluation of alternatives, describe what these issues are (outage limitations, lead time for acquiring materials, impacts to buried facilities due to changes in grade), and what level of investigation is necessary to complete the alternatives analysis. For most studies, only coordination with the utility owners will be required to determine their specific relocation needs and schedules. If there are relocations required where either hazardous or environmental consequences could occur, these should be fully investigated as part of the alternatives analysis.

4.5.2.12.6 Permits

Identify the likely permits or authorizations that will be needed (e.g., Section 401 (water quality certification), 404 (discharge of fill), NPDES (Storm water), Coastal Zone, Management Act of Compatibility, FS or NPS special use permits for material sources or plants, staging, borrow or waste). Identify any State permits anticipated (e.g., air quality, dewatering, channel alteration, burning, water quality, highway access or encroachments) and any local erosion and sediment control plans that need consideration. Refer to Section 3.3.3 for a description of commonly required permits. Identify if any local permits, special permits or coordination are needed, e.g. in heavily urbanized or highly sensitive areas.

Are there any known permits that will be required as part of the evaluation of alternatives? If special surveys are required (e.g., geotechnical, ground surveys), will special use permits be required before this work can begin? Special permits for the purpose of study investigations could include:

- USACE 404 permits, if there will be a discharge of fill into waters of the US;
- NPDES permits, if the geotechnical investigation will require pioneer roads or result in more than 1-acre of disturbance to the land;
- Access and/or ROW permits from private property owners or Tribes;
- Cultural clearances for any ground disturbing activities;
- Drilling or well permits from state or county; and
- Environmental permit or authorization pursuant to the Endangered Species Act or Migratory Bird Treat Act.

4.5.2.12.7 Geotechnical

Geotechnical specialists should perform a reconnaissance early in the conceptual studies phase. This will assist in determining the cause for instability or pavement problems on the existing highway and provide information on potential problems for constructing the alternatives under consideration. This will also assist in identifying potential sources of higher-quality materials within the area, and opportunities for optimizing the subgrade, base and pavement design. Normally, a visual inspection of the study area is performed. Hand samples may be collected and tested to categorize the materials and support the visual inspection. More extensive investigations may be required if existing information is inadequate and/or incomplete.

Typically, a geotechnical reconnaissance report addresses the following:

- Geology of the study area,
- Existing and/or potential unstable soil conditions,
- Major geological features that will constrain the design and not described above in Section 4.5.2.8, and
- Location of possible sources or sites for base, surfacing and topsoil materials.

Identify the geology of the general area. Use a geologic map if one is available. Interpret and show the relationship of the geology to the proposed route. Include the location and the extent of the following features:

- Landslide areas,
- Solid rock,
- Unconsolidated material,
- Ground water and surface water conditions,
- Availability of road construction materials within the project (e.g., type of deposits, quantity and quality), and
- Recommendations for type of materials and locations to be used (e.g., borrow, waste sites, contractor staging areas).

More in-depth investigations are conducted later in the preliminary design process as described in Section 6.3.

4.5.2.12.8 Pavements

Describe existing pavement and surfacing conditions and the type of surfacing options that should be considered during preliminary design. Describe the type and areas of existing pavement distress and document with photographs. Describe the apparent cause of any major distress areas (e.g., subgrade failures, poor drainage, severe oxidation). Describe any major factors that will influence the pavement design (e.g., heavy truck traffic, buses) and any special areas of concern (e.g., heavy truck or bus parking or stops, pedestrian or equestrian traffic). Describe the anticipated type of pavement and base construction that should be investigated (e.g., pulverization, recycling, subgrade stabilization, overlay).

4.5.2.12.9 Hydrology and Hydraulics

Describe the location of all major drainage crossings and document with photographs. Describe the overall condition, sizing, materials and performance that are evident in the existing drainage facilities. Describe any significant scour, erosion, sedimentation, debris, abrasion and other problems, and if bridge waterway issues have been documented in reports. Describe any channel modifications that are anticipated and any floodplain issues that will need to be investigated. Describe the overall level of hydrology and hydraulics improvements that are needed and proposed. Describe any overriding local or State requirements for hydrology methodology or hydraulic design. Describe if any drainage crossings will have fish passage requirements.

If the size of a new or improved drainage structure could have an impact on the outcome of the alternatives analysis, the hydrology investigation should begin during the preliminary engineering phase, as described in Chapter 7. Generally, the detailed evaluation of the drainage basin and the specific waterways for structures less than 4 ft [1.2 m] diameter will be completed during the final design phase.

4.5.2.12.10 Structures

Describe the existing structures (e.g., bridges, large box culverts, retaining walls, tunnels) including the type, span lengths, dimensions, apparent condition, railing and any utilities. Describe the waterway opening or roadway clearances, any visible scour, sediment deposition or any apparent instability around the structure. Describe the available data (e.g., as-built plans, inspection reports, structure ratings, foundation and hydraulic information). Document the existing structures, any apparent deficiencies and upstream and downstream stream channels with photographs. For proposed new structures or improvements to the existing facilities, describe the preliminary options that should be considered for structure type, layout and alignment. Describe the proposed structure's basic requirements including flow capacity, number of lanes, shoulders, sidewalk, utility, vehicle loadings, animal crossing requirements, and aesthetic considerations.

The detailed evaluation of structures and the selection of the desired type, size and location of a bridge or structure are typically completed after the roadway alternatives are complete. The detailed scope of these investigations is described in Section 10.3.

During the project scoping study, investigate and provide all available structure site data. Document typical roadway section, approach rail, potential environmental issues and apparent right-of-way limits at each structure crossing. When available, obtain roadway plan and profile sheets, mapping and right-of-way limits that could have impacts on both the construction and maintenance of the bridge. For especially large structures, also include a discussion on how materials can be delivered and erected on the site as these requirements may be constrained environmentally.

In many cases, structures provide the only source of wildlife connectivity from one side of the highway to the other. Work with the wildlife agencies to be certain clearance, openness and capacity issues for wildlife are clearly understood and agreed upon by the project team.

4.5.2.12.11 Constructability, Construction Sequencing and Construction Materials

Describe all known sources of construction materials available in the area. Identify pit sites by location and pit name or number, if known, and the location of local construction materials' suppliers. Describe any known restrictions for construction operations, equipment operation, hauling, staging, water or storage that are not described above in Section 4.5.2.8. Describe any construction staging or traffic control or traffic management requirements that may influence the type or scope of work that is proposed, sequencing of the construction work or affect construction costs. Describe any unusual housing or transportation issues for construction workers or suppliers. Describe any difficult construction problems or issues encountered on previous projects in the area.

4.5.2.13 Cost Estimate

Prepare a cost estimate, and document the extent of unknowns potentially affecting the cost, and cost risks, at the time of creating this estimate. Refer to Section 4.8.15.

4.5.2.14 Exhibits

Use exhibits to include route maps or aerial mosaics depicting the location of the existing contextual features, proposed improvements, typical roadway sections, vicinity maps, route profiles, physical characteristics outlined in project scoping forms and detailed cost estimates of the alternatives.

4.5.2.15 Site Photographs

Ground photographs and/or oblique aerial photographs should be taken of controlling elements in the field. These can be used in analysis, report illustration and for exhibits in the public involvement process.

4.5.3 CORRIDOR STUDY

When formulating improvement alternatives, it occasionally becomes apparent that a highway should be considered on new alignment in a corridor outside of the existing road. In fact, there may not even be a road connecting the termini, although this situation is not common. For most projects, the improvements are confined to the existing corridor and frequently are confined to the existing disturbed area within the corridor, such that a corridor study outside of the existing road is not applicable.

When applicable, new highway corridors are usually identified and evaluated separately from an alternative's preliminary design standards although they must be compatible with all the components that make up the alternatives. A highway corridor can be defined as a linear strip of ground that connects termini and has sufficient width and variable positioning on the terrain to allow a road with its preliminary design standards to be built within its borders.

Depending on length and terrain, most corridors are between 100 ft to 400 ft [30 m to 120 m] wide. Its position on the topography is tied to existing land forms and sometimes defined in relation to a control survey (see Section 5.4.1).

Highway corridors are normally established with three general objectives in mind:

1. **Size**. The corridor must be broad enough to allow the highway centerline to be positioned or shifted in conformance to the geometric standards and to achieve reasonable cost effectiveness.

2. **Features**. The geographical and geophysical features should be stable and compatible with the construction, operational and maintenance requirements of the highway.

3. **Environmental Impacts**. The environmental impacts should be minimized and aesthetics maximized.

Historically, the process of investigating new highways and corridors was called a location survey or reconnaissance study. Currently, much of the process is covered by the environmental analysis and documentation. However, the basic procedures in establishing feasible highway corridors are still valid.

A thorough initial investigation is essential in making effective corridor determinations. If the most feasible, serviceable and economical corridor is not determined at this stage; no amount of engineering effort can overcome the inherent deficiencies that will exist. When presenting corridor evaluations, it is imperative that the same basic data and methods of investigation be used for each corridor studied.

Most corridor reconnaissance work is done using photogrammetric or other topographic maps supplemented with field data. On occasion, ground reconnaissance surveys are made as a substitute for or supplement to the topographic mapping.

Before beginning the study, review all available maps and photographs to determine if any additional data and mapping are needed for conducting the study.

The following information is pertinent to corridor studies:

- Land use, population and density;
- Geophysical and geological formations;
- Potential of the area for future industrial, residential, farm or recreational development (i.e., land use changes);
- Frequency, condition and type of existing roads and highways serving the area;
- Existing utilities and facilities, planned and potential (e.g., transportation (other than highways), dams, power lines, gas and water lines, communication lines, sanitary or storm sewer facilities, recreational areas); and
- Photographs of controlling features.

4.5.3.1 Major Considerations and Physical Controls

Identify the termini that are the major controls of the route. From a strict user's standpoint, the most economical route is a straight line between the termini, both horizontal and vertical. However, the practical economic location and the environmentally acceptable locations are based on a compromise between construction cost, user's cost and environmental impacts. Consider physical controls (e.g., bridge sites, rock areas, valley and mountain sides, built-up areas, lakes and drainages) that affect the construction costs.

4.5.3.2 Corridor Selection for Evaluation

Specific procedures should be followed in the selection of route corridors for comparative evaluation. Common points of termini for all routes to be studied should be identified in addition to any constraints that may limit alignment, grade and route location.

Typical constraints include the following:

- Limitations imposed by design standards (e.g., maximum allowable grades and curvature);
- Physiographic controls (e.g., landform and watercourse gradients, shorelines, property or jurisdictional boundaries, preemption of lands for other use) and the avoidance of known problem areas (e.g., unstable, highly erosive land forms);
- Economic controls, including encroachment on high cost lands or improvements, and alternatives involving features of excessively high construction cost;
- Mandated points of contact (e.g., intersection with a limited access facility where the access point is predetermined, access to a major point of interest that has a fixed location); and
- Environmental controls, some of which are mandated by law, govern the avoidance of wetlands, prime and unique farm lands, habitat for endangered species, historical and archaeological sites and park lands.

4.5.3.3 Aesthetic Elements

Weigh the aesthetic qualities of the corridors under investigation as carefully as those that contribute to traffic safety, highway efficiency and structural adequacy. Gentle curves, easy grades and lanes with adequate clearance between passing vehicles contribute both to pleasant and safe driving. Both horizontal and vertical alignments should be coordinated to create a total roadway alignment that complements rather than disrupts the natural landform.

Pleasing appearance can usually be achieved at little extra cost if the road is located with these aesthetic elements in mind from the start. Further, roadside development (e.g., scenic vista, streamside parking areas), flattening and rounding slopes, contribute significantly to roadway beauty and safety as well as reduce maintenance cost. Landscape specialists should be consulted to assist integration of the roadside, structures, community and scenic considerations into the geometric design (horizontal, vertical and cross sectional elements). Consider aesthetic treatments and enhancements, such as plantings, trees, shrubs, and colored concrete.

When the merits of competing alternatives are nearly equal, scenic quality may be a deciding factor.

4.5.3.4 Map and Photograph Study

Study the various alternative corridors between the termini using a large-scale (e.g., 1:5000) map that shows the major topographic features (e.g., rivers, mountains, roads, cities, towns). Select the more representative and feasible alternatives to be evaluated in detail.

Study and analyze the collected material before gathering field information. If good photographic and map coverage is available, much of the corridor analysis can be done by stereo aerial photo analysis and map study. Impractical locations can logically be eliminated to concentrate on the more promising alternatives during the field investigation. Further refinement or screening of corridor location alternatives may occur during the field investigation.

4.5.3.4.1 Map Study

Study the topography between assigned termini to identify avenues through the terrain that may be a feasible road location and also difficult terrain that may be avoided. Ridges or watersheds are often feasible avenues, especially where there are long regular ridges leading in the desired direction. Valleys are also practical avenues if they lead in the desired direction. The most difficult corridor locations are those that cut across the natural avenues or those that lie in confusing terrain where the ridges and streams have no continuous well-defined direction.

Each possible avenue should be examined, and some may be quickly discarded as impracticable. Each practical route should be represented on the map using different colors or line symbols. Where the gradient might be controlling, the contour gradient intervals should be stepped out on the map with a divider or equivalent CADD technique to ensure that the route grade is within acceptable limits. Points where curvature may be critical should also be verified.

4.5.3.4.2 Stereo Aerial Photo Analysis

If available, examine stereo aerial photos. It is possible to check gradients on the photography using a stereoscope and an engineer’s scale. Possible lines may be represented on the photos and compared with map locations. Stereo photo examination will yield information that may not be shown on a map, so if both the map and photos are available, both should be used.

A thorough map or stereo aerial photo study should investigate all possible routes within a band that is 40 to 60 percent as wide as the distance between termini. If adequate photo and map coverage are not available, consider viewing the terrain from a plane or helicopter before traversing it in the field. Under some conditions it is desirable to have uncontrolled aerial stereo and oblique photos of the route taken for use in the corridor reconnaissance.

The effort required for the corridor reconnaissance field investigation will depend on the effectiveness of the preliminary office studies, the accessibility of the route, weather, etc., and might vary from a day to weeks. The field investigation can be made by any means available (e.g., vehicle, horseback, by-foot). During this investigation, observe and note the forest cover, drainage, potential bridge sites or major drainage crossings, the nature and classification of the soil, rock outcrops, land use and anything else that might affect the alignment location.

Oblique and terrestrial photography can be helpful in studying and depicting proposed improvement corridors, and can be enhanced by visualization techniques to illustrate future highway improvements. These visualization techniques may be roughly prepared by photo-composition, or may require a preliminary design (i.e., alignment, cross section), to accurately depict the proposed improvements.

4.5.3.5 Corridor Study Report Format

When applicable, in addition to the Project Scoping Report, a comprehensive corridor analysis of potential new alignment and corridor locations may be documented in a Corridor Study Report. More typically, however, this information is kept informal. In either case, corridor analyses are summarized in the environmental document (i.e., Environmental Assessment, Environmental Impact Statement). The corridor study report not only contains the results of the corridor analysis but also summarizes the preliminary design standards under consideration. In addition to the engineering information, the social, environmental and economic features of the alternatives (separate corridors) used in the analysis are presented at least in a general fashion.

The corridor study report, if prepared, should contain the following items:

1. **Introduction**. Describe the authority and purpose of the study.
2. **Resources Used**. Identify all sources of information, maps and data obtained for the study.
3. **Climate, Physiography and Geology**. Provide a description of the climate, significant geographic features, land uses and geology of the area.
4. **Preliminary Design Standards**. This section should include all traffic data and design criteria for the study. Describe range of proposed preliminary roadway design standards, especially alignment and grades, roadway sections, type and cost of structures and other preliminary design elements being considered. Many of these are illustrated in a roadway cross section.
5. **Corridor Descriptions**. Provide a detailed description of each corridor studied.
6. **Comparative Evaluation**. This section should contain a comparative evaluation of routes studied. Include a dissertation of the related social, economic and environmental (SEE) impacts (e.g., changes in land uses, displacement of residences, disruption of communities, environmental mitigation measures, construction costs, road user costs, secondary economic factors).
7. **Benefit Cost Analysis**. An optional section that may be used to provide a benefit cost analysis for each corridor and the basis for them.
8. **Exhibits**. Use exhibits to include route maps or aerial mosaics depicting the location of the corridors, typical roadway sections, vicinity maps, route profiles, physical characteristics outlined on reconnaissance study form and detailed cost estimates of the alternatives.
9. **Aesthetics**. Use exhibits to depict the consideration for aesthetics in the analysis of each corridor.

10. **Risks and Unknowns**. For cost estimates, time schedules, and extent of project scope, describe the potential risks and unknowns in order to qualify the basis for these estimates.

4.6 DEVELOPING THE EVALUATION FRAMEWORK

Prior to developing the preliminary design or alternatives, establish an evaluation framework. The evaluation framework outlines the preliminary design concepts, and guides the technical analysis that will be used to evaluate a recommended course of action or any alternative that may be developed in Section 4.7. Use the evaluation framework for considering various design parameters and decisions that are to be made. Relate the framework to levels of accessibility, mobility, safety, operational performance, environmental and social compatibility, sustainability, cost effectiveness, and other goals to be achieved from proposed alternative solutions.

After an evaluation framework is established, develop preliminary designs for an array of design solutions concurrently with their technical analysis. The technical analyses involve evaluating the diverse field data and assessments of the highway's transportation problems as described in Section 4.5. The analyses are preliminary or general in nature, but should be sufficient to support an overall implementation decision. A higher degree of technical detail is necessary in the final design phase. Exhibit 4.6–A shows an example evaluation framework containing various design parameters and design alternatives.

Exhibit 4.6–A EVALUATION FRAMEWORK

	Scope Alternatives								**Design Alternatives**		
	No build	Pavement Preservation	RRR	Spot Repairs	Light Reconstruction	Full Reconstruction	Corridor Alternatives	Others	Typical Sections	Design Speed	Others
Safety Performance Roadway Geometrics Roadside											
Operational Performance Speed Design Consistency Capacity Intersections Access Management											
Conditions Pavement Drainage Appurtenances Environmental											

Use the best available techniques to understand the relationships between the design choices or alternatives proposed, and the expected transportation performance, infrastructure and environmental conditions, and other outcomes. Use the established evaluation framework throughout the development of the conceptual and preliminary design to:

- Enable consideration of varying benefits, costs, and safety and operational effects,
- Accommodate consideration of diverse perspectives and values,
- Allow a collaborative, transparent project development and design process, and
- Contribute to a fully informed and well-considered decision.

Combine the preliminary engineering investigations (e.g., traffic engineering, survey/mapping, geotechnical, hydraulics, structural engineering, and roadway design) into a coordinated and comprehensive preliminary design package. The types and sequence of steps in the conceptual and preliminary design process are described in the following subsections. The technical analyses are not always presented in depth, but references are given to the other chapters where the preliminary and detail design requirements are discussed.

4.6.1 CONTEXT SENSITIVE SOLUTIONS APPROACH

FLH philosophy and standard practice is to use a context sensitive solutions (CSS) approach in all aspects of its mission including project planning, development, evaluation and design. CSS is a collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits and complements its physical setting and preserves scenic, aesthetic, historic and environmental resources, while maintaining safety and mobility. CSS approach addresses the total context within which a transportation facility will exist. Approach the project development from the basis that every project's context is unique. Each project incorporates unique, rather than generic, solutions in order to provide the needed improvements to its condition, and operational and safety performance while integrating the facility into its surrounding natural and built environment. CSS differs from the concept of context sensitive design (CSD) in that the approach extends far beyond the highway design to address how a facility is planned, implemented, and maintained. Although the CSS approach may be associated with flexibility in highway design, it involves the full range of activities from the early planning through design, construction and maintenance, and includes broad solutions involving every discipline. CSS applies to any and all projects and types of roads (i.e., every project has a unique context as defined by the terrain, the community, users and the surrounding land use). The approach includes both the outcome (qualities of the project) and the process by which it is achieved.

Incorporate the following principles, which are essential aspects to a successful project:

- Be respectful of the land, partner agency goals, tribal values, cultural significance of landforms and sites, wildlife and habitat;
- Provide safe passage for residents, travelers, visitors, tourists, recreationists, and wildlife by working cooperatively to integrate safety as a basic business principle in all activities;
- Minimize impacts to existing features and conditions in a manner that lays "lightly on the land" and minimizes construction impacts on the travelling public;

- Use interdisciplinary project development teams to develop cost-effective creative solutions that fit into the natural and human environments while functioning efficiently and operating safely;
- As appropriate, actively communicate and employ early, continuous and meaningful participation of the public and all stakeholders throughout the transportation planning, and project delivery processes in an open, honest, and respectful manner;
- Satisfy the project vision, purpose and need as developed and agreed upon early in the process by a full range of stakeholders;
- Demonstrate clearly defined, effective decision-making and implementation that meets commitments; and
- Deliver a quality transportation solution with efficient and effective use of everyone's resources including cost, time, effort and material.

During each phase of the project delivery include the active engagement and collaboration of stakeholders and technical specialists, open discussion, creativity, respect for a diversity of perspectives and effective weighing of choices to implement an appropriate context sensitive solution.

The project team should strive to exceed expectations of themselves and stakeholders thereby achieving a level of excellence in their result.

Refer to NCHRP Report 480, A G*uide to Best Practices for Achieving Context Sensitive Solutions* for guidance on CSS, and FHWA and Context Sensitive Solutions (CSS).

4.6.2 INTERAGENCY SCOPING AND STAKEHOLDER/PUBLIC INVOLVEMENT

Stakeholders include any person or group that is affected by the project. Stakeholder participation and public involvement is integral to the CSS approach and a key part of the formal environmental process requirement. It provides necessary input and benefit during conceptual studies and preliminary design. As outlined in Section 3.4.2.2, it is important to publicly announce the beginning of the conceptual studies and preliminary design phase, especially for the larger scale projects. This can help in identifying stakeholders and the local perspective on the major highway problems and operational difficulties along the route. Stakeholders should participate in development of the evaluation framework as well as in development of design concepts and alternatives. Once alternatives are developed, continue to obtain stakeholder and public input through the environmental review process for the proposed improvement alternatives and their respective scopes of work.

More importantly, the interagency scoping and stakeholder/public involvement provides essential information about the natural, cultural and historic context of the environment encompassing the project, and the values of the community, and about the transportation facility users, for inclusion in the development of preliminary design solutions. The interagency scoping and stakeholder/public involvement provides a mechanism for those affected by the project, as well as those representing the users of the facility, to add value and local expertise and to influence from the earliest possible opportunity the outcome of the transportation decisions and solutions that will affect them.

Additional information on project scoping and effective stakeholder/public involvement is provided in Chapter 2 of *A Guide for Achieving Flexibility in Highway Design*, AASHTO, May 2004.

4.6.3 DEVELOPING A PROPOSED COURSE OF ACTION

Depending on the degree of investigation and analysis in the planning and programming phase, a project's proposed course of action, as it enters the preliminary design phase, could vary greatly from a simple description of study area limits with intent to improve whatever is most needed, to a specific course of action (e.g., resurface the pavement, replacement of a particular bridge). To fully develop a complete, specific course of action, the overall highway deficiencies, transportation needs and context of the project vicinity must be well identified, quantified and evaluated in the conceptual studies phase. The initial recommended course of action developed during the preliminary engineering investigation as described in Section 4.5 should provide effective planning and launch for the more intensive activities performed during development and analysis of the preliminary design.

As the project develops during the preliminary design phase, the technical interdisciplinary investigations and analyses should provide the necessary data and technical recommendations to support development of the roadway alignments, grades, template cross sections, roadside design, structures type, size and location, anticipated construction activities, safety, traffic operations, technical performance (e.g., hydraulic, pavement, geotechnical), anticipated service life, sustainability, costs, user benefits and other aspects of the project; and that fully represent the effects, consequences and impacts of the proposed action.

For small projects, RRR improvements, and projects with limited or well-defined effects and impacts, the preliminary design and proposed course of action are readily developed with limited investigations and fewer technical disciplines that require involvement. For these type projects many of the following activities are not applicable, or should be reduced appropriately.

4.6.3.1 Definition of Project Objectives

To establish a proposed course of action, recognize the existing facility, its deficiencies and future needs, the user needs, the context of the facility and then describe the type of improvement that meets objectives. The objectives are typically to provide a facility for the highway user that fulfills the following:

- Fulfills the purpose and need for proposed action,
- Fulfills the operational and safety needs of the users,
- Meets the convenience, operational and safety standards for that system of highways,
- Is cost-effective to build,

- Is compatible with the context of the facility,
- Avoids or minimizes environmental impacts, and
- Minimizes maintenance costs.

A typical course of action addresses the road's width, alignment, surfacing, major structures, roadside features and the general types of construction items needed to implement these improvements.

The intent is to describe the type of proposed improvements, but allow flexibility so various alternatives can be considered that will accomplish the proposed course of action.

4.6.3.2 Safety and Operational Needs

Evaluate and develop the type of solutions that will address the safety and operational needs of all users, as well as non-users affected by the facility. As applicable, identify transportation performance measures that can be used to quantitatively evaluate the existing conditions, and proposed alternative solutions under the anticipated future travel demands. Traffic operation and mobility performance measures may include:

- Capacity and volume-to-capacity,
- Operating speed and consistency,
- Travel time and rate,
- Level of service,
- Stops and delay,
- Percent of time following,
- Queue characteristics for turning movements,
- Congestion and reliability,
- Density, and
- User cost of travel.

Existing and predicted highway safety performance measures may include:

- Crash frequency and rate,
- Crash severity and cost, and
- Safety index.

Also consider indirect mobility and safety performance indicators such as the availability and quality of sight distances (i.e. stopping, passing, intersection, decision), driveway frequency, access spacing, and number of potential traffic conflicts at intersections.

Refer to Section 8.3 for more detail on what safety and operational considerations are required.

As applicable for evaluation of safety and operational performance, consider using estimating tools such as:

- Interactive Highway Safety Design Model (IHSDM),
- Sketch-planning tools,
- Highway Capacity Manual,
- Macroscopic simulation models, and

- Microscopic simulation models.

Refer to the FHWA traffic analysis tools for additional information.

In addition, the preliminary design should address seasonal driving conditions including problems of removing snow and ice in winter as addressed in Section 8.5.6. Slow moving traffic (such as farm machinery in rural areas) may also present unique traffic conflict problems on the highway.

4.6.3.3 Traffic and Land Use Projections

Evaluate data on current traffic and projected growth. If necessary, conduct special traffic studies as a part of the evaluation.

Evaluate current and future traffic projections on the following subjects, as applicable:

- Traffic data on existing facilities:
  - ◊ Average daily traffic (ADT),
  - ◊ Seasonal average daily traffic (SADT),
  - ◊ Peak hourly volumes, and
  - ◊ Design hourly volumes (DHV);
- Traffic trends and growth rates, past and projected;
- Classification of vehicles (e.g., percent passenger vehicles, percent trucks and buses and percent recreation vehicles);
- Directional split;
- Turning movements at major intersections;
- Speed and delay data; and
- Conflict study data.

Refer to Section 8.6 for more details on how to develop this traffic information. Speed and delay data and conflict study data may be applicable depending on specific project requirements. Highways in urban areas will typically require more detail and traffic data than for rural projects, in order to analyze traffic operations, capacity, level of service, and other traffic operation performance measures.

4.6.3.4 Context and Environmental Objectives

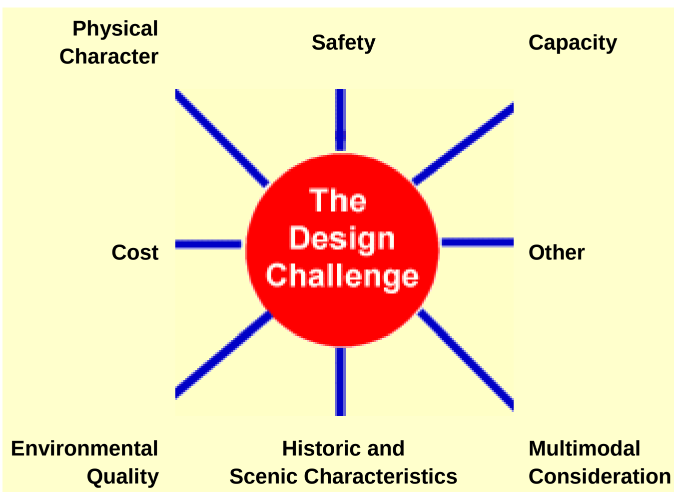
During the conceptual and preliminary design phase, designers cannot work at solving the transportation problems of a project in a vacuum. It is important that during the development of concepts that input from all of the various disciplines, agencies, stakeholders and the public, working together, can have the greatest positive impact on the design features of the project. In fact, the flexibility available for highway design during the detailed final design phase is limited a great deal by the decisions made at the earlier stages of planning, programming, conceptual studies and preliminary design. Therefore, it is important to plan ahead during the conceptual studies phase and to fully consider the potential effect that a proposed facility or improvement may have while the project is still in the preliminary design phase. During concept development, key decisions are made that will affect and limit the design options in subsequent phases. Some questions to ask at this stage include:

- How will the proposed transportation improvement fit within the general physical and social character of the area surrounding the project?
- Does the design need to have unique historic or scenic characteristics?
- How does the design reflect the safety, capacity and livability concerns of the community?

Answers for these types of questions should be found during the concept development phase, as well as in public involvement during concept planning. It is important that all of the issues, concerns and opportunities identified for maintaining the character and scenic integrity of the highway are clearly defined at the onset of the concept stage, so they can be either accommodated or mitigated. Factors to consider during the planning stage of project development are presented in Exhibit 4.6–B.

Additional insights and information for developing concepts that fit within the context of the projects surroundings can be found in FHWA-PD-97-062, *Flexibility in Highway Design*.

Exhibit 4.6–B FACTORS TO CONSIDER IN PLANNING



4.6.3.5 Reconstruction Versus Resurfacing, Restoration and Rehabilitation Improvements

As part of the project development framework and determining the scope of work, it must be clearly stated why the study effort should pursue a resurfacing, restoration and rehabilitation (RRR) approach versus a reconstruction approach to completing the improvements. This determination should provide the justification for either reconstructing the current roadway, or providing the proposed level of effort to improve the current roadway. This justification should focus on the operational benefits and user benefits for proceeding with either approach. If a RRR approach is selected, both the benefits and consequences of deferring full reconstruction improvements must also be described. These include safety risks and the operational and life cycle construction and maintenance costs.

4.6.4 PROJECT AGREEMENT

The purpose of the project agreement is to establish and reach agreement with the primary stakeholders the overall scope, schedule, budget, roles, responsibilities and quality expectations for delivery of the proposed project. The project agreement should address the principle contacts and roles and responsibilities for coordination of project delivery activities. The project agreement should address the following items:

- Description and overall scope of the project;
- Purpose for the project;
- General approach to project delivery;
- Quality expectations;
- Schedule of milestone activities and responsibilities;
- Functional activities and responsible party (e.g., environmental compliance, design and technical services, construction, maintenance, right-of-way acquisition, utility relocation);
- Funding sources, amounts, and proposed budgets of functional activities; and
- Roles and responsibilities, and signatures of primary stakeholders.

Refer to Division Supplements for guidance on the format for specific project agreements as applicable for each FLH Division.

The project agreement should be in place before significant preliminary engineering work is begun or significant costs are incurred. The project agreement is typically prepared with input and involvement of the interdisciplinary team and program agency stakeholders.

The project agreement should be updated at the conclusion of NEPA decision-making, and at other major project milestones. It is considered a living document that should be updated as major changes may occur in scope, schedule or budget, key project personnel change, key roles or responsibilities change, if major design services are outsourced, etc.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

4.7 ALTERNATIVES DEVELOPMENT AND EVALUATION

Several reasonable build alternatives may need to be investigated and considered. Alternatives should be developed using the design guidance provided in the preceding sections. While the categories of alternatives indicate the proposed action, more specific terms must be used to describe an alternative beyond the general physical characteristics to evaluate its operational, safety and structural performance. If one or more build alternatives are developed, include the following information:

- Type of improvement (e.g., traffic operations, rehabilitation, reconstruction, realignment);
- General design criteria (e.g., roadway width, design speed, surface type);
- Design elements (typical roadway cross sections, preliminary alignment and grade, grading/clearing limits, auxiliary lanes/tapers, intersection types, right-of-way widths);
- Multi-modal accommodation and operational characteristics for all users (e.g. accessibility, shared use, pedestrian or bicycle facilities, transit, traffic controls);
- Physical impacts (e.g., limits of impact, boundaries of resources, compatibility with adjacent environment, land uses and activities)
- Technical features (e.g. safety appurtenances, bridges, walls, large culverts); and
- Cost estimate.

The intent of conceptual studies and preliminary design is not to develop the final design of the project, but to provide direction and scale of the improvement. Alternatives should be developed to comparable levels for evaluation. Given this direction, a practical, cost-effective design of each of the proposed alternatives should be developed for relative comparison. The alternatives evaluation should accomplish the following:

- Identify, evaluate and compare benefits and impacts of each alternative;
- Establish design flexibility;
- Define commitments to protect and preserve the environment for each alternative; and
- Provide project implementation guidance.

The preliminary design studies should define the project by line and grade, right-of-way limits, construction quantities and roadway geometry in general terms based on projected traffic volumes, terrain and other special features. For the final design phase of the project, these features are addressed in more detail (see Chapter 9).

Once the proposed purpose and need and project objectives are established, all reasonable alternatives that can accomplish the objectives should be identified. These should be practical engineering solutions to the identified problems (e.g., current deficiencies, future needs) within the overall limits and intent of the planning and programming goals.

Initially, alternatives might cover quite a range or scale of improvements, but they should be condensed to three or four succinct alternatives for which further engineering analyses can be applied. Otherwise, the details, data and description become very cumbersome to handle.

4.7.1 TYPES OF ALTERNATIVES

The basic categories of alternatives to be considered on most road upgrading are described in the following sections.

4.7.1.1 No Action

The no-action alternative would only continue the routine maintenance of the facility and does not include any upgrading that would change the road's operation or extend its service life. Assume that the facility will be maintained in its current form, under conditions that will exist in the design year.

4.7.1.2 Transportation System Management (TSM)

Transportation system management (TSM) alternatives should always be considered when upgrading a road. TSM consists of travel controls, operational improvements, and/or limited construction to maximize the operation and efficiency of the existing facility without major reconstruction or new construction. Examples of these type controls include the following:

- Accommodating the existing traffic on other routes or with different types of vehicles,
- Posting vehicle restrictions and load limits, and
- Providing or enhancing an alternate mode of transportation.

4.7.1.3 Pavement Preservation

Pavement preservation is a systematic, long-term strategy to enhance pavement performance using an integrated, cost-effective set of practices to extend pavement life, improve safety and meet motorist expectations. Pavement preservation alternatives generally consist of preventive maintenance and minor rehabilitation.

Preventive maintenance treatments extend the service life of the surface of structurally sound pavements, and are typically applied to pavements in good condition having significant remaining service life. Examples of preventive treatments include asphalt crack sealing, chip sealing, slurry or micro-surfacing, thin and ultra-thin hot-mix asphalt overlay, concrete joint sealing, grinding, dowel-bar retrofit, and isolated, partial and/or full-depth concrete repairs to restore functionality of the slab. Minor rehabilitation consists of non-structural enhancements made to the existing pavement sections to eliminate age-related, top-down surface cracking that develop in flexible pavements due to environmental exposure.

Refer to the FHWA General Pavement Preservation Information for more information.

4.7.1.4 Resurfacing, Restoration and Rehabilitation (RRR)

Resurfacing, restoration and rehabilitation (RRR) projects are alternatives with limited construction efforts that are very cost-effective. The objective is preservation and extension of the service life of the existing highway and enhancement of safety without substantial costs, construction impacts or major right-of-way acquisitions. Generally, RRR projects do not reconstruct the highway for the purpose of achieving full geometric standards. However, a safety-conscious approach must be used to develop RRR projects. Refer to FHWA T 5040.28, *Developing Geometric Design Criteria and Processes for Non-Freeway RRR Projects*, and dated October 17, 1988 for guidance in the development of RRR projects.

Transportation Research Board, Special Report 214, *Designing Safer Roads, Practices for Resurfacing, Restoration, and Rehabilitation* (1987), documents the result of research on cost effectiveness of highway geometric design standards for RRR projects, and provides guidance on the overall approach for design of RRR improvements. Refer to Section 4.4.2 for FLH approach to developing RRR alternatives and Section 9.4 for additional design guidance.

4.7.1.5 Reconstruction (4R)

This is an improvement alternative that rebuilds a highway essentially along the same location where retention of the existing pavement structure is not a primary objective. Reconstruction (the 4^{th} R) may involve making substantial modifications to the existing highway's horizontal and vertical alignment, including alignment shifts, in order to improve safety and traffic operations or long-term structural conditions and maintainability.

Reconstruction work normally involves a substantial construction effort to rebuild the existing highway to at or near full geometric and safety standards to provide long-term, multi-modal transportation performance. The complete spectrum of design deficiencies and functional obsolescence of the roadway and structures, as well as the future transportation needs, should be addressed by this level of upgrading. Typical work includes widening, realignment, access improvement, and replacement of bridges. While reconstruction approximately follows an existing road corridor, it may deviate significantly in width and alignment from the present road to achieve full geometric standards.

4.7.1.6 New Construction

This is an improvement alternative to build a road and/or bridge on completely new alignment or substantially upgrade a highway facility along an existing alignment providing new access to or through an area. This might take the form of a bypass constructed to carry through traffic around a town or it might be a new access route linking an existing highway with a new recreational facility.

Typically, the highway is built on new alignment in a virgin corridor. It normally is constructed to full geometric standards to fulfill both the current as well as long-term transportation needs of the area.

4.7.2 DEVELOPMENT OF PRELIMINARY ENGINEERING CONCEPTS

Following the development of the Evaluation Framework and the proposed action, some elements of the preliminary engineering phase may have been modified since the completion of the project scoping report. At the onset of the preliminary engineering, clearly define the project, the design standards to be followed and the requirements for each functional classification. This is the final scope for developing the various alternatives to be considered to meet the project objectives.

Develop the design features for each viable alternative under consideration during the preliminary design phase to a similar level of detail.

4.7.2.1 Horizontal Alignment Objectives

Establish an alignment that best fits the horizontal control features, as well as the design controls described in Section 4.4.4. Conform to the guidelines for horizontal alignment described in Section 9.3.5. Determine the superelevation runoff lengths and check that tangent lengths are sufficient to accommodate superelevation transitions.

4.7.2.2 Vertical Alignment Objectives

Establish the vertical control features (e.g., driveways, bridges, adjacent private property development, etc.) and establish a profile grade to fit these control features while adhering to the standards for percent of grade and vertical curve length. Conform to the guidelines for vertical alignment described in Section 9.3.6.

4.7.2.3 Aesthetic Considerations and Relationship of Horizontal and Vertical Alignment

Ensure that aesthetics are incorporated in the highway design, and consider coordination of the horizontal and vertical alignment and interactions with other design features. Adhere to the guidelines of Section 9.3.2, Section 9.3.3, and Section 9.3.4.

4.7.3 DESCRIPTION OF THE ALTERNATIVES

Provide a detailed description of each alternative that was considered, whether it is carried forward for final consideration or not. The alignments and the impacts of each alternative should be fully described including specifics on why the improvement option was considered.

Exhibit 4.4–A is an example of how to show and describe an alternative and its preliminary design standards. This information should also be supplemented with a map depicting the location of the alternative as discussed in Section 4.7.5. When comparing numerous alternatives, it can also be effective to display them together in a conceptual setting.

A fatal flaw analysis should be performed on each alternative to determine if it has flaws which prevent meeting the established purpose and need; and if so, then to determine that the alternative cannot be modified to meet the transportation, environmental, socioeconomic, and feasibility goals of the project, and finally that the flaws make the alternative insurmountable to proceed further in the development process.

If during development of a concept or idea, an option does not appear to best meet the goals and objectives of the project, document the reasons why the alternative was not carried forward so that if, in the future, others may consider this option during final design they will have the benefit of this evaluation and effort. Documentation is of great benefit to those that may later work on the final design to know of all of the options and constraints that were considered, and not just the benefit of the recommended solution.

4.7.4 ALTERNATIVE BENEFITS AND CONSEQUENCES

The transportation related benefits and consequences of each alternative considered should be documented. The engineering and technical analysis is closely coordinated with the analysis of environmental and social impacts as described in Section 3.4.2. A suggested method of evaluation is to compare each alternative relative to its fulfillment of the project's transportation related goals and objectives of the project's purpose and need. As a means of comparison, each alternative may be evaluated for its transportation related benefits and consequences, as applicable:

- Safety performance,
- Capacity,
- Traffic operations,
- Level-of-service,
- Accommodation of pedestrian and bicycle use,
- Life-cycle cost,
- Construction time,
- Traffic management,
- Structures and drainage,
- Earthwork volumes,
- Geotechnical hazards,
- Environmental impacts,
- Right-of-way acquisition,
- Utility relocation,
- Maintenance requirements,
- Design exceptions, and
- Risk assessment for delivery and/or service life.

Alternatives may be presented in an evaluation matrix chart to show the results of the evaluation and comparison of the alternatives. The evaluation matrix visually presents the alternatives in a manner that facilitates comparison and helps ensure that the above listed benefits and consequences of each alternative are consistently considered for the purposes of screening the best option among all of the alternatives. A weighting may be assigned to each type of benefit or consequence to indicate its relative importance in the evaluation. The benefits and consequences for each alternative may then be scored and tabulated so one alternative can be directly compared to another. The criteria and weighting used to assess fulfillment of the objectives in assigning scores to the different benefits and consequences should be developed with collaboration, understanding and agreement of the agency stakeholders prior to beginning the alternatives comparison, and fully explained to stakeholders at the completion of the evaluation.

The alternatives analysis of engineering and technical feasibility described above is performed concurrently, and in combination and close coordination with the process for analysis of environmental impacts, economic viability, and public involvement described in Chapter 3.

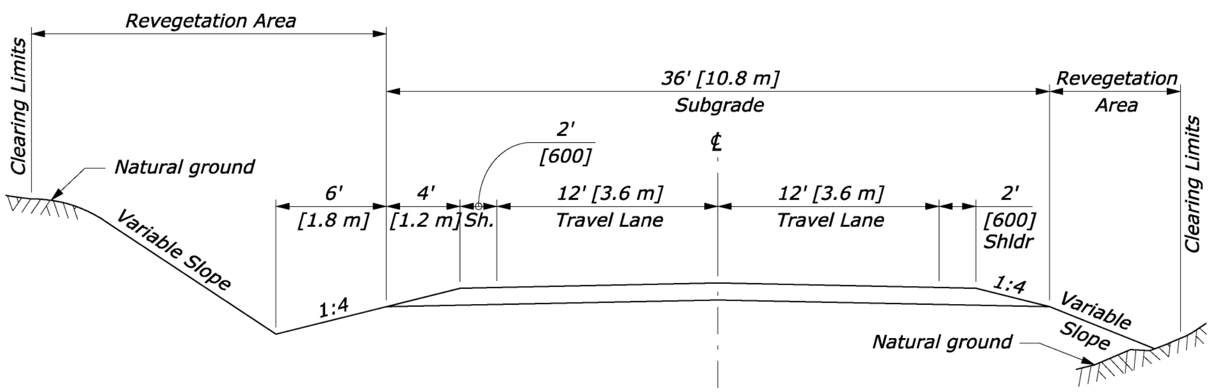
4.7.5 ALTERNATIVE EVALUATION AND RECOMMENDATIONS

After all of the conceptual and preliminary engineering and technical analysis is complete, one alternative will typically be identified as the preferred or recommended solution from a transportation standpoint. For the recommended alternative, document all of the reasons and logic used to recommend this improvement over the other alternatives considered. This should be a succinct, clear representation of the how the improvements included with this alternative meet the transportation related goals and objectives of the project's purpose and need. This information will be used as part of the environmental process and for incorporation within the decision document. The comprehensive evaluation of the alternatives developed for meeting the project purpose and need, including all the goals and objectives of the project, is addressed in the environmental process and decision document as described in Section 3.4.2.2.1.

Visual depictions and visualizations of project alternatives should be used to convey the full extent of the project.

Exhibit 4.7–A presents an example presentation of an alternative.

Exhibit 4.7–A EXAMPLE PRESENTATION OF AN ALTERNATIVE



ALTERNATIVE A

Note: This alternative for the reconstruction of 65 mi [105 km] of Flat Mountain Road by widening and adding bituminous surfacing to obtain a 8.4 m [28 ft] wide roadway consisting of two 12 ft [3.6 m] paved lanes and two 2 ft [0.6 m] paved shoulders. Roadside features such as 1V:4H foreslopes, variable ditch widths and backslopes with minimum selective clearing are included to provide a reduced, but adequate cross section with standard sight distances and roadside safety.

The horizontal and vertical alignment of the existing road will be adjusted by curve flattening, grade raises and short relocations to provide a minimum 40 mph [60 km/h] design speed. Necessary widening will be provided with the least effect on natural features and private property. Generally, widening will be made on the roadside away from the river or other sensitive features (e.g., wetlands).

The bridge over Deep Creek at MP 12.9 [km 20.1] is to be replaced in approximately the same location. The existing right-of-way can be used in constructing much of this alternative. Partial takings from parcels along the existing roadway totaling approximately 2.3 acre [0.93 ha] will be required for widening, improving the sight distance and reducing the severity of curves.

The proposed improvement of FH 72 begins at MP 12.9 [km 20.8], which is the northern terminus of previous improvements and generally follows the existing road to the vicinity of Dutch Road, about MP 12.7 [km 20.4]. At this point, an alignment shift is proposed 200 ft [60± m] to the east of the existing road. This approximately 2000 ft [600 m] long relocation would avoid a congested area formed by residences and commercial property bordering the east side of the existing road and a historic mine site bordering the west side. The proposed improvement connects with the existing road at about MP 12.9 [km 20.9] and generally follows it northerly to its terminus at an intersection with US 22 (MP 18.7 [km 30.2]).

4.8 DESIGN FEATURES OF THE PROPOSED IMPROVEMENTS

This section establishes preliminary design parameters of the proposed improvements that form the project definition in terms of highway engineering practice. Once the recommended improvement has been identified and the preliminary engineering developed, a clear and succinct summary of the known and unknown design parameters should be outlined as part of the preliminary design. This information will be used as the controlling design information as the project moves from a study perspective to a final design perspective.

This preliminary design information is also needed to quantify environmental impacts and assess compliance with numerous environmental laws and responsibilities (see Section 3.3). Specific design and engineering information is needed to support the environmental process and ultimately a NEPA decision document. A primary objective of this section is to identify the discipline-specific information that is needed to support that decision-making process.

Refer to Exhibit 4.1–A for a flow chart of the overall conceptual studies and preliminary design process.

4.8.1 GEOMETRIC DESIGN ELEMENTS

Incorporate consideration of the geometric design controls proposed for the recommended improvement. These may be identical to those controls listed in Section 4.4.4 of this chapter, but if any adjustments were necessary during the alternatives investigation, they should be clearly defined for the final design team to use during the completion of the final design.

4.8.1.1 Design Speed

Establish the design speed to be used for each type of facility to be designed (e.g., mainline, intersecting collectors, frontage/access roads, turnouts). If there are changes in the design speed due to changes in topography or capacity of the facility, describe where the changes occur and why these changes were necessary.

4.8.1.2 Superelevation

Determine the normal crown and maximum superelevation of the roadway and curves. Determine if maximum superelevation rates should vary, according to the elevation or climatic conditions on the project. Define the methodology for distribution of superelevation on the curve and on the tangent, and what the maximum and minimum rates are for various conditions. Determine if spirals should be used in the horizontal alignment.

4.8.1.3 Horizontal and Vertical Controls

Develop an alignment fulfilling the horizontal alignment objectives of Section 4.7.2.1. For the horizontal alignment, establish the minimum radius to be used for each design speed and roadway section, and the requirements for stopping and passing sight distance. Determine if there are horizontal clearance criteria constraints to be applied.

For the vertical alignment, develop an alignment fulfilling the objectives of Section 4.7.2.2. Determine the minimum and maximum gradient to be used for each design speed and roadway section. These may vary within a project as the terrain changes. If so, define where and why these changes occur. Determine the minimum vertical clearance and stopping sight distance requirements.

Document the design standards information using the process described in Section 9.1.3.4.

4.8.1.4 Typical Section

Develop a full representation of the cross section elements of the final design. For each roadway section, develop the number of lanes, lane widths, shoulder type and widths, type and location of auxiliary lanes and widths, median provisions, foreslope widths and slope, the conceptual design of the ditches, curb and gutter requirements, etc. If lane widening is required for turning movements, develop the lanes, shoulders and slopes adjacent to these facilities as well.

Determine the provisions for pedestrians including sidewalks, crosswalks and other facilities, and bicycle accommodation features.

Determine the widths of clear zones, and location and type of roadside barriers and terminal sections.

4.8.1.5 Slope Selection and Earthwork Design

Develop the cut and fill slope selection criteria, if other than provided in Exhibit 9.5-A. The general slope requirements of the roadway section are described in the typical section. If there are special slopes required due to variations in the materials or for rockfall mitigation, provide these criteria. Develop the preliminary design of cut and fill slopes.

Develop preliminary earthwork quantities, including the distribution of earthwork, for each alternative alignment and grade line being considered. It is desired that the preliminary design result in balanced earthwork quantities, but this is not always feasible because of other controlling factors. A primary consideration may be to match the existing roadway, adjacent roadside development, or natural features; which requires earthwork to be wasted or borrowed. Preliminary design of the alignment, grade, and slopes should include analysis of the earthwork distribution considering haul lengths, haul direction (upgrade or down), and the capabilities of typical earthmoving equipment. Distances and routes to potential borrow or waste sites should also be considered.

4.8.2 INTERSECTIONS

Determine the location and density of access points and intersections. Identify the standards and criteria to be used for the access points and intersections contained within the project. Determine and provide a description of the design vehicle that will use the intersection, and the minimum radius of the outside and inside radius returns. Also determine the turn lanes, acceleration and deceleration lanes that are proposed.

Determine the horizontal and vertical alignment of approaches, type of control, number and types of lanes, lane widths, median opening configuration, shoulders, islands, and auxiliary lane transitions and terminals. Also determine the intersection pavement cross slope, curve radii and tapers, sight distances, pedestrian facilities including sidewalks and crosswalks, and bicycle accommodation facilities.

For controlled access facilities determine the general configuration of interchanges, speeds, alignments and widths of ramps, and locations of auxiliary lanes.

If there are known constraints that preclude obtaining the desired intersection sight distance, provide guidance on how to mitigate this safety concern.

4.8.3 RAILROAD-HIGHWAY CROSSINGS

Define the scope of improvements to the crossing by conducting an on-ground joint inspection of the site with railroad engineering staff, the State or highway operating agency and other interested parties before starting the survey or design.

If possible, obtain a recent railroad map of the site indicating railroad right-of-way for the meeting.

This on-ground review should clarify other railroad company policies on these topics:

- The closest encroachment to the centerline of tracks permitted,
- Sight distance triangles,
- Traffic maintenance (detours),
- Drainage, bank protection or other conditions to be encountered on the proposed highway location, and
- Railroad work schedules.

Before designing improvements in the vicinity of existing crossings or new crossings, arrange for the above field inspection of the crossing site. Even if no improvements are made to the railroad crossing, coordination is needed early with the railroad company in regard to temporary traffic control that may affect the railroad. The above review should identify all matters necessary to resolve financial responsibility, scheduling, and authorization to proceed with the work. The traffic control and protection (e.g. type, number and location or railroad signals) to be installed should also be determined.

All utilities, both aerial and buried, in possible conflict with the proposed installation must be determined, including facilities interfering with the proposed railroad signals or gate installations requiring adjustments. In some instances, it may be preferable to adjust the location of the railroad signals. Consider any proposed future railroad or highway widening projects when determining placement of the signals.

Photographs should be taken during field inspections, and are very helpful to reference during the subsequent design activities for the project.

4.8.4 GEOTECHNICAL

Incorporate the results of the evaluation performed under Section 4.5.2.12.7.

Determine the scope of follow-up investigations that are still necessary to conduct for the preliminary or final design process, as described in Section 6.3.

4.8.5 HYDROLOGY AND HYDRAULICS

Develop the conceptual hydrology and hydraulic design to be applied for the drainage watersheds where the project is located, including typical roadway ditches, and determine the location, type and size of major drainage crossings and culverts that have an impact on the preliminary roadway design or which control the alignment and grade.

Determine the scope of any apparent existing drainage problems and develop the preliminary design of needed improvements based on field observations, previous safety reports or discussions with the roadway maintenance staff. Determine if there are any special measures required for erosion control or improvements to existing inlets/outlets that must occur. Also, determine any roadway profile issues that may need to be addressed during the final design (e.g., insufficient clearance over proposed culverts or adjustments in the roadway design or drainage facilities to prevent roadway flooding or overtopping).

4.8.5.1 Hydrology and Hydraulic Standards

Determine the standards and criteria that are to be used for evaluating and designing the roadway drainage improvements and river hydraulics, and apply these in the preliminary design. These are defined in Section 7.1.6.

4.8.5.2 Floodplain Considerations

Determine the limits of any floodplains either within or nearby the project that are regulated. Refer to Section 7.4.1. If there are known encroachments into these waterways by the recommended improvements, evaluate the potential effects and whether these encroachments could or could not be avoided and how they can be mitigated.

Assess the potential impacts or encroachments into floodplains and floodways, coastal waterways and fisheries and streams. Determine the scope of any channel migration concerns and any anticipated stabilization work that may be necessary. If there are potential embankments or retaining walls required adjacent to streams/channels, they should be evaluated. If there are any active waters that must be crossed during construction, access across these features should be investigated including detours, low-water crossings, timing, and temporary structures for construction activities. For any bridges over waterways, any scour and flow capacity issues must be addressed as part of the preliminary engineering study.

If a change in the floodplain is required, develop the procedures for working with the local jurisdictional agency to submit and complete these changes.

4.8.6 STRUCTURES

Determine the location, type, size, cross section, railing and transitions, and other results of the evaluation performed under Section 4.5.2.12.10.

4.8.7 PAVEMENTS

Incorporate into the preliminary design the results of the evaluation performed under Section 4.5.2.12.8. For conceptual design, the depth of the pavement structure may be an assumption based on past experience or by comparing with the depths used on an adjacent project. If this is used, provide the basis of where this information was obtained.

4.8.8 RIGHT-OF-WAY

Identify the existing right-of-way corridor and roughly approximate the proposed right-of-way area. Describe the property affected and the nature of impacts. Estimate the approximate right-of-way cost and any special right-of-way problems. If all or part of the route crosses public lands, identify the agency controlling the land.

4.8.9 ACCESS MANAGEMENT

Refer to evaluation of access management issues as described in Section 8.4.2 and Section 9.3.12.5. Consider the following issues:

- Operational effects,
- Safety effects,
- Design considerations, and

- Right-of-way considerations.

4.8.10 UTILITIES

Incorporate the results of the evaluation performed under Section 4.5.2.12.5.

4.8.11 PERMITS

Incorporate into the preliminary design the features that will be provided for any permit applications, and anticipated requirements of any necessary permits described under Section 4.5.2.12.6.

4.8.12 ENVIRONMENTAL FEATURES AND CONCERNS

Incorporate into the preliminary design the environmental, public and context sensitive issues, concerns and opportunities addressed in Section 4.6. If any of these objectives could not be achieved during the development of the preliminary design of alternatives, explain why these objectives presented such a challenge and what mitigation efforts should be considered.

4.8.13 CONSTRUCTION CONSIDERATIONS

Incorporate construction considerations into the preliminary design including the sequencing of the work and its constructability. Refer to Section 9.5.11.

4.8.14 DESIGN EXCEPTIONS

Evaluate any features of the preliminary design that do not conform to current approved standards. Refer to Section 9.1.3 for preparation of design exceptions.

4.8.15 COST ESTIMATES

Develop a construction cost estimate for the project. A Class C estimate is based on a per-mile [kilometer] cost for similar type scope of work projects in the area. A Class C estimate may have been previously prepared during the planning or programming phase, or may have been provided by the Federal land management agency. Develop, or verify, a Class C estimate for the scope of the improvements as part of the conceptual studies. At minimum, update the

Class C estimate, and preferably develop a Class B estimate for the preliminary design. Refer to Section 9.6.8.4.2 for a description of Class B estimate.

Document the cost unknowns and risks that are taken into consideration, and provide with estimates prepared in the early design phases, and in particular during the conceptual phase, since the estimate may be used to determine the project's viability or to determine when the project can be funded, or if it should be broken into multiple construction packages due to funding limitations.

4.9 IMPLEMENTATION

This section addresses how the project will be subsequently designed and delivered. Topics include how the project will be staged into multiple projects or stages if it is a long route, whether alternative delivery methods (e.g., design-build) will be used, how the PS&E is going to be developed and presented, overall final design and construction schedule, funding options, program requirements and other similar details.

4.9.1 PRELIMINARY DESIGN REVIEW

See Section 9.6.4.1 for guidance on the preliminary design review

4.9.2 PROGRAM REQUIREMENTS

The preliminary design documents should address the FLH and program-specific requirements, expectations or guidelines for final design and project delivery that will affect the project implementation. Reference to Memorandums of Agreement where they pertain to final design and delivery should be included in the project documentation. Refer to Section 2.3 for information on the various FLH programs. In addition to the program requirements described in the following sections, each project should be implemented in accordance with the project agreement that is developed specifically for the individual project, as described in Section 4.6.4.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

4.9.2.1 Forest Highways and Public Lands Highways

For Forest Highways and Public Lands Highways, the project will be located within or provide access to National Forest or other public lands. The road-owning agency is typically the State DOT if the road is a State highway or the county or city, if the road is not a State highway, or the Forest Service. The Public Lands Highways program is described in Section 2.3.1.1. The project may involve private right of way and utilities, and will typically provide access to private lands as well as public lands. The project stakeholders will generally consist of

- The Forest Service or other public land management agency,
- The road owning agency,
- Other cooperating and resource agencies, and
- Representatives of interest groups, highway users and the local public.

The project implementation should be in accordance with the Tri-agency agreement for the State in which the project is located, or a special interagency agreement.

4.9.2.2 National Park Roads and Parkways

National Park Roads and Parkways projects will typically be located entirely within a national park or parkway. The road-owning agency is typically the National Park Service, but may be a State DOT, a County or city in some cases. The Park Roads and Parkways (PRP) program is described in Section 2.3.1.2. The project may involve utilities and possibly access to private properties. For major Park Roads and Parkways projects, a value analysis may be performed by the NPS. The designer should provide the appropriate preliminary design information as described above to the Park Service and should attend the Value Analysis meeting as requested. Following the value analysis, a Development Advisory Board (DAB) review will be performed by the NPS for major reconstruction projects. As part of the preliminary design activity, provide further technical support (e.g., preliminary design details, cost estimates) for this review as requested. The project implementation should be in accordance the MOU between the FHWA and the National Park Service.

4.9.2.3 Refuge Roads

Refuge Roads are public roads within a national wildlife refuge that are owned and maintained by the Federal Government, typically by the US Fish and Wildlife Service. The Refuge Roads Program (RRP) is described in Section 2.3.1.4. The project may involve utilities and possibly access to private properties or other Federal lands. For refuge roads, the projects are intended to be rehabilitation or maintenance type improvements, and not major reconstruction or construction of new roads. The project implementation should be in accordance with the Interagency Agreement between the US Fish and Wildlife Service and the FHWA.

4.9.2.4 Defense Access Roads

Defense Access Roads are public highways that provide transportation services to a defense installation. This may also include public highways through military installations when right-of-way for these roads is dedicated to public use and a civil authority maintains the roads. These roads are generally owned by State or local governments and are typically not within the boundaries of military reservations, but they may be roads at military reservations or defense industry sites and may be closed to the public or restricted. There will generally be an agreement between the FHWA and the military command for the specific military roads or installations, and the project implementation should be in accordance with this agreement.

4.9.2.5 ERFO Projects

ERFO Projects are intended to repair or reconstruct Federal roads and bridges seriously damaged by a natural disaster or catastrophic failure. Due to their nature, these unplanned projects are generally very high priority and may need to be delivered using fast, non-traditional approaches. The projects may include any of the type roads described in the previous sections or other type roads on Federal lands. Restoration in-kind to pre-disaster conditions is expected to be the predominant type of repair. Implementation should be in accordance with the ERFO Manual.

4.9.2.6 Special Projects

Special projects are in addition to the main FLH Program projects that are described in the above sections. A special project agreement will typically be executed between the FHWA and the partner agencies or project stakeholders. The project implementation should be in accordance with this agreement.

4.9.3 STAGE CONSTRUCTION

Limited funding may restrict the sequence of reconstruction of a highway segment. When this is the case, consider Stage Construction. This is where the grading is completed first and the paving at a later time. This assures that the basic geometry (i.e., alignment, grades, cross section) is initially built to an established standard without need of further modification during later stages. For projects completed through a base course there is generally a need to re-establish the base grade staking and possibly recondition the base course if left for more than a year.

4.10 DOCUMENTATION

Conceptual studies and preliminary design provide findings and recommendations that are reviewed and commented on by various agencies and stakeholders. The studies are used to guide further design activities, environmental studies, field investigations, etc. This information can be documented and reported to the agencies in various ways or combined in other documents.

For the purposes of defining the series of investigations during the conceptual studies phase for Federal lands, they are defined as follows:

1. **Project Scoping Report**. The field inspections and compilation of existing engineering data used to identify and quantify a highway's deficiencies and needs are gathered and summarized in the Project Scoping Report. As part of this study, recommendations for further study will also be made to develop a course of action with suggestions for investigating improvement alternatives and conducting engineering analyses. The details of this report are detailed in Section 4.5.2.
2. **Corridor Study Report**. Occasionally, it becomes apparent that a highway should be considered on new alignment in a corridor outside of the existing road. These new highway corridors are usually identified and evaluated separately from preliminary engineering alternatives although they must be compatible with all the components that make up the alternatives. A highway corridor can be defined as a linear strip of ground that connects termini and has sufficient width and variable positioning on the terrain to allow a road with its preliminary design standards to be built within its borders. This report documents the decision to develop a new corridor, or contain the improvements within the existing corridor. The details for performing this work are detailed in Section 4.5.3.5.
3. **Preliminary Engineering Study Report**. After a determination is made to evaluate specific alternatives, each option considered is developed to the same level of effort (15 to 30 percent design) for similar comparisons. The Preliminary Engineering Study Report is the final report or checklist, either formal or informal, which documents the information, investigation and evaluation made during the conceptual studies and preliminary design process, and presents the engineering results of a recommended alternative for final design. The details for performing this work are detailed in Section 4.10.1.

Since the results of the conceptual studies and preliminary engineering analysis provide the critical engineering and/or reconnaissance information, array of alternatives and, in some cases, form the preferred alternative to be contained in the environmental document, these findings should be reviewed and concurred with by the appropriate Division staff responsible for the clearance of environmental documents. In addition, land management agencies should also review and concur in the engineering findings regardless of whether they have been documented by informal analyses or in a comprehensive, formal Preliminary Engineering Study Report. This will ensure the environmental process is evaluating alternatives that the land management agency is comfortable with. Concurrence of the report or informal findings does not constitute approval of a specific alternative or issue authority to commence final design activities.

4.10.1 PRELIMINARY ENGINEERING STUDY REPORT

The results of the conceptual studies and preliminary engineering analysis of the conceptual design should be documented in a Preliminary Engineering Study Report (e.g., design scoping report, project checklist, design technical memorandum). As a minimum, the findings and recommendations should be documented by a standardized form or checklist that addresses the applicability of each of the listed items and a description of existing features, design controls, proposed design standards and scope of the engineering work needed to deliver the project. Memorandums, trip reports or semi-formal checklists can be used to support the Preliminary Engineering Study Report. In any case, this information must be documented to ensure the findings and/or recommendations, as well as existing conditions can be reviewed and understood by all interested and affected parties. The report should be retained and readily retrievable until the final design is completed. All improvement alternatives should be readily supportable from an engineering position, which is contained in these study documents.

The final study report should contain the following items:

1. **Summary.** This will be a brief summary of the project's location, limits, route number, a brief summary of the project's scope, a summary of alternatives investigated and the description and cost of the preferred alternative. It should also describe any inter-agency agreements that have been made to complete the project.
2. **Introduction**. Describe the authority, the purpose and need for the project, ownership and maintenance, project objectives, brief history and a full description of the project. It should include:
    - Length of the project,
    - Termini of the project,
    - Functional classification,
    - Typical section of the project,
    - Number of lanes,
    - Existing intersections,
    - Existing site conditions,
    - Safety upgrades proposed,
    - Drainage improvements proposed,
    - Structure improvements proposed,
    - Utility issues,
    - Traffic control issues, and
    - Right-of-way constraints.
3. **Resources Used.** Identify all sources of information, input, maps and data obtained for the study.
4. **Climate, Physiography and Geology**. Provide a description of the climate, significant geographic features, land uses and geology of the area.

5. **Summary of Traffic and Crash Data**. Provide a summary of all the traffic and crash data obtained for the project.

6. **Summary of Controlling Design Criteria**. This section will describe the applicability of design standards, any non-conforming design elements of the existing facility that will be upgraded as part of the project and those elements for which design exceptions will be required.

7. **Location Analysis**. For those projects where a corridor study (see Section 4.5.3) is included, also include a location analysis.

8. **Design Concepts and Alternatives.** This section will include a description of those alternatives considered and discontinued, those studied in full, an evaluation of the studied alternatives and conclusions/recommendations for the final improvement. Design concepts and recommendations should be described for distinct segments of the route that have varying characteristics.

9. **Major Design Features of the Recommended Alternative**. Include descriptions of the major design features of the recommended alternative, which includes:

   - Design controls,
   - Horizontal and vertical alignments,
   - Intersections,
   - Drainage,
   - Geotechnical including earthwork balance and issues,
   - Pavements,
   - Structures,
   - Constructability and traffic control,
   - Intersections,
   - Utilities,
   - Right-of-way,
   - Access management, including operational effects of access management and the safety effects of access management,
   - Permits,
   - Constructability and staged construction (implementation), and
   - Design exceptions.

   See Section 9.3 for further information on geometric design.

10. **Cost Estimates**. Include a Class C or B cost estimate as appropriate. See Section 4.8.15.

11. **Construction Phasing or Scheduling**. Where a project includes construction phasing, include a description of each of the phases. Also, include a description of the construction schedule for all projects.

12. **Social, Economic and Environmental (SEE) Concerns**. Address any concerns or issues regarding the social, economic and environmental aspects of the project. See Section 3.4.2.2 for detailed information on the environmental process.

13. **Exhibits**. Examples of exhibits include:

- Typical Sections,
- Project Vicinity and Location Maps, and
- Plan/Profile Exhibits of Alternatives.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

4.10.2 ENVIRONMENTAL DOCUMENT

At the conclusion of conceptual studies and preliminary design, a decision must be made identifying which alternative is going to be advanced into the design phase. The decision-making process is described in Section 3.4.2.2.

The engineering information and descriptions of the improvement alternatives contained in the environmental documents are summarized from the conceptual studies and preliminary design. Since the final decisions are a product of the environmental process, it is imperative that environmental documents present the engineering data in an accurate, complete and understandable fashion. Close and continuous collaboration between the preliminary design and the environmental analysis and documentation is essential. The content of environmental documents is described in Section 3.5.

4.10.3 DEVELOPMENT REQUIRED FOR FINAL PLANS, SPECIFICATIONS, AND ESTIMATE (PS&E)

Formal selection of the preferred alternative occurs when the project's environmental clearance document is approved as described in Section 3.5. This also completes the conceptual study and preliminary design phase and advances the project into the final design phase and subsequent plans, specifications and estimates (PS&E) preparation.

The description of the selected alternative that is contained in the environmental decision making documents (e.g., categorical exclusion, finding of no significant impact, record of decision) should include preliminary design standards and corridor engineering information in sufficient detail to ensure the project will be designed to implement the approved concept.

Chapter 5 – SURVEYING AND MAPPING

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LIST OF EXHIBITS

CHAPTER 5

SURVEYING AND MAPPING

5.1 GENERAL

This chapter provides policies, standards and criteria for surveying and mapping of Federal Lands Highway (FLH) projects. It is applicable to new or reconstructed highways, as well as Resurfacing, Restoration and Rehabilitation (RRR) improvements. It is written for surveyors, engineers, consultants and managers responsible for requesting and/or completing surveying and mapping activities. It also provides:

- FLH-specific guidelines, methods and practices to support development of quality surveying and mapping information; and
- Background and reference material containing necessary context and relevance for FLH work, including specific information concerning techniques, theory and specifications.

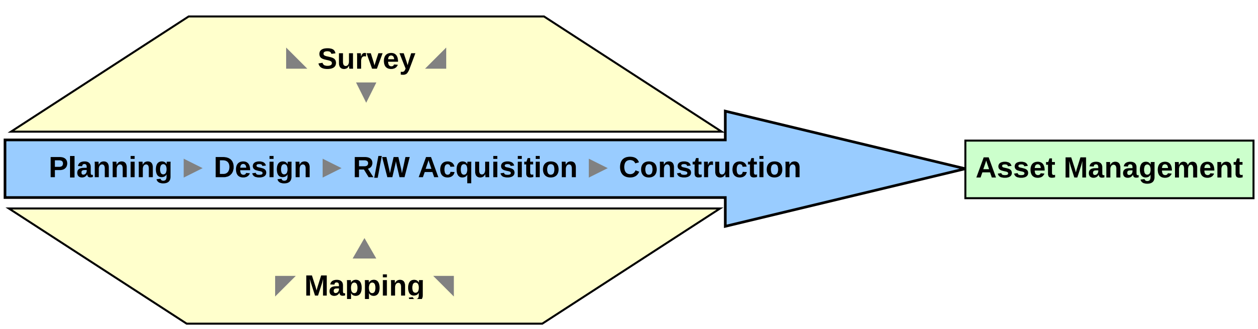
Refer to Section 1.1.1 for purpose and definitions of policy, standards, and guidance. Statements of FLH policy are shown in bold type. Statements regarding FLH Standard Practice are so indicated.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

5.1.1 SURVEYING AND MAPPING FUNCTIONS AND PROGRAMS

Surveying and mapping is fundamental to all civil engineering and roadway design work. It is a vital function linking the interdisciplinary elements of a project from planning through design, right-of-way acquisition and construction, to final asset management. Exhibit 5.1–A presents a graphic representation of the elements of project development and their interrelationships.

Exhibit 5.1–A PROJECT DEVELOPMENT ELEMENTS



Surveying and mapping connects the real world of site conditions, terrain and improvements to the virtual world of design concepts and calculations depicted in the CADD environment. To the implementation of designs in construction, surveying and mapping reverses that connection, taking the critical elements of design from CADD and accurately placing them in the context of the real world. Land surveying and right-of-way, a specialized aspect of surveying and mapping, considers the legal interpretation of evidence related to land boundaries and real property rights, to provide a comprehensive description of the physical and legal constraints to project development. Guidelines for activities specific to right-of-way acquisition documents are described in Chapter 12.

Exhibit 5.1–B lists typical surveying and mapping functions applicable to FLH projects.

5.1.2 AUTHORITY AND ADMINISTRATION

Surveying and mapping functions proceed under the authority and administration of the Division Offices of the FLH. Refer to Chapter 1 for the legislative authority as well as general policies, project development philosophy, and risk assessment.

Surveying and mapping is a professional-level practice that is generally governed by professional practice laws and regulations in each State. While Federal land surveying activities maybe exempted from some areas of land surveying by specific language in each State's legislation, these laws provide unique insight into local practices and customs.

5.1.3 SAFETY

The purpose of this section is to:

- Reinforce the importance of a safe work environment to the mission of FLH, and
- Provide guidelines to assist personnel, consultants and contractors to conduct their work in a safe and healthful manner.

Chapter 8 provides guidance for evaluating and developing highway safety alternatives for incorporation into roadway and structural designs.

Appendix 5A.1 contains a "Code of Safe Surveying Practices", outlining issues of particular concern to survey operations. Field surveyors, engineers and consultants must be familiar with these issues and take precautions to ensure that all work is conducted in a safe and healthful manner.

Exhibit 5.1–B FLH SURVEYING AND MAPPING FUNCTIONS

Function	Description	Activities
Geodetic Control	Obtaining horizontal and vertical measurements and analysis necessary to relate projects to defined local and national datum. Geodetic Control is a Federal requirement of Circular A-16.	• Global Positioning System (GPS) control • Precise Leveling • Least Squares Adjustment • Research and Recovery • Datum Modeling
Project Control	Obtaining existing and new monuments and data (measurements, computations, coordinates and elevations) needed to support project activities throughout planning design and construction.	• Monument Construction • Horizontal and Vertical Traverse • Real-Time GPS • Boundary Ties • Photogrammetric Ground Control
Deformation Monitoring	Monitoring for landslides, slopes, and constructed works, horizontal and/or vertical movement over time.	• Repeated Horizontal and Vertical Measurements • Continuous GPS • LiDAR and IFSAR or INSAR
Mapping	Depicting the configuration or relief of the earth's surface (terrain), and the location of natural and artificial objects. Includes development of imagery and remote sensing data for enhanced understanding of existing site conditions.	• Aerial Photogrammetry • Airborne and Ground-Based LiDAR • Field Topography • Contour Mapping • Cross Sections • Subsurface Utility Investigation • Cultural Features • Hydrographic and bathymetric mapping
Boundary / Right-of-way	Determining property boundaries and real property rights that define the limitation of land title interests within a project. Includes developing maps and reports necessary for appraisal and acquisition of various real property rights.	• Land Title Investigation • Cadastral Surveys • Right-of-way Engineering • Appraisal Maps • Legal Descriptions
Construction	Locating and establishing ground-based alignment and grade of construction designs.	• Alignment Staking • Slope Staking • Improvements/Utility Staking • Quantity Surveys • As-Constructed Plans
Information Management	Preparing field notes and reports. Extracting and formatting design and staking data. Includes data analysis for continuity and accuracy, development of thematic maps, CADD files, and Geographic Information Systems.	• Records Research • File Formatting/Transfer • Database Design • Report Writing • Cartography

5.2 GUIDANCE AND REFERENCES

The publications listed in this section provided much of the fundamental source information used in the development of this chapter. This list is not all-inclusive and there are numerous manuals, technical documents and journals that explain the techniques and formulas required to perform proper and accurate surveying and mapping. The user is assumed knowledgeable of basic procedures and current technology, or will consult the references for such purposes.

A glossary, including abbreviations and definitions, is described in Section 1.4. For detailed definitions on specific subjects, consult the glossaries in the references listed.

Reference should be made to State Department of Transportation Manuals for additional guidance applicable to individual projects.

1.	Definitions of Surveying	*Definitions of Surveying and Associated and Associated Terms*, American Congress on Surveying and Mapping, 1978, Reprinted 1999.
2.	Standard Handbook for Civil Engineers	*Standard Handbook for Civil Engineers*, 5th Edition, Ricketts, Loftin & Merritt, McGraw Hill Professional, 2003.
3.	CE Reference Manual	*Civil Engineering Reference Manual for the PE Exam*, 9th Edition, M.R. Lindeburg, Professional Publications, 2003
4.	Surveying	*Surveying*, 10th Edition, F.H. Moffitt, & J.D. Bossler, Harpercollins College Div, 1997.
5.	Adjustment Computations	*Adjustment Computations*, 3rd Edition, P.R. Wolf & C.D. Ghilani, Wiley-Interscience, 1997.
6.	GPS for Land Surveyors	*GPS for Land Surveyors*, 2nd Edition, Van Sickle, Jan, CRC Press, 2001.
7.	Tech Bulletin No. 6	*Manual of Surveying Instructions*, Technical Bulletin No. 6., Department of the Interior, Bureau of Land Management, 1973.
8.	Lost or Obliterated Corners	*Restoration of Lost or Obliterated Corners and Subdivision of Sections*, Department of the Interior, Bureau of Land Management. 1974.
9.	Glossary of BLM Surveying	*Glossary of BLM Surveying and Mapping Terms*, Department of the Interior, Bureau of Land Management, 1980.
10.	Boundary Location	*Evidence and Procedure for Boundary Location*, 4th Edition, W.G. Robillard & D.A. Wilson, Wiley, 2001.
11.	Boundary Control	*Brown's Boundary Control and Legal Principles*, 5th Edition, C.M. Brown, D.A. Wilson & W.G. Robillard, Wiley, 2003.

12.	Elements of Photogrammetry	*Elements of Photogrammetry*, 3rd Edition, P.R. Wolf, McGraw Hill Science/Engineering/Math, 2000.
13.	Accuracy Standards for Large-Scale Maps	*ASPRS Accuracy Standards for Large-Scale Maps*, American Society of Photogrammetry and Remote Sensing (ASPRS), 1990.
14.	FGDC-STD-007.2-1998	Geospatial Positioning Accuracy Standard, Part 2, *Geodetic Control Networks*, Federal Geographic Data Committee, FGDC-STD-007.2-1998.
15.	NSSDA	Geospatial Positioning Accuracy Standard, Part 3, *National Standard for Spatial Data Accuracy* (NSSDA), Federal Geographic Data Committee, FGDC-STD-007.3-1998
16.	FGDC-STD-001-1998	*Content Standard for Digital Geospatial Metadata* (version 2.0), Federal Geographic Data Committee, FGDC-STD-001-1998.
17.	Vertical Accuracy Reporting for LiDAR Data	ASPRS Guidelines: Vertical Accuracy Reporting for LiDAR Data, 2004.
18.	NOS NGS-05	*National Geodetic Survey NOAA Technical Memorandum NOS NGS-05*, State Plane Coordinate System of 1983, January 1989, Reprinted with minor corrections March 1990.
19.	NOS NGS-58	National Geodetic Survey NOAA Technical Memorandum NOS NGS-58, *Guidelines for Establishing GPS-derived Ellipsoidal Heights (Standards: 2 cm and 5 cm)*, Version 4.3.
20.	Circular A-16	*Office of Management and Budget Circular A-16*, Revised August 19, 2002.

5.3 SURVEY PLANNING

5.3.1 SURVEY DATUM

Multi-disciplined, partner agency project delivery efforts require the use of a common, accurate horizontal and vertical survey datum as the basis for planning design and construction. This ensures all project elements (e.g., base topographic mapping, rights-of-way, special studies, designs, and locations of fixed works) can be related throughout project development and delivery phases. Increased use of Geographic Information Systems (GIS) for the efficient sharing of both engineering and surveying data within FLH and with agency partners makes the use of a universally accepted and understood horizontal and vertical reference system even more important. The importance of a common reference frame is recognized by Circular A-16 wherein lead Federal agencies are required to implement and contribute to the National Spatial Data Infrastructure (NSDI).

As applicable, and as specifically detailed in the project plan, cooperate with the National Geodetic Survey (NGS) and others to monitor, maintain and enhance the NSDI and its geodetic survey element, the National Spatial Reference System by:

- Establishing new geodetic reference marks in accordance with NGS policies and procedures,
- Reporting on the condition of local geodetic control,
- Participating in geodetic survey observation campaigns, and
- Developing methodologies and advanced technologies to promote implementation of the NSDI.

5.3.1.1 Horizontal Datum

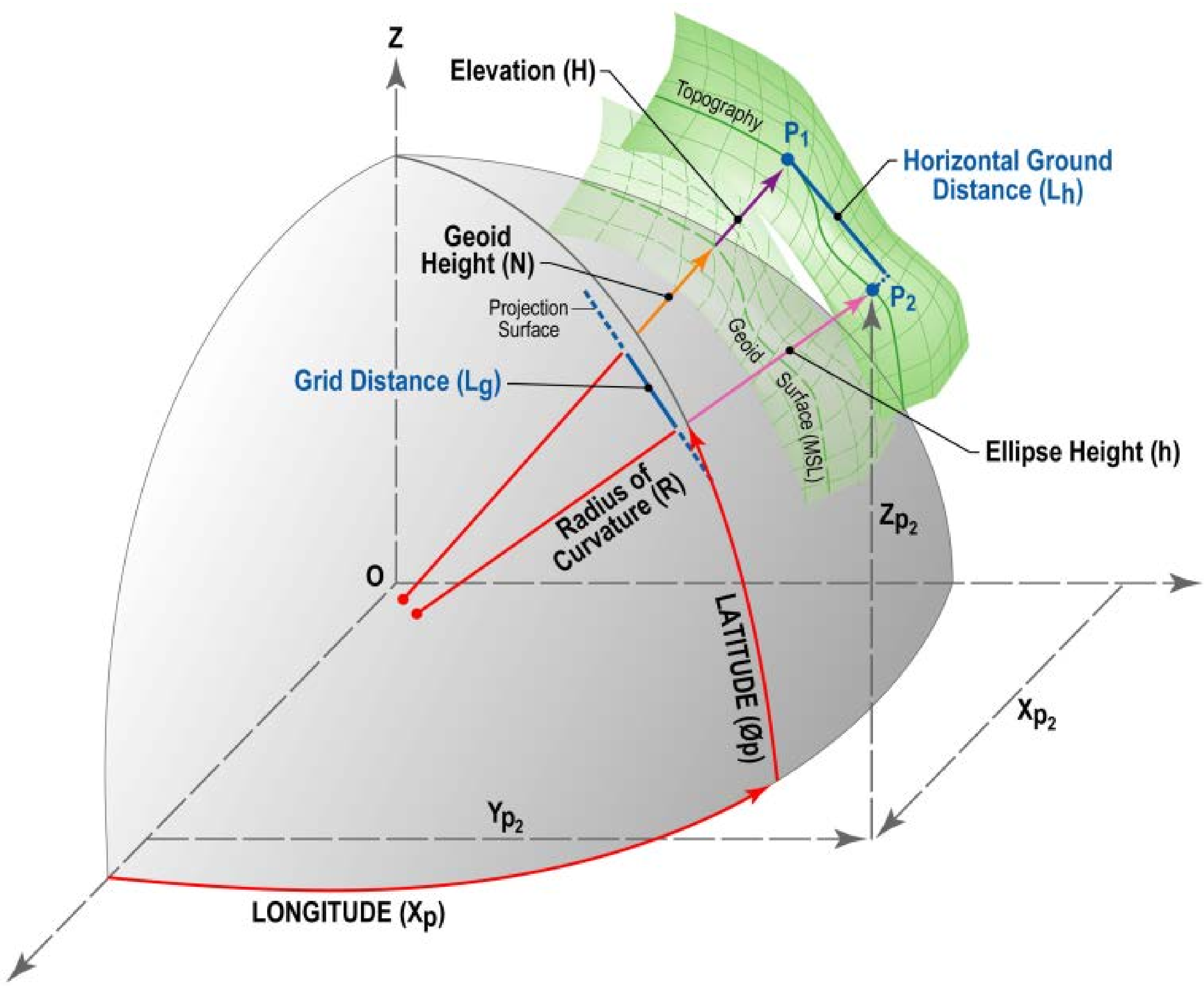
All surveying and mapping work, planning, studies and engineering designs must be based upon a common well-understood horizontal datum. **Unless unique circumstances prescribe use of an alternate reference system, the horizontal datum standard for all mapping, planning, design, right-of-way and construction on FLH projects shall be the North American Datum of 1983 (NAD83) as defined by the National Geodetic Survey (NGS).** Use of the most current realization of NAD83, from High Accuracy Reference Networks (HARN), Continuous Operating Reference Stations (CORS) or both is encouraged. Use of the *NGS Online Positioning User Service (OPUS)* is a convenient and efficient method of establishing the required horizontal control datum Project coordinates (northings and eastings) for mapping and design shall be expressed in terms of the State plane coordinate system zone in which the project exists. Definition of the State plane coordinate projections can be found in *NGS publication NOS NGS-05*.

State Plane Coordinates (SPC) are geodetic coordinates projected onto a geometric surface using a defined set of mathematical parameters and computations. Each geometric surface and the parameters defining the SPC zones are made to coincide with the NAD83 reference ellipsoid, the Geodetic Reference System of 1980 (GRS80), meaning the SPC reference surface will rarely be identical to the ground surface. Use the standard formula, contained in NGS publication *NOS NGS-05* and written into most modern surveying and mapping software, to compute the:

- Grid scale factor, variable due to location within the particular SPC zone;
- Height scale factor, dependent upon the distance above or below the SPC reference surface; and
- Combined factor, which is the product of the two.

The combined factor is the ratio of a distance measured on the grid surface to the same distance measured on the ground. Graphically and algebraically, the relationship is shown in the Exhibit 5.3–A.

Exhibit 5.3–A GRID AND GROUND DISTANCES



Differences between grid and ground distances should rarely exceed 1:10,000 at elevations near sea level. At this level, only the most exacting design elements (e.g., manufactured bridge structural members) will need to consider the variation between grid and ground distances. When, in unique situations, it is not practical to obtain State Plane Coordinates, the local ground coordinate system shall be constructed in such a way that it can never be confused with the typical number values found in the SPC zone.

5.3.1.2 Vertical Datum

All engineering work (e.g., mapping, planning, design, right-of-way engineering, and construction) for each transportation improvement project shall be based on a common vertical datum.

The vertical datum for all mapping, planning, design, right-of-way engineering and construction on transportation improvement projects, shall be the North American Vertical Datum of 1988 (NAVD88), as defined by the National Geodetic Survey (NGS). Exceptions to this policy, as determined by the Division Survey Manager in consultation with the Project Manager, are permitted for:

- Projects of small size and scope;
- Projects in remote, isolated locations;
- Maintenance, traffic safety and rehabilitation projects controlled by existing fixed works;
- Projects for which establishment of NAVD88 vertical control is cost prohibitive;
- Expedited projects for which establishment of NAVD88 vertical control is not feasible;
- Projects contiguous to the National Geodetic Vertical Datum of 1929 (NGVD29), which States that uniformity is desirable; and
- Projects in the immediate vicinity of harbors and wharfs, where tidal datum control the mapping and fixed works

Generally, the only acceptable alternate datum is NGVD29. For project locations where published NAVD88 data is not locally available, GPS survey methods using the latest approved geoid model should be considered. Assumed datum should only be considered as a last resort.

5.3.1.3 Coordinate Projections

Because geodetic surveying calculations are complex and most surveying projects are limited scope, surveyors generally prefer plane surveying to geodetic surveying methods. For local projects, plane surveying yields accurate results, but for large surveying networks, local plane surveying systems are inaccurate over large areas and cannot be easily related to other local systems.

In response to the needs of local surveyors for an accurate plane-surveying datum useful over relatively large areas, the US Coast and Geodetic Survey (the predecessor of NGS) developed the State Plane Coordinate System. The State Plane Coordinate System was established to provide a means for transferring the geodetic positions of monumented points to plane coordinates that would permit the use of these monuments in plane surveying over relatively large areas without introducing significant error.

A plane-rectangular coordinate system is by definition a flat surface. Geodetic positions on the curved surface of the earth must be “projected to their corresponding plane coordinate positions. Projecting the curved surface onto a plane requires some form of deformation. Imagine the stretching and tearing necessary to flatten a piece of orange peel.

The following provides brief descriptions of the three most common geometric surfaces used to develop coordinate projections:

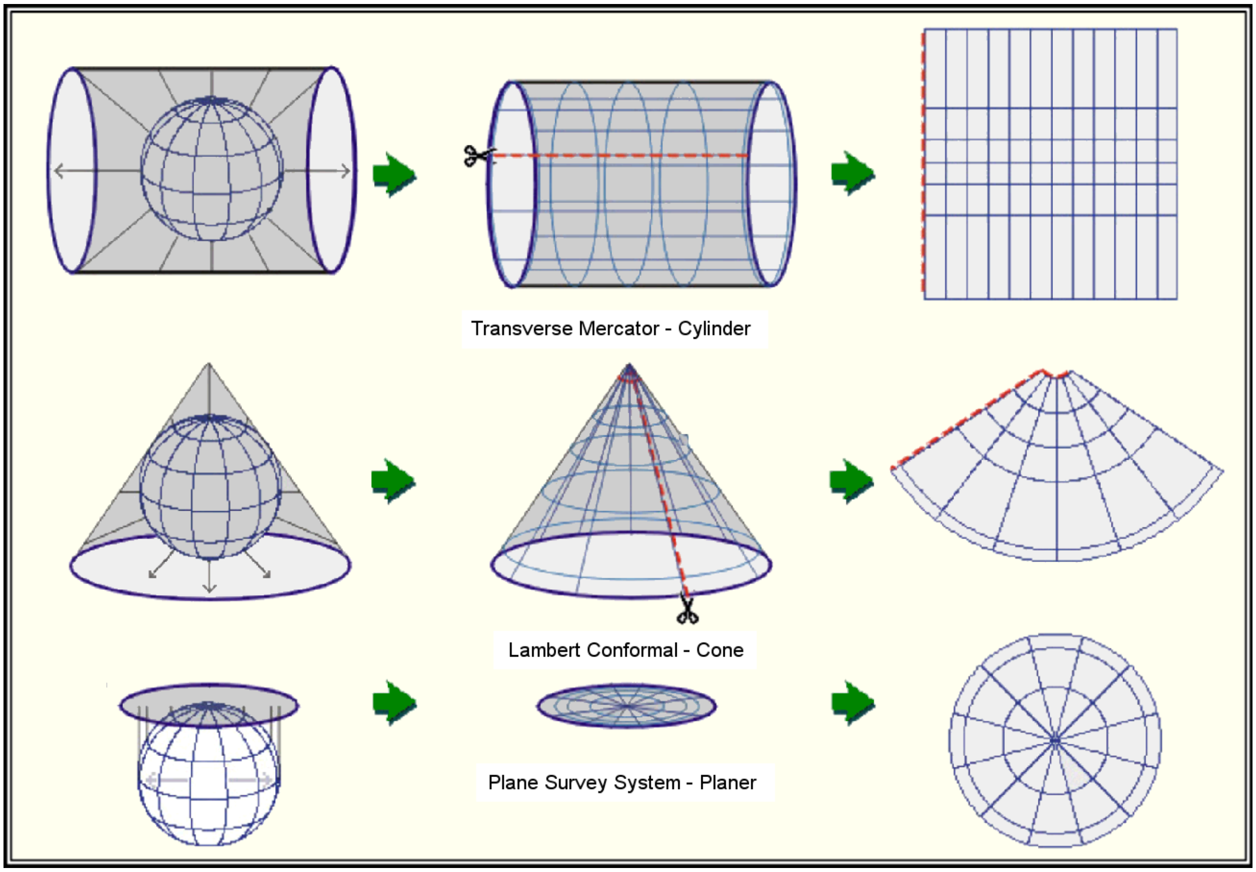
1. **Transverse Mercator.** In the Mercator projection, a cylinder intersects the ellipsoid to develop the projection surface. The cylinder is most often rotated 90 degrees so the axis of the cylinder is perpendicular to the axis of rotation of the datum surface, hence becoming a “transverse” Mercator projection. Occasionally, the cylinder is rotated into a predefined azimuth, creating an “oblique” Mercator projection. Conceptually, this is how one SPCS zone in Alaska was designed.
2. **Lambert Conformal.** The Lambert Conformal projection is illustrated by a cone that intersects the ellipsoid along two parallels of latitude. These latitudes are known as the standard parallels for the projection. Distances lying along the standard parallels are the same on both the ellipsoid and the cone. Between the standard parallels, distances projected from the ellipsoid to the conic surface become smaller. Outside the standard parallels, distances projected from the ellipsoid to the conic surface become larger. Scale factors are used to reduce and increase distances when converting between the projected surface and the ellipsoid surface. The scale factor is exactly one (1.000000) on the standard parallels, greater than one (>1.000000) outside them and less than one (<1.000000) between them. The Lambert Conformal projection provides the closest approximation to the geodetic datum surface for rectangular zones greatest in an east-west direction.
3. **Secant Cylinder.** The secant cylinder is defined by specifying the central meridian, plus the desired grid scale factor on the central meridian. The ellipses of intersection are standard lines. Their location is a function of the selected central meridian grid scale factor. The specification of the latitude-longitude of the grid origin and the linear grid values assigned to that origin are all that remain to uniquely define a zone of either the Lambert or transverse Mercator projection.

Exhibit 5.3–B provides a graphic illustration of the three most common geometric surfaces.

5.3.1.4 Coordinate System Scale Factors

The limits of each projection are generally chosen so that grid scale factors will be less than 1.00010 and greater than 0.99990 so that even if scale factors are disregarded discrepancies between ground measurements at sea level and distances on the grid will be within 1:10,000.

Exhibit 5.3–B COMMON COORDINATE PROJECT SURFACES



Distances measured on the surface of the Earth must be scaled to corresponding length on the ellipsoid. This ellipsoidal or elevation factor (generically referred to as the "height scale" factor) varies with the elevation at which the distance is measured. As the elevation of the measured line increases, the distance (radius) from the surface of the earth to its center increases, which correspondingly increases the length of the measured line. Thus, distances must be reduced in proportion to the change in radius between the ellipsoid and the radius of the Earth's surface where the measurement is made. For example, a 3280.00 ft [1000.000 m] distance measured on the ground at an approximate elevation of 10,000.00 ft [3000.000 m], will project to an approximate distance on the projection surface of 3,279.30 ft [999.520 m]. This is a change between measured and projected of 480 ppm or 1:2083.

Normally, the height scale factor (in NAD27, it is called the sea level factor) and the grid scale factor are combined by multiplication into a combined factor. Distances measured on the earth's surface are converted to grid distances by multiplying by the combined factor. Grid distances are converted to ground distances by dividing the grid distance by the combined factor.

As applicable for each project, determine the appropriate combined factor and document it for use in design and construction, including the basis for coordinate projection and method for project measurements and layout.

5.3.2 SURVEY STANDARDS

This section provides accuracy standards for project control, engineering drawings, maps and surveys used to support FLH transportation systems and related projects. This standard defines accuracy criteria, accuracy testing methodology and accuracy reporting criteria for features depicted on spatial data products and related control surveys. Using the standards and guidance contained in this section, end users of survey and mapping products (e.g., planners, designers, constructors) can specify surveying and mapping accuracy requirements needed for their projects or specific CADD/GIS layers, levels or entities. From these specifications, data producers (e.g., surveyors, cartographers, photogrammetrists) can determine the instrumentation, procedures and quality control processes required to obtain and verify the defined accuracies.

The value of any geographic data set depends on its fitness for a particular purpose. A critical measure of that fitness is data quality. When used in design and analysis, a data set's quality significantly affects confidence in the results. Unknown data quality leads to tentative decisions, increased liability and lost productivity. Decisions based on known data quality are made with greater confidence and are more easily explained and defended. Federal standards that assist in documenting and transferring data sets emphasize five important components of data quality:

1. **Positional Accuracy**. How closely the coordinate descriptions of features compare to their actual location.
2. **Attribute Accuracy**. How thoroughly and correctly the features in the data set are described.
3. **Logical Consistency**. The extent to which geometric problems and drafting inconsistencies exist within the data set.
4. **Completeness**. The decisions that determine what are contained in the data set.
5. **Lineage**. What sources are used to construct the data set and what steps are taken to process the data?

Considered together, these characteristics indicate the overall quality of a geographic database or map. The information contained in the section focuses on the first characteristic, positional accuracy.

5.3.2.1 Accuracy and Precision

Two terms common to surveying are accuracy and precision. They are commonly used without a true distinction between them. The National Geodetic Survey defines them as:

1. **Accuracy**. The degree of conformity with a standard.
2. **Precision**. The degree of refinement in the performance of an operation or in the statement of a result.

Accuracy relates to the degree of perfection obtained, and is a function of the quality of the result and the quality of the operation used to obtain the result. Accuracy is a function of precise methods, precise instruments, precise procedures, and most of all, good planning. While precise instruments are not a necessity, the use of less precise instruments may require increased time spent at a station and require more observations to achieve accurate results. Good planning and a reconnaissance trip will save many man-hours later.

Precision relates to the degree of perfection used (technique) and is a function of proper instrumentation (tools), procedures (methods), and observations. Accuracy is the degree of perfection obtained (results). Actual results must be used to compute accuracy. When the results do not compare favorably with the estimated results, it should be assumed that errors exist which should be corrected.

The accuracy of a field survey depends directly upon its precision. Although by chance (for example, compensating error) surveys with high order accuracies might be attained without high order precision, such accuracies are not valid. Therefore, all measurements and results should be shown with the number of significant figures that are commensurate with the precision used to attain the results. For instance, distances measured with an EDM should typically be shown to the nearest 0.003 ft [millimeter], while distances scaled on a USGS 7½′ quad map should typically be shown to the nearest 30 ft [10 m]. Similarly, all surveys must be performed with a precision that ensures that the desired accuracy is attained.

For each project survey, establish the appropriate levels of accuracy and precision that will meet the project requirements.

5.3.2.2 Errors

There are three general types of errors:

1. **Blunder**. A blunder is a mistake in determination of a value. Eliminating blunders is one of the most important elements in surveying. Apply the following basic rules for eliminating blunders:
   - Every value recorded in the field must be checked by some other field observations,
   - Once this check indicates that there are no blunders, the field records must never be changed, and
   - An overall check must be applied to every control survey. As many checks as practical should be programmed in the planning of the project.
2. **Systematic**. Systematic errors, or bias, are errors that, under the same conditions, will always remain the same in size and sign. These errors can only be located by recognizing conditions that create them; they are therefore very problematic. Make every effort to recognize any conditions that cause them and take the necessary steps to neutralize them. Most surveying equipment, when properly calibrated and used with the proper procedures, will automatically cancel most of these errors. Evaluate the errors that cannot be eliminated and determine the conditions that cause them.

3. **Random**. Random errors represent the limit of precision for a particular measurement technique in the determination of a true value. They obey the laws of probability. Errors of a properly conducted survey can be treated as random.

For each project survey, strive to minimize the level of errors that may occur throughout the process; and document errors that are detected during the course of the work.

5.3.2.3 Control Survey Accuracy Classifications

The classification standard for geodetic networks is based on accuracy as defined by the Federal Geographic Data Committee (FGDC). FGDC Accuracies are categorized separately according to Exhibit 5.3–C for horizontal, ellipsoid height and orthometric height.

Exhibit 5.3–C CONTROL SURVEY ACCURACY STANDARDS

Control Survey Accuracy Standards
Horizontal, Ellipsoid Height, and Orthometric Height

	Measurement	Less Than or Equal to:	
	1-Millimeter	0.001 meters	[0.003 ft]
	2-Millimeter	0.002 meters	[0.006 ft]
	5-Millimeter	0.005 meters	[0.016 ft]
FLH SURVEY PROJECTS TYPICALLY FALL INTO THIS RANGE	**1-Centimeter**	**0.010 meters**	**[0.03 ft]**
	2-Centimeter	**0.020 meters**	**[0.06 ft]**
	5-Centimeter	**0.050 meters**	**[0.16 ft]**
	1-Decimeter	0.100 meters	[0.3 ft]
	2-Decimeter	0.200 meters	[0.6 ft]
	5-Decimeter	0.500 meters	[1.6 ft]
RESOURCE MAPPING PROJECTS TYPICALLY FALL INTO THIS RANGE	**1-Meter**	**1.000 meters**	**[3.3 ft]**
	2-Meter	**2.000 meters**	**[6.6 ft]**
	5-Meter	**5.000 meters**	**[16 ft]**
	10-Meter	**10.00 meters**	**[33 ft]**

When control points in a survey are classified, they have been verified as being consistent with all other points in the network, not merely those within that particular survey. It is not observation closures within a survey that are used to classify control points, but the ability of that survey to duplicate already established control values. This comparison takes into account models of crustal motion, refraction, and any other systematic effects known to influence survey measurements.

Refer to Appendix 5A.2 for FLH standard accuracy classifications for typical survey control levels, and recommended procedures and documentation to support the survey data.

5.3.2.4 Mapping Accuracy Classification

Determine mapping accuracy by comparing the mapped location of selected well-defined points to their "true" location as determined by a method known to produce more accurate results (e.g., conventional field survey to check photogrammetry). Mapping accuracy standards classify a map as meeting a certain statistical level of accuracy. Horizontal (or planimetric) map accuracy is usually expressed in terms of two-dimensional radial positional error measures (i.e., the root mean square (RMS) statistic) and is frequently related to plotting scale. Vertical map accuracy is expressed in terms of one-dimensional RMS elevation errors, and is frequently related to contour interval.

Maps, surveys and related geospatial data that are tested and found to comply with a specified standard shall have a certification statement that clearly indicates the target map scale and contour interval of the data layer. Project documentation will include testing procedures and statistical summary of the accuracy assessment. Horizontal and vertical accuracy classification of features is reported at the 95 percent confidence level by converting RMS error statistics by Equations 5.3(1) and 5.3(2).

Horizontal (two-dimensional)	95% confidence = RMS error * 1.7308	Equation 5.3(1)
Vertical (one-dimensional)	95% confidence = RMS error * 1.9600	Equation 5.3(2)

Project specifications will specify the geographic extent of data to be tested and the amount of testing (if any) to be conducted. Due to the high cost of testing and the varying applications for mapping data, not all map products should be tested. In these cases, the statement shall indicate that the mapping procedures were designed and performed under conditions known to meet a certain level of accuracy, but that the accuracy classification is estimated. An estimated accuracy statement is especially applicable to CADD and GIS databases that may be compiled from a variety of sources containing known or unknown accuracy reliability.

Mapping accuracy standards are associated with the final development of both the target horizontal plotting scale and contour interval. Photogrammetric flying height and ground survey density requirements are specified based upon the design target scale and contour interval. The use of Computer Aided Drafting and Design (CADD) and/or Geographic Information Systems (GIS) allows planimetric features and topographic elevations to be readily separated onto various layers and depicted at any scale or contour interval. Therefore, it is critical that these spatial data layers contain descriptor information identifying the original source and mapping accuracy classification.

The FLH standard for topographic mapping is the FGDC *National Standard for Spatial Data Accuracy* (NSSDA) and the ASPRS *Accuracy Standards for Large-Scale Maps*. This standard was developed, and remains generally recognized, by the photogrammetric industry. The ASPRS accuracy standards and statistical testing criteria can also be used to truth and classify topographic mapping compiled by other methods (e.g., terrestrial field survey, LiDAR).

Exhibit 5.3–D depicts recommended scales, contour intervals and associated positional tolerances for FLH mapping projects. Functional activities are generally divided into design and

construction tasks, and planning-level tasks. For most projects, identification of the type of project is the only design assumption required.

5.3.2.5 Units of Measurement

Article I, Section 8 of the US Constitution gives Congress the power to "fix the standard of weights and measures" for the nation. The First Congress, meeting in 1789, took up the question of weights and measures. In 1832, Congress directed the Treasury Department to standardize the measures used by customs officials at US ports. The Department adopted a report describing the traditional system, and Congress allowed this report to stand without taking any formal action. This is the closest the US has ever come to adopting a single system of measurement. The US Congress passed the *Metric Conversion Act* of 1975, Public Law (PL) 94-168, to encourage the use of the metric system of measurement throughout the US. In 1988, Congress passed the *Omnibus Trade and Competitiveness Act*, which designates "the metric system of measurement as the preferred system of weights and measures for United States trade and commerce." The 1995 *Transportation Equity Act* for the 21st Century (TEA-21) relaxed certain requirements for State transportation agencies to employ International System of Measurements (SI) units on federally funded projects. These and other decisions make the decision to use metric (SI) or United States Customary Units (USCU) unique to a given project.

Surveying and mapping operations are easily adaptable to the use of either metric or USCU of measure. Care must be exercised to ensure that the required units of measurement are clearly identified in the project scope of work and work plan, and that all maps and reports note the correct units to avoid confusion.

Use of USCU with NAD83 State Plane Coordinates brings a unique issue with the appropriate conversion from coordinates in SI units (the defining system of the SPC system) and USCU. The adopted distance of a uniform foot has two official definitions in the US as follows:

1. **Survey Foot**. $1 \text{ US Survey Ft} = \frac{12}{39.37 \text{ m}}$

2. **International Foot**. 1 International Ft = 0.3048 m

The difference between the two definitions is approximately 6 ppm in a converting to USCU. This will produce differing coordinate values of approximately 3 ft in northing and 13 ft in easting for typical State Plane Coordinates. The difference is negligible for the actual measured distances between points. FLH standard practice is to use the US Survey Foot conversion. Most States have adopted official conversion definitions as part of the State's plane coordinate legislation. Where official conversion definitions have been adopted by a State, FLH projects in USCU may conform to the adopted units of conversion (i.e., US Survey Foot or International Foot). **All maps and reports must clearly state the definition used to express project coordinates.**

Exhibit 5.3–D RECOMMENDED SCALES, CONTOUR INTERVALS AND ASSOCIATED POSITIONAL TOLERANCES FOR FLH MAPPING PROJECTS

Project or Activity	Target Map Scale Accuracy Classification	Contour Interval Accuracy Classification	ASPRS Map Accuracy Classification	Horizontal Tolerance (RMSE)	Vertical Tolerance (RMSE)	Horizontal Positional Confidence 95%	Vertical Position Confidence 95%
	1"= ___ ft 1:_____	____ ft ____ m		____ ft ____ m	____ ft ____ m	____ ft ____ m	____ ft ____ m
Design and Construction of New Facilities (PS&E)							
General Site Plans and Topographic Detail	40	1	1	0.4	0.3	0.7	0.7
4R Final Design - As-Constructed - Pay Quantities	500	0.25		0.13	0.10	0.22	0.20
Building or Structure Design	40	1	1	0.4	0.3	0.7	0.7
Bridges - Structures - Culverts - Walls	500	0.25		0.13	0.10	0.22	0.20
Grading and Excavation Plans	40	2	1	0.4	0.7	0.7	1.3
4R Preliminary Design - Material Source	500	0.5		0.13	0.20	0.22	0.40
Planning and Feasibility Studies							
General Location Maps	200	5	2	3.3	3.3	5.8	6.5
Hydrology - Stream X-Sections - Geomorphology	2000	2		1.02	1.02	1.76	1.99
Flood Control Studies	400	4	2	8.3	2.7	14.4	5.2
Floodplain Mapping	5000	1		0.13	0.20	4.40	1.59
Environmental Assessment	400	N/A	3	12.5	N/A	21.6	N/A
Site Reconnaissance - Wetlands - Environmental	5000			3.81		6.59	
Archeological - Route Studies							

Special Studies and Maps

Cadastral, Property, and Right-of-Way	See Section 5.4.5 for surveying procedures.
Subsurface Utility Location	See Section 5.4.5.5 and Reference ASCE Publication C-I 38-02
Bathymetric	Reference US Army Corps of Engineers Publication EM 1110-2-103

5.3.2.6 Monumentation Standards

Provide reliable and stable survey monuments as necessary to preserve critical points of control for design and construction of FLH transportation facilities. The subset of survey points established to meet this purpose is known as Primary Project Control. Locate the coordinate and elevation control monuments along transportation corridors in secure locations. Select the station site with safety considerations for the surveyors and others given highest priority. Where possible, select sites outside of the proposed improvements, and in areas not subject to probable disturbance. Monuments should be accessible to the public, preferably in a public right-of-way or easement. **Monuments must be constructed to ensure horizontal and vertical stability.** Choose the monument type to suit the local conditions and application. Refer to Appendix 5A.3.1 for physical standards for control monuments.

Document all controlling survey monuments that are either found or placed, with recovery notes describing the monument location, character, condition and accessibility. See Exhibit 5A.3-A for an example survey monument record form.

5.4 FIELD DATA COLLECTION AND PROCESSING

5.4.1 CONTROL SURVEYS

Perform control surveys to establish the following:

- Geodetic networks of primary control stations to provide a common datum for planning design and construction projects, mapping products and Geographic Information System (GIS) applications.
- Boundary control for land title and right-of-way mapping.
- Aerial control for photogrammetry used in engineering design, right-of-way analysis, environmental constraints and planning studies.

Refer to Appendix 5A.3 for specifications for performing control surveys.

5.4.1.1 Horizontal and Vertical Control

FLH standard practice for establishing geodetic horizontal control is by the use of GPS static methods. These methods establish the relative positions of control points by observing radio signals from a constellation of satellites orbiting the earth. In relative positioning, two or more GPS geodetic receivers receive signals simultaneously from the same set of satellites. These observations are processed to obtain the components of the baseline vectors between observing stations. When the coordinates for one or more stations are known, the coordinates for new points can be determined after adjusting for the systematic differences between the reference system of GPS and the local geodetic network control. Fast static or kinematic GPS methods, or precise total station traverse methods, may be used to increase density of horizontal control, or to establish control in areas inaccessible to GPS.

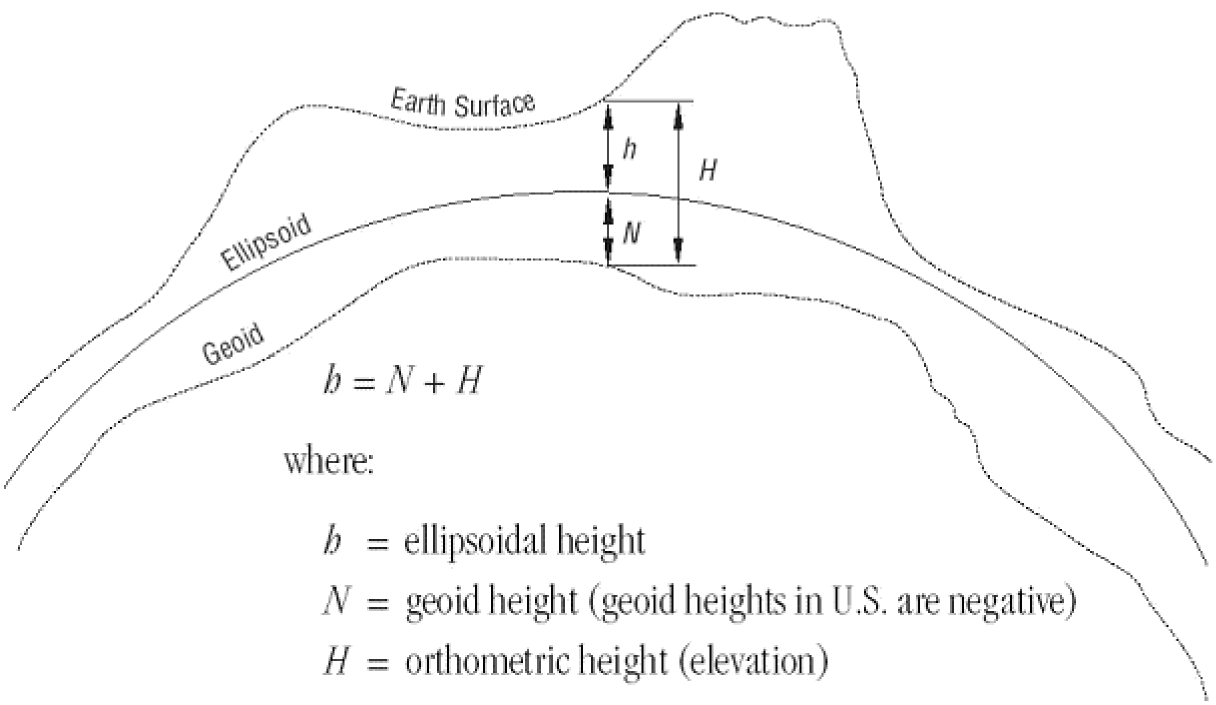
FLH standard practice for establishing geodetic vertical control is by conventional geodetic leveling. Geodetic leveling measures elevation differences observed between nearby rods. Leveling is used to extend vertical control within a project's limits. New level runs are required to tie to existing network bench marks at the beginning and end of the leveling line. These network benchmarks must have an accuracy classification equivalent to or better than the intended accuracy of the new survey. When applicable, establish a standard project vertical datum on the existing network benchmarks by GPS-derived orthometric height surveying.

Appendix 5A.2 provides a table of standard accuracy classifications of horizontal and vertical control for FLH projects. Also refer to Section 5.3.2.3 to classify the accuracy of control points and survey networks.

5.4.1.2 GPS- Derived Orthometric Heights

GPS-derived orthometric heights (elevations) are compiled from ellipsoid heights (determined by GPS observations) and modeled geoid heights (using an acceptable geoid height model for the area) using Exhibit 5.4–A.

Exhibit 5.4–A DERIVED ORTHOMETRIC HEIGHTS



Because of distortions in vertical control networks and systematic errors in geoid height models, results can be difficult to validate; however, results comparable to those obtained using differential leveling techniques are obtainable. With proper care and analysis, FLH accuracy classifications “A-E” can be achieved from GPS-derived orthometric heights. Often the cost associated with bringing a vertical datum to remote project sites by conventional geodetic leveling methods can be prohibitive. If approved by the project’s technical representative, GPS-derived orthometric heights can be used to establish the vertical datum for a project, from which conventional geodetic leveling is used to extend the vertical control throughout the project. Vertical control so established can be classified primary control accuracy Classification “A” if all other requirements are met.

5.4.1.3 Terrestrial Surveys

Terrestrial Survey methods include an electronic theodolite, electronic distance measuring instrument (EDMI) and an electronic data collecting system. The system also includes tripods, tribrachs, prisms, targets and prism poles. Terrestrial survey methods of survey include traverse, resection, multiple ties and trigonometric leveling. Typical assignments can include horizontal and vertical control, boundary ties, topographic mapping and construction layout.

5.4.1.3.1 Redundancy

When proper procedures are followed, total station surveys achieve the accuracy standards for control surveys, meeting FLH Classification "B" (see Appendix 5A.2) horizontally. The proper procedures include redundancy of observations, thereby reducing the possibility of blunders. Also, redundant angles (multiple sets and/or reversed face) are observed whenever establishing or tying existing critical points such as control points and land net points. Redundant observations (e.g., multiple ties) should be observed to improve the information available from least squares adjustments and to strengthen survey networks.

5.4.1.3.2 Survey Adjustments

All control points, meeting accuracy classifications "A-E," used for data gathering and stake out including photo control, shall be adjusted by the method of least squares.

5.4.1.4 Global Positioning System (GPS)

Where applicable, use Global Positioning System (GPS) surveying methods. The GPS methodologies used may vary in the type of equipment used, length of observation times and the computations and analysis required. GPS survey methods include, but are not limited to:

- Static GPS Surveys,
- Fast-static GPS Surveys,
- Real-time GPS Surveys (RTK), and
- Post-Processed Kinematic GPS Surveys.

GPS and other Global Navigation Satellite Systems (GNSS) surveying is an evolving technology. As GPS hardware and processing software are improved, new specifications will be developed and existing specifications will be changed. The specifications described in this section are intended to encourage application of the latest GPS methods and technologies that may be appropriate for individual projects.

5.4.1.4.1 Static GPS Surveys

Static GPS procedures allow various systematic errors to be resolved when high-accuracy positioning is required. Static procedures are used to measure baselines between stationary GPS receivers by recording data over an extended period of time during which the satellite geometry changes. GPS vectors are processed from raw GPS phase observations and the network of vectors is adjusted by least squares to compute coordinates, ellipsoid heights and elevations for the network points.

5.4.1.4.2 Fast-Static GPS Surveys

Fast-static GPS surveys are similar to static GPS surveys, but with shorter observation periods (approximately 5 to 10 min). Fast-static GPS survey procedures require more advanced equipment and data reduction techniques than static GPS methods require. Typically, fast-static GPS methods are limited to vector lengths of less than 6.2 miles [10 km].

5.4.1.4.3 Real-Time GPS Surveys (Real-Time Kinematic)

Kinematic GPS surveys make use of two or more GPS receivers. At least one receiver is set up over a known (reference) point and remains stationary, while another (rover) receiver is moved from point to point. All baselines are measured from the reference receiver to the roving receiver. Kinematic GPS surveys can be either continuous or “stop and go.” Stop-and-go station observation periods are of short duration, typically under two minutes. Real-time surveys are achieved with a radio or cellular data link between a reference receiver and the roving receiver. Measurement data from the reference receiver is transmitted to the roving receiver, enabling the rover to compute its position in real time. The distance between the reference receiver and the rover typically should not exceed 6.2 miles [10 km].

5.4.1.4.4 Post-Processed Kinematic GPS Surveys

Kinematic GPS surveying can also be conducted in a post-processed mode, where the phase observations are recorded in memory to process vectors and positions after the field work is complete. Also, modern GPS data collectors are capable of recording real-time Kinematic GPS vector data consisting of difference in position (delta X, Y and Z) and statistical information on the estimated reliability of that vector (co-variance/variance). In a post-processed mode, Kinematic GPS vectors can be adjusted in a least squares network to improve the analysis capability of establishing survey control with Kinematic GPS methods.

5.4.1.4.5 Leveling

Leveling is the surveying operation performed to:

- Determine elevations of points,
- Determine differences in elevations between points, and
- Control grades and roadway templates in construction surveys.

The traditional instrument used is a spirit level that establishes a horizontal line-of-sight by a telescope fitted with a set of cross hairs and a level bubble. Other instruments used for determining vertical distances are the transit, total station, aneroid barometer, and hand level. GPS may also provide sufficiently accurate elevations for many purposes.

When differences of elevation are determined either trigonometrically or by using a level and a rod, the effects of curvature and refraction must be considered. This is particularly true when the horizontal distances are long and when a high degree of precision is required. The curvature error results from measuring distances horizontally (flat) instead of measuring them along the arc or curvature of the earth. Refraction errors occur because the earth’s atmosphere bends light wave from the horizontal towards the earth’s surface.

The combined effects of curvature and refraction may be negated in differential leveling by balancing the length of foresights and back sights. They may also be negated by using the mean of the vertical angles looking both ahead and back when using trigonometric leveling. In situations where negating curvature and refraction is not practical, formulae for the corrections may be found in any standard surveying textbook.

Many modern automatic levels employ a laser scanning technique with a bar coded rod to observe and record differential level measurements digitally. Digital leveling has the advantage of decreased errors due to misreading the rod or manually recording the measurement, combined with improved accuracy due to the laser's ability to "read" the entire rod scale.

All differential leveling equipment must be properly maintained and regularly checked for accuracy. Systematic errors due to poorly maintained equipment must be eliminated to ensure valid survey adjustments.

5.4.1.5 Network Adjustments

After all blunders have been removed and the observation data has met the project requirements for accuracy and completeness, the FLH standard practice requires control survey observation data undergo analysis and adjustment both internally (i.e., minimally-constrained) for consistency and externally (i.e., fully-constrained) to local horizontal and vertical constraints. Least squares adjustment methods are standard practice for FLH control networks and are used to analyze and adjust all Primary Project Controls. Standard project reporting and metadata includes results from the minimally-constrained network adjustment used to quality control check the observation data and weighting strategy. The fully-constrained network adjustment, used to establish the final coordinate and elevation values is documented with a summary of final network constraints, observation residuals, variance of unit weight, and error ellipse values propagated at the 95 percent confidence level.

5.4.2 TOPOGRAPHIC SURVEYS - AERIAL

The choice of topographic survey by ground or aerial methods is determined by the needs of the project and cost considerations. Each project has a unique set of conditions that will determine which mapping techniques should be used.

Consider using photogrammetry where the needed benefits are:

- A cost-efficient surveying method for mapping large areas;
- May be safer than other surveying methods, especially in dangerous locations;
- Enables field crews to survey and map inaccessible areas;
- Creates a photographic record of the project site (referred to as a snapshot in time); and
- Produces useful digital products (e.g., orthophotos, Digital Terrain Models (DTM)).

Photogrammetry is not the best solution for all mapping situations. Photogrammetry may not be appropriate for conditions where:

- The accuracy required for a mapping project is greater than the accuracy achievable with photogrammetric methods;

- The density of vegetation is too great to provide a reasonable depiction of the ground surface;
- Conditions of light or weather preclude collection of usable photography; or
- The scope of the work is not large enough to justify the costs of surveying the photo control and performing the subsequent photogrammetric process. However, when unsafe field conditions are encountered, safety outweighs cost in the decision process.

Where applicable, utilize the following photogrammetric products:

- Stock aerial photography (existing or commercial),
- New aerial photography,
- Topographic mapping,
- Digital terrain models (DTM),
- Digital orthophotography,
- Satellite imagery, and
- Light Detection and Ranging (LiDAR).

5.4.2.1 Flight Planning

Fully define the scope of a photogrammetry project at the earliest stage possible, to minimize changes and expedite the entire process. Consider expanding the mapping limits in areas where there is some uncertainty in the needed coverage rather than potentially performing additional mapping later in the project life cycle.

The project flight plan should include specific information about the:

- Area to be mapped,
- Horizontal and vertical control datum,
- Potential safety problems,
- Plotting scale of the final mapping and/or imagery,
- The required contour interval, and
- Required photogrammetric deliverables and delivery dates.

The flight planning process should include:

- Obtaining maps depicting the location of the photo control, and
- Determining the beginning and ending of flight lines upon which aerial photography is to be obtained.

The goal of the flight planning process is to produce a flight plan that will provide the best balance between safety, accuracy and economy. This is accomplished by considering the:

- Location and amount of photo control to be set,
- Number of photographs to be obtained,
- Safety conditions of the project area, and
- Required accuracy of the photogrammetric products requested.

Exhibit 5A.4-A provides typical relationships between plotting scale, contour interval, aerial photography scale and pixel resolution.

5.4.2.2 Ground Control

The project flight plan identifies an appropriate control scheme. The necessary control scheme depends on the photogrammetric products produced and their required accuracy. Other considerations include:

- Safety factors,
- Size and shape of the area to be mapped,
- Addition of airborne positioning,
- Accuracy requirements of the photogrammetric products required,
- Terrain of the project area, and
- Accessibility to areas where the photo control is to be placed.

Marking control points with targets before the flight is the most reliable and accurate way to establish photogrammetric ground control. Survey monuments in the primary control network can also be targeted to make them photo identifiable Premark targeting produces a well-defined image in the proper location.

Ground control targets are designed to produce the best possible photo control image point.

The main elements in target design are:

- Good color contrast,
- A symmetrical target that can be centered over the control point, and
- A target size that yields a satisfactory image on the resulting photographs.

Examples of control schemes information on the purpose of each is found in Appendix 5A.3.

5.4.2.3 LiDAR Mapping

Airborne Light Detection and Ranging (LiDAR) systems are increasingly applied on FLH projects due to their highly efficient capability of collecting digital elevation model (DEM) data. LiDAR is an active sensor system that uses laser light to measure distances. When mounted in an airborne platform (fixed wing or rotary wing), this device can rapidly measure distances between the sensor on the airborne platform and points on the ground, building, tree, etc., to collect and generate densely spaced and highly accurate elevation data. In order to achieve these accuracies, LiDAR systems rely on the Global Positioning System (GPS) and an Inertial Measurement Unit (IMU) to accurately position the sensor during flight. Three measurement components make up the LiDAR system:

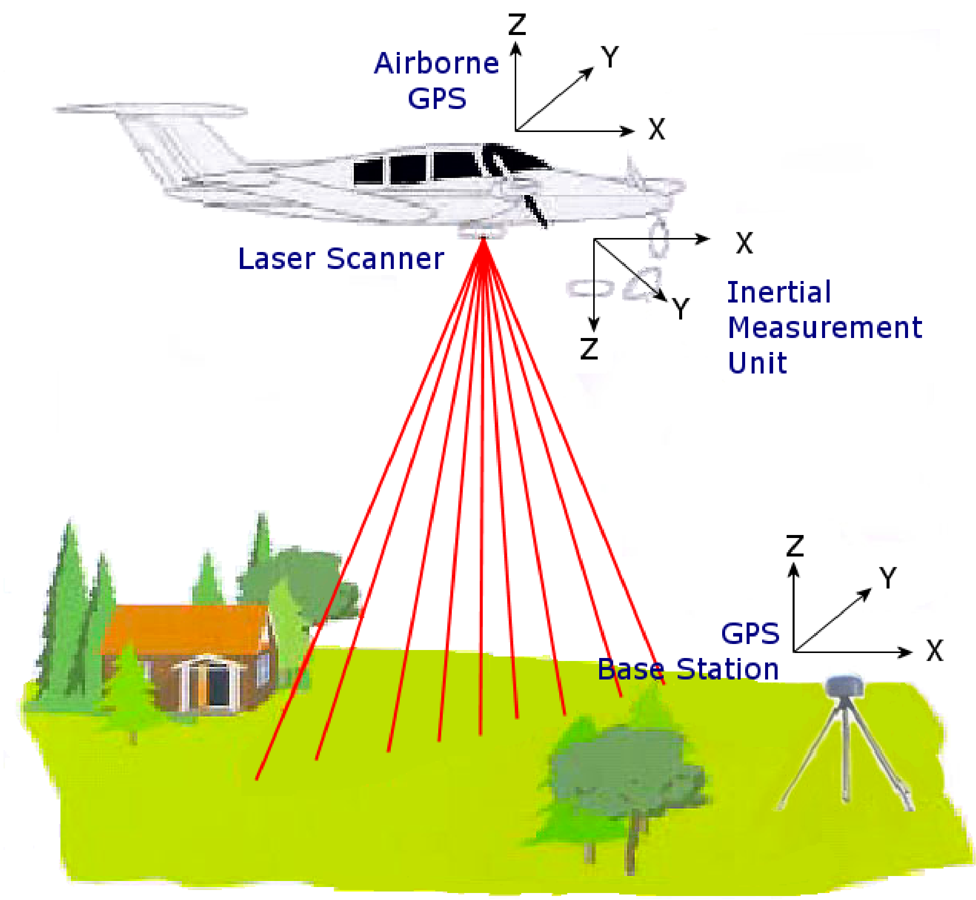
- GPS for horizontal and vertical position,
- Inertial Measurement Unit for angular attitude, and
- Laser scanner for ranging to points on the ground.

The LiDAR laser scanner is mounted in the bottom of an airplane (similar to an aerial camera) or helicopter, along with an Inertial Measurement Unit and GPS receiver and antenna. LiDAR systems record multiple returns for each laser pulse, along with the signal strength of the reflected light. The first pulse return (or 1st return) of LiDAR data measures the elevations of the canopy, building roof elevations and other unobstructed surfaces.

While in flight, the system gathers information on a massive base of scattered ground points and stores them in digital format. The Inertial Measurement Unit (IMU) records the pitch, roll and heading of the platform. Kinematic GPS provides spatial position of the aircraft. Additionally, many systems include a digital camera to capture photographic imagery of the terrain that is being scanned. Some systems have incorporated a video camera for reviewing areas collected. The raw LiDAR data are then combined with GPS positional data to georeference the data sets. Once the flight data is recorded, appropriate software processes the data that can be displayed on the computer monitor. This data can then be edited and processed to generate surface models, elevation models and contours.

Exhibit 5.4–B illustrates the LiDAR System Components.

Exhibit 5.4–B LiDAR SYSTEM COMPONENTS



LiDAR system tolerance for inclement weather conditions (e.g., high winds, wet snow, rain, fog high humidity, low cloud cover) is generally higher than that of other photogrammetric methods.

High point densities sometimes allow satisfactory data collection in areas of dense foliage where aerial photography would not produce satisfactory results. When planning missions, care must be taken regarding both natural (vegetative) and manmade (structure) ground cover. Pulse width, beam divergence, first and last pulse return discrimination, and choice of the post-processing algorithms may all affect the accuracy of LiDAR-derived data in areas of dense foliage.

Regardless of the data collection methods used (i.e., LiDAR, Aerial Photogrammetry, Ground Surveying), all topographic surveys for FLH projects are required to meet specific accuracy standards, as detailed in Section 5.3.2, with the same testing and reporting expectations.

In the following sections, considerations that are unique to LiDAR are described that should be evaluated in the project planning, data collection and testing.

5.4.2.3.1 GPS Base Stations

These active control stations must be located in the vicinity of the project site – typically within 18.6 miles [30 km] – and must be rigorously tied to the project horizontal and vertical control system. Multiple base stations are recommended to improve the confidence in a successful mission and to provide quality control processing of the kinematic GPS data.

5.4.2.3.2 System Calibration

LiDAR system optical components are subject to certain misalignments and calibration which must be accounted for in the project planning. Manufacture calibration certification and standard calibration test courses are often used to insure proper operation of the equipment.

5.4.2.3.3 Flight Planning

The LiDAR mission must be designed to cover the required project limits and mitigate potential error sources. Flying height and scan width should be planned to provide the required coverage and data posting in consideration of such factors as steep terrain and dense foliage. Multiple flight lines could be needed to provide the necessary verticality of laser pulses to successfully penetrate. Cross flights should be incorporated perpendicular to the project corridor at regular intervals for quality control purposes.

5.4.2.3.4 Inertial Measurement Data

Simultaneous solution of kinematic GPS and IMU data using advanced software processors is encouraged. The complementary nature of the two measurement systems, combined with advanced Kalman filtering algorithms provides a superior airborne position and attitude solution. Multiple high-speed on-board GPS receivers are also beginning to be used for dynamic positioning applications.

5.4.2.3.5 Data Voids

Regular posting of DEM points within the interval specified in the project plan is expected. Missing segments of data resulting from flight problems, system malfunction or ground conditions must be investigated. If warranted, ground surveying shall be conducted to fill in void areas and to verify DEM data in the surrounding areas.

5.4.2.3.6 Artifacts

Anomalous DEM points resulting from systematic errors, environmental conditions and remaining canopy points can adversely affect the quality of the resulting topographic mapping. Aerial imagery and ground truth surveying should be used to isolate and correct any artifacts in the DEM data.

5.4.2.3.7 Break Lines

LiDAR mapping by its self is unable to directly measure break lines and other linear features. Features not falling precisely at a regularly posted data point are practically invisible to LiDAR. FLH projects most often require accurate identification of edge of traveled way, flow lines and other break line features. For this reason, conventional aerial photogrammetry is often flown in conjunction with the LiDAR mission. Together the two systems are mutually supportive providing efficiency of DEM data collection with the accuracy and quality control of photogrammetry.

Though definitions in use sometimes vary, a digital elevation model (DEM) consists of a grid of regularly spaced points representing the irregular surface to be depicted. The distance between these points is referred to as the posting interval. A digital terrain model (DTM) includes mass points, as in a DEM, supplemented with three-dimensional break lines that depict linear surface features such as creeks, toe of slope or ridge lines. Topographic Mapping intended for use in design and construction of new facilities (see Exhibit 5.3–A) must be developed from a DTM including necessary break lines.

5.4.3 PHOTOGRAMMETRY

Photogrammetry is generally defined as the art and science of making accurate measurements from aerial photography. Aerial photographs, as they are initially exposed, do not allow accurate measurements. Distortions in the camera systems, combined with the curvature of the earth and irregular topography must be accounted for and eliminated. These photogrammetric processes allow the photogrammetrist to view, measure and plot three dimensions from a two-dimensional surface (aerial photograph).

5.4.3.1 Photogrammetric Processes

Photogrammetric mapping is achieved through four general processes known as:

- Imagery Acquisition (Aerial Photography),
- Ground Control Acquisition (covered in Section 5.4.2),
- Aerotriangulation and Model Set-up, and
- Digital Terrain Compilation and Planimetric Feature Compilation.

Each photogrammetric mapping project is unique. Each project is defined by spatial data collection for a unique piece of the earth with specific feature collection requirements (e.g., accuracy, feature types). The general processes listed above may involve several significant sub-processes based on the feature collection requirements for a specific project.

5.4.3.2 Aerial Photography

The success of all photogrammetric processes and the quality of the resulting products is largely dependent on the success of the aerial photography mission. The resulting photography must be checked to ensure sufficient coverage, adequate stereo overlap (lap) and image quality.

Aerial photography should be checked for image quality and correct end lap and side lap coverage between the photos. If the photography lacks adequate end lap and side lap coverage, the photography must be redone. Ideally, the end lap coverage will be 60 percent; however, end lap coverage ranging from 55 percent to 65 percent will produce adequate results. The side lap coverage percentages will vary with the photogrammetry job but most typically are planned for 40 percent over relatively flat terrain.

The photography should also be checked for stereo coverage within the project limits. It is important to have adequate stereo coverage since an object cannot be mapped if it only appears in one photograph.

Stereo coverage and end lap coverage can also be affected by the flight trajectory of the aircraft. These are most commonly manifested in either crab or drift. Crab occurs when constant corrections to the flight path cause the photos to twist with respect to one another. Drift occurs when the plane deviates from the intended flight line.

In steep terrain, the end lap coverage may need to be increased to avoid sliver shaped gaps in stereo coverage between exposures.

All aerial photographs must be checked to ensure image quality. Important aspects to inspect include:

1. **Image Motion**. Elongation of features on the photograph caused by the movement of the aircraft during exposure.
2. **Halation**. Spreading of an image beyond its proper boundaries, particularly common for bright or reflective objects.
3. **Graininess**. Large grain size resulting from poor developing techniques and decreasing the resolution of the photograph.

4. **Contrast**. Problems viewing details, especially in shadowy areas, caused by excessive or minimal density between the whitest and the blackest areas of the photograph.
5. **Hot Spots**. Bright areas of low detail caused by low sun angles.
6. **Fiducial Marks**. Marks imaged by the camera on each exposure and are used to orient photogrammetric instruments to the camera coordinate system. Fiducial marks are required for photogrammetric measurement.

5.4.3.3 Aerotriangulation

The process of adjusting the aerial photography to the earth is critical to the accuracy of final mapping products. Most projects are adjusted using aerotriangulation methods, which require fewer ground control points than other conventional adjustment methods.

Refer to Appendix 5A.5 for additional guidelines for analytical aerial triangulation.

5.4.3.3.1 Aerotriangulation Principles

Aerotriangulation is the simultaneous space resection and space intersection of image rays recorded by an aerial mapping camera. Image rays projected from two or more overlapping photographs intersect at the common ground points to define the three-dimensional space (3-D) coordinates of each point. The entire assembly of image rays is fit to known ground control points in an adjustment process. Thus, when the adjustment is complete, ground coordinates of unknown ground points and the precise orientation of each photographic image are determined by the intersection of adjusted image rays.

Aerotriangulation is essentially an interpolation tool, capable of extending control points to areas between ground survey control points using several contiguous uncontrolled stereo models. An aerotriangulation solution should never be extended or cantilevered beyond the ground control. Ground control should be located at the ends of single strips and along the perimeter of block configurations. Within a strip or block, ground control is added at intervals of several stereo models to limit error propagation in the adjusted pass point coordinates. Extending control by aerotriangulation methods is often referred to as bridging since the spatial image ray triangulation spans the gap between ground control.

5.4.3.3.2 Softcopy Methods

Aerotriangulation procedures that involve softcopy workstations must include fully analytical aerotriangulation software and high-resolution scanners. Diapositives are not required and all interior, exterior and control point mensuration are read from the scanned images. The elimination of diapositives eliminates the need to identify and drill mark the points for mensuration.

Softcopy aerotriangulation must follow procedures and use equipment that will enable the operator the ability to ascertain feature resolution at a level that will achieve the aerotriangulation accuracy required. A major advantage of softcopy aerotriangulation is that the software is generally interactive and thus provides excellent quality control. The results of point selection, measurements and weighting are shown to the operator immediately.

5.4.3.3.3 Aerotriangulation Adjustment

Measured positions of the photo control and the analytical points are processed in an independent unconstrained adjustment to determine if there are any problems with the photo mensuration.

Concerns with respect to the aerotriangulation measurements of the photo control and the analytic points should be resolved. Verified values of the photo control are applied in order to perform a constrained adjustment.

To complete the aerotriangulation process, the position and attitude, or tilt, of the aircraft at each exposure (or exposure station) is determined in the Aerotriangulation Solution by resecting the position from the known photo control. The values of the unknown analytic points are then determined by performing an intersection from two or more exposure stations through the analytic points to the ground.

5.4.3.4 Digital Terrain Compilation

Photogrammetric mapping generally considers topography compilation to include contours (lines of equal elevation), high and low points and lines defining abrupt changes in elevation break lines. The process of creating topographic data is typically done by generating mass points and break lines that, if desired, may be processed through software to generate contour lines. Direct digitizing of contours from the stereo model is occasionally used on FLH projects. The process chosen for topography compilation should be based on available compilation equipment, contour interval required, character of the area that is being mapped, available time and funding budget. Generally, terrain model development and processing are used for contour generation.

Digital Terrain Model surfaces compiled for FLH projects are expected to meet the accuracy classifications described in Section 5.3.2.3. Mass points and break lines must be collected from the stereo model, in sufficient detail and accuracy to ensure the required accuracy. The limiting Root Mean Square Error (RMSE) allowable under ASPRS Class 1 Standards is 1/3 the indicated contour interval. Spot elevations are restricted to an RMSE of 1/6 the contour interval. Regions of the project that cannot meet this accuracy requirement are required to be distinctly separated in the DTM surface and contour data files.

Additional guidelines and specifications for photogrammetric mapping are contained in Appendix 5A.4. Refer to Division Supplements for CADD file formats.

5.4.4 TOPOGRAPHIC SURVEYS - TERRESTRIAL

When applicable, perform topographic surveys using terrestrial methods to establish the following:

- Surface and subsurface features used in engineering design, right-of-way analysis, environmental constraints and planning studies;
- Areas that are not appropriate to aerial photogrammetric, LiDAR, or ground GPS surveys;
- Critical design areas;
- Floodplain mapping; and
- Bridge site and tributary mapping.

Refer to Appendix 5A.6 for additional guidelines for ground topography and planimetry.

5.4.4.1 Terrain Surface Depiction

Terrestrial survey methods for completing a topographic survey require the field collection of enough ground surface information to prepare a Digital Terrain Model (DTM). The use of the topographic survey will determine the appropriate amount of critical data collection. The limits of the survey will need to extend beyond the design area to complete the DTM.

A DTM is a representation of the surface of the earth using a Triangulated Irregular Network (TIN). The TIN models the surface with a series of triangular planes. Each of the vertices of an individual triangle is a coordinated (x, y, z) topographic data point. The triangles are formed from the data points by a computer program that creates a seamless, triangulated surface without gaps or overlaps between triangles. Triangles are created so that their sides do not cross breaklines. Triangles on each side of breaklines have common sides along the breakline.

Provide breaklines to define the points where slopes change in grade (the intersection of two planes). Examples of breaklines are the:

- Crown-of-pavement,
- Edge-of-pavement,
- Edge-of-shoulder,
- Flow line,
- Top-of-curb,
- Back-of-sidewalk,
- Toe-of-slope,
- Top-of-cut, and
- Top-of-bank.

Breaklines within existing highway rights-of-way should be clearly defined, while breaklines on natural ground may more difficult to determine.

DTMs are created by locating topographic data points that define breaklines and random spot elevation points. The data points are collected at random intervals along longitudinal break lines with observations spaced sufficiently close together to accurately define the profile of the breakline. Like contours, break lines do not cross themselves or other break lines. Cross-sections can be generated from the finished DTM for any given alignment.

When creating field-generated DTMs, gather data points along DTM breaklines and randomly at spot elevation points, using the total station survey methods. This method is called a DTM breakline survey. The number of breaklines actually surveyed can be reduced for objects of a constant shape (e.g., curbs). To do this, a standard cross section is sketched and made part of the field notes. Field-collected breaklines are identified by line numbers and noted on the sketch. With this information in the field notes, only selected breaklines need to be located in the field, while others are generated in the office based on the standard cross section.

Exercise skill to visualize in the field the TIN that must be created to accurately model the ground surface and where breaklines are needed to control placement of triangles. The following standard practices apply:

- Use proper feature codes, point numbering and line numbers;
- If ground around trees is uniform, tree locations may be used as DTM data points;
- Keep site distances to a length that will ensure that data point elevations meet desired accuracies; and
- Gather one extra line of terrain points 15 ft to 30 ft [5 m to 10 m] outside the work limits

5.4.4.2 Feature Location and Attributes

Terrestrial surveys for topographic mapping require a standard feature code format. Each FLH Division has developed standard survey feature code libraries for the common topographic survey assignments. Documentation of the feature code library, whether for standard FLH codes or for other codes, is required for every topographic mapping project. For all topographic data points collected assign a code relating to the feature being defined. Whenever possible, collect an elevation at the ground level for features with a vertical component so that the location can be used to compute the DTM. The horizontal component should be the center of the feature. For example, a power pole is recorded in the field data collector with a ground elevation of the power pole and then the center of the pole is then collected to obtain the horizontal location. The size, type, height, depth, width and other descriptive information is collected as an attribute along with the feature code.

5.4.4.3 Floodplain Mapping

Field surveying for floodplain mapping is uniquely different from topographic design surveys in that the data collected is not necessarily intended to describe a continuous DTM surface. Survey cross-sections are typically requested by hydraulic engineering in selected locations so as to depict the volumetric capacity of the flood valley. The following guidelines identify some of the typical requirements for floodplain mapping surveys:

- Proposed road alignments in parallel with adjacent rivers and their floodplains should have stream cross-sections taken every 500 ft to 1000 ft [150 m to 300 m]. Take a minimum of three stream cross-sections per location.
- Cross-sections must include the full width of the flood valley.
- Cross-section survey points are required at significant breaks in the ground line. The highest density of survey points will probably lie in the flow channels. Floodplain data points should emphasize the general slope of the plain and its width. For hydraulic purposes, a river's floodplain is defined using the 100-year flood event.
- Survey data is also required to define the edge-of-water, high-water marks, change in vegetation (tree lines), high points on gravel bars, top and bottom of channel banks, the stream thalweg (low point in the flow channels), and any other significant physical features (e.g., buildings). This information is useful in developing a comprehensive planimetric map of the area.
- Aerial photographs of the road and any adjacent rivers are often the best way to provide a complete depiction of the floodplain valley. A plan scale of 1:6000 [1:5000] should suffice in most cases. In some instances, a controlled aerial survey may prove more economical in getting flood plain survey data, particularly when aerial photogrammetry is being conducted as part of the roadway design. Consult with hydraulic engineering specialists in these instances to determine the limits of coverage desired.

5.4.4.4 Bridge Site and Tributary Surveys

The mainstream channel may influence bridges that cross its tributaries. In these situations, survey crews should take at least three river cross-sections on the main channel just downstream of the tributary confluence. Upstream of the tributary confluence, survey crews should take at least two river cross-sections on the main channel.

1. **Culverts**. Survey data collection should include the pipe length, the pipe inlet, the pipe condition and outlet elevations and the pipe area dimensions (e.g., diameter, span and rise) on all culverts within the project limits. For culverts crossing perennial streams, collect this data plus stream cross-sections 100 ft [30 m] upstream and 100 ft [30 m] downstream from the culvert inlet and outlet, taking cross-sections at 25 ft [10 m] intervals. Consult with the hydraulic engineering specialist to determine the preferred location and number of cross sections required for a specific project.
2. **Bridges**. Survey data collection should include stream cross-sections 500 ft [150 m] upstream and 500 ft [150 m] downstream of the proposed bridge site, taking cross-sections at 100 ft [30 m] intervals. Collect at least one section at the proposed bridge site, preferably two (e.g., upstream face, downstream face).

5.4.4.5 Subsurface Utility Location

Positive locations of all underground utilities are accomplished in accordance with the American Society of Civil Engineers (ASCE) National Consensus Standard titled ASCE C-I 38-02, Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data. Field surveying is required for Quality Levels C, B and A of the standards. Positive identification can be accomplished from visible above-ground features and as-built plans by electromagnetic detection instruments, potholing, probe or other acceptable methods. Combinations of methods may be more effective than a single method. The determinations of the proper methods are based specifically on identifying the type of facility being located and the accuracy needs of the horizontal and vertical position. These determinations are made through coordination with the design team and in accordance with the required Quality Level identified.

5.4.4.6 Railroad-Highway Grade Crossings

Coordinate with the railroad to obtain necessary safety and permit information.

Within the roadway corridor, survey and map each railroad structure and record the type of structure, the opening length and other information for comparison with railroad mapping. Tie railroad utilities or other utility poles and any facilities located on the railroad right-of-way. Show all utility poles and vertical clearance of utility lines at grade crossings.

When the project involves raising or lowering a railroad track, obtain the following data:

- Railroad alignment data (all tracks),
- All features along the centerline of railroad tracks through the entire area affected,
- Elevation of the roadway features along the highway, and
- Profile of each rail (top) for 500 ft [150 m] each side of highway centerline.

Refer to Section 9.3.15 for highway design considerations and requirements that need to be addressed by the survey and mapping activities.

5.4.4.7 Data Processing/Map Compilation

Data processing includes preparing and checking survey products. Supplemental control established during the topographic survey must be adjusted to fit the existing project control before calculating coordinates for topographic data points. The adjusted control is then used to compute three-dimensional coordinates for the data points. The adjusted coordinates are then edited for coding problems and then a draft DTM is prepared.

The draft DTM is reviewed for quality with check shots. Errors in field procedures and in the original collection files are identified and corrected. Potential sources of error are height-of-instrument, rod height, prism offset, improper labeling of breaklines and instrument or backsight occupation number mislabeling. The revised collector files are then rerun and a new draft contour map is created. This map should be reviewed for proper density of collected points, limits of survey and flow lines of pipes used in the DTM.

Final field verification of the topographic survey, if possible, is a valuable tool in confirming the quality of the survey before delivering it to the designer. Aerial photography, digital ground photos and/or video segments should be used to enhance the descriptive ability of the field survey and for quality review when field verification is not possible.

Additional guidelines and specifications for topographic surveys by ground methods are found in Appendix 5A.6.

5.4.5 RIGHT-OF-WAY AND CADASTRAL SURVEYS

Right-of-way and cadastral surveys are performed to gather data on existing property lines corners and monuments for use in conjunction with existing records and right-of-way requirements to determine, delineate, appraise, acquire, monument and map rights-of-way, in support of due process for appraisal and acquisition.

Cadastral surveying in support of right-of-way mapping is uniquely different from land surveying for boundary determination. The land net developed for right-of-way mapping must be sufficiently resolved to identify partial and whole land parcels impacted by the real property requirements for the transportation improvement project. Resolution of the land lines must be accurate enough to support appraisal, preparation of legal descriptions and acquisition of the necessary real property. Typically, record boundary information that is tied to some of the controlling land net corners is sufficient to fulfill these purposes. In certain circumstances (e.g., very high land values, close design tolerances, ambiguous land tenure, boundary conflicts), complete boundary determination survey of some or all affected parcels may be necessary.

5.4.5.1 Records Research

Thorough research of relevant land and survey records forms the foundation of a right-of-way and cadastral survey. Overall survey efficiency and quality of deliverables will be determined, in part, by the quality of the research. During the project planning phase, the overall scope of the project and specific project requirements will be determined. The project scoping and preliminary engineering planning is described in Section 4.3.2.

The record data search is the first action taken in the monument recovery process and provides the necessary survey and land ownership data required for the field survey and for analysis and mapping of the recovered land-net information. The goals of the record data search are:

- Identify ownership and existing rights,
- Identify controlling land net information, and
- Assemble all other information necessary for the right-of-way or cadastral survey.

Land and survey records are available in Government agencies, utility companies, title companies and other public/private entities. Research for a right-of-way and cadastral survey should be included within the research and planning for the overall transportation improvement project.

Typical sources of land survey records include:

- United State Geologic Survey (USGS) map sales – quad maps, county series and electronic Digital Ortho Quarter Quads (DOQQ) and Digital Raster Graphs (DRG);

- BLM State Office – master title plats, historical index, utility and road easements, GCDB, cadastral plats, mineral surveys, HES, field notes;
- US Forest Service, Regional Office – maps, plats, easements, special use permits;
- Forest Supervisor – maps, easements, special use permits, monument records;
- County Offices, Public Works, Recorder – tax assessor maps, index of owner/address, survey records, plats, monument records, as-builts, deeds, existing right-of-way;
- Court Records;
- Title Search;
- State Records – as-builts, State right-of-way plans and documents, land board records;
- Utilities;
- Railroads;
- Land Owners – plats, deeds; and
- Private Surveyors – plats.

5.4.5.2 Monument Recovery and Survey

The right-of-way and cadastral survey fieldwork will be coordinated with other transportation improvement project surveying activities. The right-of-way and cadastral fieldwork activities include:

- Cadastral monument research and recovery;
- Locating cadastral monuments, both record and non-record; and
- Locating physical features that may affect title (e.g., fences, roads, buildings).

Other survey activities include:

- Recovering and/or setting the project control,
- Performing photogrammetry control surveys,
- Performing topographic surveys, and
- Performing construction surveys.

The practical advantage of coordinating all transportation improvement project activities is to save time by reducing the number of trips to the field and to allow for a simultaneous adjustment of the survey data. Timing right-of-way and cadastral survey fieldwork to occur early in the process and synchronizing it with other transportation improvement project survey activities also allows for the early referencing of project control, land-net corners and lines of basic importance to ensure their perpetuation.

5.4.5.3 Right-of-Way Survey Field Notes

Field notes are a combination of electronically recorded measurement data and hand-written or computer generated notes that together represent an accurate, clear, complete and concise record of everything that occurred during the course of the right-of-way survey. The final quality of all record maps and documents depends on the quality of the information and data contained in these notes. Survey field notes are of such vital importance that they are at times called into review by courts. Field notes should include all evidence even if it may disagree with record data, a recovered monument, or with an analysis of its location.

5.4.5.4 Boundary Mapping and Data Compilation

Boundary mapping for right-of-way purposes begins with the collection and analysis of real property records and evidence necessary to develop the property lines, existing rights-of-way and easements that make up the land tenure within the project area. This base map of existing real property rights is known as the boundary compilation, and as noted earlier in this section, must be developed to a sufficient level of accuracy to support due process for right-of-way appraisal and acquisition. Boundary mapping continues through identification of necessary parcels for acquisition (i.e., fee simple title, deed restrictions, permanent easements, temporary construction easements) and the preparation and delivery of maps, descriptions and acquisition documents. Development of right-of-way documents for appraisal and acquisition is covered in Chapter 12.

5.4.5.5 Compile Title Search and Field Survey Data

The boundary compilation base file is compiled in the coordinate system and datum consistent with the horizontal control established for the project. This often requires that record boundary data be scaled to conform to grid distances (see Section 5.3.1 for information on horizontal coordinate systems). The final boundary compilation base file consists of a vector map in Computer Aided Design and Drafting (CADD) format. The boundary compilation includes a combination of field evidence, title information and surveying judgment to provide the user with a clear understanding of the data being depicted. Ambiguous or disputed boundaries need to be depicted and described so the acquiring agency can resolve these disputes and facilitate the acquisition process.

The final boundary compilation must provide an accurate portrayal of property lines, ownership, existing rights-of-way and other rights or interests that may be impacted by the project. The map will be used to determine the parcels necessary for right-of-way acquisition for the project and compensation due to the landowners. Adhere to applicable State statutes, professional standards and FLH standards and specifications in the development of this compilation and subsequent right-of-way plans and legal descriptions.

5.5 FINAL DESIGN SURVEYS

Before progressing to final design levels (e.g., 50 percent, 70 percent, 95 percent and 100 percent milestones), terrain verification and design location surveys may be necessary to ensure that the proposed design conforms to actual field conditions, and that critical tie-in points are known to a sufficient level of accuracy. Typical final design survey tasks include:

- Aerial topography check profiles,
- Ground truth field topography,
- Design centerline location,
- Reference hub or slope staking,
- Proposed right-of-way or utility location,
- Cross-section surveys, and
- Existing pavement and bridge grid grades.

As discussed in Section 5.3.2.2 and Section 5.4.3.3, all topographic mapping is tested by comparing mapped locations of selected well-defined points to their "true" location as determined by a method known to produce more accurate results. Field surveyed profiles, well distributed throughout the photogrammetric flight plan, are used for testing aerial topography compiled for concept studies and preliminary engineering. Check profile surveys are usually completed in conjunction with ground control surveying and the comparisons completed immediately following compilation. Following the preliminary (30 percent) design phase, additional ground truth topographic or planimetric survey tasks may be necessary to support final roadway design. For low-risk projects in generally flat and open areas, original ground check profiles along the proposed design centerline may be sufficient to facilitate the final design effort to proceed. Carefully review the site conditions, which will often reveal areas requiring additional attention. Areas of limited visibility from trees or brush may require additional field surveys to establish accurate topographic data. Areas where field topographic data is collected should be compiled and edited or merged into the original topographic surface so that the project topographic base file always reflects the most reliable data. Section 5.4.4 provides direction on how to conduct field topographic surveys.

Critical design features (e.g., existing drainage improvements, streams, tree-save areas and utilities) are often not identified as critical until after preliminary designs are complete. For these and similar issues, ground truth field topography of selected areas and features is frequently required. Comprehensive staking and cross-section surveys may be required in places where the final engineering has greater risk due to steep terrain, heavy tree cover or unsatisfactory ground truth found early in the project.

5.5.1 REFERENCE HUB STAKING

When required, set hubs and accompanying stakes to reference the preliminary design catch points for slope construction, either through slope staking methods, or at the fixed design distance from the roadway alignment. Define standard offsets from reference hubs to cut and fill slope catches and collect cross-section elevations between the reference hubs. Exercise care to ensure that cross-section points accurately depict the relief along the existing terrain line. This requires that all points of relief (e.g., toe-of-slope, flow line, crown) be collected, and that the cross-section be taken very closely in line to the design station. The cross-sections are used to develop or validate the final design independent of the original base topography. For this reason, cross-section data is not merged into the topographic base file.

At times, reference hubs, or reference stakes, or centerline staking, or combination thereof, is also required for some or all of a roadway alignment to facilitate site inspections or other engineering studies (e.g., geotechnical work). Cross-section surveys are not typically completed for these situations.

5.5.2 PAVEMENT AND BRIDGE GRID GRADES

On occasion, critical design elements are encountered that require extensive field survey efforts to depict existing conditions in sufficient detail. Highly detailed surveys for pavement design and bridges and drainage structures are more often encountered in urban roadway projects where matching proposed design grade lines with existing improvements become critical. Pavement and bridge design can impose some of the highest accuracy requirements for topographic mapping. Before beginning such detailed survey field work, closely coordinate with the design engineer to ensure a clear understanding of the required work and a well crafted work plan. The work plan should include sketches showing the features to be located and a written description of the required grade point interval and necessary mapping accuracy.

5.6 RECORDS AND REPORTS

5.6.1 PURPOSE

Document the surveying and mapping data, and maintain accurate project records in the form of field notes; correspondence, metadata and reports as an essential activity to provide the context, documentation and conclusions. Carefully prepare records and provide information to users at all stages of a project such that the resulting data is properly applied, questions can be resolved and decisions can be efficiently made. Regardless of the reporting format (e.g., digital files, hand drawn notes, illustrations, written reports), the goal of project reporting is to effectively communicate the necessary facts to a potentially unfamiliar user to correctly interpret and apply the surveying and mapping data.

Provide a project control report for all project control surveys. Refer to applicable Division Supplements for the report content and format.

5.6.2 METADATA STANDARDS

Metadata is descriptive information about the content, quality, condition and other characteristics of data. Formal Content Standards for Geospatial Metadata have been developed and adopted by the Federal Geographic Data Committee (FGDC). As a geospatial content provider, FLH is expected to comply with the guidelines and standards endorsed by FGDC. Metadata is contained in a standard digital file format (Text, HTML, XML) using some or all of the structured data tags included in the content standards. Metadata does not eliminate the need to complete and archive other project records; however, the metadata file should be diligently completed, and should answer the following questions related to surveying and mapping tasks:

1. What does the data set describe?
2. Who produced the data set?
3. Why was the data set created?
4. How was the data set created?
5. How reliable are the data and what problems remain in the data set?
6. How can someone get a copy of the data set?
7. Who wrote the metadata?

Appendix 5A.7 is an example metadata file, using a reduced set of data tags, applicable to typical FLH surveying and mapping projects.

5.6.3 ELEMENTS OF SURVEY FIELD NOTES

Whenever possible, apply electronic data collection methods that provide an efficient automated process for collecting and recording raw and processed survey measurements. Use electronic data collection to maintain the accuracy and consistency of survey measurement records. Carefully record electronic data in the field, using a well-understood process including standard point numbers and feature codes, such that the transfer of digital field data from the field survey to a finished map can be a seamless, nearly hands-free process.

Refer to applicable Division Supplements for the content and format of electronic data and manually recorded survey field notes and reports.

Chapter 5 – SURVEYING AND MAPPING

LIST OF APPENDICES

LIST OF APPENDIX EXHIBITS

5A.1 CODE OF SAFE SURVEYING PRACTICE

Surveyors and field engineers face unique hazards, namely site conditions and logistics, which must be afforded proper consideration to ensure health and safety of employees, consultants, contractors and visitors. The following Code of Safe Surveying Practice was developed to summarize health and safety policies uniquely pertinent to surveying and field engineering work:

1. **Distribution**. All surveyors and field engineers, including employees, consultants and contractors, shall have ready access to this Code.

2. **Philosophy**. No project is so important or urgent enough to warrant compromising safe field practices.

3. **Responsibilities**. The following describes the responsibilities that apply to individuals and supervisors:

   a. *Individuals*. All field personnel shall have a practical working knowledge of this Code and the health and safety policies and practices of FLHO. Individuals are responsible for:

      - Doing everything reasonably necessary to protect life, safety and the health of themselves, other field personnel and the public.
      - Complying with all occupational safety and health policies, procedures, laws, rules and regulations.
      - Promptly reporting injuries, illness, accidents and unsafe conditions, tools and equipment, to their supervisor or the lead worker in charge.
      - Reporting to work mentally and physically able to perform all their assigned duties without jeopardizing the health and safety of themselves, other personnel, consultants, contractors or the public.

   b. *Supervisors*. Supervisors or lead workers in charge are responsible for:

      - Monitoring safety conditions and employee performance.
      - Instructing employees about safety policies and practices affecting them.
      - Prohibiting employees from working either when they appear to be unable to perform their duties or if there is concern about their or others' health and/or safety.

4. **Planning for Safety**. Safety shall be given top priority in planning all surveys and field engineering assignments. Factors considered when planning an assignment shall include:

   a. Scheduling work for the safest time of day.

   b. Assigning the optimum number of personnel to accomplish the assignment safely.

   c. Assigning specially trained and qualified personnel to the more hazardous jobs.

   d. Using methods that minimize exposure of personnel to hazardous conditions.

e. Ensuring access to, and sufficiency of, specialized tools and equipment necessary to conduct the assignment safely.

5. **Personal Protective Equipment**. Each employee must provide and wear clothing and footwear that will provide adequate protection for the assigned task, including as required or directed:

   a. Necessary clothing, hat, gloves and boots to adequately protect against the outdoor elements (e.g., heat, cold, rain, snow, rugged terrain, construction hazards).

   b. Orange or strong yellow-green vests, shirts or other highly visible garments when exposed to vehicular or equipment traffic.

   c. Hard hats and eye protection while exposed to vehicular and equipment traffic, falling or flying material and other similar hazards.

   d. Earplugs or muffs must be worn when working around noise levels that may cause injury or hearing loss.

   e. Other special safety equipment (e.g., chaps, climbing gear, boot covers).

6. **Personal Health**. Every employee must take precautions to avoid dehydration during strenuous outdoor activity by drinking sufficient fluids and electrolyte replacement drinks throughout the workday and by carrying water while working for long periods in remote locations.

   Additionally, each employee must have proper food, nutrition, lunch, etc.

   It is important that every employee be in fit physical condition before performing work, especially strenuous activity.

7. **Safety Meetings**. Special attention shall be given to matters of health and safety at the project initiation meeting conducted at the start of the project. A project safety briefing will be prepared including, as a minimum:

   - Points of contact for reporting purposes.
   - Phone numbers and locations of emergency medical support resources.
   - Any special considerations related to the particular project.

   Tailgate safety meetings shall be held at least once every ten working days. Hold safety meetings as applicable to prepare for imminent and especially potent hazards, such as:

   - Poisonous plants,
   - Snakes,
   - Insects,
   - Animal hazards,
   - Mountainous terrain,
   - High fire hazard areas,
   - Traffic,
   - Heavy equipment,
   - Water exposure, and
   - Temperature extremes.

8. **Vehicular Traffic**. Work, no matter how short the duration, must not be performed on or adjacent to traveled roadways without instituting proper protective measures to protect other drivers and pedestrians. These measures include using appropriate signs, flaggers, lookouts and/or lane closures, as required to work safely.

9. **Tools and Equipment**. Only the proper tool, in the proper condition, should be used for each job. Equipment should not be operated unless the employee is familiar with its use and convinced it is functioning properly.

10. **First-Aid Requirements**. At least one member of each field survey team shall have received first-aid training and possess a current certification. Each survey team vehicle shall be equipped with a standard first-aid kit, *Red Cross Manual* and a fire extinguisher.

11. **Vehicle Operation**. Every field survey team member shall have a current driver's license. Each driver must drive defensively and observe all applicable traffic laws. Every survey team vehicle shall have a current certificate of liability insurance.

12. **Operational Precautions**. Each field survey team member shall observe operational precautions by:

    - Not entering ditches, trenches or confined spaces until you are certain it is safe to do so.
    - Suspending operations when unsafe conditions or uncontrollable hazards develop; and resuming work only when safe conditions have been restored.
    - Check with others about safe procedures when working in an unfamiliar environment.
    - Using particular caution when working at night.
    - Wearing reflective clothing when working near equipment or traffic during hours of darkness.

5A.2 STANDARDS FOR CONTROL SURVEY ACCURACY CLASSIFICATION

Exhibit 5A.2–A STANDARDS FOR CONTROL SURVEY ACCURACY CLASSIFICATION

Accuracy Standards by Type of Survey

FLH Class	PT Series	Type of Survey	95% Probability Circle*
A	2000	GPS	0.06 ft [0.020 m]
B	3000 5000	Primary (Terrestrial or GPS)	0.10 ft [0.030 m]
C	4000	Secondary (A Lines) (Terrestrial or GPS)	0.25 ft [0.080 m]
D	6000	Cadastral (Terrestrial or GPS)	0.25 ft [0.080 m]
E	8000	Wing Points (Terrestrial or GPS)	0.30 ft [0.100 m]

Notes:

1. *The semi-major axis of the error ellipse may be substituted and noted.*
2. *Exceptions to these standards must be noted in the control report.*

GPS Only Standards

Local Accuracy (95% Probability Circle)	Network Accuracy (95% Probability)	GPS Orthometric Heights (95% Probability Circle)
0.06 ft [0.02 m]	0.10 ft [0.03 m]	0.30 ft [0.1 m]

Vertical Accuracy Standards

FLH Class	Type of Survey	Accuracy
A	Primary Control Network (Differential leveling)	0.05 ft/√Mi [0.008 m/√K]
B	Secondary Control (A Lines) (Differential leveling, trigonometric leveling)	0.06 ft [0.020 m]
C	Wing Points (Differential leveling, trigonometric leveling, GPS observations)	0.30 ft [0.1 m]

5A.3 SPECIFICATIONS FOR CONTROL SURVEYS

Exhibit 5A.3–A provides a sample Survey Monument Record.

5A.3.1 PHYSICAL STANDARDS FOR CONTROL MONUMENTS

1. Primary Control and Supplemental Control Monuments shall be set no more than 1,450 ft [450 m] apart and shall be inter-visible with at least two other control points. Monuments shall be set flush with natural ground or approximately 0.2 ft [5 cm] below the existing road surface. Monuments shall be placed outside of the proposed construction limits.
2. Monuments shall be constructed and set in the ground such that the monument can be reasonably anticipated to remain stable horizontally and vertically for a minimum of 10 years. The monuments shall have durable markings that identify the monument uniquely and unambiguously.
3. Type III Monument (Class D) shall meet the standards set forth by State statute in the state which the project is located.
4. A 2½ in x 4 ft [63 mm x 1.2 m] brown fiberglass marker post, Carsonite Pattern No. 7092-SM or equivalent, shall be placed at each control point and be marked with decals of the control point number.

5A.3.2 GPS CONTROL POINTS ESTABLISHED BY ANY METHOD (STATIC OR RTK)

A minimum of two occupations is required with a significantly different constellation required for the second observations (minimum of two hours).

5A.3.3 TERRESTRIAL TRAVERSE FOR PRIMARY CONTROL (3000 SERIES)

1. Multiple pointings: 3D 3R, rejection limit 6 sec from mean; positional tolerance = 0.01 ft [3 mm] (e.g., 0.01 ft/200 ft [3 mm/60 m] = 10 sec).
2. 10 to 12 stations between azimuth checks (GPS pairs or known azimuth).
3. Azimuth closure = 3 sec/N (N = number of stations).
4. Reciprocal zenith angles: 3D 3R, rejection limit = 10 from mean.
5. Positional tolerance = 0.2 ft /Mi (Mi = distance in miles) [0.04 m /K (K = distance in kilometers)]
6. Recommend maximum distance between primary control NTE 1450 ft [450 m].
7. Traverse must be closed on a point other than the beginning point.
8. Length standard errors not to exceed 30 ppm.

5A.3.4 TERRESTRIAL TRAVERSE FOR SECONDARY MAPPING CONTROL (4000 SERIES)

1. Multiple pointings – 2D 2R, rejection limit 8 sec from mean; positional tolerance = 0.015 ft [5 mm].
2. 20 stations maximum between primary control checks.
3. Distances measured forward and back; reciprocal zeniths.
4. Zenith Angles: 1D 1R.
5. Positional tolerance = 0.26 sft [0.080 m]
6. Traverse must be closed on a point other than the beginning point.

5A.3.5 TERRESTRIAL TRAVERSE FOR WING POINTS

1. Multiple pointings: 1D 1R, rejection limit 5 sec from the mean.
2. Distances measured forward and back; reciprocal zeniths.
3. Open traverse, no geometric redundancy.
4. The photogrammetrist checks the accuracy of the points.

5A.3.6 TERRESTRIAL LEVELS

1. Electronic levels.
2. Positional tolerance = 0.033 ft * the square root of the length of the circuit in miles [0.008 m *the square root of the length of the circuit in kilometers].
3. Always closed on know point (previously established elevation) of equal or higher standards and specifications. A terrestrial traverse is not closed under this definition unless an angular closure can be computed from the field data.

5A.3.7 CADASTRAL OR RIGHT-OF-WAY TIES

1. ALTA Standards (Rural surveys adopted 1997).
2. Cadastral ties can be made from A, B, or C class points.
3. RTK methods can be utilized for cadastral ties.
   - Two sessions at least ten minutes long, at least two hours apart.
   - The antenna shall be supported by either a bipod or tripod.

5A.3.8 NOTES ON SPECIFICATIONS

1. Instruments shall be calibrated before and after the project at a NGS/NOA5A-approved calibration course using the methods specified by NGS in a publication titled "Use of Calibration Base Lines." Also, see calibration baseline locations.
2. The Firm shall pay the cost of calibration.
3. Instruments shall be adjusted to compensate for atmospheric conditions (PPM). Many FLHD projects are at high elevations. Barometric pressures need to be verified and PPM corrections made without adjusting the pressure to sea level.
4. "Primary Control", refers to reasonably permanent monumentation that is coordinated to provide the basis for all surveying, mapping and construction operations for a particular project.
5. "Secondary Control", refers to monumentation that has been coordinated to serve a particular short term surveying application.
6. "Wing Points", refer to aerial targets that are coordinated to provide control for photogrammetric mapping.
7. "D", means direct reading with terrestrial instrument in the direct position.
8. "R", means reverse reading with the terrestrial instrument in the inverted position.
9. "Multiple pointings", means the number of times a reading is taken with the instrument cross hairs centered on a target centered on a remote point.
10. "Positional tolerance", with respect to angular observations means a trigonometric computation of the linear uncertainty based on the product of the sine (or the tangent) of the angular discrepancy and the length of the measured line.
11. "Azimuth check" means comparing a computed azimuth based on field observations to a reliable known azimuth derived independently from equal or higher standard and specifications than the current survey.
12. "Traverse must be closed", means that coordinate calculations can be made for each point and sufficient redundancy is provided for valid statistical analysis. A known point is one for which coordinates have been calculated by independent means from field observations of equal or higher standards and specifications. A terrestrial traverse is not closed under this definition unless an angular closure can be computed from the field data.
13. "Electronic Level" means an electronic digital level instrument capable of reading bar-coded level rod.
14. "ALTA" standards refer to the standards and specifications established by the American Land Title Association and the American Congress on Surveying and Mapping adopted in 1997.
15. "Rural surveys" refer to the positional tolerance chart and the maximum angle, distance and closure requirements for Survey Measurements Which Control Land Boundaries chart contained within the document. No other requirements contained with the ALTA standards document are applicable.

Exhibit 5A.3–A SURVEY MONUMENT RECORD

FEDERAL LANDS HIGHWAY
SURVEY MONUMENT RECORD

PARK: ______________________________	MONUMENT	STAMPED
DEVELOPED AREA: ______________________ ______________________________	ESTABLISHED ______________________ DATE: RECOVERED ______________________	
TYPE OF PROJECT: ______________________ ______________________________	SET BY: □ FHWA □ OTHER AGENCY □ A / E FIRM ______________	
SHEET____OF____DRAWING NO.______________		

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _STATE SYSTEM OF PLANE COORDINATES_ _ _ _ _ _ _ _ZONE_ _ _ _ _ _ _ _ _

LATITUDE:	°	‘	“	NORTHING (y) =
LONGITUDE:	°	‘	“	EASTING (x) =
MAPPING ANGLE θ :	°	‘	“	ELEVATION =

GRID SCALE FACTOR:	HEIGHT FACTOR:	COMBINED FACTOR:
DATUM	ORDER OF SURVEY	ACCURACY
HORZ: □ NAD 1927 □ LOCAL	□ 1ST □ 2ND □ 3RD □ 4TH	1 PART IN
VERT: □ NAD 1929 □ LOCAL	□ 1ST □ 2ND □ 3RD □ 4TH	

OBJECT	GRID BEARING	GRID DISTANCE (FEET) (METERS)

DESCRIPTION: □ ALUM.CAP □ BRASS CAP □ COPPERWELD □ OTHER ______________________

SKETCH

5A.4 GUIDELINES FOR PLANNING AERIAL PHOTOGRAMMETRY

5A.4.1 RELATIONSHIPS

Exhibit 5A.4–A provides the typical relationships between plotting scale, contour interval, aerial photography scale and pixel resolution.

Design of the ground control scheme and placement of aerial premarks must provide accuracy and distribution sufficient to solve each photogrammetric model. Project constraints in the field often impose constraints that must be accommodated. Typical issues include steep terrain, limited visibility to the ground and environmental restrictions.

Exhibit 5A.4–B and Exhibit 5A.4–C depict examples of ground control schemes and provide information on the purpose of each.

5A.4.2 GUIDELINES FOR AERIAL PHOTOGRAPHIC PRODUCTS

Each flight line will have full stereoscopic coverage, for its entire length. Normal forward overlap is 60 percent at the mean terrain elevation of each flight strip and is never less than 55 percent. Ground control is established before the flight date.

Photography for a typical design project is planned at an average scale of 1:4800. The photography is obtained using a precision aerial mapping camera having a focal length of approximately 6 in [150 mm] with a 9 in by 9 in [228 mm by 228 mm] negative format. Photography for FLH projects is suitable for mapping and digitizing with a second order, optical train stereo plotter as well as a Photogrammetric Work Station (softcopy).

The suitability of the camera is determinable from the camera calibration report, which is based on adequate tests and measurements made by an approved aerial camera testing authority. Camera calibration reports are valid if completed within 36 months prior to the date of the photo mission.

Factors influencing acceptable photography products include:

- No breaks in the flight line;
- No crabbing or tilting in excess of 5 degrees;
- No flight strips deviating from the proposed flight path;
- No blurring of imagery when magnified up to 6 diameters;
- No deep shadows, smoke, haze, snow or clouds; or
- The sun is at least 30 degrees above the horizon.

Aerial photography deliverables typically include:

- Contact prints in color and black and white,
- Photo index in black and white and its negative,

- Digital photo index (in lieu of hard copy listed above),
- Film roll in canister, and
- Digital image file for each photograph.

Exhibit 5A.4–A AERIAL PHOTOGRAMMETRY COVERAGE
(US Customary)

Photo Scale 1"= ___'	Flying Height (ft)	Topo Plotting Scale 1"= ___'	Contour Interval (ft)	Forward Model Coverage (ft)	Forward Model Coverage (ft)	Pixal Resolution	Ortho Plotting Scale 1"= ___'
167	1002	20	1	601	1052	0.10	20
200	1200	20	1	720	1260	0.17	30
300	1800	30	1	1080	1890	0.25	40
400	2400	40	1	1440	2520	0.33	50
500	3000	50	2	1800	3150	0.42	70
600	3600	60	2	2160	3780	0.50	80
800	4800	80	3	2880	5040	0.67	110
1000	6000	100	3	3600	6300	0.83	140
1200	7200	120	4	4320	7560	1.00	170
1500	9000	150	5	5400	9450	1.25	230
2000	12000	200	7	7200	12600	1.67	330
3000	18000	300	10	10800	18900	2.50	550
5000	30000	500	17	18000	31500	4.17	1000

Exhibit 5A.4–A AERIAL PHOTOGRAMMETRY COVERAGE
(Metric)

Photo Scale 1:___	Flying Height (m)	Topo Plotting Scale 1:___	Contour Interval (m)	Forward Model Coverage (m)	Forward Model Coverage (m)	Pixal Resolution	Ortho Plotting Scale 1:___
2000	300	250	0.2	183	320	0.05	250
2500	380	250	0.2	229	400	0.10	300
3000	450	300	0.25	274	480	0.10	400
5000	760	500	0.5	457	800	0.15	700
7500	1140	750	0.5	686	1200	0.15	1000
10000	1520	1000	1	914	1600	0.20	1500
15000	2300	1500	2	1372	2400	0.30	2000
20000	3000	2000	2	1829	3200	0.50	3000
50000	7600	5000	5	4572	8001	1.00	6000
100000	15000	10000	10	9144	16002	2.00	13000

Exhibit 5A.4–B TYPICAL CORRIDOR PHOTOGRAPHY MISSION

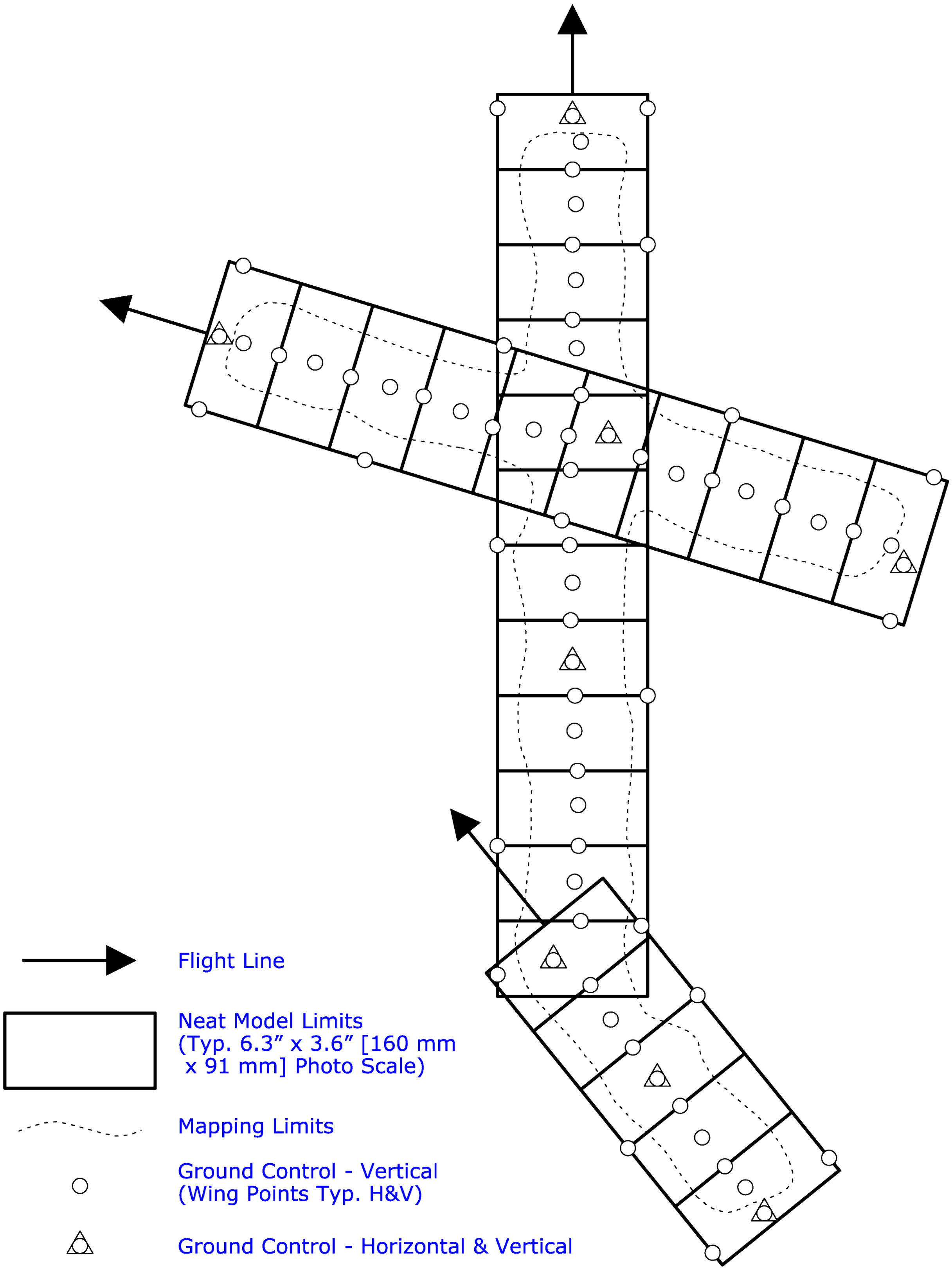
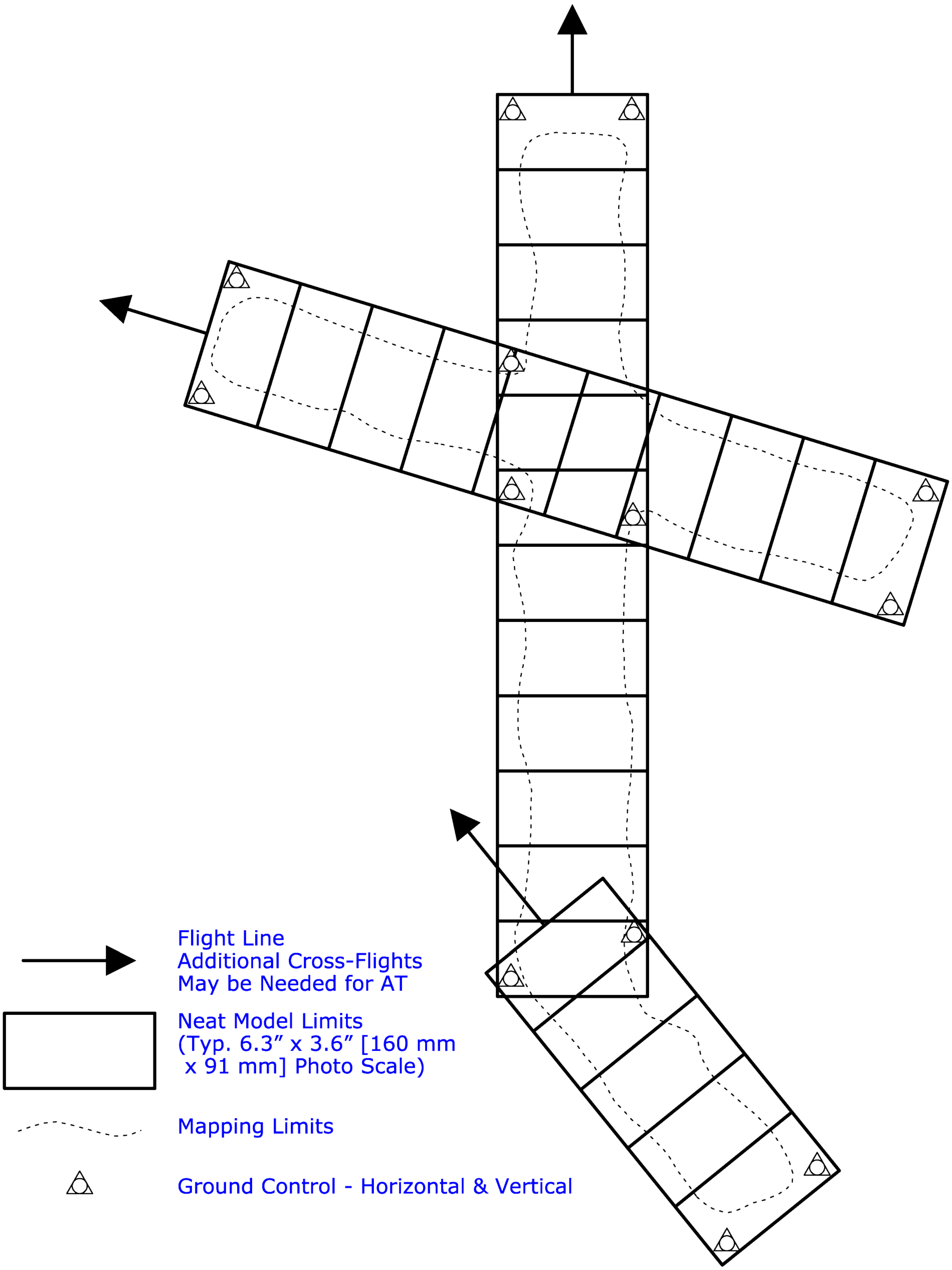


Exhibit 5A.4–C TYPICAL AIRBORNE GPS-ASSISTED CORRIDOR PHOTOGRAPHY MISSION



5A.5 GUIDELINES FOR ANALYTICAL AERIAL TRIANGULATION

5A.5.1 SECOND ORDER OPTICAL TRAIN STEREO PLOTTER

Each exposure in an aerial photography flight line needs at least three supplemental control points. These points (normally required by the analytical aerial triangulation process) are located approximately perpendicular to the flight line and through the photo center. They should not fall outside the area of triple overlap for each exposure. The distance between the two outermost points should be between 4.5 and 7.5 in [115 and 190 mm]. When practical, the centerpoint should be within a 0.5 in [13 mm] radius of the photo center. Additional analytical points in the area of overlapping flight lines can be created as necessary to ensure good results.

The accuracy of the analytically computed control, as determined by the Root Mean Square (RMS) method for X, Y, Z coordinates, should be in keeping with the National Map Accuracy Standards for Second Order aerial surveys. This accuracy is dependent on several factors including:

- Quality of the photography;
- Average photo scale;
- Type of aerial camera used and its calibrated focal length;
- Quantity, quality, placement and accuracy of the pre-marked (targeted) ground control; and
- Other controls used (e.g., photo identifiable features).

The method of measurement and computations for the aerial triangulation should be fully analytical; meaning no intermediate solutions derived by analog methods will be used (as in semi-analytical triangulation, where an analog stereo plotter is incorporated). The RMS residual error shall be computed for all input field control points in the three coordinate directions. Any field control point found to be in error by more than an acceptable amount may be omitted from the field control input list, provided it does not adversely affect the analytical transformation of points in that area.

The camera coordinated three-dimensional points position should be computed for each exposure, be furnished on all projects and include:

- X, Y & Z and roll [Ω] (omega);
- Pitch [Φ] (phi); and
- Yaw [K] (kappa).

The suggested point naming convention for the analytical control is 5 digits. For example, 01053 would represent flight line No. 1, exposure No. 5 and analytical point No. 3.

Flight Line Number	Exposure Number	Analytical Point Number
01	05	3

The naming convention for camera coordinates shall be the flight line number followed by a hyphen followed by the exposure number.

Flight Line Number	-	Exposure Number
01	-	05

5A.5.2 SOFTCOPY AEROTRIANGULATION CONSIDERATIONS

- The analytic points shall have a maximum diameter of 0.002” [50 µm].
- The combination of photo control and analytic points shall be a minimum of seven per neat model.
- There shall be an analytic point or photo control near each corner of all neat models.
- The combination of photo control and analytic points shall be a minimum of three between two adjacent neat models.
- Additional analytical control points shall be created as geometrically warranted between overlapping flight lines

5A.5.3 MENSURATION

Requirements for the mensuration of the photo control and the analytic points include the following:

- The maximum residual shall be 0.0008” [20 µm] on the mensuration of a photo control or analytic point.
- The standard error of the mean shall have a maximum value of 0.0002” [6 µm] for the mensuration of the photo control and analytic points.
- No mensuration shall take place outside of a neat model’s symmetric plane.

Verified values of the photo control are applied in order to perform a constrained adjustment.

Requirements for the analysis of the constrained aerotriangulation adjustment include the following:

- The standard mean error value of the adjusted image shall not exceed 0.0002” [5 µm].
- The maximum standard mean error value of the adjusted photo control and analytic point’s elevation shall not exceed 1/10,000 of the flying height.

The maximum standard mean error of the adjusted photo control and analytic point’s horizontal coordinates shall not exceed 1/15,000 of the flying height.

5A.6 GUIDELINES FOR GROUND TOPOGRAPHY AND PLANIMETRY

FLH field mapping consists of obtaining three dimensional data for all break lines, natural and cultural (man made) features, utilities and ground surface data. Measurements are taken longitudinally along all natural and man-made features and along break lines. All breaks and features that vary from the prevailing ground terrain by more than one half the contour interval are collected. A measurement along features is recorded at regular intervals and at all breaks such that the distance between recorded shots does not exceed 30 ft [10 m]. Features typically include:

- Edge-of-road,
- Roadway ditch,
- Top-of-roadway cut,
- Toe-of-roadway fill,
- Drainage flow line,
- Ridges,
- Edge-of-water, and
- Retaining walls.

Break lines have a unique point code that describes the break. FLH uses the following codes along features, as needed:

- Begin Line (BL*),
- End Line (EL*), and
- Close Figure (CL*).

Ground terrain is mapped by taking ground shots as needed, not to exceed 30 ft [10 m] transversely and longitudinally toward the direction of the roadway centerline. Additional shots are taken where spot elevations need to be shown on the final map. These areas include all high points, ridges, swales, saddles and depressions. Other locations pertinent to highway engineering needing spot elevations include:

- Road intersections,
- Road crests and sags,
- Road centerline at culvert crossings,
- Culvert inlets at the flow line, and
- Culvert outlets at the flow line.

Because digital terrain files will be generated from this field data and used for triangulation and cross section extraction, they require a high degree of accuracy. Measurements of well-defined features that are easily recovered on the ground have a vertical accuracy of 0.13 ft [40 mm] and a horizontal accuracy of 0.20 ft □[60 mm], based on measurements of higher accuracy for all planimetrics.

Vertical accuracy of at least 67 percent of all spot elevations at well-defined points, ground shots, break line shots, etc., will fall within one-third the contour interval of the map. Additionally, per National Map Accuracy Standards, 90 percent of the values should fall within one-half a contour interval.

5A.7 SAMPLE METADATA FOR HORIZONTAL AND VERTICAL CONTROL PROJECT

5A.7.1 SUMMARY OF METADATA

- Identification_Information
- Data_Quality_Information
- Spatial_Data_Organization_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Distribution_Information
- Metadata_Reference_Information

5A.7.2 IDENTIFICATION_INFORMATION

Originator: [*responsible agency, department or consultant*]

Publication_Date: 20XX

Title: Sample Highway - Horizonal and Vertical Project Control Survey

Edition: Version [date]

Geospatial_Data_Presentation_Form: Control Listing and Report

Publication_Place: FHwA Central Federal Lands Highways Division, Lakewood, CO

Publisher: FHWA Central Federal Lands Highways Division

Online_Linkage: < http://www.cflhd.gov/project.html>

Description: Primary horizontal and vertical control for Sample Highway, Stations 00+00 to ___

Abstract: GPS geodetic control network using combined static and RTK methods. Project control tied to national CORS network through OPUS solutions at four (4) project points. Project elevation datum is based upon NAVD88 with GPS ties to two NGS benchmarks and GeoidXX model. Precise digital leveling completed between all project points.

Purpose: Provide a base base of reference for latitude, longitude and height throughout the United States.

Time_Period_of_Content: [*date range*]

Status: Complete

West_Bounding_Coordinate: [*signed longitude in d.dd*]

East_Bounding_Coordinate: [*signed longitude in d.dd*]

North_Bounding_Coordinate: [*signed latitude in d.dd*]

South_Bounding_Coordinate: [*signed latitude in d.dd*]

Point_of_Contact: [*Name*]

Contact_Organization: [*agency, department, consultant]*

Contact_Position: [*title*]

Contact_Address: [*number and street*]

City: [*city*]

State_or_Province: [*State*]

Postal_Code: [*zip*]

Country: USA

Contact_Voice_Telephone: [*phone*]

Contact_Facsimile_Telephone: [*fax*]

Contact_Electronic_Mail_Address: [*email*]

5A.7.3 DATA_QUALITY_INFORMATION

Attribute_Accuracy: Monument descriptions are included in the project report on file with FLH. Point numbering is in accordance with Appendix 5A.2 and Chapter 5. No digital feature coding was part of the data collection or processing.

Attribute_Accuracy_Explanation: [*additional notes as necessary for clarity, i.e., reference to feature code data dictionary*].

Positional_Accuracy: Horizontal and vertical control was established in accordance with procedures and methods outlined in Chapter 5. The methods and procedures are designed to provide local project control, tied to the National Spatial Reference System, and evaluated for local accuracy classification in accordance with the Federal Geographic Data Committee's Geospatial Positioning Accuracy Standard, Part 2, Geodetic Control Networks, FGDC-STD-007.2-1998.

2000, 3000 and 4000 series point numbers are in accordance with Appendix 5A.2 and Chapter 5 for accuracy classification. All other points are for reference only and have not been classified for positional accuracy.

Horizontal_Positional_Accuracy: Primary survey control points (3000 series point numbers) meet a local accuracy of +/- 0.05 ft [15 mm] at the 95 percent confidence level.

Secondary survey control points (5000 series point numbers) meet a local accuracy of +/- 0.10 ft [30 mm] at the 95 percent confidence level.

Horizontal_Positional_Accuracy_Report: GPS observation data was post-processed for GPS vectors with Trimble TGO software suite, version x.x. Post-processed vectors and RTK vectors were combined in a least squares network adjustment using Star*Net Pro, version y.y. OPUS solutions at three (3) project stations were held fixed for latitude, longitude and two NGS benchmarks were held fixed for othometric height in the final over-constrained adjustment.

Horizontal_Positional_Accuracy_Explanation: [*additional notes of explanation as needed*].

Vertical_Positional_Accuracy: Primary survey control points (3000 series point numbers) meet a local accuracy of +/- 0.05 ft [15 mm] at the 95 percent confidence level.

Secondary survey control points (5000 series point numbers) meet a local accuracy of +/- 0.20 ft [60 mm] at the 95 percent confidence level.

Vertical_Positional_Accuracy_Report: Project elevations were computed from precise digital leveling holding fixed the derived orthometric height for station ___. Misclosure of the precise level loop was less than 0.02 ft [6 mm] and deemed small enough that no adjustment was applied.

Vertical_Positional_Accuracy_Explanation: [*additional notes of explanation as needed*].

Process_Description: [*descriptive notes of data processing procedures; more applicable to mapping data sets*].

5A.7.4 SPATIAL_DATA_ORGANIZATION_INFORMATION

SDTS_Point_and_Vector_Object_Type: point

Point_and_Vector_Object_Count: 1,500,000

5A.7.5 SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition: [*State*] State Plane Coordinate System of 1983, Zone [zone].

Geographic:

Latitude_Resolution: 0.00001.

Longitude_Resolution: 0.00001.

Geographic_Coordinate_Units: degrees, minutes, and decimal seconds.

Geodetic_Model: Geoid xx.

Horizontal_Datum_Name: North American Datum of 1983 (NAD 83), Epoch 2002.00.

Ellipsoid_Name: Geodetic Reference System 80 (GRS80).

Semi-major_Axis: 6378137 m.

Denominator_of_Flattening_Ratio: 298.26.

Vertical_Coordinate_System_Definition:

Altitude_System_Definition: Local project control based upon NAVD88.

Altitude_Datum_Name:

North American Vertical Datum of 1988 (NAVD 88), including Ellipsoidal and Orthometric Heights.

Altitude_Resolution: .01.

Altitude_Distance_Units: US Survey Foot.

5A.7.6 ENTITY_AND_ATTRIBUTE_INFORMATION

Overview_Description: [*describe CADD or GIS software and general process*].

Entity_and_Attribute_Overview: [listing feature codes, abbreviations, levels and line styles as appropriate].

5A.7.7 DISTRIBUTION_INFORMATION

Distributor: Federal Highways Administration, __ Federal Lands Highway Division

Contact_Person: [*name*]

Contact_Organization: [*agency, department*]

Contact_Position: [*title*]

Contact_Address: [*number and street*]

City: [*city*]

State_or_Province: [*State*]

Postal_Code: [*zip*]

Country: USA

Contact_Voice_Telephone: [*phone*]

Contact_Facsimile_Telephone: [*fax*]

Contact_Electronic_Mail_Address: [*email*]

Resource_Description: Project control listing

Fees: free if downloaded via FTP

5A.7.8 METADATA_REFERENCE_INFORMATION

Metadata_Date: [*date*]

Contact_Person: [*name*]

Contact_Organization: [*agency, department, consultant*]

Contact_Position: [*title*]

Contact_Address: [*number and street*]

City: [*city*]

State_or_Province: [*State*]

Postal_Code: [*zip*]

Country: USA

Contact_Voice_Telephone: [*phone*]

Contact_Facsimile_Telephone: [*fax*]

Contact_Electronic_Mail_Address: [*email*]

Metadata_Standard_Name: Reduced data tag FGDC Content Standards for Digital Geospatial Metadata.

Metadata_Standard_Version: FGDC-STD-001-1998

Chapter 6 – GEOTECHNICAL

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LIST OF EXHIBITS

CHAPTER 6

GEOTECHNICAL

6.1 GENERAL

This chapter provides an overview of practice for geotechnical work performed by the Federal Lands Highway (FLH) Divisions. It provides direction for understanding policies, standards and criteria in recognition of the need to manage financial and public safety risk and accomplish the missions of FHWA Federal Lands Highway and partner agencies. Specific topics include reconnaissance, site and subsurface investigation, analysis and design, reporting, PS&E involvement, construction support, monitoring, and consultant roles.

There are a few principles that guide all geotechnical work for FLH and they are represented by existing policy. Chapter 1 presents interpretations of existing policy in a way that is relevant to all project delivery disciplines. Section 6.2.1 of this chapter presents interpretations of these policies that are particularly relevant to geotechnical practice. The policies are as follows:

- Support the mission, vision and program management objectives of FLH and FHWA;
- Meet the technical scope requirements defined by the *PDDM*;
- Advance the state of practice by seeking and implementing new technology;
- Demonstrate environmental stewardship in investigations and designs;
- Demonstrate financial, cultural and natural resource stewardship;
- Conduct work safely and seek safety improvement solutions; and
- Achieve quality through established quality assurance and oversight procedures.

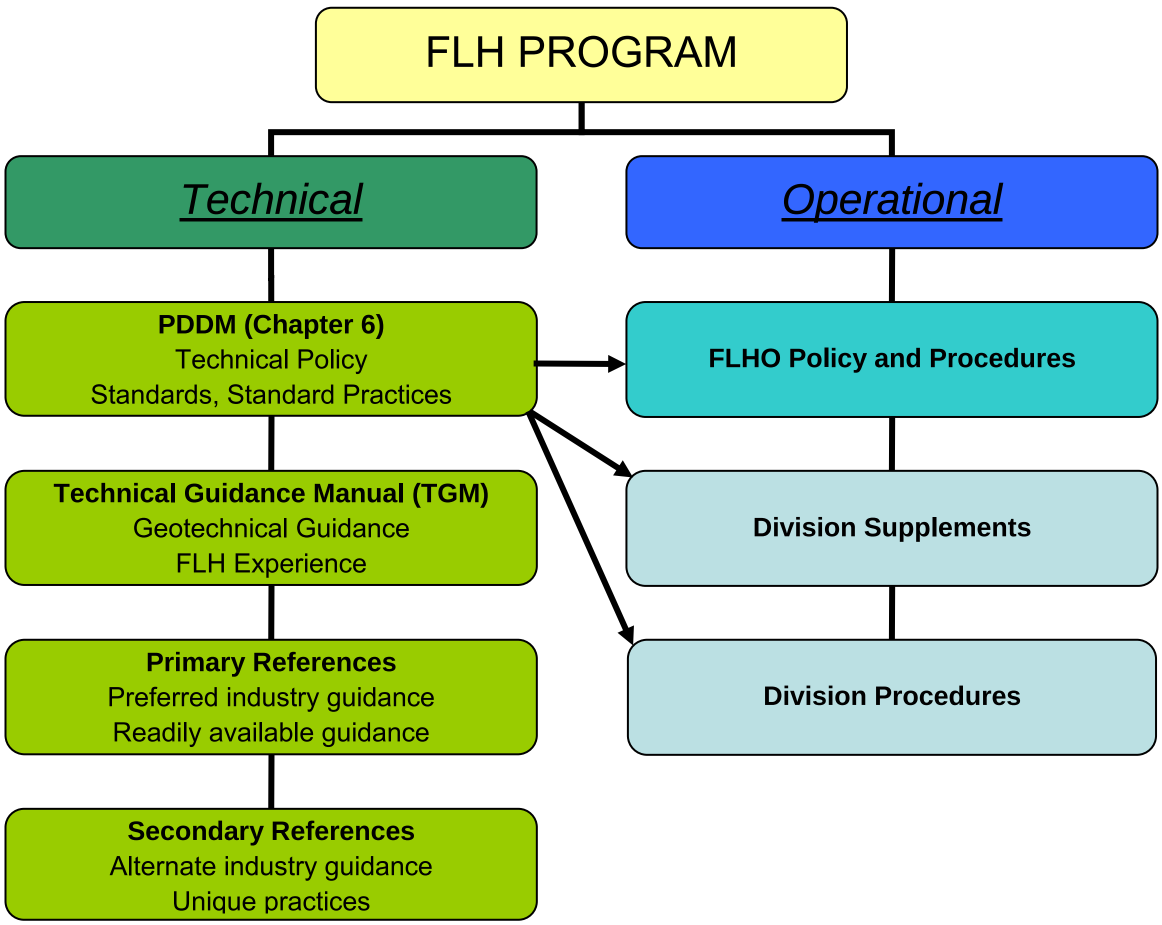
This chapter also serves as a “portal” to technical information and resources required for conducting geotechnical services for Federal Lands Highway. It presents standards for tasks and activities to be delivered, not technical guidance of how to perform them. For assistance with how-to guidance the reader is directed through links to FLH guidance in the *Geotechnical Technical Guidance Manual (TGM)* and through citations and links to more widely published technical guidance reference documents.

Technical guidance references in this chapter are classified as either “Primary”, or “Secondary”. When guidance beyond that presented in the TGM is required, Primary sources are refered to first. Primary sources either present preferred guidance on how to accomplish a task or, when equal guidance is available through many sources, the Primary source is most widely available. “Secondary” sources are additional documents that are often relied on for FLH work; they present guidance to augment the Primary source. Guidance sources do not constitute standards unless they are specifically identified as standards in this chapter. Tertiary-level references are additional references that are needed less often but are of particular value for certain specific needs. They are contained in the TGM Bibliography.

This chapter provides general direction on “what” should be performed, whereas guidance at the technical level (TGM and technical references) provides requirements, recommendations, and options for “how” to perform the technical aspects of each geotechnical task. The TGM is an important companion manual to this *PDDM* chapter and provides greater detail and institutional guidance. **It is FLH policy to perform geotechnical work in accordance with the *PDDM* and to review TGM guidance**; practitioners involved in FLH projects are responsible for knowing and using both manuals.

Other documents exist within FLH to provide guidance on unique technical practices or procedures at the FLH Division level; where these exist they should be followed for work within that Division. Also, although the organization of each of the Divisions is similar, there are differences. For this reason, the project delivery process, and how the Geotechnical Discipline works within that process, is described at the Division level. The relationship between the *PDDM* (this chapter) and other available guidance and manuals is shown in Exhibit 6.1–A.

Exhibit 6.1–A RELATIONSHIP OF PDDM TO OTHER GUIDANCE, REFERENCES, AND PROCEDURES



Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

6.1.1 GEOTECHNICAL DISCIPLINE

The FLH Geotechnical Discipline in each of the three Division offices provides geotechnical engineering and engineering geology services for geotechnical related aspects of design, emergency response and construction support. The discipline is comprised of in-house and contracted geotechnical engineers, engineering geologists, and geologists collectively named 'Geotechnical Professionals'. The FLH Headquarters office provides administrative direction and policy related assistance to the Division offices, including the Geotechnical Discipline.

The state-of-the-practice of the geotechnical field involves engineering judgment to provide the most efficient and economical investigations and designs. While this chapter provides standards and direction to specific guidance, it is not intended to limit the individual Geotechnical Professional from exercising their professional judgment and experience. Dealing with the variability of FLH projects, terrains, climates and partner agency constraints requires flexibility and resourcefulness. Geotechnical work is to be conducted in accordance with accepted geotechnical standards-of-care by engineers or engineering geologists who possess adequate geotechnical training and experience.

6.1.2 GEOTECHNICAL ROLE IN PROJECT DEVELOPMENT

The role of the Geotechnical Discipline is generally to provide geotechnical recommendations to a Project Manager or other designated members of a interdisciplinary (cross-functional), and possibly multi-agency, project team. The Project Manager and other team members need geotechnical recommendations at multiple stages of project development and delivery, so the Geotechnical Discipline is an integral part of a interdisciplinary work plan. In general there is a chronology to geotechnical tasks, as shown in Exhibit 6.1–B, and work is planned accordingly.

Exhibit 6.1–B PLANNING GEOTECHNICAL TASKS

Initiate and Scope the Project (Section 6.3.1)

- Participate in early project planning with the Project Manager and cross-functional team, defining the objectives and general scope of the project.

Study Available Geotechnical Data (Section 6.3.1)

- Assemble and review pertinent geotechnical information prior to site scoping, including available ground survey data, aerial photos, "as-built" plans for the existing roadway and/or structures, new construction features, geology information, USDA soils data, etc.

Perform Field Reconnaissance (Section 6.3.2.1)

- Conduct reconnaissance-level site investigation, generally not including subsurface investigation.

Perform Preliminary Project Investigations (Section 6.3.2.1 and Section 6.3.2.2)

- Conduct preliminary site investigations supporting line and grade planning, including observational assessment of roadway conditions, hazards, structures, and drainage, and limited sampling of material sources, soil/rock cuts, and subexcavation locations.

- Prepare a preliminary geotechnical memorandum characterizing earthwork requirements, available material sources, geotechnical hazards, corrosive soil/rock/water conditions, drainage issues, candidate structure foundation types, and construction issues, all based on the preliminary work. Make recommendations for supplemental investigations.

Perform Supplemental Project Investigations (Section 6.3.2.2 and Section 6.3.2.3)

- Conduct surface/subsurface investigations in support of intermediate and final PS&E packages, including soil/rock surface mapping, drilling and sampling programs, geophysical investigations, in situ testing, and instrumentation deployment
- Develop and implement a testing program supportive of project requirements.

Compile and Summarize Data (Section 6.4.1)

- Compile subsurface exploration logs, geophysical logs, materials data, soil surveys, groundwater/subexcavation problem areas, field and laboratory test results, instrumentation monitoring data, and soil/rock profile data

Perform Geotechnical Analyses (Section 6.4)

- Determine the scope of the analyses,
- Evaluate the accuracy and relevance of the available geotechnical data.
- Select values for design with an understanding of uncertainty and variability.
- Conduct the range of geotechnical analyses required to support the project, including assessment of construction options.
- Provide preliminary recommendations.

Prepare Geotechnical Report (Section 6.5.1)

- Review applicable FHWA report checklists to properly summarize relevant project investigation and design analyses information.
- Prepare a Geotechnical Report for the project, including a description of investigations, findings, analyses, and recommendations.
- Follow accepted QA/QC procedures for ensuring the quality of the analyses, recommendations, and final report.

Provide Design (Section 6.5.2) and Construction (Section 6.5.3) Support

- Attend project meetings concerning geotechnical issues, checking that all geotechnical recommendations are being adequately incorporated into designs.
- Review PS&E packages (Exhibit 6.5–A).
- Assist Construction with monitoring and troubleshooting of geotechnical related construction issues and activities (Exhibit 6.5–B).

The Geotechnical Discipline is responsible for participating in an interdisciplinary team approach, lead by the Project Manager, for evaluating geotechnical issues and developing geotechnical solutions for the project delivery. The Geotechnical Discipline is responsible for evaluating alternatives and for informing stakeholders of the geotechnical risks and benefits of various alternatives. The Geotechnical Discipline is responsible for collaborating with other disciplines to assure that risks and benefits are understood and that recommendations are incorporated in designs and actions. The following briefly summarizes the role and responsibility of the Geotechnical Discipline in relation to some other disciplines described in this manual.

- Chapter 3 – **Environmental Stewardship.** Environmental documents will include the decisions and commitments made for mitigation of impacts and concerns of the project. The Geotechnical Discipline will review or be briefed on environmental documents for decisions, mitigation measures and commitments made during the conceptual studies and preliminary design phase that affect development and construction of the project or operation of the highway following construction. Any proposed deviation from the decisions, mitigation measures and commitments will be coordinated through the Project Manager with the Environmental and Highway Design Disciplines, and affected resource agencies.

  The Geotechnical Discipline's role is to convey geotechnical recommendations in such a way that designers can evaluate whether or not they satisfy the environmental documents.

- Chapter 4 – **Conceptual Studies and Preliminary Design.** Chapter 4 covers the highway design activities done as part of the conceptual and preliminary design phase, which is typically through approximately the 30 percent level of design detail. Refer to Chapter 4 for the development of conceptual studies and preliminary design, including the development of the recommended roadway location, design concepts and the basic design criteria for the facility, including geotechnical constraints. These engineering studies and preliminary designs are developed in conjunction with the environmental process using an interdisciplinary and interagency team approach, lead by the Project Manager. Conceptual studies and preliminary design development include significant input from the highway owner agency, Federal land management agency, project stakeholders, the public and from other interested parties.

  The Geotechnical Discipline's role is to consider this input during development of geotechnical recommendations. Chapter 4 includes explicit references to geotechnical work generally pertaining to project scoping reports, investigations at the conceptual project phase, and scoping of future investigations.

- Chapter 5 – **Survey and Mapping.** The Survey and Mapping Discipline provides information on the field survey, property ties, right-of-way and utility locations and related data. The data collected are used to provide topographic maps, site maps, aerial imagery, right-of-way exhibits, land boundary and ownership information, utility maps and control information for developing the design.

The Geotechnical Professional's role is to work with the Project Manager, Design Discipline and Survey and Mapping Discipline to closely coordinate the survey and mapping with the geotechnical needs and determine the type and limits of the survey and mapping required to complete the geotechnical work. Coordinate closely with the Survey and Mapping Discipline to identify any additional information needs for developing the geotechnical investigation and recommendations, and for locating geotechnical explorations. When field reviews specifically for this coordination purpose are not possible, it is especially important for the Geotechnical Discipline and Survey and Mapping Discipline to discuss the field information required.

- Chapter 7 – **Hydrology and Hydraulics.** The Hydrology and Hydraulics Discipline provides estimates of runoff data, and recommendations for developing the roadside drainage design to be used around major geotechnical project features. This unit also provides scour depth recommendations to the Structural Design Discipline for major drainage structures, walls and bridges.

  The Geotechnical Discipline's role is to communicate with Hydrology/Hydraulics with respect to hydrology and scour depth, and layout of major drainage structures, walls, and bridges. This can be an iterative process, as initial recommendations may prompt design and layout changes that impact geotechnical recommendations and, once again, hydrology/hydraulics recommendations. The Geotechnical Discipline's role is to be part of this ongoing communication during design development.

- Chapter 9 – **Highway Design.** The Highway Design Discipline provides the geometric design and incorporates structural designs and recommendations from all other disciplines into the Plans, Specifications, and Estimate (PS&E) package ready for advertisement.

  The Geotechnical Professional's role is to coordinate with the Highway Design Unit during the development of the geometric design. For example, provide recommendations and preferences for moving into cut or fill sections, geotechnical criteria for wall layouts, risk associated with different alternatives, rockfall risk mitigation features, constructability sequencing and other issues. Assist with writing Special Contract Requirements (SCRs) and preparing cost estimates for geotechnical features.

- Chapter 10 – **Structural Design.** The Structural Design Discipline designs bridges, major retaining structures and special structural elements. The Structural Unit will provide preliminary structural plans, loads, settlement and other criteria early in the design process and will finalize designs only after geotechnical recommendations have been incorporated.

  The Geotechnical Discipline's role is to work with the structural unit during the investigation phase so that explorations are appropriately located and sufficient for the loads envisioned and other criteria, such as deformation limits. The Geotechnical Professional provides geotechnical recommendations for final design, and the Structural Unit finalizes the design and passes the design to the Highway Design Unit for inclusion in the PS&E. The Geotechnical Professional reviews the PS&E to ensure geotechnical recommendations are addressed.

- **Chapter 11 – Pavements.** The Pavement Discipline performs investigations, analysis and design for pavements, including subgrade considerations, except where subgrade conditions are related to broader issues such as geologic setting. There is some overlap between the investigation needs of the Pavement Discipline and the Geotechnical Discipline and collaboration, including shared resources, is accomplished in different ways by the different Divisions.

  The Geotechnical Discipline's role is to coordinate with the Pavement Discipline to minimize investigation costs and impacts. Additionally, the Geotechnical Professional provides support to the Pavement Discipline when pavement design and performance issues may be related to subsurface conditions and settings that are deep and influenced by geological setting.

6.1.3 INTENDED CHAPTER USE

The *PDDM* is intended for interdisciplinary use by FLH staff and contractors. This chapter of the *PDDM* is written primarily for the Geotechnical Discipline, though it will also be of value to those practicing in related disciplines. Similarly, the Geotechnical Professional will find important guidance for other disciplines in other chapters of the manual and familiarity with this guidance will help in the collaborative, cross-functional team approach to project delivery.

This chapter is intended to be used primarily in two ways. First, it is the source of the highest-level FLH technical guidance and should be used to educate or reacquaint the Geotechnical Professional with the guiding principles, standard practices, and standards of FLH geotechnical work. It identifies "what" needs to be done. If not explicitly included in the chapter, all FLH geotechnical standards can be identified and, in many cases, downloaded from links within the chapter. Second, this chapter is a portal to topic-based information of interest to the Geotechnical Discipline. Within specific topics, this chapter provides links to the appropriate sections of the TGM for institutional experience and guidance on "how" to accomplish certain tasks. Also within these topical areas, the chapter provides convenient and prioritized links and references to primary and secondary sources of technical guidance.

It is the responsibility of all FLH Geotechnical Professionals and consultants to become familiar with the materials presented in this chapter and the TGM and apply them appropriately while performing Geotechnical Discipline work. Any questions involving interpretation of or exception to the content of this chapter are to be referred to the Geotechnical Functional Discipline Leader or Division Geotechnical Team Leaders. Any properly authorized exceptions to the standards in this chapter are to be considered as "one time only" changes, unless otherwise directed. See Section 6.2.3 for making exceptions to standards.

See the Division Supplements for differences in standards or guidance between Divisions and for divisional guidance on processes, and quality control and assurance.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

6.2 GUIDANCE AND REFERENCES

This section provides guidance on technical policies for the geotechnical discipline, risk management, and standards and standard practices. Direction is given on how to use the TGM for technical guidance and for where standards are not applicable. A hierarchy of other technical references is also presented.

6.2.1 POLICIES FOR FLH GEOTECHNICAL DISCIPLINE

The seven technical policies presented in Section 1.1.2 provide high level guidance for the Geotechnical Discipline and are followed without exception. The policies are summarized as follows:

1. **Support the mission, vision and program management objectives of FLH and FHWA**
2. **Meet the technical scope requirements defined by the PDDM**
3. **Advance the state of practice by seeking and implementing new technology**
4. **Demonstrate environmental stewardship in investigations and designs**
5. **Demonstrate financial, cultural and natural resource stewardship**
6. **Conduct work safely and seek safety improvement solutions**
7. **Achieve quality through established quality assurance and oversight procedures**

The policies are general guiding principles and serve the purpose of defining a philosophy, rather than defining specifically what to do. Policies often guide in somewhat different directions. When policies guide in different directions the Geotechnical Professional should use the policies to keep their work and recommendations centered.

The policies are interpretations of agency directives and objectives based on legislation and federal regulations pertaining to FLH project delivery. The following policy sources are most relevant to the Geotechnical Discipline and, in support of the discussion in Section 1.1.2. These sources will help the Geotechnical Professional understand the context of FLH geotechnical work:

1. 23 CFR 625 — Code of Federal Regulations Highways Title 23 Part 625.4 specifies that *AASHTO Standard Specifications for Highway Bridges* be followed

2. NS 23 CFR 635 — Federal Aid Policy Guide Transmittal 16 NS 23 CFR 635 (1996) specifies that a differing site conditions clause be incorporated in contracts and directs towards *Geotechnical Engineering Notebook Issuance GT-15* for guidance.

3. FLH Business Plan — *FLH Business Plan* specifies goals of improving safety and of evaluating, reporting and promoting new technology deployment.

4. FLH Safety Memo — *FLH Safety Philosophy* (2004) describes the philosophy of enhancing safety and collaborating with partner agencies relating to safety, which is further explained in Chapter 8.

5. FLHM 3-C-2 — Federal Lands Highway Manual, Chapter 3, Section C, Subsection 2, Transmittal 12 (1983) provides guidelines for deviating from standards if deviation is desirable.

6. FLHM 1-A-1 — Federal Lands Highway Manual, Chapter 1, Section A, Subsection 1, Transmittal 18 (1983) provides overall FLH history, mission, capabilities and program direction.

7. FLHM 1-A-2 — Federal Lands Highway Manual, Chapter 1, Section A, Subsection 2, Transmittal 21 (1983) provides roles and responsibilities, including that policy is issued by FHLO (Headquarters).

Policies are most often followed by using standards and standard practices, but sometimes project specific methods are required to deliver a context-sensitive solution, or otherwise be responsive to our partners' needs. Situations where standards are deviated from in order to follow policy and provide centered recommendations may occur at any project stage. For example, during the investigation phase it may be too invasive or expensive to conduct the full scope of investigations in accordance with AASHTO guidance. After evaluating, communicating and documenting the risks of not doing so, the project may elect to go forward with a non-standard investigation scope. Conversely, a similar process on a different project might arrive at the decision to investigate the subsurface more thoroughly than the AASHTO guidance provides for. These are deviations in standards, not policy.

6.2.2 RISK MANAGEMENT

Risk is inherent in geotechnical work and FLH projects, and it comes in several forms. Risk is incurred with respect to cost when, for example, decisions are made regarding the scope of a geotechnical investigation. A greater investigation scope generally means fewer unknowns are carried into construction, thereby reducing the risk of construction cost escalation. Risk is incurred with respect to serviceability when designs are advanced that do not fully address all possible modes of failure. For example, a slump repair along a road that crosses a much larger, but more slowly moving landslide. Risk is incurred with respect to safety when geotechnical recommendations are incorporated into critical structures such as bridges, walls, and rock slopes. The Geotechnical Discipline's responsibility lies in identifying risks incurred through geotechnical issues, informing project team members and partners of these risks, and assisting in evaluating whether the risks are tolerable.

Risks are more tolerable when they are low relative to the potential benefit of the action incurring the risk. Risk assessment is the process of assessing the probability of adverse consequences associated with activities, recommendations or designs, and for geotechnical matters it is a Geotechnical Discipline responsibility. Risk is also incurred in other disciplines and risk assessment is discussed for all disciplines in Section 1.1.3.

The evaluation of potential benefit of a geotechnically-based risk is not solely a Geotechnical Discipline responsibility as it is an interdisciplinary process requiring involvement of the Project Manager and other disciplines that have knowledge of other project aspects and different perspectives on the value of a potential benefit. The responsibility of the Geotechnical Discipline is to inform and educate the Project Manager, and other team members and stakeholders, as appropriate, of risk based on geotechnical issues and to participate in evaluation of the tolerability of that risk.

The geotechnical policies presented in the previous section help assure that projects have a tolerable level of risk associated with them because they prescribe seeking safety, quality, and following the standards in the *PDDM* and consulting the guidance in the TGM. In fact, on most projects, where standards and standard practices are used, risk assessment and evaluation is often implicit and does not require further attention. For this reason, standards and standard practices are used wherever possible. Standards and standard practices are introduced in Section 6.2.3 and presented throughout the rest of this chapter.

6.2.3 STANDARDS AND STANDARD PRACTICE

Standards are defined in Chapter 1 as a fixed reference to guide the approach (standard practice) and content (standard) of FLH work. Geotechnical standards and standard practices address investigation, sampling, testing, analysis, reporting, design details and special contract requirements. Standards are based on many things, including successful past precedent on FLH projects and they help achieve FLH goals related to risk management, quality and efficiency.

Standards have been established where it has been found that a single approach or product works well in most cases. Standards have a history of use where quality has been demonstrated through successful completion and performance of projects. Standards tend to reduce time during design development and review, reduce bid prices because of familiarity developed within the construction industry, and reduce FLH oversight needs during construction. Project delivery and construction are team endeavors and standards improve efficiency because team members gain greater understanding of what to expect and how to work with what is delivered. Standards also acknowledge an understanding and acceptance of a certain, consistent level of risk.

Standards are not always appropriate in the Geotechnical Discipline. Over standardization can lead to inefficient designs, insensitivity to the context of individual projects, and lack of innovation. Given the wide variety of FLH projects, project constraints, and stakeholder interests, considerable flexibility is needed. This *PDDM* chapter presents a hierarchy of policy, standards, and guidance (through the TGM) to allow flexibility when needed and to also keep the geotechnical practice as standard as possible so that the goals of risk management, quality, and efficiency are realized.

For example, the subsection on "Structure Foundations" (in section "6.4 Analysis and Design") includes the standard to design structure foundations in accordance with the current edition of the AASHTO Standard Specifications for Design of Highway Bridges (AASHTO HB-17). This is a widely accepted standard in the industry and it should be used whenever possible. Note, however, that designing in accordance with AASHTO HB-17 is not a policy and there are occasions where in order to satisfy a centered approach to the policies in Section 6.2.1, the AASHTO HB-17 standard should not be followed.

Another example would be with respect to investigation. Most FLH projects are low volume roads (NPS, USFS Forest Highway, USFS recreation roads, US Fish and Wildlife Service, Forest Highway State and County roads, BLM, and BIA). Very limited geotechnical design guidance exists specifically for low volume roads. One example is the TRB Compendiums 1 through 16 prepared in 1979 (see TGM Bibliography). On many of these low volume road projects, application of investigation standards for high volume roads such as set forth in FHWA-ED-88-053 may be impractical or insufficient and not in accord with Geotechnical Policies, or an acceptable level of contractual risk deemed suitable on that specific project.

When the Geotechnical Discipline determines that variance from existing geotechnical standards is desired, this determination is shared with the Project Manager for concurrence. The Geotechnical Professional writes to the Project Manager to explain the justification for the variance and how the issues of risk management, quality, and efficiency are addressed. Significant variances are first discussed with the Geotechnical Discipline Leader and/or Division Geotechnical Team Leaders for technical endorsement, and may require endorsement of FLH management.

6.2.4 TECHNICAL GUIDANCE

Through specific direction to the TGM and, in some cases, Primary Sources, this manual provides guidance for where standards do not exist and for when it is appropriate to deviate from an existing standard. The TGM presents institutional experience in the form of practices that have worked well in the past on FLH projects and commentary on guidance published elsewhere. The TGM presents considerably more "how to" discussion than this chapter, but does not simply reproduce most of the technical guidance that has been previously published. Rather, the TGM uses extensive links and commentary to technical references to direct the reader to additional published and on-line sources of technical guidance.

6.2.5 TECHNICAL REFERENCES

The guidance in the TGM is supported by published technical references. Primary Sources are the first information sources that the Geotechnical Professional refers to; they either present preferred guidance on how to accomplish a task or, when equal guidance is available through many sources, the Primary Source is most widely available. Secondary Sources are additional documents that are often relied on for FLH work; they present guidance to augment the Primary Source. Primary and Secondary Sources are not standards unless specifically identified as such in this chapter.

Although Primary and Secondary Sources follow the TGM in the succession of guidance, the sources are identified in each of the topical sections of this chapter for convenient reference, especially for the repeat user that knows the contents of the TGM. The complete listing of all Primary and Secondary Sources, which constitutes an excellent FLH geotechnical reference library, is listed in Section 6.6. The TGM includes these sources and has a bibliography that also includes tertiary sources of geotechnical guidance (TGM Bibliography).

6.2.6 STATE DOT REFERENCES

Geotechnical practice commonly includes regional bias related to regional geology, climate, resource availability, etc. State DOTs have often developed practices based on these regional factors and such experience and practice may be reflected in their published guidelines. On occasion, it is necessary to interface with the state DOT or to design according to their standards as a stakeholder and possibly a maintaining agency for the finished project. Published state DOT geotechnical guidance is listed in TGM Section 2.6. Unless specific project criteria direct otherwise, where state DOT guidance differs from FLH guidance presented in this chapter and the TGM, FLH guidance has precedence.

6.3 GEOTECHNICAL INVESTIGATIONS

This section presents FLH standards and links to FLH guidance on site and subsurface investigation. The standard practices, designs and specifications presented in this section have evolved from FLH experience and are used unless an exception is justified as described in Section 6.2.3.

Follow the established quality control and assurance procedures for investigation tasks. Procedures are unique to each Division and can be accessed through Division Supplements.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

6.3.1 PLANNING AND MANAGEMENT

The Geotechnical Discipline's standard practice is to perform and manage geotechnical investigations in accordance with a project-specific plan to characterize surface and subsurface conditions and address specific geotechnical issues, hazards, risks and uncertainties. The Geotechnical Discipline works within project constraints identified by FLH partners, the FLH Project Manager, and the multi-disciplinary Cross Functional Team, and within approved budgets. During project scoping (Exhibit 6.1–B) the scope of geotechnical investigations is developed to be commensurate with the geologic and project complexity, and project constraints.

The Geotechnical Discipline participates in scoping activities with the Cross Functional Team and, if this occurs through an on-site meeting, the Geotechnical Discipline prepares a brief geotechnical scoping report including an overview of project background information and requirements. Whether or not the Geotechnical Discipline attended a site visit, the Geotechnical Discipline prepares preliminary geotechnical recommendations and anticipated site investigation needs for discussion and concurrence with the Project Manager and Cross-Functional Team.

6.3.1.1 Project Requirements

Prior to commencing work and throughout the project, the Geotechnical Discipline seeks a clear understanding of project goals, objectives, requirements, constraints, values, criteria, and funding levels from the FLH Project Manger. The Geotechnical Discipline plans investigations with flexibility to evaluate evolving roadway designs, structure options, and locations.

A standard project investigation includes field reconnaissance, preliminary investigation, and supplemental investigation(s). Field reconnaissance is used to develop an overall scope of explorations. Preliminary investigation is conducted in support of early line and grade planning and project estimation, providing preliminary earthwork requirements, material source availability and suitability, identification of geotechnical hazards, determination of corrosive soil/rock/water conditions, location of substantial drainage issues, and identification of candidate structure foundation types and constructability issues. Supplemental investigations to improve site characterization are used to optimize design and to reduce risk carried into construction.

Supplemental site investigations (if necessary) are conducted in support of intermediate and final PS&E packages, providing the geotechnical information necessary to design structure foundations, mitigate geotechnical hazards related to landslides, rock slopes, etc., design cut and fill slopes, mitigate drainage issues, and support earthwork estimation and management.

For some projects, all investigation, preliminary and supplemental, is conducted at one time and there is essentially no distinction. Investigation plans follow the guidelines in *Subsurface Investigations – Geotechnical Site Characterization* NHI 132031 and include the following standard practices:

- Perform a desk review of available geotechnical information as the first step in planning an efficient geotechnical investigation.
- Plan the exploration program cost-effectively. Utilize the least-expensive method that is capable of obtaining the necessary subsurface information.
- Optimize the use of field reconnaissance, geologic mapping and simple test pits/ test holes to minimize the amount of higher-cost site explorations required (such as drilled borings and specialized in situ tests).
- Consider geophysical methods, selected to identify specific material contrasts, to augment subsurface explorations, possibly reducing the number of borings or other explorations below the standard criteria (Exhibit 6.3–C).
- Develop the exploration program using methods that minimize environmental impacts.
- Plan the investigation program within approved budgets.
- Plan a phased investigation approach with well-defined scopes to align with FLH Division and environmental compliance processes, thereby minimizing unnecessary costs and impacts and supporting the approved schedule. Use each phase of investigation to optimize the value and minimize the impact of subsequent phases. Consider reducing the number of phases when mobilization costs are high

The Geotechnical Discipline uses the investigation plan to manage the field work. The Geotechnical Professional coordinates explorations with the partner agencies, and exploration and traffic control subcontractors, and documents field activities, including:

- Crew participants;
- Equipment used;
- Explorations completed, with photographs;
- Site conditions encountered; and
- Individual logs (records) of surface and subsurface explorations, and samples recovered.

In addition to general roadway investigations, Geotechnical Discipline provides a wide variety of specialized investigations to fulfill the individual partner and specific project needs. Standard practices for roadway, material sources, structures, and landslide geotechnical investigations performed by FLH are provided in Section 6.3.2. Common boring types are presented in Exhibit 6.3–A, and other common types of explorations are presented in Exhibit 6.3–B. Standard practice is to use the exploration types in these exhibits whenever practical.

Standards for minimum boring and sampling frequency are provided in Exhibit 6.3–C and Exhibit 6.3–D, respectively.

Refer to TGM Section 3.1 for guidance on investigation tasks.

The primary source supporting investigation standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

6.3.1.2 Typical Project Practice

The primary purpose of site and subsurface geotechnical investigations is to provide design engineers with knowledge of the subsurface conditions, any geohazards, and available soil, aggregate and rock resources. The investigation also provides the construction project engineers and contractors with information concerning the materials and conditions that are expected to be encountered. A variety of standard investigations are performed to fulfill individual project needs, as described in the following subsections.

6.3.1.2.1 Roadway Alignment and Earthwork Investigations

Soil Cut and Fill Slopes – Conduct soil slope investigations, including surface and subsurface exploration, sufficient to support the development of stable slope designs for all soil cut and fill slopes. Assess material suitability for project needs. Investigation methods range from visual reconnaissance of existing surface conditions at shallow cuts to drilling, sampling, testing and instrumentation of critical slope designs. Use the methods and practices described throughout Section 6.3.2 and the minimum standards in Exhibit 6.3–C and Exhibit 6.3–D. Guidelines for cut slope investigations are in TGM Section 3.1.2.1. Pavement subgrade is addressed by the Pavement Discipline as described in Chapter 11.

Rock Slopes – Ascertain the relative performance of existing rock slopes on roadway projects, identifying hazard potentials and risks associated with slope failures, and incorporating the findings in recommended hazard mitigation methods for existing and planned rock slope excavations. Conduct rock mass investigations, including structure mapping and subsurface exploration, sufficient to support slope designs that mitigate significant rock mass failures and recurring rock fall hazards for rock cut slopes greater than 15 ft [5 m] high. Use the methods and practices described throughout Section 6.3.2 and the minimum standards in Exhibit 6.3–C and Exhibit 6.3–D. Guidelines for rock slope investigations are in TGM Section 3.1.2.1.

6.3.1.2.2 Material Sources

Government-Owned - Provide materials type, estimated quantity, and quality, and source accessibility, development, and reclamation information sufficient to support earthwork, construction materials, and paving materials planning and quantities estimation. If data are not available and investigation is required, FLH standard practice is defined throughout Section 6.3.2. Material source investigation guidelines are in TGM Section 3.1.2.2.

Commercial – In the absence of government-owned material sources, identify potential commercial sources and confirm quality and quantity availability for the various materials and aggregates required on the project.

Contractor Provided – Verify, through contractor submitted samples, that the proposed source meets the project rock quality requirements.

6.3.1.2.3 Structures

Conduct subsurface investigations for all significant structures (bridges, retaining walls, ground anchors, large culverts, etc.). Plan the investigation to include evaluation of all candidate foundation types and long-term performance requirements. Use the methods and practices described throughout Section 6.3.2 and the minimum standards in Exhibit 6.3–C and Exhibit 6.3–D. Guidelines for structure investigations are in TGM Section 3.1.2.3.

6.3.1.2.4 Landslides

Investigate surficial extent, depth, strength parameters, surface and ground water conditions, and seasonal movement of landslides with the potential to adversely impact roadway projects and monitor stability concerns throughout construction. Use the methods and practices described throughout Section 6.3.2 and the minimum standards in Exhibit 6.3–C and Exhibit 6.3–D. Guidelines for landslide investigations are in TGM Section 3.1.2.4.

6.3.1.2.5 Pavement Subgrade

The Pavements Discipline performs subgrade investigations, as described in Chapter 11. The Geotechnical Discipline coordinates with the Pavements Discipline when geotechnical investigations are also needed. For example, if the project includes constructing embankment and paving on the embankment section then the Geotechnical Discipline provides data on the material source, whether it is from cuts or an offsite location. The need for samples is discussed with the Pavements Discipline.

> Refer to TGM Section 3.1 for guidance on investigation tasks.
>
> The primary source supporting investigation standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

6.3.1.3 Safety

It is FLH standard practice to perform geotechnical work using safety practices that strive to minimize the risk of injury to the field crew and traveling public. The nature of the equipment used and climatic conditions often encountered present potential hazards that require site-specific safety evaluation. It is the responsibility of the Geotechnical Discipline and field crew members to adjust the investigation program and/or provide equipment, training, and other means to provide safe working conditions. These standard safety practices apply:

- Prepare a safety plan for use by field staff, including unique safety practices that apply to specific projects or are required by partner agencies, emergency contact information, and considerations for first aid in the event of an injury.
- Plan appropriate traffic control, consistent with road/traffic conditions, partner agency requirements, the MUTCD and local codes.
- Provide training and other means to provide safe working conditions. Drilling safety procedures can be found in the *National Drilling Association (NDA) Drilling Safety Guide.*
- Arrange for utility locates to identify probable locations of buried utilities that could potentially create hazards to subsurface explorations. Identify overhead power lines. Guidance on safety as related to utility location is in TGM Section 3.1.3.
- Follow applicable state and federal safety regulations pertaining to job site safety and management of hazardous materials. On-site safety requirements are defined in OSHA Section 29.

> Refer to TGM Section 3.1.3 for guidance on safety.
>
> The primary sources supporting safety standards and guidance are NDA for drilling and MUTCD for traffic. Secondary sources are BOR Drillers Safety, USACE EM 1110-1-1804, and FHWA-CFL/TD-05-00.

6.3.2 METHODS AND PRACTICE

FLH standard practice is to use appropriate methods for recovering physical samples of soil and rock strata for testing, and for characterizing subsurface materials and conditions in-situ. This means that multiple methods of investigation and sampling are generally needed for each project. This section presents standard methods and practices for:

- Surface and subsurface exploration;
- Logging and sampling;
- Laboratory and in-situ testing; and
- Instrumentation and monitoring.

6.3.2.1 Preliminary Study and Reconnaissance

After the preliminary planning described in Section 6.3.1, it is standard practice for the Geotechnical Discipline to perform a preliminary study and reconnaissance to identify and preliminarily address geotechnical issues, hazards, risks, and project constraints. Base the site study and reconnaissance on a clear understanding of project goals, objectives, constraints, values and criteria. Perform tasks to the extent necessary to disclose the probable materials and conditions to be encountered. Include an assessment of risk and uncertainty associated with each of the preliminarily recommended design options. Multiple design alternatives are often advanced at this stage.

Refer to TGM Section 3.2.1 for guidance on preliminary study and reconnaissance.

The primary supporting sources are NHI 132031 for office and field work, and FHWA-ED-88-053 for reporting. Secondary sources are AASHTO MSI-1 and USACE EM 1110-1-1804.

6.3.2.2 Surface Exploration Methods

Use appropriate surface exploration methods corresponding with project needs and goals. Standard surface exploration methods include field reconnaissance, wherein visual observations are recorded according to stationing, mile post or other location information such as GPS coordinates. Geologic mapping is standard where preliminary study indicates geologic features and rock units have direct bearing on project design or construction, and suitable geologic mapping does not already exist. Field-developed sketched cross sections or digital photographs are standard at locations of explorations and key features.

Refer to TGM Section 3.2.2 for guidance on surface exploration methods.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and NHI 132035.

6.3.2.3 Subsurface Exploration Methods

Subsurface investigation methods most commonly include drilled borings, and/or excavated test pits and trenches. Drilling is the standard and preferred method for subsurface exploration and sampling. Use the appropriate exploration methods for the anticipated ground conditions to optimize surface and subsurface characterization and sample recovery for roadway and structure design.

6.3.2.3.1 Geotechnical Equipment

FLH standard practice is to use equipment that is most advantageous to the project. This may be in-house drilling or geophysics equipment, or it may require rental of equipment or contract of equipment and services.

Guidance for selection of the applicable exploration methods is tabulated in Exhibit 6.3–A (borings) and Exhibit 6.3–B (probes, test pits, trenches and shafts). FLH standards on these methods and the steps of subsurface investigation are in the following subsections. Additional guidance on methods is in TGM Section 3.2.4.

6.3.2.3.2 Geophysical Methods

Evaluate the potential use of geophysical methods and the value they might add in terms of improved understanding of subsurface conditions, lower impact and/or cost, etc. Though geophysics may be used under other circumstances, standard practice is to incorporate geophysical methods where they are likely to lead to lower overall investigation, design and/or construction costs. Multi-channel seismic refraction with a sledge hammer source is the standard method used to help identify depth to bedrock and excavation requirements (e.g. rippability), and to extrapolate between borings. Other methods may be more appropriate for specific projects or other project needs.

Refer to TGM Section 3.2.3.2 for guidance on geophysical methods.

The primary source supporting the guidance is FHWA-Geophysical. Secondary sources are NHI 132031 and USACE EM 1110-1-1802.

Exhibit 6.3–A TEST BORINGS: TYPES AND APPLICATION

Boring Method	Procedure Utilized	Applicability
Auger Boring (AASHTO T203)	Hand or power operated augering with periodic removal of material. In some cases continuous auger may be used requiring only one withdrawal. Stratum changes indicated by examination of material removed.	Probe investigations to bedrock and shallow disturbed soil samples, typically less than 20 ft [6 m] in depth. <u>Typical Uses</u> Disturbed soil sampling. Determine overburden depth.
Hollow-Stem Auger (AASHTO T251)	Power operated augering. Hollow stem serves as casing.	General purpose drilling method for soil and very weak rock locations requiring a cased hole. <u>Typical Uses</u> Disturbed/undisturbed soil sampling. In situ testing. Foundation investigations.
Rotary Drilling (AASHTO T225)	Power rotation of drilling bit as circulating fluid removes cuttings from hole. Stratum changes indicated by rate of progress, action of drilling tools, and examination of cuttings in drilling fluid. Casing usually not required, except near surface.	Relatively fast and economical method to advance borings through wide variety of materials, including large boulders and broken rock. <u>Typical Uses</u> Obtaining rock cores. Probe drilling. Instrumentation installation. Foundation, landslide, and rock cut investigations.

Boring Method	Procedure Utilized	Applicability
Wire-Line Drilling	Rotary-type drilling method where coring device is integral part of drill rod string, which also serves as casing. Core samples obtained by removing inner barrel assembly from core barrel portion of drill rod. Inner barrel is released by retriever lowered by wire-line through the drilling rod.	Efficient method for recovering quality core samples of rock. Typical Uses General rock coring applications. Foundation, landslide, rock cut, and material source investigations.
Air Drilling	Uses compressed air to remove cuttings from the borehole as drilling advances. Both rotary and percussion techniques can be used with either open-hole (rotary reverse circulation) or under-reamed casing advancement (ODEX). SPT samples possible; however, materials between samples are highly disturbed.	This type of drilling is generally fast, but expensive. Typical Uses Deep holes in dense gravels and boulders where Hollow Stem Auger and Rotary methods cannot drill or sample effectively. Fast-moving landslides. Rock anchor drilling.

Exhibit 6.3–B USE OF PROBES, TEST PITS, TRENCHES AND SHAFTS

Exploration Method	General Use	Advantages and Capabilities	Limitations
Hand Auger Probes	Bulk sampling. Visual inspection. Depth of shallow soft deposits and top of shallow bedrock.	Useful in difficult access areas. Results in minor ground disturbance. Rapid, cost-effective exploration. Good for shallow deposits (< 15 ft [5 m] deep).	Difficult to advance in rocky or dense materials.

Exploration Method	General Use	Advantages and Capabilities	Limitations
Hand-Excavated Test Pits and Shafts	Bulk sampling. Visual inspection. In situ testing. Depth of shallow bedrock and groundwater.	Useful in difficult access areas. Results in less disturbance of surrounding ground.	Relatively time-consuming and expensive. Limited to depths above groundwater level.
Backhoe-Excavated Test Pits and Trenches	Bulk sampling. Visual inspection. In situ testing. Rapid excavation rates. Depth of shallow bedrock and groundwater.	Rapid, cost-effective exploration. Depths up to 20 ft [6 m] can be explored.	Limited equipment access. Generally limited to depths above groundwater level. Limited undisturbed sampling. Significant surrounding ground disturbance.
Drilled Shafts	Bulk sampling. Visual inspection. In situ testing. Depth of bedrock and groundwater. Pre-excavation for piles and shafts. Landslide investigations. Drainage wells.	Rapid, cost-effective exploration (compared to hand methods). Minimum 2.5 ft [0.75 m] to maximum 6 ft [2 m] diameter.	Limited equipment access. Costly mobilization. Visual inspection possibly obscured by casing. Limited undisturbed sampling. Significant surrounding ground disturbance.
Dozer Cuts	Bulk sampling. Visual inspection. In situ testing. Rapid excavation rates. Depth of shallow bedrock and groundwater. Rippability determinations. Increase backhoe depth capabilities. Provide access for other exploration equipment.	Rapid, cost-effective exploration (compared to hand methods). Provides exposures for geologic mapping.	Limited equipment access. Generally limited to depths above groundwater level. Limited undisturbed sampling. Significant surrounding ground disturbance.

6.3.2.3.3 Drilling and Soil Sampling

Drilling and sampling is the most common means of subsurface exploration. Standards are presented in Exhibit 6.3–C for boring layout and depth with respect to structure types, locations and sizes, and proposed earthwork. Standard drilling methods include hollow-stem auger in soils and wire-line core drilling in rock. Rotary-wash, casing advancer, solid-stem auger and other methods are also used to fulfill specific project needs.

Exhibit 6.3–C STANDARDS FOR BORING LAYOUT AND DEPTH

Geotechnical Feature	Minimum Boring Layout	Minimum Boring Depth
Structure Foundation	A minimum of two borings for piers or abutments over 100 ft [30 m] wide. A minimum of one boring for piers or abutments under 100 ft [30 m] wide. Provide additional borings in areas with erratic subsurface conditions.	All borings extend below estimated scour. Spread Footings (on soil) 2B where L < 2B; 4B where L > 5B; and Interpolate between 2B and 4B when 2B ≤ L ≤ 5B. (L is footing breadth and B is footing width.) Deep Foundations In soil, 20 ft [6 m] below tip elevation or twice maximum pile group dimension, whichever is greater. For piles on rock, 10 ft [3 m] into bedrock below tip elevation. For shafts on rock, extend borings below tip elevation 10 ft [3 m] into bedrock or 3D into bedrock for isolated shafts or twice the maximum shaft group dimension into bedrock, whichever is greater. (D is shaft diameter.)
Retaining Structures	A minimum of one boring for each retaining structure. Space borings every 100 ft [30 m] to 200 ft [60 m]. Characterize wall toe and anchorage zones with additional borings, as needed.	Extend borings 0.75 to 1.5 times the retaining structure height. When stratum indicates potential deep stability or settlement problem, extend borings to hard stratum. For deep foundations, use Structure Foundation criteria above.

Geotechnical Feature	Minimum Boring Layout	Minimum Boring Depth
Cuts and Embankments	A minimum of one boring per cut slope. Space borings every 200 ft [60 m] (erratic conditions) to 400 ft [120 m] (uniform conditions), with one boring per landform. Place borings in high cuts and fills perpendicular to the roadway to establish geologic cross-sections. Use additional shallow explorations to determine depth and extent of topsoil and/or unsuitable surface soils.	Cuts: In stable materials, 15 ft [5 m] below depth of cut at the ditch line. In weak materials, extend borings to firm materials or twice the cut depth, whichever is less. Embankments: Extend borings to a firm stratum or to a depth twice the embankment height, whichever is less.
Landslides	Place borings perpendicular to the roadway to establish geologic cross-sections for analysis. Locate at least one boring above the sliding area.	Extend borings below failure surface into firm stratum, or to a depth which failure is unlikely. Extend inclinometers below the base of the slide.
Culverts	A minimum of one boring per major culvert. Perform additional borings for long culverts or in areas of erratic subsurface conditions.	Use criteria presented above for embankments.
Material Sources	Space borings every 100 ft [30 m] to 200 ft [60 m].	Extend borings 5 ft [1.5 m] beyond the base of the deposit or depth required to provide needed quantity.

Note: Table is modified from FHWA Geotechnical Checklist and Guidelines (FHWA-ED-88-053) as discussed in TGM Section 3.2.3.3.

Select the most appropriate drilling technique to achieve the project specific information and sampling requirements. Do not use equipment design for other site conditions or purposes and expect to get adequate subsurface characterization and sample recovery. Sampling type and frequency is dependent upon both the type of material encountered and the purpose of the investigation. Disturbed and undisturbed samples can be obtained with a number of different sampling devices. The split barrel from the Standard Penetration Test (SPT) is the standard disturbed soil sampling method. Minimum disturbed and undisturbed soil and rock sampling standards are presented in Exhibit 6.3–D.

Exhibit 6.3–D MINIMUM STANDARDS FOR SAMPLING AND TESTING FROM BORINGS

Material	Sampling and Testing Criteria
Sand-Gravel Soils	• Obtain SPT (split-spoon) samples at 5 ft [1.5 m] intervals, or at significant changes in soil strata. • Continuous SPT samples are obtained in the top 15 ft [4.5 m] of borings at locations where spread footings may be placed in natural soils. • Submit representative SPT jar or bag samples to the lab for classification testing and verification of field visual soil identification.
Silt-Clay Soils	• Obtain SPT and undisturbed thin-wall tube samples at 5 ft [1.5 m] intervals or at significant changes in strata. Obtain a sufficient number of samples, suitable for the types of testing intended, within each soil layer. • Take alternate SPT and tube samples in the same boring, or take tube samples in separate undisturbed boring. • Submit representative SPT jar or bag samples to the lab for classification testing and verification of field visual soil identification. • Submit representative tube samples to the lab for consolidation testing (for settlement analyses) and strength testing (for slope stability and foundation bearing capacity analyses).
Rock	• Obtain continuous cores using double or triple tube core barrels. Photograph rock core as soon as possible after being taken from the boring and before shipping core boxes. • For structural foundation investigations, core a minimum of 10 ft [3 m] into rock to ensure it is bedrock and not a boulder. • Determine percent core recovery and Rock Quality Designation (RQD) in the field for each core run, and record on the boring log. • Submit representative core samples to the lab for unconfined compressive strength testing (foundation bearing capacity analyses, rock mass classification, and modulus estimation).
Groundwater	• Record water level encountered during drilling, at completion of boring, and (if boring remains open) 24 hours after completion of boring. • In low permeability soils, such as silts and clays, a false indication of the water level may be obtained when water is used as the drilling fluid and adequate time is not permitted after hole completion for the water level to stabilize (more than one week may be required). In such soils and where water level is critical to design, install a plastic standpipe observation well to allow monitoring of the water level over a period of time. • Determine seasonal fluctuation of the water table where such fluctuation will have a significant impact on design or construction (e.g., borrow sources, footing excavation, excavations at toe of landslide, etc.). • Measure and record zones of artesian water and seepage.

Material	Sampling and Testing Criteria
Soil Borrow Sources	• Use backhoes, dozers, or large diameter augers where possible for exploration above the water table. • Use borings for exploration extending below the water table. Obtain SPT (split-spoon) samples at 5 ft [1.5 m] intervals, or at significant changes in soil strata. • Submit representative SPT jar or bag samples to the lab for classification testing and verification of field visual soil identification. • Record groundwater levels. Install piezometers or observation wells to monitor water levels where significant seasonal fluctuation is anticipated.
Rock Quarry Sources	• Utilize rock coring to explore new quarry sites. Use double or triple tube core barrels to maximize core recovery. • For riprap source, measure rock mass fracture spacing to assess riprap sizes that can be produced by blasting. • For aggregate sources, note the amount and type of joint in-filling. • Base source assessment on exposed quarry face only if exposures are large relative to required quantities and quality is apparently very good with respect to requirements; otherwise augment with coring or geophysical techniques to verify that the nature of the rock does not change behind the face or at depth. • Submit representative core samples to the lab for rock quality tests to determine suitability for riprap or aggregates.

Note: Table is modified from FHWA Geotechnical Checklist and Guidelines (FHWA-ED-88-053) as discussed in TGM Section 3.2.3.3.

Refer to TGM Section 3.2.3.3 for guidance on drilling and sampling.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

6.3.2.3.4 Rock Coring

Use rock coring techniques to explore and sample bedrock, and to confirm bedrock locations beneath structures. Use double or triple tube core barrels to minimize disturbance. Measure and record percent recovery and Rock Quality Designation (RQD) as soon as the core is recovered, and classify the rock according to Exhibit 6.3–F. Log rock coring in accordance with the standards in Section 6.3.2.5.

Refer to TGM Section 3.2.3.4 for guidance on rock coring.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

6.3.2.3.5 Test Pits, Trenches, and Surface Exposures

Use surface exposures, test pits and trenches in lieu of drilling to quickly and cost-effectively investigate soils and highly weathered rock masses when shallow explorations (< 15 ft [5 m] deep) are planned. Use test pits and trenches only when the impact to the site is acceptable. Follow safety standards in Section 6.3.1.2.

Bulk disturbed soil samples are collected from distinct material types in test pits, trenches and exposures. Where practical obtain samples large enough to include representative gradation. Otherwise, note that this was not done and describe presence of larger particles. Tube samples and plastic bags of smaller samples are collected for in-situ water content and density when this information might be representative and useful.

Standard rock sampling includes "grab" samples obtained from outcrops or test pits. Obtain sample sizes small enough to carry, but large enough to be tested in a point load device or used as hand specimens. Label grab samples with the location where they were obtained and identify the location on a site map.

> Refer to TGM Section 3.2.3.5 for guidance on various explorations and sampling.
>
> The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and CalTrans 2001.

6.3.2.3.6 Boring and Test Pit Closure

Backfill and/or seal abandoned boreholes in consideration of guidelines for boring closure in TGM Section 3.2.3.6. Minimum standard practice is to backfill and compact all test pits to match original grade and replace conserved topsoil or revegetate with an owner-approved mulch/seed mix. Minimum standard practice for borings is use of cuttings, bentonite or grout in consideration of the guidelines in the TGM. Borings through asphalt pavement are covered with asphalt cold patch.

> Refer to TGM Section 3.2.3.6 for guidance on closing exploration sites.
>
> The primary source supporting the standards and guidance is NHI 132031. Secondary sources are NCHRP RR 378 and AASHTO R 22-97.

6.3.2.3.7 Care and Retention of Samples

Collect, transport, and store rock and soil samples in a manner suitable for maintaining sample integrity prior to testing, and for maintaining the character and integrity of the sample for review by engineers and contractors. Retain representative soil samples and all untested rock core samples until the construction contract is awarded, or longer if Division or project-specific requirements are set.

Refer to TGM Section 3.2.3.7 for guidance on care and retention of samples.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

6.3.2.4 Soil and Rock Classification

FLH standard practice is to classify soils in accordance with the ASTM Unified Soil Classification System (USCS) and/or the AASHTO Soil Classification System (NHI 132031). Field classification of soil and rock follow the standards presented in Exhibit 6.3–E and Exhibit 6.3–F, respectively. Rock and rock mass descriptions and classification follow the ISRM classification system presented in GEC-5.

Refer to TGM Section 3.2.4 for guidance on soil and rock classification.

The primary source supporting the standards and guidance is NHI 132031 and the secondary source is GEC-5.

6.3.2.5 Exploration Logs

FLH standard practice is to prepare exploration logs within the gINT™ boring/test pit log platform, though a variety of presentation formats may be used to best represent the field data. Use standardized logging and data collection forms for all field measurements to ensure accurate, concise, and consistent data management. Collect data during the field work on a field log and revise this log later to be a final log by including laboratory test data. The log is a record of factual data and observations, interpretations are generally not included and if they are they are explicitly identified as such.

Logs have a heading that identifies who did what, when, where and how. Otherwise they are a factual record of materials encountered versus depth using a consistent description format that is explained either on the log or on an attached legend sheet. Logs include sample types and locations, and also include other observations such as progress, water, and remarks by drillers. FLH does not have a standard format but uses the example in NHI 132031 for reference.

Refer to TGM Section 3.2.5 for guidance on exploration logging.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

Exhibit 6.3–E FIELD CLASSIFICATIONS FOR SOIL

Particle Size Limits of Soils Constituents[1]		Cohesive Soils[2]			Granular Soils[2]	
Constituent	Sieve Size	Consistency	Field Identification	SPT Resistance	Relative Density	SPT Resistance
Boulder (BLDR)	12" [305 mm] +	Very Soft	Easily penetrated 4"-6" [100-150 mm] by fist.	0-1	Very Loose	0-4
Cobble (COBB)	3" to 12" [75 to 305 mm]	Soft	Easily penetrated 2"-3" [50-75 mm] by thumb.	2-4	Loose	5-10
Gravel (GR)	No.4 to 3" [4.75 to 75 mm]	Firm	Penetrated 2"-3" [50-75 mm] by thumb with moderate effort.	5-8	Medium Dense	11-30
Sand (SA)	No. 200 to No. 4 [0.075 to 4.75 mm]	Stiff	Readily indented by thumb, but penetrated only with great effort.	9-15	Dense	31-50
Silt (SL)	2 to 75 µm	Very Stiff	Readily indented by thumb.	16-30	Very Dense	50+
Clay (CL)	Less than 2 µm	Hard	Indented with difficulty by thumbnail.	31-60		
		Very Hard	Cannot be indented by thumbnail.	>60		

[1] *ASTM D653.*
[2] *N' from Standard Penetration Test, AASHTO T-206-87(2000)*

6.3.2.6 In Situ Testing

The Standard Penetration Test (SPT) is the standard in situ test for FLH site investigations and is performed whenever subsurface conditions and drilling methods allow the use of this test. Automatic hammers are preferred to the "cathead" method. N-values and N-values corrected for energy ratio and overburden are used to evaluate soil variability and to estimate soil density and shear strength parameters.

Refer to TGM Section 3.2.6 for guidance on applying the SPT and other in-situ testing.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are FHWA-SA-91-043 and FHWA-SA-91-044.

Exhibit 6.3–F FIELD CLASSIFICATIONS FOR ROCK

Rock Strength			Rock Quality		Weathering	
Description (Grade)	Field Identification	Uniaxial Compressive Strength	Structural Quality	RQD[1]	Description (Grade)	Field Identification
Extremely Weak (R0)	Indented by thumbnail.	36-145 psi [0.25-1.0 MPa]	Very Poor	0-25%	Fresh (I)	No visible sign of weathering. Slight discoloration on major discontinuity surface possible.
Very Weak (R1)	Crumples under firm blows with point of geologist pick. Can be peeled by pocket knife.	145-725 psi [1.0-5.0 MPa]	Poor	25-50%	Slightly Weathered (II)	Rock discolored by weathering, and external surface somewhat weaker than in its fresh condition.
Weak (R2)	Can be peeled by a pocket knife with difficulty. Shallow indentations made by firm blow of point on geologists pick.	0.73-3.6 ksi [5.0-25 Mpa]	Fair	50-75%	Moderately Weathered (III)	Less than half of the rock is decom-posed and/or disintegrated to soil. Fresh or discolored rock present as discon-tinuous frame-work/corestones.
Medium Strong (R3)	Cannot be scrap-ed or peeled with a pocket knife. Specimen can be fractured with single firm blow of hammer end of geologist pick.	3.6-7.3 ksi [25-50 MPa]	Good	75-90%	Highly Weathered (IV)	More than half of rock is decompos-ed and / or disint-egrated to soil. Fresh or discolor-ed rock present as discontinuous framework / corestones.
Strong (R4)	Specimen requires more than one blow with hammer end of geologist pick to cause fractures.	7.3-14.5 ksi [50-100 Mpa]	Excellent	90-100%	Completely Weathered (V)	All rock is decomposed and / or disintegrated to soil. Original mass structure is still largely intact.

Rock Strength			Rock Quality		Weathering	
Description (Grade)	Field Identification	Uniaxial Compressive Strength	Structural Quality	RQD[1]	Description (Grade)	Field Identification
Very Strong (R5)	Specimen requires many blows of the hammer end of geologist pick to cause fractures.	14.5-36 ksi [100-250 MPa]			Residual Soil (VI)	All rock material is converted to soil. Mass structure and fabric are destroyed, but apparent structure remains intact. May be a in change in volume, but soil has not been significantly transported.
Extremely Strong (R6)	Specimen can only be chipped with geologist pick	> 36 ksi [250 Mpa]				

Note: Modified from Evaluation of Soil and Rock Properties, GEC-5.
[1] *"Rock Quality Designation"*

6.3.2.7 Laboratory Testing

FLH standard practice is to routinely perform laboratory and index property tests to verify field classifications and quantify material properties. Appropriate testing methods are dependent on materials encountered and on project requirements so they are not standardized. A laboratory testing plan is developed prior to exploration based on anticipated sample recovery and materials. The plan is finalized after exploration and sampling to best use the recovered materials to find the material properties and parameters needed for design and construction. Standard practice is to conduct relatively few complex tests, such as tests for shear strength or compressibility, and to use index tests to extrapolate their results to the extent practical.

Minimum testing standards are defined in Exhibit 6.3–D. Whenever possible, laboratory tests are performed according to standards of AASHTO. ASTM Standards are followed if AASHTO does not have an appropriate standard. Tests that are not standards of AASHTO and ASTM are seldom used and if they are specific laboratory procedures are included with laboratory reporting.

> Refer to TGM Section 3.2.7 for guidance on laboratory testing.
>
> The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and AASHTO Stds HM-25-M.

6.3.2.8 Instrumentation and Monitoring

Install and monitor instrumentation where necessary to answer specific critical questions relevant to project features and designs. Instrumentation is commonly used to measure water table depth and fluctuation, and/or slope movement. Standard instruments are standpipe piezometers, slope inclinometers and surface monuments. Prepare an instrumentation and monitoring plan to include: (1) the safety or economic justification for instruments and monitoring, (2) the timely monitoring of instrumentation to capture seasonal or other expected variations in ground conditions and displacements, (3) detailed and standardized data collection and record keeping processes, and (4) timely communication of findings to the design team members.

It is standard practice to install groundwater and ground deformation instrumentation at major landslides potentially impacting planned roadway construction. Locate deformation instrumentation within the slide in a manner supportive of slope and structure analyses, and install as early in the roadway design process as possible to maximize the monitoring period. Even though design and construction decisions will have been made, continue monitoring through design, and construction, if practicable. Convey results to Cross Functional Team and Project Manager with geotechnical interpretation of observations.

Refer to TGM Section 3.2.8 for guidance on instrumentation and monitoring.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and NHI 132012.

6.4 ANALYSIS AND DESIGN

This section presents FLH standards and links to FLH guidance for geotechnical analysis and design recommendations. Standards and standard practices presented in this section have evolved from FLH experience and are to be used unless an exception is justified (Section 6.2.3). In many cases, standards are not provided for many geotechnical analysis and design tasks because the needs are project-specific; consult TGM Section 4 for guidance if no standard exists and for further guidance where one does.

Standard practice for FLH is to do analysis and provide design recommendations for structures in accordance with *Standard Specifications for Highway Bridges*, AASHTO HB-17. There are many aspects of FLH geotechnical work not covered by AASHTO HB-17. Accordingly, standards presented in this section and the referenced guidance are to be used for design of earthwork, rock slopes, rockfall mitigation, landslide stabilization, dewatering, drainage and other geotechnical items not addressed by AASHTO HB-17. Referenced guidance is also for where AASHTO HB-17 requirements for foundations and retaining structures are deemed to be impractical or not inline with the project objectives or FLH technical policy (Section 6.2.1). Such determination is made by the Geotechnical Discipline following multi-disciplinary Cross Functional Team discussion of project objectives and geotechnical risks associated with alternate solutions either not addressed or not in accordance with AASHTO HB-17.

Follow the established quality control and assurance procedures for analysis and design tasks. Procedures are unique to each Division and can be accessed through Division Supplements.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

6.4.1 EVALUATION OF DATA, PROJECT REQUIREMENTS, AND DESIGN PARAMETERS

The first phase of the analysis and recommendations stage of project work is to evaluate the data present and the needs of the project. Evaluate if the data are suitable, the project needs are understood, and the appropriate scope of analysis is included in the budget. Evaluate if the data are suitable to support the analyses necessary to identify feasible design options, including assessments of cost, risk and uncertainty associated with each. Standard practices for data evaluation are as follows:

- Confirm understanding of project requirements and design criteria. Review preliminary plans and provide guidance and recommendations on geotechnical issues involving roadway alignment selection and the type, size, and location of roadway structures.
- Evaluate the accuracy and relevance of the available geotechnical data and whether they were collected according to standard or documented procedures. Section 6.3.2 provides standard site investigation methods and practices.
- Confirm suitability of data. Recommend supplemental explorations when additional geotechnical information is needed.

- Organize, tabulate, and format the field and laboratory data in order to extract suitable soil and rock properties and design parameters, and representative subsurface profiles and cross-sections supportive of required roadway and structure analyses.
- Document design parameters and design assumptions provided by others.
- Select values for geotechnical properties and design parameters with an understanding of uncertainty and variability. Refer to Section 6.2.2 for geotechnical discussion of risk management.

Refer to TGM Section 4.1 for guidance on data evaluation.

The primary source supporting the standards and guidance is GEC-5. Secondary sources are NHI 132031 and EPRI EL-6800.

6.4.2 SCOPE OF ANALYSIS

Perform analyses to address specific project requirements. FLH standard practice is to use simple, inexpensive methods when they suffice, such as simply inspecting and comparing with precedent on the project or in the vicinity. These methods usually suffice when there is abundant precedent and the consequence of failure is low. An example is new cut slopes of less than 15 feet [5 meters] height on a route that contains many such stable slopes already.

Use more rigorous methods where there is not ample precedent and where the consequence of failure is more significant. Most structures and some earthwork features (embankments and cuts) fall into this category. For unique conditions and uncertainties, project features, or project risk tolerance, use multiple methods to evaluate the same design criteria. For example, combine limit equilibrium and finite element analysis of slope stability, or use alternate methods of drilled shaft capacity or settlement.

Conduct analyses and provide recommendations to accommodate evolving roadway and structure options and locations by providing recommendations that can be used for a variety of configurations where possible (e.g. plots of bearing capacity versus depth and diameter for drilled shafts). Regardless of how simple or rigorous the analyses are, maintain analyses and calculations, including problem statements, given input, assumptions, reasoning, solution, and conclusions in a file.

Refer to TGM Section 4.2 for general guidance on analysis.

The primary source supporting the standards and guidance is FHWA-ED-88-053.

6.4.3 STRUCTURE FOUNDATIONS

FLH Geotechnical Discipline standard is to follow AASHTO HB-17 for design of foundations for structures wherever practical. Select and design foundations based on AASHTO requirements to meet minimum requirements for static and seismic loading and limiting settlement. Use AASHTO recommended minimum and typical ranges for factor of safety under static conditions, and design bridge foundations for a minimum service life of 75 years. Provide seismic analysis input based on the requirements of AASHTO Division I-A. Additional FLH standard practices are listed here for analysis and design of shallow and deep foundations.

Coordinate with the Structures Discipline, Design Discipline, and Hydrology and Hydraulics Discipline to select the most appropriate foundation type(s) for a given structure based on geotechnical subsurface investigations, material testing results, surface and groundwater issues, and design constraints. Specifically, select the foundation type based on an assessment of the magnitude and direction of loading, depth to suitable bearing materials, potential for liquefaction, undermining or scour, swelling potential, frost depth and ease and cost of construction. Provide effective peak firm ground acceleration and probability of exceedence based on AASHTO or USGS Hazmaps. Classify the site according to the AASHTO Standard Specifications for Highway Bridges seismic site soil profile “Type” classification and corresponding site coefficient factor, “S”.

Guidelines for general foundation selection are presented in TGM Exhibit 4.3-A and *Soils and Foundations Workshop*, NHI 132012. The standard foundation selection process includes the following steps:

- Identify the type of superstructure and loads to be applied to the foundation.
- Define and summarize subsurface conditions.
- Assess the applicability of each type of foundation for their capability of carrying the required loads and estimate (qualitatively) the amount of settlement that is likely.
- Eliminate obviously unsuitable foundation types and prepare detailed studies and/or tentative designs for suitable foundation types.
- Select and recommend the foundation type that meets structure requirements, is best suited for site subsurface conditions, and is the most economical. Consider spread footings, driven piles, drilled shafts and micropiles first and, if these aren’t well suited to the project, then consider alternative solutions (auger-cast piles, rammed aggregate piers, etc.).
- Document expected site and subsurface conditions that could significantly impact construction of the selected foundation type in a Geotechnical Advisory Statement for inclusion in the geotechnical report and contract documents.

Design all foundation elements per the AASHTO service load approach (SLD) unless the project specific design requirements specify use of the load and resistance factor design approach (LRFD). Use the safety factors for static loading conditions (interim ASD designs) presented in Exhibit 6.4–A. Consult TGM Section 4.3 for guidance on selecting values within given ranges.

Provide foundation recommendations for the range of candidate foundation types, anticipated site conditions, and anticipated foundation loads.

Refer to TGM Section 4.3 for general guidance on structure foundations.

The primary source supporting the standards and guidance is NHI 132012. Secondary sources are FHWA-ED-88-053 , AASHTO HB-17, USACE EM 1110-1-1905 and USACE EM 1110-1-1904.

Exhibit 6.4–A AASHTO FOUNDATION CRITERIA (FACTORS OF SAFETY)

Foundation Type	Analysis Condition	Minimum Factor of Safety (FOS)[1]
Shallow Foundations	Bearing capacity	3.0
	Slide along base	1.5
	Overturning (Rotational Failure)	2.0
Deep Foundations	Driven piles (Static Method)	2.0 to 3.0
	Drilled shafts	2.0 to 2.5
Slope Stability at Structure Foundation Locations	Global Stability	1.3 to 1.5

[1] *Factor of Safety based on AASHTO Standard Specification for Highway Bridges, AASHTO HB-17.*

6.4.3.1 Shallow Foundations

Shallow foundations are often used where they satisfy design criteria because they are generally less expensive to construct. The following is a list of standard shallow foundation analysis tasks for footings on soil. Footings on rock are presented with other rock engineering tasks and discussed in Section 6.4.8.4. Many projects have additional specific needs and require additional analysis tasks that are addressed in the cited TGM sections and guidance documents.

- Recommend minimum embedment depth or footing elevation (including frost and scour considerations), allowable bearing capacity, and estimated total and post-construction settlement. Estimate potential for post-construction differential settlement between foundation units.
- Discuss excavation requirements, dewatering expectations, and minimum footing size.
- Recommend limits on proximity to slopes and other project features based on global stability considerations or analysis.

Refer to TGM Section 4.3.1 for guidance on shallow foundation analysis and design.

The primary source supporting the standards and guidance is GEC-6. Secondary sources are AASHTO HB-17, NHI 132012, and FHWA-RD-86-185.

6.4.3.2 Driven Pile Foundations

Driven pile foundations are generally used when shallow foundations are not feasible. The choice of driven pile over drilled shaft foundations is based on many factors, but generally driven piles are found to be less expensive and are used where they satisfy project criteria. The following is a list of standard pile driving analysis tasks. Many projects have additional specific needs and require additional analysis tasks that are addressed in the cited TGM sections and guidance documents.

- Recommend pile type, estimated tip elevations and allowable axial capacity. Unless piles are to be end bearing on rock or a certain strata, present results as a plot of capacity versus depth.
- Provide graphs of ultimate and allowable axial capacity versus depth for various sizes of piles. Include separate graphs of both skin friction and end bearing (if appropriate). Standard practice does not use the driving formula in FP-XX Section 551 or any other such formula.
- Provide a tabulation of soil properties used in the foundation analysis, including unit weight and strength parameters, and recommended values of subgrade modulus (k) and soil strain parameters E^{50} for lateral load analysis using LPILE or COM624P.
- Provide analysis that discounts depth of scour susceptible material for capacity but includes it for driveability. Coordinate with the Hydrology and Hydraulics discipline to confirm anticipated scour depth as discussed in Chapter 7.
- Calculate anticipated pile group settlement.
- Use wave equation analysis to verify that the recommended driven pile type can be driven to the estimated tip elevation without damage. Recommend means for driving piles past obstructions, such as pile tips, pre-drilling, or blasting, as most appropriate.
- Recommend the means for evaluating installed pile capacity or drilled shaft integrity. For example, WEAP, Pile Driving Analyzer (PDA), and/or CAPWAP, dynamic or static tests.

Refer to TGM Section 4.3.2 for guidance on pile foundation analysis and design.

The primary source supporting the standards and guidance, including a step by step procedure, is NHI 132021. Secondary sources are AASHTO HB-17, NHI 132012 and WSDOT WA-M-46-03.

6.4.3.3 Drilled Shaft Foundations

Drilled shaft foundations are generally used when shallow foundations and driven piles are not feasible. The choice of drilled shaft foundations is based on many factors, but generally shafts are used where the site is not very suitable for driving because of hard layers or possible obstructions in the soil, or environmental restrictions exist to prohibit driving. The following is a list of standard drilled shaft analysis tasks. Many projects have additional specific needs and require additional analysis tasks that are addressed in the cited TGM sections and guidance documents.

- Recommend shaft diameter, estimated tip elevations, rock socket requirements, and allowable axial capacity. Unless piles are to be end bearing on rock or a certain strata, present results as a plot of capacity versus depth.
- Provide graphs of ultimate and allowable axial capacity versus penetration for various sizes of shafts. Include separate graphs of both skin friction and end bearing (if appropriate).
- Provide a tabulation of soil properties used in the foundation analysis, including unit weight and strength parameters, and recommended values of subgrade modulus (k) and soil strain parameters E^{50} for lateral load analysis using LPILE or COM624P.
- Provide analysis that discounts depth of scour susceptible material. Coordinate with the Hydrology and Hydraulics discipline to confirm anticipated scour depth as discussed in Chapter 7.
- Calculate anticipated shaft settlement and, if appropriate, group settlement.
- Provide a geotechnical advisory statement to document anticipated conditions and obstructions for construction.
- Recommend the means for evaluating installed shaft integrity.

> Refer to TGM Section 4.3.3 for guidance on drilled shaft foundation analysis and design.
>
> The primary source supporting the standards and guidance, including a step by step procedure, is GEC-10. Secondary sources are AASHTO HB-17, FHWA-RD-95-172, NHI 132012 and WSDOT WA-M-46-03.

6.4.3.4 Micropile Foundations

Micropile foundations are often more expensive than other alternatives and are therefore generally used when shallow foundations, driven piles and drilled shafts are not practical. The choice of micropile foundations is based on many factors, but generally micropiles are selected either because ground conditions are such that driving pile or drilling shafts is not practical, or access for the larger, pile and shaft equipment is not available. The following is a list of standard micropile analysis tasks. Projects may have additional specific needs and require additional analysis tasks that are addressed in the cited TGM sections and guidance documents.

- Recommend pile diameter, estimated tip elevations, rock socket requirements, and allowable axial capacity. Unless piles are to be end bearing on rock or a certain strata, present results as a plot of capacity versus depth. Recommend casing and plunge length, if applicable.
- Provide graphs of ultimate and allowable axial capacity versus penetration for various sizes of micropiles.
- Provide a tabulation of soil properties used in the foundation analysis, including unit weight and strength parameters, and recommended values of subgrade modulus (k) and soil strain parameters E^{50} for lateral load analysis using LPILE or COM624P.
- Provide analysis that discounts depth of scour susceptible material. Coordinate with the Hydrology and Hydraulics discipline to confirm anticipated scour depth as discussed in Chapter 7.
- Calculate anticipated settlement for pile groups.
- Recommend the means for evaluating installed pile capacity or drilled shaft integrity.

> Refer to TGM Section 4.3.4 for guidance on micropile foundation analysis and design.
>
> The primary source supporting the standards and guidance, including a step by step procedure, is FHWA-NHI-05-039. The secondary source is FHWA-SA-97-070.

6.4.4 EARTH RETENTION SYSTEMS

Earth retention systems are engineered systems to retain soil temporarily or permanently. Retaining walls are the most common example, but patterned ground anchors, rockeries, and temporary shoring of cuts are other systems common to FLH practice and are also included.

FLH Geotechnical Discipline standard practice is to follow AASHTO HB-17 for retaining walls wherever practical. Select and design retaining walls based on AASHTO requirements to meet minimum requirements for static and seismic loading and limiting settlement. Use AASHTO recommended minimum and typical ranges for factor of safety under static conditions, and design retaining walls for a minimum service life of 75 years. Perform seismic analyses based on the requirements of AASHTO Division I-A. FLH standard practices are listed in this section for analysis and design of earth retention systems. General standards are presented first, followed by subsections addressing specific earth retention systems.

Select the permanent earth retention system type based on an assessment of the magnitude and direction of loading, depth to suitable bearing materials, potential for liquefaction, undermining or scour, swelling potential, frost depth, ease and cost of construction, tolerable total and differential settlement, and facing durability and aesthetics. Select temporary cuts and shoring requirements to be as economical as possible.

Coordinate with the Structures Discipline, Design Discipline, and Hydrology and Hydraulics Discipline to select the most appropriate earth retention system for a given setting based on geotechnical subsurface investigations, material testing results, surface and groundwater issues, and design constraints. Provide soil/rock classification, density, lateral earth pressure, and strength parameters for design. Provide expectations of encountering water during construction and recommendations for managing it during construction, and for short- and long-term performance. Provide temporary excavation slope recommendations (including height restrictions and steepest slope ratio) and advise of the need for shoring, and specific geotechnical conditions that might impact shoring type selection, as in Section 6.4.4.7.

For seismic design, provide effective peak firm ground acceleration and probability of exceedence based on a literature review. Classify the site according to the AASHTO Standard Specifications for Highway Bridges seismic site soil profile "Type" classification and corresponding site coefficient factor, "S".

Perform global stability and bearing capacity analysis for the selected earth retention systems. Use safety factors presented in Exhibit 6.4–B. For global stability analysis of walls on steep slopes consider the initial stability of the slope and the impact (or lack of) that the proposed construction has on the slope. This consideration may be more important than the theoretical minimum factor of safety for evaluating suitability of designs.

Exhibit 6.4–B AASHTO RETAINING STRUCTURES CRITERIA (FACTORS OF SAFETY)

Analysis Condition	Minimum Factor of Safety (FOS)[1,2]
Sliding (Static)	1.5
Sliding (Seismic)	1.125
Overturning (Static)	2.0 for footings on soil 1.5 for footings on rock
Overturning (Seismic)	1.5 for footings on soil 1.125 for footings on rock
Bearing capacity (Static)	3.0 (Shallow foundations)
Bearing Capacity (Seismic)	1.5 (Shallow foundations)

[1] *Based on AASHTO Standard Specification for Highway Bridges, AASHTO HB-17.*
[2] *Seismic factors of safety are applicable where the peak ground acceleration is greater than 0.09g.*

Refer to TGM Section 4.4 for guidance on wall selection and analysis tasks.

The primary source supporting the standards and guidance is GEC-2. Secondary sources are AASHTO HB-17, FHWA-FLP-94-006 and USACE EM 1110-2-2502.

6.4.4.1 Concrete Walls

The Structures Discipline designs concrete walls, usually and preferably according to FLH Standard Drawings. The Structures Discipline will use geotechnical recommendations to confirm the applicability of the standard plans. In addition to the standards listed in Section 6.4.4, provide soil, rock and groundwater design parameters for concrete gravity and cantilever walls. Include recommendations for the foundation and the retained soil, requirements for backfill, and the suitability of onsite material.

6.4.4.2 MSE Walls

In addition to the standards presented in Section 6.4.4, the following specific tasks are standard for MSE wall analysis and design. Include required minimum wall setback from a slope, embedment, and reinforcement length as a function of wall height. Final wall design including internal, sliding and overturning stability may be by FLH or by the construction contractor for FLH review, depending on the project; either way, MSE walls are designed or reviewed using MSEW and the procedures in GEC-11. Provide construction details and specifications using FP-XX Section 255 and Division specifications and Details (see Section 1.2.5) as appropriate

> Refer to TGM Section 4.4.2 for guidance on MSE wall analysis and design.
>
> The primary source supporting the standards and guidance is GEC-11. Secondary sources are WSDOT WA-M-46-03 and FHWA-NHI-09-087.

6.4.4.3 Soil Nail Walls

In addition to the general earth retention standards presented in Section 6.4.4, the following specific tasks are standard for soil nail analysis and design. Perform soil nail wall designs to evaluate nail lengths, spacing, layout, and global stability. Collaborate with the Structures Discipline to complete the least expensive satisfactory facing design. Evaluate corrosion and frost protection requirements and recommend how to address them. Use GoldNail or SNAIL to perform analyses for the final wall and at interim phases during construction, as in FHWA-SA-96-069R. Provide all details and specifications (using SCRs) necessary to construct the wall.

> Refer to TGM Section 4.4.3 for guidance on soil nail wall analysis and design.
>
> The primary source supporting the standards and guidance is GEC-7. Secondary sources are FHWA-SA-96-069R and FHWA-SA-93-068.

6.4.4.4 Pile Walls

Pile walls and other non-gravity, non-anchored cantilevered walls are used on FLH projects, but not frequently enough to have established analysis and design standards. Standard practice is, therefore, to follow the earth retention standards in Section 6.4.4 and the pile wall guidance in the TGM and GEC-2.

Refer to TGM Section 4.4.4 for guidance on pile wall analysis and design.

The primary source supporting the guidance is GEC-2. Secondary sources are AASHTO HB-17 and NAVFAC DM 7.2.

6.4.4.5 Ground Anchor Systems

In addition to the general earth retention standards presented in Section 6.4.4, the following specific standards for analysis and design of patterned ground anchors and ground anchor walls. Standard practice is also to follow the guidance in the TGM and GEC-4.

Perform preliminary ground-anchor designs for tieback walls and ground anchor systems to evaluate all modes of failure. Identify, with the project team, tolerable deformations and design accordingly. Provide requirements for factors of safety, allowable anchor capacity, unbonded length and hole diameter (if any), and minimum and maximum values for bond length. Use presumptive values of bond capacity and the results of field and laboratory exploration to estimate bond length for quantity estimation only. Do not design the anchor bond length or hole diameter, as these are contractor responsibilities based on their proposed installation method. Verify and prove the anchor capacity using the testing program presented in GEC-4.

Refer to TGM Section 4.4.5 for guidance on ground anchor systems and wall design.

The primary source supporting the standards and guidance is GEC-4. Secondary sources are PTI 2004 and FHWA-DP-68-1R.

6.4.4.6 Rockeries

A rockery is a retaining and slope protection structure that consists of stacked rocks without mortar, concrete or reinforcing steel. Rockeries are sometimes used where minimal earth retention is needed, the aesthetics of stacked rock is desired and there is cost savings over other retaining walls. In addition to the general standards presented in Section 6.4.4, standard practice is to follow the guidance in the TGM and FHWA-CFL/TD-06-006.

Refer to TGM Section 4.4.6 for guidance on rockery analysis and design.

The primary source supporting the standards and guidance is FHWA-CFL/TD-06-006. Secondary sources are ARC 2000 and WSDOT WA-M-46-03.

6.4.4.7 Temporary Cuts and Shoring

Maximum temporary un-shored slope heights and ratios are recommended based on observations, experience, and representative limit equilibrium slope stability analysis. Limit equilibrium slope stability analysis is used when observation and experience are not conclusive. Standard practice is to demonstrate a short-term factor of safety of 1.1 to 1.2 depending on uncertainty and consequences of failure. It is also standard to recommend in contract documents that the contractor evaluate the slope for safety during excavation and do what is required to maintain a safe working environment.

Shoring is recommended where the height and slope ratio limits cannot be met. Geotechnical based recommendations are provided on shoring types and on ground and water conditions to be expected. Shoring construction considerations and limits on types of shoring are developed based on-site conditions and project needs. Shoring design is the responsibility of the contractor, not FLH, is designed according to the appropriate general standards of Section 6.4.4 and must satisfy OSHA Section 29.

Refer to TGM Section 4.4.7 for guidance on temporary cuts and shoring.

The primary source supporting the standards and guidance is OSHA Section 29. Secondary sources are Ratay 1996 and CalTrans 2001.

6.4.5 OTHER STRUCTURES

6.4.5.1 Culverts and Pipes

Project specific geotechnical recommendations on culverts and pipes are not usually provided. FLH Standard Drawings address considerations such as bedding and minimum cover based on pipe diameter and material type. Standard practice is to provide foundation recommendations for box culverts in accordance with Section 6.4.3, and including backfill requirements and lateral earth pressure design parameters.

Refer to TGM Section 4.5.1 for guidance on geotechnical recommendations for culverts and pipes.

The primary source supporting the standards and guidance is USACE EM 1110-2-2902. Secondary sources are Spangler & Handy 1982 and FHWA-RD-98-191.

6.4.5.2 Building Foundations

Buildings are constructed on FLH projects, but not frequently enough to have established analysis and design standards. The same principles apply to building foundations as do to highway structure foundations so the investigation, analysis and design steps are the same. Standard practice is to design to local building code, the guidance in the TGM and NAVFAC DM 7.2.

Refer to TGM Section 4.5.2 for guidance on building foundations.

The primary source supporting the standards and guidance is NAVFAC DM 7.2 and the secondary source is NAVFAC DM-7.1.

6.4.5.3 Microtunnels and Trenchless Construction

Microtunnels and trenchless construction methods are used on FLH projects, but not frequently enough to have established analysis and design standards. Standard practice is, therefore, to follow the guidance in the TGM and FHWA-IF-02-064.

Refer to TGM Section 4.5.3 for guidance on geotechnical recommendations for mictrotunnels and trenchless construction.

The primary source supporting the standards and guidance is FHWA-IF-02-064 and the secondary source is CI/ASCE 36-01.

6.4.6 EARTHWORK

FLH standard practice is for the Geotechnical Discipline to provide the Design Discipline and Cross Functional Team specific materials and construction guidance for roadway earthwork. This guidance should include rippability, shrink/swell factors, usage of materials encountered on the project, embankment construction and stabilization requirements, embankment design, erosion and sediment control, and ground improvement alternatives. FLH standard practice for earthwork engineering is presented in this section through subsections directed towards specific aspects of earthwork.

Refer to TGM Section 4.6 for general guidance on earthwork.

The primary source supporting the standards and guidance is NHI 132012. Secondary sources are WSDOT WA-M-46-03, TRB SAR 8 and BOR Earth Manual.

6.4.6.1 Rippability

Bedrock rippability is based on bedrock characterizations from surface and subsurface exploration. Because rippability and seismic velocity are similarly influenced by intact rock strength, discontinuity frequency and strength, and discontinuity orientation, standard practice is to rely on published charts of seismic velocity versus rippability by standard excavating equipment as a first estimate of rippability. An example of such a plot is TGM Exhibit 4.6-D. Figures such as this are sometimes not consistent with experience, however, and it is standard practice to also consider and document other findings related to rippability, such as rock types, strengths and rock mass structure. Judgments on rippability are used during the design process to evaluate alternatives and costs, but it is standard practice to present only data in contract documents and to allow contractors to make the ultimate assessment of rippability based on their equipment and experience.

> Refer to TGM Section 4.6.1 for guidance on rippability.
>
> The primary source supporting the standards and guidance is FHWA-Geophysical, for seismic velocity, and the secondary source is NHI 132035.

6.4.6.2 Shrink/Swell Factors

FLH standard practice is to estimate shrink or swell of all excavation when placed as embankment in station-by-station, cut-by-cut, or material-by-material format (where the association of materials to cuts is also provided). Estimation is based on previous projects, published data, collected data, or in-situ density and lab measurement of density when compacted according to project specifications. Describe anticipated variances and complex soil/rock units, and note factors that impact earthwork quantities, such as topsoil stripping operations, clearing and grubbing requirements, survey accuracy, complex alignment, fill compaction and/or construction practices.

Shrink/swell factors provided by the Geotechnical Discipline account for only the difference in density between cut and embankment, and are noted as such in the Geotechnical Report. Unless otherwise specified, other factors that impact material balance such as survey, waste, or construction practices are not included. Estimates of shrink/swell factors for common materials are presented in TGM Exhibit 4.6-E. This source is usually tempered by other observations or experience.

> Refer to TGM Section 4.6.2 for guidance on geotechnical recommendations for shrink/swell.
>
> The primary source supporting the standards and guidance is Burch 2006 and the secondary source is Church 1981.

6.4.6.3 Material Sources and Excavation

FLH standard analysis and design tasks for material sources and excavated material consist of estimating locations and quantities of unsuitable materials, and identifying what could be done to make them suitable. Materials not identified as unsuitable or in need of processing are assumed to be suitable as is. Identify what type of processing is required to make materials suitable, if possible; for example, crushing, screening, blending, drying, or admixtures.

Identify if materials are suitable only for specific project features and uses. Refer to FP-XX *Section 703 – Aggregate, Section 704 – Soil, and Section 705 – Rock* for standard material designations, and use these where possible. Describe special required handling and placement requirements, or confirm that use of standard procedures in Division 200 of FP-XX is appropriate, and designate appropriate FP-03 Sections.

Because of the difficulty distinguishing between material types during construction, it is standard practice to not classify excavation as either rock or soil based on investigation results. See FP-XX *Section 204 – Excavation and Embankment*.

> Refer to TGM Section 4.6.3 for guidance on analysis of materials and sources.
>
> The primary source supporting the standards and guidance is FHWA-ED-88-053 and the secondary source is WSDOT WA-M-46-03.

6.4.6.4 Subgrade Stabilization

Subgrade stabilization within the roadway pavement prism is the responsibility of the Pavement Discipline and is covered in Section 11.3.1.3. It is standard practice for the geotechnical professional to coordinate with the Pavement Discipline and to provide geotechnical interpretation of subgrade conditions when requested. In addition to Chapter 11, geotechnical guidance is in the TGM and supporting documents.

> Refer to TGM Section 4.6.4 for geotechnical guidance on subgrade stabilization.
>
> The primary source supporting the guidance is FHWA-SA-93-004/5. Secondary sources are FHWA-HI-95-038 and FHWA-TS-80-236.

6.4.6.5 Embankments

Standard practice is to perform analyses and provide design recommendations with respect to embankment materials, special compaction requirements, foundation settlement, bearing capacity, and slope stability for embankments greater than 10 feet [3 meters] in height. Standards are presented in the following paragraphs.

Specify project materials suitable for embankment construction and recommended construction methods. Evaluate special embankment compaction requirements, if needed, and develop special contract requirements to address embankment compaction issues. Standard construction methods and specifications are shown in FP-XX *Section 204 – Excavation and Embankment*. Guidance is in the TGM and the primary source: *Soil Slopes and Embankments*, NHI 132033.

Evaluate settlement of large embankments using consolidation and elastic settlement methods, such as present in EMBANK or FoSSA. Evaluate ground improvement technologies where settlement predictions are not acceptable. Develop alternative embankment construction plans, as requested, to expedite settlement or improve embankment foundation conditions. Ground improvement guidelines are presented in Section 6.4.10.

Evaluate bearing capacity of the embankment foundation soils by inspection. If the possibility of bearing capacity failure cannot be ruled out by experience or precedent, complete a bearing capacity analysis (TGM Section 4.6.5). If necessary, make recommendations to modify the design using geosynthetics, staged construction or other means to prevent bearing capacity failure. Guidance on the use of geosynthetics is in TGM Section 4.10 and NHI 132034.

Evaluate embankment stability and provide maximum embankment slope ratios. It is FLH standard practice to design most small embankment fills using engineering judgment and precedents in the vicinity, and to not design slopes steeper than 1.5H to 1V. Perform limit equilibrium stability analyses for embankments where foundation conditions, material characteristics, and drainage conditions are poor. Evaluate slope stability of representative sections using limit equilibrium slope stability analysis procedures, automatic searches and/or specified surfaces. Distinguish between short-term (construction-phase) and long-term slope stability and consider the need for seismic stability analysis. The standard minimum short-term and long-term factors of safety are 1.1 to 1.2, and 1.3 to 1.5, respectively, depending on consequences of potential failure and uncertainty in how well the analysis model and its input parameters represent actual conditions; see the TGM section for further guidance.

Refer to TGM Section 4.6.5 for guidance on embankment analysis and design.

The primary source supporting the standards and guidance is NHI 132033. Secondary sources are WSDOT WA-M-46-03, and USACE EM 1110-1-1904 for settlement, and USACE EM 1110-2-1902 and FHWA-SA-94-005 for stability.

6.4.6.6 Reinforced Soil Slopes

Consider reinforced soil slopes (RSS) where design constraints require minimizing the footprint of a proposed embankment. FLH standard practice is to use ReSSA to evaluate RSS internal and external stability and design the type, length and spacing of the reinforcement elements. Evaluate global stability and subsurface drainage requirements. Provide slope treatment options that are compatible with project and partner agency goals. Guidelines for analysis and design of RSS are presented in the TGM and GEC-11.

Refer to TGM Section 4.6.6 for guidance on reinforced soil slopes.

The primary source supporting the standards and guidance is GEC-11 and the secondary source is GEC-1.

6.4.7 SLOPE STABILITY

FLH standard practice is to use precedence and limit equilibrium methods to analyze and design fill and cut slopes. It is standard practice to analyze landslides and design their mitigation using limit equilibrium methods. These standards are discussed in the following subsections for soil cut slopes and all landslides. Fill slopes and embankments are covered with other embankment design standards in Section 6.4.6.5 and rock slope stability is covered with other rock engineering tasks in Section 6.4.8.1.

6.4.7.1 Soil Cut Slopes

Evaluate the stability of planned and existing cut slopes along the roadway. Standard cut slope evaluation practice considers local precedence and engineering judgment. Slope design by local precedence applies where new soil cuts are less than 20 feet [6 meters] deep, slope height and/or slope ratio does not change appreciably, there is no prior evidence of instability, seepage is not evident or anticipated in the cut, and material types do not appear to change within the cut.

Limit equilibrium analysis is the standard method used to assess slope stability where local precedence does not apply. The standard minimum short-term and long-term factors of safety are 1.1 to 1.2, and 1.3 to 1.5, respectively, depending on consequences of potential failure and uncertainty in how well the analysis model and its input parameters represent actual conditions; see TGM section for further guidance.

> Refer to TGM Section 4.7.1 for guidance on cut slope stability.
>
> The primary source supporting the standards and guidance is USACE EM 1110-2-1902. Secondary sources are USFS EM 7170-13, Duncan & Wright 2005 and FHWA-SA-94-005.

6.4.7.2 Landslides

Use field mapping, survey, surficial geology reports, photography and monitoring to identify landslide extents and failure modes. FLH standard practice is to conduct landslide stability assessments based on soil/rock and groundwater profile information obtained during field exploration. Use measured soil/rock strength parameters and back-analysis of existing slide conditions. Analyze landslides on representative two-dimensional sections using limit equilibrium methods, with automatic searches and/or specified surfaces. Distinguish between short-term (construction-phase) and long-term slope stability and consider the need for seismic stability analysis (Section 6.4.11). The standard minimum long-term factor of safety is 1.25 to 1.5, depending on consequences of potential failure and uncertainty in how well the analysis model and its input parameters represent actual conditions. Guidance on safety factor ranges, including during construction, is presented in the TGM.

Recommend landslide mitigation measures based on cost, constructability, project constraints, and an understanding of risk and tolerance for ongoing movement. Include consideration of regrading/unloading of the slope, toe buttressing, enhanced slope drainage, ground conditioning, tieback retention, roadway realignment, etc.

> Refer to TGM Section 4.7.2 for guidance on landslide analysis and mitigation design.
>
> The primary source supporting the standards and guidance is TRB SR 247. Secondary sources are Cornforth 2005, FHWA-RT-88-040 and FHWA-ED-88-053.

6.4.8 ROCK ENGINEERING

This section addresses rock slopes, rockfall, foundations on rock, and rock tunneling. Standards are presented in the following sections for rock slopes, including rockfall evaluation and mitigation, and for rock foundations. Several FLH projects include rock tunnels, but tunnel analysis and design is relatively rare and FLH standards do not exist. The reader is directed to guidance in the TGM.

6.4.8.1 Rock Slopes

FLH standard practice is to make design recommendations for cut slopes in rock. The practice varies depending on the size of the cut.

- Design rock cuts less than 15 feet [5 meters] high or less than 10 feet [3 meters] deep (sliver cuts) by applying engineering judgment based on past performance of slopes in the project vicinity. Evaluate if changes in slope height or slope ratio are acceptable or desired based on past performance. Recommend maximum safe unreinforced slope ratios, slope heights and geometry based on observations and experience.
- For larger cuts and cuts where consequences of failure are especially critical, use geologic structure mapping and interpretation and/or kinematic and limit equilibrium analysis to augment observations and engineering judgment. For projects with complex geology, use stereonet-based kinematic analyses to determine the range of potential failure modes possible for a given slope, and then evaluate failure potential based on the shear strength of discontinuities and water conditions. The acceptable range of safety factors is 1.3 to 1.5, depending on consequence of failure and uncertainty in the data and how representative the analysis is of actual conditions. Additional guidance on analysis and factors of safety is provided in the TGM. If reinforcement can be used to considerably steepen a slope, reducing excavation and impact, recommend reinforcement requirements and maximum reinforced slope ratio.

> Refer to TGM Section 4.8.1 for guidance on rock slope analysis and design.
>
> The primary source supporting the standards and guidance is NHI 132035. Secondary sources are FHWA-TS-89-045 and FHWA-HI-92-001.

6.4.8.2 Rockfall Analysis

FLH standard practice is to provide rockfall hazard evaluation where rockfall hazards exist from previous highway work or will result from construction of the project. Hazard evaluation is the process of identifying the likelihood of rockfall occurring because of adverse geological (discontinuities, differential weathering, boulders, etc.) and environmental (water, ice, vegetation, slope angle and aspect, etc.) conditions. Hazard is evaluated by an experienced Geotechnical Professional with respect to other slopes on the project or similar projects. Hazard evaluation is based on site observations, boring logs and other explorations.

Key tasks are as follows:

- Conduct rock slope surveys that address the historic and potential future rockfall activity and hazard this activity presents to the proposed project.
- Assess rockfall risk for rock cuts on the project (new and/or existing). Rockfall risk is the potential for adverse consequence, such as maintenance cost, closure, injury or death. Standard practice is to do this in an efficient way for the project and to prioritize rockfall mitigation towards areas where hazard and risk are high. Use the Rockfall Catchment Area Design approach and/or numerical simulations such as the Colorado Rockfall Simulation Program (Section 6.4.8.3) to evaluate rockfall impact and runout.

> Refer to TGM Section 4.8.2 for guidance on rockfall hazard analysis.
>
> The primary source supporting the standards and guidance is FHWA-SA-93-057. Secondary sources are FHWA-OR-RD-01-04 and NHI 132035.

6.4.8.3 Rockfall Mitigation

Provide rockfall mitigation recommendations where rockfall hazards and risk exist from previous highway work or will result from construction of the project.

Key tasks are as follows:

- Recommend rockfall hazard mitigation methods, if needed, including proper excavation techniques, erosion control, rock reinforcement/conditioning, slope drainage, and failure management systems.
- Provide rockfall catchment ditch recommendations based on the Rockfall Catchment Area Design approach (FHWA-CFL/TD-05-008) and/or numerical simulations such as the Colorado Rockfall Simulation Program (CRSP). Discuss with the project team the rockfall hazard, the potential effectiveness of the ditch, and alternatives to modify both. Guidance for rockfall catchment ditch design is provided in the TGM.
- Convey long-term slope performance and maintenance expectations to the project team.

> Refer to TGM Section 4.8.3 for guidance on rockfall mitigation design.
>
> The primary source supporting the standards and guidance is FHWA-SA-93-085. Secondary sources are FHWA-CFL/TD-05-008, USACE EM 1110-1-2907, and NHI 132035.

6.4.8.4 Foundations on Rock

Foundations on rock are analyzed for bearing capacity and settlement. Standard practice for single span bridges and for walls is to recommend allowable bearing pressure based on published presumptive values for bearing capacity and 1 inch [25 mm] settlement (AASHTO HB-17 Table 1 in NAVFAC DM 7.2 or Figure 6-6 in USACE EM 1110-1-2908). Boring logs are used to characterize the foundation materials and conditions. Unconfined strength, if available, is used to refine classification of rock and optimize selection of bearing capacity.

For foundations of multi span bridges, structures with multiple foundation types, or structures that are particularly sensitive to settlement, and for foundations on intermediate geomaterials, FLH standard practice is to follow AASHTO HB-17 and the guidance in the TGM to develop design recommendations.

Refer to TGM Section 4.8.4 for guidance on rock foundations.

The primary source supporting the standards and guidance is AASHTO HB-17. Secondary sources are USACE EM 1110-1-2908, Wyllie 1992 and Canadian Foundation.

6.4.8.5 Tunnels

Rock tunnels exist on several FLH projects, but tunneling work is relatively rare and FLH analysis and design standards do not exist. For work on existing tunnels and for new tunnels, the Geotechnical Professional is directed to guidance through the TGM.

Refer to TGM Section 4.8.5 for guidance on tunnel analysis and design.

The primary source supporting the standards and guidance is FHWA-IF-05-023.

6.4.9 DRAINAGE, DEWATERING, AND EROSION CONTROL

FLH standard practice for the Geotechnical Discipline is to evaluate dewatering and drainage needs by observational methods except in locations where slope stability is analyzed. In analysis of slope stability dewatering is included in limit equilibrium analyses through use of a lower water table or water pressure. Assess site conditions, material types, drainage paths, hydrology, and planned geotechnical improvements. Assess drainage, dewatering and erosion control requirements associated with other geotechnical recommendations, such as slope stability, bearing capacity and settlement. Design and locate required surface and subsurface drainage including underdrains, horizontal drains, lateral trench drains, French drains, blanket drains, and cut-off drains. Coordinate with the Design Discipline and Hydraulics Discipline for the location and outlet of drains and ditches.

When geosynthetics are specified for drainage, dewatering and erosion control applications, identify the intended use of the geosynthetic (separation, filtration, drainage, strength, etc.), the general type of geotextile to be used (e.g. woven, non-woven), and specify soil and performance parameters for geotextile selection. Use standard drainage design details and construction specifications when practical. Standard specifications are in FP-XX *Section 602 – Culverts and Drains, Section 605 – Underdrains, Sheet Drains, and Pavement Edge Drains, Section 608 – Paved Waterways,* and *Section 610 – Horizontal Drains*. Standard designs are available through Chapter 9 and Chapter 7, and Geotechnical Discipline standards of practice are discussed in this section.

6.4.9.1 Surface Drainage

Provide design recommendations to control surface drainage when integral to the design or performance of specific geotechnical features, such as ditches on walls or integral to slopes. Surface drains include interceptor ditches, drainage channels and dry wells. Coordinate with the Hydrology and Hydraulics, and Design Disciplines. These Disciplines provide project-wide surface drainage design for the control of surface drainage as provided in Chapter 7 and Chapter 9.

Evaluate temporary construction erosion control requirements on cut and fill slopes when integral to geotechnical design or performance. For example, the requirement to provide bench drainage during top-down construction of slopes and walls might be required to assure construction phase stability. Incorporate appropriate design details or requirements in the geotechnical report and construction plans.

Refer to TGM Section 4.9.1 for Geotechnical Discipline guidance on surface drainage.

The primary source supporting the standards and guidance is FHWA-FLP-94-005. Secondary sources are FHWA-TS-80-218 and FHWA-RT-88-040.

6.4.9.2 Subsurface Drainage

Evaluate subsurface drainage needs, feasibility, and constructability, from a perspective of balancing risk and cost. Consider environmental and project design constraints, as defined by the Environmental Specialist, Hydraulics Engineer, and/or Designer, as well as specific geotechnical needs. Coordinate with the Hydraulics and Design disciplines, which provide project-wide surface drainage design.

Provide subsurface drainage design recommendations to reduce adverse effects of groundwater on the project. Subsurface drainage systems include pavement underdrains and edge drains, trench drains, horizontal drains, vertical relief drains, granular drainage blankets, chimney drains and interceptor drains.

Geotextiles and geocomposites are often used as part of subsurface drainage and standard practice is to provide recommendations including material requirements and construction methods. When geotextiles are specified for subsurface drainage applications, identify the intended use of the geotextile (separation, filtration, strength, or multiple uses, etc.), the general type of geotextile to be used (e.g. woven, non-woven), and specify soil and performance parameters for geotextile selection. Geotextile material specifications are in FP-XX *Section 714 – Geotextile and Geocomposite Drain Material*.

Refer to TGM Section 4.9.2 for Geotechnical Discipline guidance on subsurface drainage.

The primary source supporting the standards and guidance is FHWA-TS-80-224. Secondary sources are FHWA-RD-86-171, NHI 132013A, FHWA-SA-93-004/5 and FHWA-CA-TL-80-16.

6.4.9.3 Dewatering

Dewatering is the temporary removal of surface water or groundwater, either from within the ground or in excavations. Evaluate dewatering needs as they relate to slope stability and temporary construction requirements. If dewatering is potentially required, consider potential impacts dewatering may have to surrounding property, such as excessive settlement, and the environmental effects of the discharge water. Provide recommendations for geotechnical issues that may impact dewatering methods and requirements or may arise from dewatering.

Refer to TGM Section 4.9.3 for Geotechnical Discipline guidance on dewatering.

The primary source supporting the standards and guidance is Powers 1981. Secondary sources are USACE EM 1110-2-1914 and ASCE 1985.

6.4.9.4 Erosion Control

FLH standard Geotechnical Discipline practice is to evaluate surface erosion potential around structure foundations and unique geotechnical project features such as MSE walls, reinforced slopes, and ground anchors. Base evaluation on characterization of materials, potential water sources, roadway geometrics and slope design. Provide recommendations for erosion control needs.

Routine erosion control design is a function of design and is addressed in Chapter 7 and Chapter 9. Erosion control material specifications are in FP-XX *Section 713 - Roadside Improvement Materials and Section 714 – Geotextile and Geocomposite Drain Materials*. Standard construction specifications are *Section 629 – Rolled Erosion Control Products and Cellular Confinement Systems*.

Refer to TGM Section 4.9.4 for Geotechnical Discipline guidance on erosion control.

The primary source supporting the standards and guidance is FHWA-FLP-94-005 and the secondary source is NHI 142054.

6.4.10 GROUND IMPROVEMENT

FLH standard practice is to evaluate and use ground improvement methods where they can significantly impact a project by making construction feasible, faster, with less impact, or more economical. Where ground improvement may have significant value, assess site conditions, material types, and project needs, and follow the guidance in TGM Section 4.10. The primary source for guidance is *Ground Improvement Techniques*, NHI 132034. Exhibit 6.4–C shows method-specific sources.

When geotextiles are specified for geotechnical applications, identify the intended use of the geotextile (separation, filtration, strength, etc.), the general type of geotextile to be used (e.g. woven, non-woven), and specify soil and performance parameters for geotextile selection. Soil stabilization requirements specific to pavement structural sections are provided by the Pavement Discipline, as discussed in Chapter 11.

Exhibit 6.4–C REFERENCES FOR GROUND IMPROVEMENT ANALYSIS AND DESIGN

Subject	Secondary Sources
General	NCHRP Synthesis 147 FHWA-SA-98-086R FHWA-SA-92-041 FHWA-ED-88-053
Geosynthetics	Koerner 1994 WSDOT WA-M-46-03
Deep Soil Mixing	FHWA-RD-99-138
Dynamic Compaction	GEC-1
Blast Densification	WSDOT WA-M-46-03
Soil Stabilization	FHWA-SA-93-004/5
Stone Columns	FHWA-RD-83-026

6.4.11 GEOTECHNICAL EARTHQUAKE ENGINEERING

FLH standard practice is to evaluate geotechnical earthquake engineering needs for bridges by assessing site conditions, material types, and project needs, and by consulting AASHTO HB-17 Division 1-A. Provide AASHTO-derived seismic and site coefficients to the Structures group.

Standard practice is to perform seismic analysis for walls and anchored slopes when the peak ground acceleration (10 percent exceedance in 50 years) is estimated to be greater than 0.1g. Standard practice is that seismic analysis is not performed on slopes or landslides except where ground anchors or other structures are installed for stabilization, or the consequence of failure is exceptionally high. Pseudo static analysis is the standard analysis procedure in these cases.

Standard practice is to review available geologic maps and seismic hazard maps to augment AASHTO HB-17. The USGS Hazmaps is the standard source. Liquefaction potential is evaluated using published maps of susceptibility, where they exist, and SPT methods. Evaluate liquefaction impacts on projects such as drawdown on piles and embankment stability. Guidance on these standards and many other non-standardized issues related to earthquake engineering is available in TGM Section 4.11. Supporting sources, which are all identified and linked through the TGM section, are also listed in Exhibit 6.4–D.

Exhibit 6.4–D REFERENCES FOR GEOTECHNICAL EARTHQUAKE ENGINEERING AND DESIGN

Subject	Primary Source	Secondary Sources
Geotechnical Earthquake Design	GEC-3	AASHTO HB-17 NHI 132039A WSDOT WA-M-46-03 Kramer 1996
Liquefaction Potential and Mitigation	GEC-3	AASHTO HB-17 WSDOT WA-M-46-03

6.5 DOCUMENTATION AND SUPPORT

This section presents FLH standards and links to FLH guidance for geotechnical documentation and reporting, review of plans and specifications, construction support, post-construction (ongoing) monitoring, and emergency response. The standard practices presented in this section have evolved from FLH experience and are to be used unless an exception is justified (Section 6.2.3). These standards support the policies presented in Section 6.2.1 guiding FLH geotechnical practice. Standards are not written for many geotechnical documentation and support tasks because the needs are project-specific; consult TGM Section 5 for guidance.

Follow the established quality control and assurance procedures for reporting and documentation. Procedures are unique to each Division and can be accessed through Division Supplements.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

6.5.1 GEOTECHNICAL REPORTS AND DOCUMENTS

FLH standard practice is to prepare geotechnical memoranda and reports that clearly and succinctly document field investigation and laboratory data and design/construction recommendations. Develop the final geotechnical report to provide designers, construction project engineers and contractors with information concerning the materials and conditions that are expected to be encountered in the field. These standards are discussed in this section. Guidance on these standards and other non-standardized issues related to reporting and documentation is available in TGM Section 5.

6.5.1.1 General

Organize geotechnical memoranda and reports to be consistent and to follow the same general format to allow for familiarity by even the occasional reader. Ensure that factual data is presented separately from interpretation and opinion, and that all interpretations are clearly identified as such. Describe potential problems disclosed by analyses and recommend potential feasible solutions. Provide an assessment of relative cost and uncertainty associated with each of the recommended options. Include recommendations for design and considerations for construction.

Reports and memoranda are prepared at all stages of projects and they are to be clearly identified as “preliminary”, “interim”, or “final” to refer to the stage of the project, not the correspondence. When correspondence at any stage is going through development or review it is identified as “draft”.

6.5.1.2 Standard Reporting Organization and Content

The following list presents the standard reporting format for technical project. Each section might be a sentence, a paragraph or a chapter depending on the scope of work and the purpose of the correspondence. Omit sections when they are not relevant. Format reports so as to be suitable as hard copy and for electronic posting.

1. Executive Summary. Optionally included in larger reports with complicated scopes and content.
2. Introduction. Present the purpose of the correspondence/report.
3. Project Description. Describe the project only as needed to put recommendations in context.
4. Geology. Start regionally and end with site-specific observations and geohazards, including seismicity.
5. Site Conditions. Describe the physical setting based on above ground observations.
6. Subsurface Conditions. Describe subsurface investigation procedures and findings.
7. Analysis. Present analysis methods, assumptions, and input, and summarize results.
8. Design Recommendations. Present recommendations directed toward preferred alternatives, with a discussion on geotechnically-based risks, and in a station-by-station and/or feature-by-feature format.
9. Construction Considerations. Recommend construction specifications (FP-XX, SCR, or other) and present geotechnical observations that may impact construction methods and progress.
10. References. List of complete references (including previous work)specifically cited in the correspondence/report.

> Refer to TGM Section 5.1 for Geotechnical Discipline guidance on reporting and documents.
>
> The primary source supporting the standards and guidance is NHI 132031. Secondary sources are FHWA-ED-88-053 for geotechnical reports and ASCE GBR for baseline reports.

6.5.1.3 Review of Calculations and Reports

FLH standard practice is to review calculations and reports whether they are generated internally or by consultants. When reviewing internal calculations and reports the review is part of the Division QA/QC process, which is found through the Division Supplements link in Section 6.5. When reviewing external calculations and reports the review is part of the FLH oversight process that occurs after the consultant has conducted their own QA/QC process.

> Refer to TGM Section 5.1.3 for Geotechnical Discipline guidance on work review.
>
> The primary source supporting the standards and guidance is FHWA-ED-88-053. The secondary sources are ASFE Guidelines, for reports, and Division QA/QC plans for calculations.

6.5.2 FINAL DESIGN AND REVIEW OF PLANS AND SPECIFICATIONS

FLH standard practice is to review submittals of design plans and specifications with respect to the previous preliminary submittal and previous review comments. This is done for projects that include geotechnical aspects, such as walls, bridges, other structures with foundations, cuts or fills higher than 10 feet [3 meters], or any non-standard earthwork. Geotechnical recommendations will have been prepared for these projects. Geotechnical reports and memoranda will have been prepared for these projects and the Geotechnical Discipline checks that geotechnical recommendations are adequately included.

Review standards are discussed in this section. Guidance on these standards and many other non-standardized issues related to plan and specification review and finalization is available in TGM Section 5.2 and other sources listed in Exhibit 6.5–A. Specific standard practice tasks during submittal reviews are as follows:

- Ensure that the plans, specifications, and estimates of cost and/or quantity adequately reflect the geotechnical recommendations
- Assist the Project Manager with resolving inconsistencies between geotechnical recommendations and roadway/bridge preliminary designs
- Adapt or modify previous analyses and recommendations as necessary to evaluate changes made during final design and the preparation of plans and specifications
- Evaluate the reasonableness and acceptability of risks and consequences of design options. Ensure that the FP-XX is used where applicable and that project SCRs and design standards (including FLH Standard Drawings) are current and appropriate.
- Prepare addendum or revised geotechnical reports if conclusions and recommendations change during the design phase
- Where instrumentation exists, monitor using guidance in TGM Section 5.2 and Geotechnical Instrumentation, NHI 132041 and verify design recommendations based on new data.
- Confirm that if a Geotechnical Advisory was recommended it is included in the plans or specifications.

FLH standard practice is to compile comments on PS&E review forms as provided by the FLH Project Manager. Identify whether unique or complex construction would warrant geotechnical assistance or advice during the construction phase and communicate such needs in advance with construction personnel to help them plan for the construction phase. Where needed, the Geotechnical Discipline participates in pre-award support, pre-construction meetings, and during construction at key times.

Exhibit 6.5–A FINAL DESIGN AND REVIEW REFERENCES

Subject	Primary Source	Secondary Sources
Final Design	FHWA-ED-88-053	
Plans and Specifications	FP-XX	FLH Standard Drawings
Cost Estimates	FLH Engineer's Estimate Program	RS Means USACE ER 1110-2-1302
Instrumentation Monitoring	NHI 132041	TRB SR 247
Addendum Reports	FHWA-ED-88-053	
Planning Geotechnical Services for Construction Phase	NHI 132012	

6.5.3 CONSTRUCTION SUPPORT

The Geotechnical Discipline provides geotechnical support to construction management during bidding and construction. Inform the construction Project Engineer of any specialized geotechnical concerns or requirements and help provide related orientation or training for project inspectors. The Geotechnical Discipline participates in prebid and preconstruction meetings for projects that have major or complex geotechnical issues and designs.

FLH standard practice is to respond to calls from construction staff on geotechnical issues. Priority is given to construction needs so construction progress is not held up.

Review contractor submittals that include geotechnical items. Exhibit 6.5–B lists common work elements that require contractor submittals and Geotechnical Discipline involvement and support. In completing reviews, provide comments to seek clarification or correction of contractor designs, as necessary. Contractor submittal review should be in consideration of the standard design processes described in Section 6.4 and the guidance in TGM Section 5.3. In addition to FLH-specific guidance, the TGM provides links to primary industry construction inspection references and secondary sources. These links are repeated in Exhibit 6.5–B.

The Geotechnical Discipline visits the site as needed and requested to assist with special geotechnical inspection and to address unanticipated conditions, design changes or differing site condition claims. Coordinate monitoring of instrumentation that is required to evaluate the progress of construction and the performance of potentially impacted facilities. Perform prompt investigations of claimed or apparent “changed conditions” to assist in the resolution of issues and design or construction changes. Document the site visit observations and findings according to Division procedures.

Exhibit 6.5–B CONSTRUCTION SUPPORT REFERENCES

Subject	Primary Source	Secondary Sources
Contractor Submittals		
Footing Inspection		
Pile Inspection	NHI 132022	NHI 132021 NHI 132069
Drilled Shaft Inspection	NHI 132070	ADSC 1989
Micropile Inspection	FHWA-NHI-05-039	FHWA-SA-97-070
MSE Wall Inspection	GEC-11	
Soil Nail Inspection	FHWA-SA-93-068	
Anchor Inspection	GEC-4	FLH Anchor Inspection
Earthwork Inspection	TRB SAR 8	
Ground Improvement Inspection	NHI 132034	
Instrumentation Installation and Monitoring	NHI 132031	AASHTO MSI-1 NHI 132012 NHI 132041 NCHRP Synthesis 89 TRB SR 247
Geotechnical Documentation	NHI 132031	

6.5.4 POST-CONSTRUCTION MONITORING AND EMERGENCY RESPONSE

FLH standard practice is to monitor geotechnical instrumentation that is necessary to verify satisfactory performance of constructed facilities. Guidance on monitoring geotechnical performance is provided in TGM Section 5.4.

The Geotechnical Discipline provides emergency geotechnical support for evaluating geologic hazards and designing repairs to facilities harmed by natural disasters through the ERFO program. Guidance on ERFO repair is provided in TGM Section 5.4. The TGM guidance is supported by FHWA-RT-88-040 for highway slopes in general and FHWA-SA-93-085 for rock slopes in particular. Exhibit 6.5–C provides links to these and other sources of guidance.

Exhibit 6.5–C POST CONSTRUCTION MONITORING AND EMERGENCY RESPONSE REFERENCES

Subject	Primary Source	Secondary Sources
Monitoring Geotechnical Performance	NHI 132031 FHWA-SA-93-057	AASHTO MSI-1 NHI 132012 NHI 132041 NCHRP Synthesis 89 TRB SR 247
Repair of Geotechnical Features	FHWA-SA-93-085 FHWA-RT-88-040	FHWA-OR-RD-01-04 TRB SR 247
Responding to Emergencies	ERFO	OSHA Section 29 MUTCD

6.6 PRIMARY AND SECONDARY SOURCES

1.	AASHTO HB-17	AASHTO, Standard Specifications for Highway Bridges, 17th ed., HB-17, 2002
2.	AASHTO MSI-1	AASHTO, *Manual on Subsurface Investigation*, MSI-1, 1988.
3.	AASHTO R 22-97	AASHTO, Standard Recommended Practice for Decommissioning Geotechnical Exploratory Boreholes, AASHTO R 22-97, Standard Specifications, 2005.
4.	AASHTO Stds HM-25-M	AASHTO, *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, Part II: Tests, HM-25-M, 2005.
5.	ADSC 1989	ADSC, Drilled Shaft Inspector's Manual, 1989.
6.	ARC 2000	Associated Rockery Contractors, *Rock Wall Construction Guidelines*, Woodinville, WA, 2000 or current edition.
7.	ASCE 1985	ASCE, Dewatering: Avoiding Its Unwanted Side Effects, ISBN 0-87262-459-5, 1985.
8.	ASCE GBR	ASCE, Geotechnical Baseline Reports for Underground Construction - Guidelines and Practices, 1997.
9.	ASFE Guidelines	ASFE, The ASFE Guide to the In-House Review of Reports
10.	ASTM Standards	ASTM Standards
11.	BOR Drillers Safety	US Bureau of Reclamation, Driller's Safety Manual, US Department of the Interior, 1973.
12.	BOR Earth Manual	US Bureau of Reclamation, *Earth Manual, Third Edition*, US Department of the Interior, 1998.
13.	Burch 2006	Burch, Deryl, Estimating Excavation, Craftsman Book Company, 2006.
14.	CalTrans 2001	CalTrans, *Trenching and Shoring Manual*, 2011
15.	Canadian Foundation	Canadian Geotechnical Society, Canadian Foundation Engineering Manual, 3rd ed., 1992.
16.	Church 1981	Church, H.K., Excavation Handbook, McGraw-Hill, 1981.
17.	CI/ASCE 36-01	Standard Construction Guidelines for Microtunneling, 2001

18.	Cornforth 2005	Cornforth, D.H., Landslides in Practice: Investigation, Analysis, and Remedial/Preventative Options in Soil, Wiley & Sons, 2005.
19.	COM624P	Laterally Loaded Pile Analysis, Version 2.0 software.
20.	Duncan & Wright 2005	Duncan, J.M. & Wright, S. G., Soil Strength and Slope Stability, Wiley & Sons, 2005.
21.	EPRI EL-6800	EPRI, Manual on Estimating Soil Properties for Foundation Design, Electrical Power Research Institute, Report No. EL-6800, 1990.
22.	ERFO	FHWA, *Emergency Relief for Federally Owned Roads, Disaster Assistance Manual*, FHWA-FLH-11-001, 2011.
23.	FHWA-CA-TL-80-16	Cal Trans, The Effectiveness of Horizontal Drains, Final Report FHWA-CA-TL-80-16, 1980.
24.	FHWA-CFL/TD-05-008	FHWA, Rockfall Catchment Area Design Guide - Implementation Guide, FHWA and CFL, FHWA-CFL/TD-05-008, 2005.
25.	FHWA-CFL/TD-05-001	Guidelines for Temporary Traffic Control, FHWA-CFL/TD-05-001
26.	FHWA-CFL/TD-06-006	Rockery Design and Construction Guidelines, FHWA-CFL/TD-06-006, 2006.
27.	FHWA-DP-68-1R	FHWA, Permanent Ground Anchors, FHWA-DP-68-1R, 1988.
28.	FHWA-ED-88-053	FHWA, *Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications*, FHWA-ED-88-053, 1988, revised 2003.
29.	FHWA-FLP-94-005	FHWA, *Best Management Practices for Erosion and Sediment Control*, EFLHD, FHWA-FLP-94-005, 1995.
30.	FHWA-FLP-94-006	US Forest Service, Retaining Wall Design Guide, 2nd ed., FHWA-FLP-94-006, US Department of Agriculture, 1994.
31.	FHWA-Geophysical	FHWA, *Application of Geophysical Methods to Highway Related Problems*, cooperatively with Blackhawk Geosciences, 2003.
32.	FHWA-HI-92-001	FHWA, *Rock Blasting and Overbreak Control*, NHI Course No. 13211, FHWA-HI-92-001, 1991.

33. FHWA-HI-95-038 FHWA, *Geosynthetic Design and Construction Guidelines*, NHI Course No. 132013A, FHWA HI-95-038, 1995.

34. FHWA-IF-02-064 FHWA, Manual for Controlling and Reducing the Frequency of Pavement Utility Cuts, October 2002

35. FHWA-IF-05-023 FHWA, FHWA Road Tunnel Design Guidelines, FHWA-IF-05-023, 2005.

36. FHWA-NHI-05-039 FHWA, Micropile Design and Construction Guidelines - Reference Manual, NHI Course No. 132078, 2005.

37. FHWA-NHI-09-087 FHWA, *Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Slopes*, FHWA-NHI-09-087, 2009.

38. FHWA-OR-RD-01-04 Oregon DOT, Rockfall Catchment Area Design Guide, Oregon DOT and FHWA Final Report SPR-3 (032), FHWA-OR-RD-01-04, 2001.

39. FHWA-RD-83-026 FHWA, *Design and Construction of Stone Columns*, Vol. 1, FHWA-RD-83-026 & Vol. 2 Appendices, FHWA-RD-83-027, 1983

40. FHWA-RD-86-171 FHWA, Geocomposite Drains, Volume 1, FHWA-RD-86-171, 1986.

41. FHWA-RD-86-185 FHWA, Spread Footings for Highway Bridges, FHWA-RD-86-185, 1986.

42. FHWA-RD-95-172 FHWA, Load Transfer for Drilled Shafts in Intermediate Geomaterials, FHWA-RD-95-172, 1996.

43. FHWA-RD-98-191 FHWA, Pipe Interaction with the Backfill Envelope, FHWA-RD-98-191, 1999.

44. FHWA-RD-99-138 FHWA, An Introduction to the Deep Soil Mixing Methods as used in Geotechnical Applications, FHWA-RD-99-138, 2000.

45. FHWA-RT-88-040 FHWA, *Highway and Slope Maintenance and Slide Restoration Workshop Manual*, FHWA-RT-88-040, 1988.

46. FHWA-SA-91-043 FHWA, The Cone Penetrometer Test, FHWA-SA-91-043, 1992.

47. FHWA-SA-91-044 FHWA, Flat Dilatometer Test, FHWA- SA-91-044, 1991.

48. FHWA-SA-92-041 — AASHTO, In Situ Improvement Techniques, Task Force 27 Report and FHWA-SA-92-041, 1990.

49. FHWA-SA-93-004/5 — FHWA, Soil and Base Stabilization and Associated Drainage Considerations, Vol. 1, FHWA-SA-93-004, and Vol. 2, FHWA-SA-93-005, 1993.

50. FHWA-SA-93-057 — FHWA, *Rockfall Hazard Rating System, "Participants Manual"*, FHWA-SA-93-057, NHI Course No. 13220, 1993.

51. FHWA-SA-93-068 — FHWA, *Soil Nailing Field Inspectors Manual*, FHWA-SA-93-068, 1994.

52. FHWA-SA-93-085 — FHWA, Rockfall Hazard Mitigation Methods, Participant Workbook, NHI Course No. 13219, FHWA-SA-93-085, 1994.

53. FHWA-SA-94-005 — FHWA, Advanced Course on Slope Stability, Vol. 1, FHWA-SA-94-005, 1994.

54. FHWA-SA-96-069R — FHWA, *Manual for Design & Construction Monitoring of Soil Nail Walls*, FHWA-SA-96-069R, 1999.

55. FHWA-SA-97-070 — FHWA, *Micropile Design and Construction Guidelines - Implementation Manual*, FHWA- SA-97-070, 1997.

56. FHWA-SA-98-086R — FHWA, Ground Improvement Technical Summaries, Vols. 1 and 2, FHWA-SA-98-086R, 1998.

57. FHWA-TS-80-218 — FHWA, Underground Disposal of Storm Water Runoff, FHWA-TS-80-218, 1980.

58. FHWA-TS-80-224 — FHWA, Highway Subdrainage Design, FHWA-TS-80-224, 1980.

59. FHWA-TS-80-236 — FHWA, Expansive Soils in Highway Subgrades Summary, FHWA-TS-80-236, 1980.

60. FHWA-TS-89-045 — FHWA, Rock Slopes: Design, Excavation, Stabilization, Turner-Fairbank Highway Research Center, FHWA-TS-89-045, 1989.

61. FLH Anchor Inspection — FLH, Inspection of Ground Anchors, 2 disk CD, Coordinated Federal Lands Technology Implementation Program, 2004.

62. FLH Engineer's Estimate Program — FLH, Engineer's Estimate Program, Federal Lands Highway, 2006.

63. FLH Standard Drawings — FLH, *Standard Drawings*.

64. FP-XX — FLH, *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects*, FP-XX, current edition.

65. GEC-1 — FHWA, *Dynamic Compaction*, Geotechnical Engineering Circular No. 1, FHWA-SA-95-037, 1995.

66. GEC-2 — FHWA, Earth Retaining Systems, Geotechnical Engineering Circular No. 2, FHWA-SA-96-038, 1996.

67. GEC-3 — FHWA, *Earthquake Engineering for Highways*, Geotechnical Engineering Circular No. 3, Vol. 1 - Design Principles, FHWA-SA-97-076, 1997. Vol. 2 – Design Examples, FHWA-SA-97-077, 1997.

68. GEC-4 — FHWA, *Ground Anchors and Anchors Systems*, Geotechnical Engineering Circular, No. 4, FHWA-IF-99-015, 1999.

69. GEC-5 — FHWA, *Evaluation of Soil and Rock Properties*, Geotechnical Engineering Circular No. 5, FHWA-IF-02-034, 2002.

70. GEC-6 — FHWA, *Shallow Foundations*, Geotechnical Engineering Circular No. 6, FHWA-IF-02-054, 2002.

71. GEC-7 — FHWA, *Soil Nail Walls*, Geotechnical Engineering Circular No. 7, (FHWA-SA-96-069) FHWA-IF-02-054, 2002.

72. GEC-10 — FHWA, *Drilled Shafts: Construction Procedures and LRFD Design Methods*, Geotechnical Engineering Circular No. 10, FHWA-NHI-10-016, 2010.

73. GEC-11 — FHWA, *Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes*, Geotechnical Engineering Circular No. 11, FHWA-NHI-10-024, 2009.

74. Koerner 1994 — Koerner, R.M., Designing with Geosynthetics, Third Edition, Prentice Hall, 1994.

75. Kramer 1996 — Kramer, S.L., Geotechnical Earthquake Engineering, Prentice-Hall, 1996.

76. LPILE — LPILE Plus, A Program for the Analysis of Piles and Drilled Shafts Under Lateral Loads.

77. MUTCD — FHWA, *Manual on Uniform Traffic Control Devices for Streets and Highways*, current edition.

78.	NAVFAC DM-7.1	US Department of the Navy, *Soil Mechanics*, Design Manual NAVFAC DM-7.1, 1986
79.	NAVFAC DM 7.2	US Department of the Navy, *Foundation and Earth Structures*, Design Manual NAVFAC DM-7.2, 1982.
80.	NCHRP RR 378	NCHRP, Recommended Guidelines for Sealing Geotechnical Exploratory Holes, Research Report 378, TRB, 1995.
81.	NCHRP Synthesis 89	NCHRP, Geotechnical Instrumentation for Monitoring Field Performance, NCHRP Synthesis 89, 1982.
82.	NCHRP Synthesis 147	NCHRP, Treatment of Problem Foundations for Highway Embankments, Synthesis 147, TRB, 1989.
83.	NDA	National Drilling Association, Drilling Safety Guide, revised 1997
84.	NHI 132012	FHWA, Soils and Foundations Workshop, NHI Course No. 132012, 3rd Edition, FHWA NHI-00-045, 2000.
85.	NHI 132013A	FHWA, Geosynthetics Engineering Workshop, NHI Course No. 132013A.
86.	NHI 132021	FHWA, Design and Construction of Driven Pile Foundations, Vol. 1 and Vol. 2, NHI Course No. 132021, FHWA-HI-97-013 and FHWA-HI-97-014, 1996.
87.	NHI 132022	FHWA, Driven Pile Foundations – Construction Monitoring, NHI Course No. 132022.
88.	NHI 132031	FHWA, *Subsurface Investigations - Geotechnical Site Characterization*, NHI Course Manual No. 132031, FHWA-NHI-01-031, 2002.
89.	NHI 132033	FHWA, Soil Slopes and Embankments - Training Course in Geotechnical and Foundation Engineering, NHI Course No. 132033 - Module 3, FHWA, 2004.
90.	NHI 132034	FHWA, Ground Improvement Techniques - Training Course in Geotechnical and Foundation Engineering, NHI Course No. 132034 - Module 4, 2004.
91.	NHI 132035	FHWA, Rock Slopes - Training Course in Geotechnical and Foundation Engineering, Participants Manual, NHI Course No. 132035 - Module 5, FHWA-NH-99-007, 1998.

92.	NHI 132039A	FHWA, Geotechnical Earthquake Engineering – Training Course in Geotechnical and Foundation Engineering, Participant's Manual, NHI Course No. 132039A - Module 9, FHWA-HI-99-012, 2000.
93.	NHI 132041	FHWA, Geotechnical Instrumentation, Reference Manual, NHI Course No. 132041 – Module 11, FHWA-HI-98-034, 1998.
94.	NHI 132069	FHWA, Driven Pile Foundation Inspection, NHI Course No. 132069.
95.	NHI 132070	FHWA, Driven Shaft Foundation Inspection, NHI Course No. 132070.
96.	NHI 142054	FHWA, Design and Implementation of Erosion and Sediment Control, NHI Course 142054, Participant Workbook, 2004.
97.	OSHA Section 29	OSHA, *Code of Federal Regulations Section 29*, OSHA Standards, current edition.
98.	Powers 1981	Powers, J.P., Construction Dewatering: A Guide to Theory and Practice, Wiley & Sons, 1981.
99.	PTI 2004	Post Tensioning Institute (PTI), Recommendations for Prestressed Rock and Soil Anchors, 4th Edition, 2004.
100.	Ratay 1996	Ratay, R., Handbook of Temporary Structures in Construction; Engineering Standards, Designs, Practices and Procedures, Second ed., McGraw-Hill, 1996.
101.	RS Means	Heavy Construction Cost Data, 20th ed., 2006
102.	Spangler & Handy 1982	Spangler, M.G. and Handy R.L., Soil Engineering, Fourth Edition, Harper & Row, 1982.
103.	TRB SAR 8	TRB, *Guide to Earthwork Construction*, State of the Art Report No. 8, ISBN 0-309-04957-1, 1990.
104.	TRB SR 247	TRB, Landslides: Investigation and Mitigation, Special Report 247, ISBN 0-309-06151-2, 1996.
105.	USACE EM 1110-1-1802	US Army Corps of Engineers, *Engineering and Design - Geophysical Exploration for Engineering and Environmental Investigations*, Manual EM 1110-1-1802, Department of the Army, 1995.

106. USACE EM 1110-1-1804 — US Army Corps of Engineers, *Engineering and Design – Geotechnical Investigations*, Manual 1110-1-1804, Department of the Army, 2001.

107. USACE EM 1110-1-1904 — US Army Corps of Engineers, *Engineering and Design - Settlement Analysis*, Manual EM 1110-1-1904, Department of the Army, 1990.

108. USACE EM 1110-1-1905 — US Army Corps of Engineers, *Engineering and Design - Bearing Capacity of Soils*, Manual EM 1110-1-1905, Department of the Army, 1992.

109. USACE EM 1110-1-2907 — US Army Corps of Engineers, *Engineering and Design - Rock Reinforcement*, Manual EM 1110-1-2907, Department of the Army, 1980.

110. USACE EM 1110-1-2908 — US Army Corps of Engineers, *Engineering and Design - Rock Foundations*, Manual EM 1110-1-2908, Department of the Army, 1994.

111. USACE EM 1110-2-1902 — US Army Corps of Engineers, Engineering *and Design - Slope Stability*, Manual EM-1110-2-1902, Department of the Army, 2003.

112. USACE EM 1110-2-1914 — US Army Corps of Engineers, *Engineering and Design - Design, Construction, and Maintenance of Relief Wells*, Manual EM 1110-2-1914, Department of the Army, 1992.

113. USACE EM 1110-2-2502 — US Army Corps of Engineers, *Engineering and Design - Retaining and Flood Walls*, Manual EM 1110-2-2502, Department of the Army, 1989

114. USACE EM 1110-2-2902 — US Army Corps of Engineers, *Engineering & Design - Conduits, Culverts, and Pipes*, Manual EM 1110-2-2902, Department of the Army, 1998.

115. USACE ER 1110-2-1302 — US Army Corps of Engineers, *Engineering and Design – Civil Works Cost Engineering*, Regulation ER 1110-2-1302, Department of the Army 2008.

116. USFS EM 7170-13 — US Forest Service, Slope Stability Reference Guide for National Forests in the United States, Vol. 1, Publication EM-7170-13, US Department of Agriculture, 1994.

117. USGS Hazmaps — USGS Seismic Hazard Maps

118.	WSDOT WA-M-46-03	Washington State DOT, Geotechnical Design Manual, WA-M-46-03, 2005.
119.	Wyllie 1992	Wyllie, D.C., Foundations on Rock, 2nd ed., E & FN Spon, 1999.

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LIST OF EXHIBITS

CHAPTER 7

HYDROLOGY AND HYDRAULICS

7.1 GENERAL

This chapter identifies the hydrologic and hydraulic related policies, standards, standard practices, criteria, guidance, and references approved for use in developing highway and bridge designs in the Federal Lands Highway Programs. Refer to Chapter 1 for definitions of policy, standards, standard practices, criteria, and guidance. Where appropriate, relevant procedures, instructional aids, and publications such as engineering manuals, AASHTO guidelines, federal regulations, and computer programs are referenced. Detailed descriptions and examples of technical methods or procedures are not included. Users of this chapter are expected to be knowledgeable in the use of all referenced methods and procedures, and otherwise stay informed of current, related technologies.

The chapter is organized by topics within broad categories of related work. Policies, standard practices, standards, criteria, and guidance are condensed and addressed separately for the user under each topic. In addition, a quick reference guide that summarizes standards and criteria by topic is provided in Exhibit 7.1-A. Compliance with all policies and standards in this manual is essential to ensure consistency in project development throughout Federal Lands Highways projects. Although policy cannot be compromised, flexibility of standards is sometimes necessary to meet project-specific objectives. (See Section 7.1.9 for exceptions and variances to standards.)

As changes in policies, standards, or criteria occur, updates to this chapter will be made as described in Section 1.1.5

The information presented in this section will be applied as Standard Practices to any and all hydraulic work executed to develop and deliver projects of the Federal Lands Highway Programs.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

7.1.1 QUICK REFERENCE GUIDE

Exhibit 7.1-A provides a quick reference guide for the standards, criteria, and recommended methods provided in this chapter. Wherever possible, numerical standards and criteria are listed. Links are provided to applicable sections in this chapter and to recommended methods outside the PDDM. See Section 7.1.6.1 for the definition of high- and low-standard roadways.

Exhibit 7.1-A QUICK REFERENCE GUIDE

Topic	Standard	Criteria	Method Reference
HYDROLOGY			
Peak Flow Methods			HDS 2, HEC 22, NEH Part 630, TR-55, TM 4-A6, Bulletin 17B
Hydrograph Methods			HDS 2, WinTR-55
ROADWAY HYDRAULICS			
Culverts	Capacity Design and Stability Design: High-Standard road: 50-year flood Low-Standard road: 25-year flood Roadside ditch: 10-year flood Capacity Check Flood: Evaluate potential for adverse impacts for the overtopping flood Exception: See Floodplain Encroachments	Headwater New: WSEL ≤ bottom of aggregate base layer Existing: WSEL ≤ shoulder hinge point. HW/D ratio: 48” [1200 mm] or smaller = 1.5 Larger than 48” [1200 mm] = 1.2 Other: WSEL limited by unacceptable hazards to human life or property. Minimum Size: Cross-road culvert = 24” [600 mm] Parallel culvert = 18” [450 mm] Slope: Stream Crossings: Match streambed Ditch Relief: Min. = 2%, Max. = 10% Cover Pipe Anchors: Concrete > 10% slope, Metal > 25% slope	HDS 5, HEC 14

Exhibit 7.1-A QUICK REFERENCE GUIDE *(Continued)*

Topic	Standard	Criteria	Method Reference
Ditches	Capacity Design: 10-year flood Stability Design: Permanent Linings 10-year flood Temporary Linings: 2-year flood	Depth: New: WSEL ≤ bottom of aggregate base layer Existing: WSEL ≤ shoulder hinge point Slope: Min. = 0.5% Stability: Permissible shear stress	HDS 3, HEC 15
Pavement Drainage	Capacity Design: 10-year flood, 50-year in sumps	Spread: High-Standard road: 3 ft [900 mm] into one travel lane, Low-Standard road: Half of one travel lane Depth: On-grade and Sags: Allowable spread, not to exceed curb height, Sumps and Parking Areas: 6” [150 mm]. Inlet Clogging Factor: Grate Inlets in sag or sump, 50%	HEC 21, HEC 22
Storm Drains	Capacity Design: 10-year flood, 50-year in sumps	Minimum Size: 15” [375 mm]. Minimum Slope: Pipe-full velocity ≥ 3 ft/sec [0.9 m/s]	HEC 22
Outlet Protection			HEC 14
Alternative Pipe Materials	Service Life: 50-years Minimum Pipe Classification: RCP: Class II Metal: 0.064” [1.63 mm]		FHWA-RD-97-140, Caltrans Chapter 850

Exhibit 7.1-A QUICK REFERENCE GUIDE *(Continued)*

Topic	Standard	Criteria	Method Reference
RIVER HYDRAULICS			
Floodplain Encroachment	Design Flood: 100-year Check Flood: Overtopping flood, not to exceed 500-year	FEMA Regulated Base Floodplain with Detailed Study: With floodway defined, no floodway encroachment With no defined floodway or no detailed study, rise ≤ 1.0 ft [0.3 m] Unregulated Base Floodplain: Rise ≤ 1.0 ft [0.3 m]	HEC-RAS
Scour and Stream Stability			HDS 6, HEC 18, HEC 20,HEC 23
Bridged Waterways	Capacity Design: Design Flood: 50-year Check Flood: Greater of overtopping flood or 100-year, not to exceed 500-year Stability Design: Design Flood: 100-year Check Flood: 500-year	Freeboard: 2.0 ft [0.6 m], greater where potential for debris or ice Stability Design: Design Flood: Normal geotechnical and structural safety factors Check Flood: Safety Factor ≥ 1.0	HEC-RAS, HEC 18, HEC 20, HEC 23
Longitudinal Embankments	Capacity Design: High-Standard road: 50-year flood Low-Standard road: 25-year flood Check Flood: Greater of overtopping or 100-year Stability Design: High-Standard road: 50-year flood Low-Standard road: 25-year flood	Capacity Design: Freeboard: 2.0 ft [0.6 m]	HEC 14, HEC 23

Exhibit 7.1-A QUICK REFERENCE GUIDE *(Continued)*

Topic	Standard	Criteria	Method Reference
Retaining Walls	Longitudinal Flow Scour: Wall height > 6.5 ft [2 m]: 100-year Wall height ≤ 6.5 ft [2 m] on High-Standard road: 50-year Wall height ≤ 6.5 ft [2 m] on Low-Standard road: 25-year Pipe Penetrations: High-Standard road: 50-year Low-Standard road: 25-year	Stability Design: Normal geotechnical and structural safety factors	HEC 14, HEC 23
Low-Water Crossings	Allowable Uses: ADT ≤ 200 or existing feature Capacity Design: Vented: 10-year Stability Design: 25-year flood	Capacity Design: Vented: No overtopping Stability Design	Low Volume Roads Engineering, HDS 5, HEC 20, HEC 23
Channel Changes	Capacity Design: Duplicate existing stream characteristics Stability Design: High-Standard road: 50-year Low-Standard road: 25-year	Capacity Design Stability Design	HDS 6, HEC 20, HEC 23
Scour and Stream Instability Counter-measures			HDS 6, HEC 11, HEC 14, HEC 23
Energy Dissipators	Design Standard: Range of discharges	Design Guidance: Natural or stable channel velocity	HEC 14

Exhibit 7.1-A QUICK REFERENCE GUIDE *(Continued)*

Topic	Standard	Criteria	Method Reference
COASTAL HYDRAULICS			
General			HEC 25
Hydrology			HEC 25, EM 1110-2-1100
Scour and Stream Stability			HDS 6, HEC 18, HEC 20, HEC 23, HEC 25
Bridged Waterways	Capacity Design: 50-year storm tide plus wave height Stability Design: Design Flood: 100-year Check Flood: 500-year	Design Criteria Same as riverine except freeboard measurement reference datum	HDS 6, HEC 11, HEC 23, HEC 25
Roadway Embankments	Capacity Design: High-Standard road: 50-year storm tide plus wave height Low-Standard road: Highest astronomic tide plus 25-year wave height Stability Design: High-Standard road: 50-year storm tide plus wave height Low-Standard road: 25-year wave	Capacity Design: High Standard road Freeboard: 2.0 ft [0.6 m] Stability Design	HEC 14, HEC 23
Scour and Stream Instability Counter-measures			HDS 6, HEC 11, HEC 14, HEC 23

7.1.2 PROJECT MANAGEMENT AND COORDINATION

The identification and definition of project development activities needed to deliver Federal Lands Highway projects is typically achieved through an interdisciplinary team approach, led by a project manager. Consequently, to ensure consistency and effectiveness, it is essential that hydraulic related work be planned and executed in close coordination with the project manager and the other technical disciplines involved in the project (e.g., environment, roadway design, bridge design, etc.). Coordination may include the establishment of design standards and criteria different from those contained in this chapter. Such coordination may require direct contact with the partner agencies or other stakeholders.

7.1.3 RECONNAISSANCE AND SCOPING

Project reconnaissance and scoping is a combination of conducting field inspections and gathering existing engineering data needed to identify and quantify a highway's deficiencies and needs. The information is then assessed to identify a course of action for investigating improvement alternatives and conducting necessary engineering analyses that will ultimately result in a preferred alternative. Within Federal Lands Highways, these activities are collectively referred to as a Project Scoping Study as described in Section 4.5.1.

The project scoping study initially identifies the major needs, issues, constraints, scope, and feasibility of proposed improvements from which the more comprehensive, interdisciplinary preliminary engineering activities, surveys, investigations, environmental studies, and analysis can be effectively planned and budgeted. This includes the major elements of hydrologic and hydraulic work necessary to develop the project. The results of the study are summarized and documented in a Project Scoping Report as described in Section 4.5.2 and Section 4.5.2.12.9.

The following list includes broad categories of information that would be expected to be sought, collected, and used, as a standard practice for the reconnaissance and scoping, whenever available and applicable.

- Previous Hydrology/Hydraulic Studies and Reports
- Hydrological Data (rainfall, gage data, flood history, etc.)
- Aerial/Site Photography
- Survey and Mapping
- Land use, Ground cover, Soils information
- Fluvial Geomorphic data (plan forms, bed and bank sediment characteristics, etc.)
- As-Built Plans
- Bridge Inspection Reports
- Maintenance Reports

7.1.3.1 New vs. Rehabilitated Structures

The type of work proposed for drainage structures will affect the level of hydrologic and hydraulic analysis and the applicability of the standards and criteria presented in this chapter.

This chapter defines rehabilitated structures as existing structures that are not to be replaced, but may be substantially repaired, modified, or extended as part of the project. Common examples of rehabilitated structures include, but are not limited to:

- A culvert that is to be extended to accommodate roadway widening
- A culvert needing repair due to heavy corrosion
- A bridge deck to be reconstructed or widened
- A cross drainage structure beneath a road that is to be reconstructed
- A structure being retrofitted for fish passage
- Pavement drainage improvements

Include an appropriate assessment of the existing physical condition and the hydraulic performance of all cross-drainage structures in the scoping and reconnaissance efforts. The findings of the assessment will lead to recommendations as to whether existing structures are to be replaced, rehabilitated, modified, abandoned, or left undisturbed.

7.1.3.1.1 Assessment of Existing Cross-Drainage Structures

Structures Spanning less than 20 feet

Unless otherwise documented in the Project Agreement, apply the following guidelines for assessing condition and performance of such structures on all projects qualifying for 3R or broader scope of work:

- Assess all structures with known condition or performance problems
- Assess all structures when access is unimpeded
- Assess the following when access is impeded:
    - ◊ All known structures with a 48-inch vertical opening or greater
    - ◊ All structures spanning “blue-line streams” as shown on applicable USGS 7.5’ Quad maps
    - ◊ All structures spanning “live streams,” as identified in the field
    - ◊ A minimum of two structures per project mile (or total for projects less than one mile in length)
- Assess drainage structures that do not cross the roadway (i.e. parallel structures) as directed by the Cross-Functional Team (CFT)

When assessments identify condition or performance problems and all structures within the project limits have not been assessed, assess additional structures, as directed by the CFT or Hydraulic Engineer, in order to fully define the scope of work.

The guidance in "*Culvert Assessment and Decision-Making Procedures Manual*", September 2010 (Publication No. FHWA-CFL/TD-10-005) is recommended for assessing the condition and performance of such structures.

Structures Spanning 20 feet or greater

Assess all structures according to the National Bridge Inspection Standards (NBIS). Such structures are defined as bridges by regulation and receive routine inspections and appraisals of condition and performance.

7.1.3.2 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

Reference		Description
1.	AASHTO HDG Vol. I	AASHTO Highway Drainage Guidelines, Volume I – *Hydraulic Considerations in Highway Planning and Location*
2.	AASHTO HDG Vol. VIII	AASHTO Highway Drainage Guidelines, Volume VIII – *Hydraulic Aspects in Restoration and Upgrading of Highways*

7.1.4 RISK CONSIDERATIONS

This chapter presents policy, standards, criteria, and guidance for general application on projects undertaken by the Federal Lands Highway Divisions. These standards and criteria represent the minimum for most projects. Consequently, conformance with these standards and criteria may not ensure that all risks have been fully addressed. A project can be fully compliant with the policy, standards, and criteria described within this chapter, yet still incur an inappropriate level of risk. Consequently, all sources of potential risk will be considered as part of the hydrology/hydraulic investigation for all hydraulic structures on all projects in order to determine whether modified site-specific standards or criteria are appropriate. The consideration of risk will typically begin with the evaluation of an applicable check flood, as defined in Section 7.1.7.

For the purposes of this chapter, risk is defined as the consequences associated with the probability of flooding attributable to the project, including the potential for property loss and hazard to life during the service life of the highway. If the consideration of risks appears to warrant design standards or criteria other than those outlined in this chapter, a risk assessment will be conducted. As described below, the assessment of risk can either be qualitative or quantitative in nature. If the results of the assessment confirm that lower standards are warranted, the assessment will be documented through the design exception process (see Section 7.1.9) and coordinated with project management.

7.1.4.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. 23 CFR 650A — Code of Federal Regulations, Title 23, Part 650 Subpart A, *Location and Hydraulic Design of Encroachments on Flood Plains*
2. NS 23 — Federal-Aid Policy Guide, *Non-regulatory Supplements to Title 23*
3. HEC 17 — FHWA HEC 17, *Design of Encroachments on Flood Plains Using Risk Analysis*, 1981

7.1.4.2 Qualitative Risk Assessment

When necessary, most projects will require only a qualitative risk assessment. A qualitative risk assessment may determine that the standards and criteria of this chapter are appropriate or inappropriate based on such considerations as the presence or absence of upstream structures that could be impacted by the project, the perceived economic impact of temporary road closures, the environmental impact, or the cost of the roadway facility itself.

7.1.4.3 Quantitative Risk Analysis

Highly complex or expensive projects or those with particularly high levels of risk may justify detailed and quantitative risk analyses. A quantitative risk analysis provides a detailed economic comparison of design alternatives using expected total costs (construction costs plus risk costs) to determine the alternative with the least total expected cost to the public. This type of analysis supports the appropriate design discharge and criteria based on the economic comparison of alternatives rather than a set of predetermined design frequencies and criteria such as those presented in this chapter. Federal Lands Highway projects will rarely require quantitative risk analyses.

7.1.5 BASELINE VS. PROPOSED CONDITIONS

The hydrologic and hydraulic analysis will include a comparison of proposed conditions (post-project) to baseline conditions when the project includes one or more of the following:

- An encroachment onto a floodplain designated by FEMA
- A structure that is defined as a bridge (total span greater than or equal to 20 ft [6.1 m]

Projects that do not include either item listed above may require a comparison of proposed conditions to baseline conditions based on site-specific risk.

Baseline conditions may represent either existing, pre-project conditions, or some pre-existing state, depending on project and partner agency requirements. Comparing the post-project conditions to baseline conditions allows an accurate assessment and documentation of the impacts of the project and the associated risks to neighboring properties and facilities. Bases for comparison may include, but will not necessarily be limited to:

- The water-surface profile for floods of various frequencies
- The average and maximum channel velocities
- The waterway's capacity to entrain and transport sediment
- The long-term and flood-event stability of the channel in the project vicinity

The comparison between baseline and proposed conditions may refer to more than one alternative proposed condition, depending on the needs of the project.

7.1.6 DESIGN STANDARDS AND CRITERIA

7.1.6.1 Roadway Classifications

For the design of roadway hydraulic structures, the design standards and criteria will vary based on the roadway classification. There are two roadway classifications used in this chapter, defined below:

- *High-Standard Road* – A roadway will be classified as a high-standard road if any of the following conditions apply to any section of the project:
  - ◊ Design speed > 45 mph [70 km/hr]
  - ◊ Design Average Daily Traffic (ADT) > 1500
  - ◊ Designated as a critical access road

  Examples of critical access roads are emergency evacuation routes, sole access to a community, or sole access to critical facilities, such as hospitals, power plants, water supply and wastewater treatment facilities.
- *Low-Standard Road* – All others.

7.1.6.2 New Structures

The standards and criteria presented in this chapter represent the minimum acceptable for projects involving new drainage structures or replacements of existing structures. Exceptions to standards may be justified by a qualitative risk assessment or a detailed risk analysis.

7.1.6.3 Existing and Rehabilitated Structures

The design standards and criteria of this chapter need not be considered minimum for existing structures to be retained or rehabilitated. However, where condition or performance problems are evident, existing structures will be evaluated against the standards and criteria contained in this chapter. Where problems are not evident, consider the estimated service life and future performance of the existing structure in relation to the design standards and criteria, the overall roadway facility and scope of other roadway improvements when deciding to retain, rehabilitate or replace existing structures.

The goal of a rehabilitation design should be to increase the hydraulic performance toward those standards if appropriate and cost effective. A rehabilitation design should not decrease the safety characteristics of the existing facility. As with all projects, the needs, desires, and regulations of partner agencies and local authorities must be considered when establishing project-specific standards and criteria.

7.1.7 CAPACITY VS. STABILITY DESIGN

The capacity standards relate to the ability of the structure to convey the discharge rate anticipated for the design event. Stability standards relate to the ability of the structure or facility to withstand the discharge, velocity, shear stress, and scour induced by the design event without collapsing or sustaining substantial damage. Where appropriate, the later sections of this chapter define design and check flood standards separately for the capacity of the structure and the stability of the structure.

7.1.8 DESIGN AND CHECK FLOODS

The design of a drainage system begins with the selection of an appropriate design flood frequency. The later sections of this chapter define the standards for determining the design flood for various drainage structures or features on Federal Lands Highway projects. Where appropriate, the chapter also defines check flood standards. The purpose of evaluating a check flood is to assess the potential consequences or risks associated with floods exceeding the design flood. A flood that exceeds the capacity design may cause road overtopping, for example, and extensive damage to structures in the floodplain. A flood that exceeds the stability design flood for a bridge may undermine a foundation and lead to failure of the structure.

If evaluation of the check flood indicates undue risk, then an increase of the design flood above the normal standard should be considered for that structure, or the design should incorporate other measures to reduce the level of risk. Small structures, such as small-diameter culverts, will seldom require a formal check flood evaluation. Risk potential will be quickly assessed by evaluating impacts associated with roadway or structure overtopping elevation.

7.1.9 DESIGN EXCEPTIONS/VARIANCES

Deviation from standards cited within this chapter will require formal justification and approval by project management and the facility owner. (See Section 9.1.3 for a description of the Design Exception process). Significant deviations from the criteria cited within this chapter will be justified, approved by the local Federal Lands Hydraulics Office, and documented in the project file.

7.1.10 QUALITY CONTROL AND QUALITY ASSURANCE

Quality control and assurance procedures (QC/QA) will be incorporated and executed in all hydrology and hydraulics investigations, evaluations, and designs. Those responsible for hydrology and hydraulics activities will define the QC/QA procedures early in the project and provide signed documentation as evidence of conforming to the procedures throughout the duration of the hydrologic and hydraulics activities.

7.1.11 DOCUMENTATION AND DELIVERABLES

The type and nature of documentation and deliverables required will vary depending upon the project. The later sections of this chapter define the documentation required for each type of hydraulic element of the project. Typical hydraulic design projects will include the following submittal requirements:

- Hydraulics Reconnaissance Documentation. Summarize the following hydrologic/ hydraulic tasks:
  - ◊ Data collection
  - ◊ Needed hydrologic and hydraulic analyses
  - ◊ Definition of baseline hydraulic conditions, as required

  Also incorporate this documentation into the Project Scoping Report described in Section 4.5.2.
- Preliminary Hydraulics Documentation. Summarize the following commensurate with the potential risks and adverse impacts:
  - ◊ Applicable design standards and criteria
  - ◊ Alternatives considered and evaluated and the results of the evaluations
  - ◊ Required risk assessment or analysis
  - ◊ Preliminary design recommendations

  This documentation represents the Location Hydraulic Study required by 23 CFR 650A. Also incorporate this documentation into the Preliminary Engineering Study Report described in Section 4.10.1. Information developed during this phase of development may be incorporated into the project environmental document, as appropriate. Therefore, close coordination with the local Federal Lands Environmental Office may be required.
- Final Hydraulics Documentation. Support the final design of the selected alternative. Fully document, to a level commensurate with project complexity and risk, the following:
  - ◊ Project description

- ◊ Base data and sources
- ◊ Analytical approaches, methods, and results
- ◊ Design approaches and methods
- ◊ Final design recommendations
- ◊ Supporting information

Documentation will typically include the following support information when applicable and appropriate:

- Annotated maps and aerial photographs
- Drainage area data
- Field survey data
- Field photographs
- Floodplain mapping with cross-section locations/orientation
- Manual and electronic calculations
- Flood history data
- Applicable correspondence
- Required QC/QA documentation

7.1.12 APPLICABLE LAWS

This section presents the federal laws and regulations relating to hydrology and hydraulics.

7.1.12.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	AASHTO HDG Vol. V	AASHTO Highway Drainage Guidelines, Volume V – *Legal Aspects of Highway Drainage*
2.	AASHTO MDM Chap. 2	AASHTO Model Drainage Manual, *Chapter 2 – Legal Aspects*

7.1.12.2 FHWA Policy

Certain federal regulations comprise FHWA policy. All Federal Lands projects will conform to FHWA policy. The policy statements of particular interest in hydrology and hydraulics include:

1.	23 CFR 650A	**FHWA Policy 23 CFR 650 Subpart A** – *Location and Hydraulic Design of Encroachments on Floodplains*. This federal law establishes policy affecting any project that includes an encroachment on a base floodplain. See Section 7.4.1 for a detailed discussion of this policy

2. 23 CFR 650C **FHWA Policy 23 CFR 650 Subpart C** – *National Bridge Inspection Standards.* This federal law defines the national standards for the proper safety inspection and evaluation of all highway bridges including the evaluation of bridges for scour susceptibility in accordance with the guidance outlined in Technical Advisory T 5140.23.

3. 23 CFR 650H **FHWA Policy 23 CFR 650 Subpart H** – *Navigational Clearances for Bridges.* This federal law requires coordination with the United States Coast Guard (USCG) and United States Army Corps of Engineers (USACE) in providing adequate vertical and horizontal clearance for navigation on navigable waterways.

4. 23 CFR 635D **FHWA Policy 23 CFR 635 Subpart D** – *General Material Requirements*,

7.1.12.3 Other Federal Laws

Other federal laws may affect hydraulic tasks, analyses, design, or construction of Federal Lands Highway projects. These laws are formulated under the following legislative acts:

- The National Environmental Policy Act (1969)
- The Flood Disaster Protection Act (1973)
- The Rivers and Harbors Act (1899)
- The Federal Water Pollution Control Act (1972)
- The Fish and Wildlife Coordination Act (1956)
- The Tennessee Valley Authority Act (1933)
- The Coastal Zone Management Act (1972)
- Wild and Scenic Rivers Act (1968)

7.1.12.4 State and Local Laws

At the state and local levels, the most common water-related legal concerns involve diversion, collection, concentration, quality, obstruction, erosion, and sedimentation. The reconnaissance and scoping effort should identify the state and local laws affecting the design of the project and the appropriate agencies to be contacted for coordination relating to those laws. Since laws related to these problems vary from state to state, the following is a brief generalization of each topic as it relates to this chapter:

7.1.12.4.1 Diversion

Diversion relates to the detention, or changing the course, of a stream or drainage way from its natural or existing condition. Depending on the type of resource system (human or natural) that the diversion affects, the state laws will vary in their scope of jurisdiction. Water diversions should be evaluated for their impact on property owners upstream, downstream, and adjacent to the project. Changes in the flow characteristics due to the diversion may require mitigation with the affected property owners. Diversions should be evaluated for their impact upon fish and wildlife habitat. The state fish and wildlife agencies should be contacted for questions of jurisdiction and possible mitigations. Design diversions of streams or drainage ways to preserve flow conditions that are as similar as possible to those that existed before the diversion while still accomplishing the highway design objectives. A comparison of baseline versus proposed conditions will allow for identification, quantification, and mitigation of impacts related to diversions.

7.1.12.4.2 Storm Water Management

A highway drainage system can collect or concentrate floodwaters, causing discharge rates at the point of discharge to exceed those discharge rates that would naturally occur without the project. A comparison of baseline versus proposed conditions will allow for identification, quantification, and mitigation of impacts related to collection and concentration, including potential water quality concerns.

7.1.12.4.3 Obstruction

Drainage structures form partial obstructions that can cause backwater upstream, increase velocities in the structure area, and cause other hydraulic impacts. A comparison of baseline versus proposed conditions will allow identification, quantification, and mitigation of impacts related to the obstructions caused by drainage structures.

7.1.12.4.4 Stream Erosion and Sedimentation

Highways and their structures can have pronounced impacts on erosion and sedimentation characteristics of a water resource system. If the flow characteristics of rivers and streams are significantly changed, then the erosion and sedimentation characteristics will also be changed.

7.1.12.4.5 Floodplain Management and Administration

Local and state agencies are responsible for managing development within base floodplains. Compliance with FHWA Policy 23 CFR 650A will normally ensure that the local and state floodplain ordinances and statutes are satisfied.

7.2 HYDROLOGY

The hydrologic analysis is a necessary component to the design and evaluation of highway hydraulic structures. The calculation of the design flood is contingent on several factors, the primary two being selection of a design flood standard and an appropriate hydrologic method.

For any given site, there may be several methods available for estimating flows and their return periods. No single method is applicable to all watersheds. Engineering judgment and a good understanding of hydrology are essential in selecting the method to be used in a particular design or for a given watershed. The method chosen should be a function of drainage area (i.e., size and type), availability of data, the validity of the method for the site, land use, and the degree of accuracy desired. When applicable, several methods should be used and the results compared before selecting the most appropriate method.

7.2.1 REFERENCES

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HDS 2	FHWA HDS 2, *Highway Hydrology*, NHI-02-001, 2002
2.	HEC 22	FHWA HEC 22, *Urban Drainage Design Manual*, Third Edition, FHWA NHI-10-009, 2009
3.	AASHTO MDM Chap. 7	AASHTO Model Drainage Manual, Chapter 7 – *Hydrology*
4.	AASHTO HDG Vol. II	AASHTO Highway Drainage Guidelines, Volume II – *Hydrology*
5.	NEH Part 630	NRCS National Engineering Handbook, *Part 630 – Hydrology*
6.	TR-55	NRCS TR-55, *Urban Hydrology for Small Watersheds*, 1986.
7.	WinTR-55	NRCS WinTR-55, Windows version if TR-55 program
8.	TM 4-A6	USGS TM 4-A6, The National Streamflow Statistics Program: *A Computer Program for Estimating Streamflow Statistics for Ungaged Sites*
9.	NSS	USGS National Streamflow Statistics (NSS) computer program
10.	Bulletin 17B	Bulletin 17B of the Hydrology Subcommittee, *Guidelines for Determining Flood Flow Frequency*, 1982.

11. PFDS Precipitation Frequency Data Server, National Weather Service

12. National Map USGS National Map

7.2.2 DESIGN STANDARDS

The selection of a design flood standard is the first step in the design of highway hydraulic structures. The minimum design flood standards for each type of hydraulic analysis or design are provided in this chapter, and summarized in the quick reference guide in Exhibit 7.1-A.

7.2.3 DESIGN GUIDANCE

7.2.3.1 Peak Flow vs. Hydrograph

Depending on the type of hydraulic investigation, either a peak discharge will be computed or a hydrograph will be developed. The majority of highway drainage structures are analyzed and designed using only the peak discharge for a given design flood. A hydrograph (time distribution of discharge) may be required where either the volume of runoff or the storm duration is needed.

Hydrographs will be used for the design or evaluation of highway hydraulic structures where roadway overtopping duration, storage routing, sediment routing, or unsteady flow modeling are required.

7.2.3.2 Statistical vs. Deterministic

All analytical methods can be grouped into two broad categories of deterministic and statistical models. Deterministic methods model the physical aspects of the rainfall-runoff process, where each element of the runoff process is accounted for, generally based on empirical equations. Statistical methods utilize measured gage data and procedures of statistical analysis to determine flood-frequency relationships.

Simple statistical or deterministic methods are often sufficient for applications within this chapter. More sophisticated models, such as the U.S. Army Corps of Engineers' HEC-HMS and the NRCS TR-20 programs, which use deterministic unit hydrograph methods, may be required and are acceptable for both peak flow and hydrograph needs.

7.2.3.3 Urban vs. Rural

Land use changes affect watershed hydrology and also impact the applicability of hydrologic methods used for design. Urbanization, channelization, and other land use changes (e.g., logging) result in a decrease in infiltration and depression storage, a decrease in travel time, and an increase in runoff volume, resulting in an increase to the peak discharge. The engineer should be aware of past and proposed changes in the watershed land use when selecting a hydrologic method and performing the hydrologic calculations.

Urbanization can also have an adverse impact on stream morphology. There can be a temporary increase in sediment supply due to construction-site erosion, and a long-term reduction in sediment production. Urbanization also typically increases the normal base flow in stream channels. These changes can result in channel stability problems, both lateral and vertical, that may impact highway structures.

Regional regression equations are primarily for natural, undeveloped watersheds. Development should be accounted for using urban regression equations, where available. For regions where urban regression equations have not been specifically developed, both the NSS program and HDS 2 provide methods and procedures for calculating a peak discharge for urban areas, based on the drainage area, the peak discharge for the same watershed in a natural condition, and a basin development factor, which measures the degree of urbanization in the watershed.

7.2.3.4 Potential Future Development

In general, the hydrologic investigations will only account for existing land use conditions, which includes planned development that is funded and has received approval from the local land use permitting authority. Future development may be accounted for in circumstances where the partner agency has a cooperative agreement with the land developer or local community.

7.2.3.5 Local Procedures

There are many local hydrologic procedures or regional modifications to general hydrologic procedures. The engineer may use local procedures within their limits of applicability, with advanced approval of Federal Lands Highway Hydraulics and concurrence of the partner agency. Local procedures are encouraged for use as a check method when available and applicable.

7.2.3.6 Previous Studies

Results of previously documented hydrologic studies may be used with advanced approval of the local Federal Lands Hydraulics Office, if the engineer is confident in the applicability of the hydrologic method and correctness of the calculations.

7.2.3.7 Historical Observations

Field data can sometimes be obtained that can be used to estimate the discharge of historical floods through stage-discharge relationships or open-channel flow calculations. Useful information might include high water marks, bridge inspection reports, and eyewitness reports of overtopping depths of highways and bridges.

Flows determined by historical observations should be used when available as a check on other methods. Flood-frequency magnitudes should not be developed solely from this method because of the small number of observations and inherent inaccuracies.

7.2.3.8 Special Considerations

The standard hydrologic procedures are appropriate for the majority of highway design projects. Conditions that may require special hydrologic investigation and represent hydrological design challenges not anticipated by standard hydrologic procedures include:

- Wetland mitigation analysis and design
- Snowmelt flood hydrology
- Arid lands runoff

Chapter 9 of HDS 2 addresses hydrologic methods and procedures that are associated with such conditions.

7.2.3.9 Data Sources

Data needs frequently include information on the watershed (maps, topography, soils, and land use), stream flow records, and precipitation records. Data must be reliable, accurate, and as current as possible. The sources for the required data may be the partner agency, federal agencies, or state, and local agencies. The geoSpatial Data Acquisition (GSDA) website provides a clearinghouse for much of the publicly available digital data. Acceptable sources of commonly needed data are described below.

In addition to the data sources described in the following sections, hydrologic modeling data may be compiled by state departments of transportation or local flood control agencies (typically in a drainage manual or criteria and procedures manual). Reference Chapter 3 of HDS 2 for information on required data and acceptable sources.

7.2.3.9.1 Stream Flow

The major source of stream flow information is the U.S. Geological Survey (USGS). The USGS stream flow database, including daily, monthly, and annual stream flow statistics is available on the Internet. Also, the U.S. Army Corps of Engineers (USACE), Bureau of Reclamation, and U.S. Forest Service collect stream flow data. Other potential sources of data are state and local governments, utility companies, water-intensive industries, and academic institutions.

7.2.3.9.2 Rainfall

The major source of precipitation data is the National Weather Service (NWS), an agency of the National Oceanic and Atmospheric Administration (NOAA). Historically, NWS publications have been the primary source for precipitation depth-duration-frequency data across the United States. The following NWS publications can be accessed from the Internet:

- Technical Paper 40 – *Rainfall Frequency Atlas of the United States for Durations from 30 minutes to 24 hours and Return Periods from 1 to 100 Years* (1961)
- Technical Paper 42 – *Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and Virgin Islands*
- Technical Paper 43 – *Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years*
- HYDRO 35 – *Five to 60-minutes Precipitation Frequency for Eastern and Central United States* (1977)
- NOAA Atlas 2 – *Precipitation Frequency Atlas of the Western United States* (1973)
- *Short Duration Rainfall Relations for the Western United States* (1986)
- NOAA Atlas 14 – *Precipitation Frequency Atlas of the United States* (Vol. 1 and 2, 2004)

The PFDS should be referenced to ensure that the most up-to-date publication is used for the hydrologic design calculations. For raw rainfall data, NOAA's National Climatic Data Center (NCDC) can be referenced.

Other sources of rainfall data may include state and local agencies. Specifically, many state departments of transportation and local flood control agencies have developed Intensity-Duration-Frequency (IDF) curves and rainfall hyetographs that may be of use to the engineer.

7.2.3.9.3 Land Use

Land use data are available in different forms, including aerial photographs and zoning maps. Data can be obtained from a broad variety of sources, such as state and local planning organizations. The USGS has a nationwide network of maps (1:100,000 and 1:24,000 scale) and aerial photographs. The USGS maps can be obtained in print. The USGS maps and aerial photographs can be accessed from the USGS National Map.

7.2.3.9.4 Soil Type

Information on soil type is needed for some hydrologic methods, primarily NRCS methods, including TR-55. The major source of information on soil types is the NRCS, which has prepared soil maps for most of the counties in the country. The NRCS Soil Survey publications can be obtained from the NRCS or county extension service. The NRCS also has a website that allows online viewing of soil survey maps and reports. The TR-55 publication and Chapter 7 of NEH Part 630 of the NRCS *National Engineering Handbook* give a correlation between NRCS soil type and hydrologic soil group. For soil types not identified in those publications, a correlation can be found in the NRCS Soil Survey for the county.

7.2.3.9.5 Topographic Maps

Topographic mapping can be obtained from a broad variety of sources, such as state and local planning organizations. The USGS has a nationwide network of maps (1:100,000 and 1:24,000 scale) that can be obtained in print and digital formats. The USGS maps can be accessed from the USGS National Map.

7.2.4 RECOMMENDED METHODS FOR ESTIMATING PEAK FLOW

Peak flow estimates obtained by one method should be compared to estimates obtained by other applicable methods. Significant differences may indicate the need to review data from other comparable watersheds or the need to obtain historical data.

7.2.4.1 Ungaged Watersheds

There are many methods available for estimating peak flows at sites without gages. These methods include the Rational Method, Natural Resource Conservation Service (NRCS, formerly SCS) methods, US Geological Survey (USGS) regression equations, and other local methods. Following are brief descriptions of the most frequently used methods:

7.2.4.1.1 Rational Method

The Rational Method is the most commonly used procedure for estimating peak flows from urban, rural, or combined areas for watersheds smaller than 200 acres [80 hectares]. Perform hydrologic calculations using the Rational Method in accordance with the methods presented in HDS 2 *Highway Hydrology.* Additional guidance for the usage of the Rational Method in the design or evaluation of urban storm drain systems is given in HEC 22 *Urban Drainage Design Manual*.

The rainfall intensity is determined using the time of concentration and an Intensity-Duration-Frequency (IDF) curve. IDF curves may be available from state departments of transportation or local flood control agencies. For states that are included in the NOAA Atlas 14, an IDF curve can be obtained directly from the NWS PFDS. For states not yet covered by NOAA Atlas 14, follow the procedures given in Appendix A of HEC 12.

7.2.4.1.2 NRCS Methods

The NRCS Technical Release 55, *Urban Hydrology for Small Watersheds*, commonly referred to as TR-55, provides a graphical peak discharge method that is applicable for small drainage areas (time of concentration between 0.1 and 10 hours).

The NRCS has also released the WinTR-55 computer software package, which will calculate peak flows for watersheds with areas smaller than 25 square miles [6,500 hectares].

Further background information on TR-55 and NRCS hydrologic methods in general, can be found in NEH Part 630 of the NRCS *National Engineering Handbook.* The NRCS method was developed for rolling agricultural and rolling undeveloped land, but is applicable to urbanized areas. Specific application of the NRCS methods to the design of highway drainage structures can be found in Chapter 5 of HDS 2 and Chapter 3 of HEC 22.

7.2.4.1.3 Regional Regression Equations

Regression equations are one of the most commonly accepted methods for estimating peak flows for watersheds without gages or sites with insufficient gage data. Regional regression equations are an extrapolation of data from nearby watersheds with similar hydrologic, physiographic, and climatological characteristics. The USGS, in cooperation with the States, has developed a comprehensive series of regional regression equations for most of the United States into the National Streamflow Statistics (NSS) computer program. The USGS has also published documentation for the NSS program and for each of the States. These regression equations permit peak flows to be estimated for recurrence intervals ranging from 2 to 500 years for natural streams. Regression equations are developed using independent variables (i.e., basin characteristics) within given ranges for each state and hydrologic region. To ensure the stated accuracy of the estimated discharges, the equations should only be applied within the range of independent variables utilized in their development.

The regional regression equations used in the NSS program are primarily for natural, undeveloped watersheds, although some urban regression equations have been developed. For regions where urban regression equations have not been specifically developed, both the NSS program and HDS 2 provide methods and procedures for calculating a peak discharge for urban areas, based on the drainage area, the peak discharge for the same watershed in a natural condition, and a basin development factor, which measures the degree of urbanization in the watershed.

7.2.4.2 Gaged Watersheds

When a sufficient period of record is available, a desirable method for determining the peak flow is a flood-frequency analysis of flows that have occurred at or near the site. Analyzing flood-frequency relationships from actual streamflow data uses records of past events and statistical relationships to predict future flow occurrences. The best circumstance for estimating peak flows is to have a stream gage near the site for a large number of years. The more years of record, the more accurate the estimate will be. It is recommended that the period of record should be at least 10 years. Where the site being studied is on the same stream and near a gaging station, peak discharges can be adjusted to the site by drainage area ratios using drainage area to some power. For this method to be valid, the gage data used must be homogeneous, i.e., no significant changes in the characteristics of the drainage basin or climatological patterns have occurred over the period of record.

Several of the more popular analysis techniques include Log-Pearson Type III, Normal and Log-Normal, and Gumbel Extreme Value Distributions. Log-Pearson Type III will be used unless it can be shown that the data does not fit this distribution function. Refer to Chapter 4 of HDS 2 and Bulletin 17B for analysis methods of gaged data. The USGS PeakFQ computer program is a method for performing Log-Pearson Type III analyses on raw gaging data. Regional equations may improve peak flow estimate at gaged sites by weighting the statistical analysis estimate with the regression estimate.

7.2.4.3 Guidance on Peak Flow Method Selection

Select methods for calculating the peak flow appropriate for the size and hydrologic characteristics of the tributary watershed. Discretion in the selection of the most appropriate method is given to the engineer. General guidance on the applicability of peak flow methods is given as follows:

- For streams with gaging data, with a sufficient period of record (a minimum of 10 years, refer to Chapter 4 of HDS 2), it is recommended that the engineer perform an appropriate statistical analysis of the flood frequency.
- In ungaged watersheds less than 200 acres [80 hectares], Rational Method is applicable
- In ungaged watersheds greater than 200 acres [80 hectares], regional regression equations or the NRCS TR-55 method are typically applicable.

7.2.5 RECOMMENDED METHODS FOR COMPUTING HYDROGRAPHS

7.2.5.1 Unit Hydrographs

Unit hydrograph techniques are used to approximate the rainfall-runoff response from a watershed. A unit hydrograph is defined as the direct runoff resulting from an excess rainfall event that falls uniformly over the watershed at a constant intensity and has a volume equal to one unit of depth over the watershed. Unit hydrographs are either determined from gaged data or are derived using empirically based synthetic unit hydrograph procedures.

Unit hydrographs are most accurate when based on continuous readings from stream and rainfall gages. When gage data is not available for stream crossings, the NRCS, Snyder, or Clark synthetic unit hydrographs methods may be used. Documentation for unit hydrograph methods can be found in Chapter 6 of HDS 2.

The most common unit hydrograph method for computing a discharge hydrograph for highway drainage structures is the NRCS procedure documented in NEH Part 630 of the NRCS *National Engineering Handbook.* The WinTR-55 computer program is generally applicable for areas less than 25 square miles [6,500 hectares], with additional limitations set by the time of concentration for the watershed. Specific application of the NRCS methods to the design of highway drainage structures can be found in Chapter 6 of HDS 2

7.2.5.2 Regional Regression Equations

The National Streamflow Statistics program contains a procedure for computing a dimensionless hydrograph, representing the average runoff for a given peak discharge. The hydrograph is not representative of any rainfall distribution. Runoff calculations performed using regional regression equations should be done in accordance with the methods and procedures documented for the NSS computer program. Specific application of the USGS regression equations to the design of highway drainage structures can be found in Chapter 6 of HDS 2.

7.2.5.3 Storage Routing

Where detention ponds are required for Federal Lands Highway projects, such as for storm water management applications, storage routing can be performed using the Storage-Indication method as documented in Chapters 7 and 8 of HDS 2 and Chapter 8 of HEC 22.

Storage routing may also be used to evaluate existing or rehabilitated culverts that do not have the capacity to convey the peak discharge prescribed by the applicable standard.

7.2.6 REPORTING

All hydrologic analyses will be supported by appropriate documentation, which at a minimum will include:

- Data and data sources
- Reference for methods used
- Assumptions
- Conclusions
- Recommendations

7.3 ROADWAY HYDRAULICS

7.3.1 CULVERTS

Culverts are physically simple structures used to convey surface runoff through, around, and away from roadways and associated facilities. They typically consist of a pipe barrel with an inlet and outlet structure. Although simple structurally, the hydraulic design of culverts requires the investigation of numerous physical, operational, and regulatory elements during the data collection phase, which must then be applied, as appropriate, during project development. Examples of physical elements include geometrics (e.g. size, shape, length, alignment, material roughness, slope, and entrance treatments); and hydraulic characteristics (outlet tailwater depth, outlet velocity, headwater depth, scour/erosion potential, sediment transport, debris production). Operational elements include frequency of maintenance and vehicular safety.

Regulatory elements may include federal and state hydraulic criteria such as the requirements of the National Flood Insurance Program (NFIP) administered by the Federal Emergency Management Agency (FEMA). Other federal laws/regulations that may impact culvert design include: NEPA, Fish and Wildlife Act, TVA, Coastal Zone Management Act, and Wild and Scenic Rivers Act.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

7.3.1.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. HDS 5 — FHWA HDS 5, *Hydraulic Design of Highway Culverts*, FHWA NHI-01-020, 2005
2. HEC 14 — FHWA HEC 14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*, FHWA NHI-06-086, 2006
3. AASHTO MDM Chap. 9 — AASHTO Model Drainage Manual, *Chapter 9 – Culverts*
4. AASHTO HDG Vol. IV — AASHTO Highway Drainage Guidelines, *Volume IV – Hydraulic Design of Culverts*
5. FLH Standard Drawings — Federal Lands Highway Standard Drawings, current edition.

7.3.1.2 Standard Practices

7.3.1.2.1 Floodplain Encroachment

If a waterway crossing constitutes a new or expanded encroachment on a base (100-year) floodplain that is regulated by FEMA or potentially creates an adverse impact to private property or insurable buildings, reference Section 7.4.1 for details on appropriate design policy, standards, and criteria, as well as guidance on FEMA coordination, if required.

7.3.1.2.2 New vs. Rehabilitation

All existing culverts identified to be retained as part of a roadway rehabilitation project will receive an appropriate evaluation of condition, hydraulic performance and long term risk to determine whether replacement or rehabilitation is necessary. Inform partner agency of all condition and performance problems if correction is not included within the project scope.

7.3.1.3 Design Standards

7.3.1.3.1 Capacity Design

Design Flood

The design flood standards for culverts are based on two roadway classifications – High Standard and Low Standard (reference Section 7.1.6).

- *High Standard:* Design cross culverts using the following standards:
  - ◊ Culverts will convey runoff from the 50-year flood
  - ◊ Culverts for temporary detours will convey runoff from the 10-year flood, unless seasonal construction justifies a lower standard
- *Low Standard:* Design cross culverts using the following standards:
  - ◊ Culverts will convey runoff from the 25-year flood
  - ◊ Culverts for temporary detours will convey runoff from the 2-year flood, unless seasonal construction justifies a lower standard
- *Roadside Ditches:* Culverts required for roadside ditches should be designed to convey the runoff from the 10-year flood for both High- and Low-Standard roadways. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

Check Flood

Evaluate the potential for adverse impacts to private property or insurable buildings upstream of the roadway at the roadway overtopping elevation. If such adverse impacts can occur, refer to Section 7.4.1 for direction on applicable design policy, standards, criteria, and guidance.

7.3.1.3.2 Stability Design

Design Flood

The stability design flood standards for culverts are based on two roadway classifications – High-Standard and Low-Standard (reference Section 7.1.6).

- *High-Standard:* roadway culverts and embankments at culvert locations will be stable for the 50-year flood
- *Low-Standard:* roadway culverts and embankments at culvert locations will be stable for the 25-year flood

7.3.1.3.3 Surveying and Mapping

When survey is needed to quantify hydraulic impacts, refer to Chapter 5 for standards on survey and mapping for culverts.

7.3.1.4 Design Criteria

7.3.1.4.1 Headwater Elevation

The headwater elevation is defined as the water-surface elevation (WSEL) at the culvert entrance. There are three sets of criteria used to determine the allowable headwater elevation: 1) new vs. existing culvert, 2) ratio of headwater depth to culvert diameter or rise (HW/D), where depth is measured from the water surface to the inlet invert, and 3) site-specific reference elevations. The criterion that results in the lowest headwater elevation will govern the design.

New vs. Existing

- *New Culverts*: Headwater elevation will not be greater than the bottom of the aggregate base layer for the roadway pavement structure at the local roadway low point.
- *Existing Culverts:* Headwater elevation will not be greater than the shoulder hinge point at the local roadway low point (i.e. ponding will not be allowed to spread onto the shoulder of the roadway).
- *Temporary Culverts:* Headwater elevation will not be greater than the shoulder hinge point at the local roadway low point (i.e. ponding will not be allowed to spread onto the shoulder of the roadway).

HW/D Ratio

- *48" [1200 mm] equivalent and smaller culverts:* Limit ratio to 1.5.
- *Larger than 48" [1200 mm] equivalent culverts:* Limit ratio to 1.2.
- *Debris or Sediment:* A ratio range of 0.8 to 1.0, depending on severity, is suggested where the potential for heavy debris or sediment bed loads are a concern.

Reference Elevations

Elevations that represent unacceptable hazards to human life or private property, or exceed local sub-basin divides such as ditch invert elevations that would allow runoff to flow away from the desired crossing point.

7.3.1.4.2 Minimum Size

To limit maintenance problems due to debris or sedimentation and to facilitate inside access to culverts, minimum pipe size criteria are:

- 24" [600 mm] or equivalent for cross-road culverts
- 18" [450 mm] or equivalent for parallel culverts in roadside ditches and channels

7.3.1.4.3 Slope

Site conditions determine the slope for a particular cross culvert. For determining appropriate slope, cross culverts can be divided into two categories:

Ditch Relief

For culverts used as cross-drains to carry away intermittent roadside ditch water, the pipe slope should not be flatter than 2% whenever possible, with 0.5% being the minimum. Where practical, the pipe slope should equal or exceed the roadside ditch grade. The maximum slope should not exceed 10% for concrete pipe, or 25% for metal pipes, without using pipe anchors.

Stream Crossings

These culverts are individually designed to carry the design discharge from a basin without exceeding the allowable headwater criteria. The pipe slope will generally conform to the average streambed flow line and should match the channel elevations on both the upstream and downstream sides.

7.3.1.4.4 Cover

Refer to FLH Standard Drawings for the minimum and maximum cover on pipes.

7.3.1.4.5 Pipe Anchors

Pipe anchors are required for any exposed pipe (i.e., laid on embankment fill or natural ground). Additionally, because culverts placed on very steep slopes can experience joint separation, incorporate pipe anchors for concrete pipe on a slope of 10% or greater and for corrugated metal pipes on a slope of 25% or greater.

7.3.1.4.6 Materials

Refer to Section 7.3.6 for standards and guidance regarding the selection of alternative materials. All proposed culvert installations will meet the selected design criteria regardless of which alternative material is selected.

7.3.1.5 Design Guidance

7.3.1.5.1 Alignment

The recommended maximum culvert skew, relative to the roadway centerline, is 45 degrees.

7.3.1.5.2 Entrance Treatments

The culvert end treatments affect hydraulic efficiency, embankment stability, aesthetics, and safety for run-off-the-road vehicles. There are several types of entrance treatments for culverts:

- Thin edge projecting
- Mitered to conform to slope
- Flared end section
- Square edge in a headwall (with or without wingwalls)
- Beveled edge in a headwall (with or without wingwalls)
- Grooved end projecting
- Side-tapered and slope-tapered inlets

For the design of new structures, flared end sections are recommended for 48” [1200 mm] equivalent and smaller pipes. For larger pipes, a headwall end treatment is recommended to offset buoyant forces. Headwalls are also recommended for multiple pipe installations. Beveled edges should be used on all headwalls. For long culverts operating under inlet control conditions, tapered inlets, also known as “improved inlets,” may be used to increase hydraulic efficiency and allow the designer to reduce the pipe size.

For existing, lengthened, or rehabilitated structures with insufficient capacity to convey the design discharge, the designer should consider adding a more efficient entrance treatment.

7.3.1.5.3 Outlet Treatments

End sections and headwall/wing-wall treatments are typically used at culvert outlets using the same criteria as for inlets. The diverging geometry of these end treatments helps redistribute the outlet discharge and associated velocities to the natural channel width. Culvert outlets will be stable for the design discharge. Reference Section 7.3.5 for design of outlet protection, when required.

7.3.1.5.4 Fish Passage

At some culvert locations, the ability of the structure to accommodate migrating fish is an important design consideration. For these sites, consult state fish and wildlife agencies early in the roadway planning process. For existing culverts that obstruct fish passage, modifications can often meet the fish and wildlife agencies' design criteria. Design standards, criteria, and guidance for fish passage are provided in Section 7.5.1 of this document.

7.3.1.5.5 Camber

Under high fill conditions, the engineer should incorporate sufficient camber to allow for settlement. Refer to FLH Standard Drawings for the recommended camber.

7.3.1.5.6 Open-Bottom Culverts

Open-bottom culverts, either concrete or metal, are sometimes designed for fish passage, environmental, aesthetic, or economic reasons. These structures have a natural bottom and must be supported on both sides by a foundation. Because of the likelihood of local scour, evaluate and design the foundations using bridge criteria, unless they can be founded on bedrock. Refer to Section 7.4.3 for information on foundation design.

7.3.1.5.7 Box Culverts

Use standard drawings from the applicable State, unless a custom design is required. If a custom design is required, consult the Bridge Design Group.

7.3.1.6 Recommended Methods

Design and evaluate culverts for hydraulic performance according to the methods and procedures presented in HDS 5 *Hydraulic Design of Highway Culverts.*

For standard riprap outlet protection, refer to FLH Standard Drawings or the methods in HEC 14. For outlets requiring energy dissipators, refer to Section 7.4.9.

7.3.1.7 Reporting

Documentation on the design of culverts should contain, at a minimum, the following data, as applicable:

- Project identification
- Location of proposed installations
- Drainage area map and site topography
- Stream profile and cross sections
- Information on existing structures
- Historical high water data
- Site investigation data (e.g., stream stability information)

- Hydrologic design computations
- Hydraulic design calculations and culvert performance curves
- Economic analysis

7.3.1.8 Plans

In the plans for culvert installations, include the following for each culvert location:

- Size
- Alignment
- Length
- Acceptable materials, including class, gauge, and any special coatings
- Joint gasket treatments, if any
- End treatment
- Cover depth
- Camber, if any

For the location and design of simple riprap outlet protection, include the following for each culvert location:

- Dimensions and extent of riprap
- Gradation
- Bedding and Filter Material
- Grading or slope details, if needed

In addition, culvert pipe 48" [1200 mm] or equivalent and larger will include individual cross sections showing slope, inlet/outlet invert elevations, design headwater or headwater/diameter ratio, design discharge, drainage area, and any special foundation work or end treatment. Headwalls, energy dissipators, or riprap must be shown. Also include any necessary FLH Standard Drawings or special detail drawings.

Include a Drainage Summary Sheet in the plans for all culverts. Show maximum pipe cover, structure excavation, type of pipe (e.g., wall thickness, size, length), and acceptable alternative pipe materials. See Division Supplements for an example Drainage Summary Sheet.

7.3.2 DITCHES

Ditches are engineered channels, such as roadside ditches in cut sections, toe-of-slope ditches, and interceptor ditches placed at the top of cut slopes. Capacities will be less than 50 cfs [1.5 cms]. This section addresses the design of ditches, including selecting the appropriate design frequency, and evaluating the physical geometry (shape, slope, side slopes, roughness, depth, and freeboard) and channel stability (velocity, shear stress, and channel lining).

For the design or evaluation of channels with capacities of 50 cfs [1.5 cms] or greater, refer to the River Hydraulics Section 7.4.

7.3.2.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HDS 3	FHWA HDS 3, *Design Charts for Open Channel Flow*, 1961
2.	HDS 4	FHWA HDS 4, *Introduction to Highway Hydraulics*, FHWA NHI-08-090, 2008
3.	HEC 15	FHWA HEC 15, *Design of Roadside Channels with Flexible Linings*, FHWA IF-05-114, 2005
4.	HEC 22	FHWA HEC 22, *Urban Drainage Design Manual*
5.	AASHTO MDM Chap. 8	AASHTO Model Drainage Manual, *Chapter 8 – Channels*
6.	AASHTO HDG Vol. VI	AASHTO Highway Drainage Guidelines, *Volume VI – Hydraulic Analysis and Design of Open Channels*

7.3.2.2 Design Standards

7.3.2.2.1 Capacity Design

Design Flood

Design roadside ditches for the 10-year flood for both High- and Low-Standard roadways. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

7.3.2.2.2 Stability Design

Design Flood

Design roadside ditches for stability for the 10-year flood for both High- and Low-Standard roadways. (Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.)

Temporary Linings

Temporary linings may be needed to protect ditches from erosion over the transitional period before permanent protective vegetation can become established. Design temporary channel linings to be stable for the 2-year flood.

7.3.2.3 Design Criteria

7.3.2.3.1 Depth

Depth is defined as the allowable depth of flow relative to the ditch invert.

New Ditches

Limit the design depth to the elevation of the bottom of the aggregate base layer for the roadway pavement structure.

Existing Ditches

When evaluating capacity of existing ditches, limit the depth to the elevation of the shoulder hinge point on the roadway (i.e. flow should not spread onto the shoulder of the roadway).

7.3.2.3.2 Slope

Minimum ditch slope is 0.5% where possible. Where practical, provide a desired 1.0% minimum ditch slope.

7.3.2.3.3 Stability

Design all engineered channels to be stable for the prescribed stability discharge based on permissible shear. The shear stress approach focuses on stresses developed at the interface between the channel boundary and flowing water. The permissible shear stress is the maximum that will not cause serious soil erosion from the channel bed or banks. Acceptable channel linings are outlined in HEC 15 and identified in the FLH *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects* (FP).

7.3.2.3.4 Ditch Relief

Design permanent ditch relief (culverts, spillways, or inlets), as necessary, to meet conveyance or stability criteria.

7.3.2.3.5 Outlet Protection

Ditch outlets will be stable for the stability design discharge. Scour at ditch outlets is a common occurrence that can undermine and cause embankment failure. For most outlets, properly designed riprap outlet protection is sufficient. Reference Section 7.4.9 for discussion on applications where the outlet velocity, relative to soil erodibility, dictates the use of an energy dissipator to prevent excessive outlet scour.

7.3.2.4 Design Guidance

7.3.2.4.1 Cross Section Shape

Ditch cross sections are typically designed based on minimum standard dimensions that permit easy construction and maintenance with highway equipment. Minor drainage channels may have vee, trapezoidal, rectangular, parabolic, or triangular shapes.

7.3.2.4.2 Slope

The ditch slope need not follow that of the roadbed. Although preferred, the roadside ditch geometry need not be standardized for any length of highway. Wider, deeper, or flat-bottom ditches may be used as required to meet different amounts of runoff, channel slopes, lining types, and distances between points of discharge. Ditch relief structures should be provided, where necessary, to maintain the standard ditch section to the extent possible.

7.3.2.4.3 Erosion Protection

Various types of vegetation, rolled erosion control products, rock, and rigid linings are available to provide erosion protection for ditches. Temporary linings are often required to allow protective vegetation time to establish. Temporary lining options should be included and incorporated into the project Storm Water Pollution Prevention Plan (SWPPP). In cases where vegetation will not provide adequate erosion protection, ditches may be lined with rock or stone of suitable size, or with asphalt or concrete. Smooth linings, such as asphalt and concrete, generate higher velocities than rougher vegetation and rock linings and may require energy dissipation devices at ditch outlets.

7.3.2.5 Recommended Methods

Design roadside channels using methods given in HEC 15, *Design of Roadside Channels with Flexible Linings.* Evaluate the channel stability for the immediate post-construction condition and for the final condition using the permissible shear stress, as documented in HEC 15. The values for permissible shear stress are given in HEC 15.

The permissible shear stress values for many temporary and permanent erosion control blankets have been determined in laboratory studies by manufacturers. The engineer may use a manufacturer-specified permissible shear stress, if developed according to ASTM D6460, *Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion.*

7.3.2.6 Reporting

Documentation on the design of roadside channels should contain the following minimum data:

- Project identification
- Location of proposed work

- Design discharge and frequency
- Hydrologic calculations
- Channel cross section and gradient
- Type of lining
- Design calculations

7.3.2.7 Plans

The plans will show all details necessary to construct the channel according to the hydraulic design. The following information should be included, at a minimum:

- Location
- Alignment
- Slope and elevations
- Cross section (bottom width, side slope, depth)
- Channel linings (both temporary and permanent)
- Special structure details, if any

7.3.3 PAVEMENT DRAINAGE

Pavement drainage refers to the above-ground hydraulic considerations associated with the design of systems to collect and drain runoff from roadways with curb and gutter. Design considerations include selecting the storm event, defining surface drainage patterns, limiting the allowable spread (extent of water on the road surface), locating and spacing inlets, and special considerations associated with sag locations. This section provides design discussion and guidance on all areas of roadway surface drainage, including bridge deck drainage.

7.3.3.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HEC 21	FHWA HEC 21, *Bridge Deck Drainage*, FHWA SA-92-010, 1993
2.	HEC 22	FHWA HEC 22, *Urban Drainage Design Manual*
3.	AASHTO MDM Chap. 13	AASHTO Model Drainage Manual Chapter 13 – *Storm Drainage Systems*
4.	AASHTO HDG Vol. IX	AASHTO Highway Drainage Guidelines Volume IX – *Storm Drain Systems*

7.3.3.2 Design Standards

7.3.3.2.1 Capacity Design

Design Flood

These standards apply to both High- and Low-Standard roadways. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

- *On-grade, Sags, and Parking Areas:* Design the roadway conveyance and collection systems (i.e. gutter flow and inlet design) for the 10-year flood.
- *Sumps:* Roadway sumps are defined as deep roadway sags that must have storm drain systems to outlet runoff and limit gutter depths. In roadway sump locations where a storm drain system is the only outlet, design the drainage inlet system to accommodate the 50-year flood.

7.3.3.3 Design Criteria

7.3.3.3.1 Spread

Spread refers to the allowable width of flow encroachment onto the pavement section during storm events. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

- *High-Standard Roadways:* Limit the spread to 3 ft [900 mm] of one travel lane for gutter flow, both on-grade and in roadway sags.
- *Low-Standard Roadways:* Limit the spread to half of one travel lane for gutter flow, both on-grade and in roadway sags.
- *Roadways with less than 3 ft [900 mm] of pavement width outside the travel lane:* Limit spread to half of one travel lane for gutter flow, both on-grade and in roadway sags.

7.3.3.3.2 Depth

Applies to High- and Low-Standard roadways. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

On-grade and Sags

Flow depth at the curb should not exceed the curb height or the allowable spread for the design discharge.

Sumps

Limit the depth of flow at the gutter flow line to 6" [150 mm].

Parking Areas

For inlets adjacent to curbs, flow depth should not exceed the curb height. For sags limit the depth of flow at the gutter flow line to 6" [150 mm].

7.3.3.3.3 Inlet Clogging Factor

Applies to High- and Low-Standard roadways. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

On-grade

Assume that on-grade inlets are not subject to debris clogging, unless clogging is a known problem.

Sumps and Sags

- *Grate Inlets:* Design grate inlets in roadway sags and parking areas using an inlet clogging factor of 50 percent. In other words, reduce the grate perimeter or open area parameters by 50 percent of the actual values.
- *Curb-opening Inlets:* Assume that curb-opening inlets are not subject to debris clogging, unless clogging is a known problem
- *Rehabilitation Projects:* Assume all inlets are not subject to clogging, unless clogging is a known problem.

7.3.3.4 Roadway Design Guidance

The roadway pavement and geometry should be designed for the efficient removal of rainfall from the traveled lanes of the roadway. The roadway pavement materials and finishes, cross-slope, and longitudinal slope should be designed to promote the removal of water from the traveled lanes.

In rural areas, avoid the use of curbed sections whenever possible to avoid runoff concentration and potential erosion.

7.3.3.4.1 Gutter Flow

A gutter is defined as the section of roadway next to the curb that conveys water during a storm runoff event. Gutter cross sections have a triangular shape with the curb forming the near-vertical leg of the triangle. The gutter may have a uniform cross slope or a composite cross slope. Composite gutter sections are encouraged, where possible, because of the associated increase in gutter capacity and inlet efficiency.

7.3.3.4.2 Inlet Location

There are numerous locations where inlets are required based on the geometry of the roadway. The following list includes locations where inlets are recommended based solely on roadway geometry:

- At all low points in the gutter grade
- Immediately upstream of median breaks, entrance/exit ramp gores, cross walks, and street intersections, i.e., at any location where a concentrated flow path could flow onto the travel lanes
- Immediately upgrade of bridges (to prevent water from flowing onto bridge decks)
- Immediately downstream of bridges (to intercept bridge deck drainage)
- Immediately upgrade of cross-slope reversals
- Immediately upgrade from pedestrian cross walks
- On side streets immediately upgrade from intersections
- At the end of channels in cut sections
- Behind curbs, shoulders, or sidewalks to drain low areas

Additional on-grade inlets will be spaced to meet the allowable spread criteria. The minimum recommended capture efficiency for on-grade inlets is 70%.

Where curbs are used, runoff from cut slopes and areas off the right-of-way should, wherever possible, be intercepted by ditches at the top of slopes or in a swale behind the curb. This reduces the amount of water that has to be picked up by the inlets and the amount of mud and debris carried onto the pavement.

7.3.3.4.3 Inlet Type

Select the type of inlet to best meet the design criteria, considering cost, hydraulic efficiency, interference with traffic, pedestrian and bicycle safety, and debris clogging. Grate inlets, curb-opening inlets, slotted drain pipe inlets, or a combination of curb opening and grate inlets may be used for intercepting runoff. Some of the major operational characteristics for each inlet type are provided below. Refer to the following FLH Standard Drawings list for general application of Federal Lands inlets:

- Type 1 Catch Basin – Grate Inlet with a tilt-bar grate (Type A or B), intended for use on-grade in a curb and gutter section or in a ditch flow line
- Type 2 Catch Basin with Down Drain – Grate Inlet with a tilt-bar grate (Type A or B), intended for use on-grade in a curb and gutter section, roadway in fill
- Type 5A Inlet – Grate Inlet with a P 2.5 x 4.25 [P 64 x 108] grate, for use on-grade or in sags
- Type 6B Inlet – Grate inlet with a cast iron grate, for use in valley gutters or parabolic ditches

- Type 7A/B Inlet – Grate inlet with wide bar-spacing, for use in a ditch flow line

Grate Inlets

Grate inlets consist of a collection box below the gutter, covered with a grate.

- *Continuous Grade*
    - ◊ Grate inlets on a continuous grade will intercept all or nearly all of the gutter flow passing over the grate, or the frontal flow. A portion of the flow along the side of the grate will be intercepted, depending on the cross slope of the pavement, the length of the grate and flow velocity.
    - ◊ On-grade grate inlets maintain interception capacity on steeper slopes.
    - ◊ Interception capacity of grate inlets is reduced by debris clogging.
    - ◊ The length of grate inlets is relatively inflexible. Increased length typically does not significantly affect interception capacity
- *Sag Locations*
    - ◊ A grate inlet in a sag location operates as a weir at shallow depths and as an orifice at greater depths.
    - ◊ In a sag the length of the grate inlet can be varied to increase interception capacity.
    - ◊ Interception capacity of grate inlets is reduced by debris clogging.

Curb-opening Inlets

Curb-opening inlets are vertical openings in the curb, covered by a top slab.

- Curb-opening inlets are relatively free of clogging tendencies and offer little interference to traffic operation.
- Curb-opening inlets may be preferred over grate inlets in locations where grates would be in traffic lanes or would be hazardous for pedestrians or bicyclists.
- Curb-opening inlets are preferred on longitudinal grades 3 percent or less because of decreasing capture capacity and efficiency at steeper grades.

Slotted Inlets

Slotted inlets consist of a pipe cut along its longitudinal axis with perpendicular bars used to maintain a continuous opening.

- Slotted inlets function in essentially the same manner as curb opening inlets on a continuous grade.
- Slotted drains are susceptible to clogging and can be difficult to maintain.
- Due to the high potential for debris clogging, the use of slotted drain inlets located in sags is discouraged.

<u>Combination Inlets</u>

Combinations of grate and curb-opening inlets can be used. Combination inlets can either be equal-length or sweeper inlets, where the curb opening extends upstream of the grate.

- *Equal-length Combination Inlets*
    - ◊ Equal-length combination inlets have both a grate and a curb opening, with the same length.
    - ◊ Equal-length combination inlets on a continuous grade are not recommended because the capacity is not appreciably greater than with the grate inlet alone.
    - ◊ Equal-length combination inlets are recommended in sag locations because of increased capacity and the fact that the curb opening provides relief should the grate inlet become clogged.
- *Sweeper Inlets*
    - ◊ Sweeper inlets have both a grate and a curb opening, with the curb opening being longer than the grate in the upstream direction.
    - ◊ Sweeper inlets on a continuous grade are relatively free of debris clogging tendencies and can be used where increased interception efficiency is required.

<u>Median and Roadside Ditch Inlets</u>

- Grate inlets similar to those used for pavement drainage may be used to drain medians and roadside ditches. Additionally, since bicycle safety is typically not a factor at these locations, these inlets/grates should provide maximum open area to minimize clogging potential.
- Grate inlets should be flush with the ditch bottom and cross drainage structures should be continuous across the median unless the median width makes this impractical.
- Ditches tend to erode at grate inlets. Paving around the inlets may help prevent erosion and may increase the interception capacity of the inlet marginally by reducing bypass flow.
- Small dikes placed immediately downstream of median or ditch inlets can ensure complete interception of the flow.

7.3.3.5 Bridge Deck Design Guidance

The hydraulic principles of bridge deck drainage are similar to roadway drainage principles. The surface drainage, gutter flow and inlet design standards, criteria, and guidance provided in the previous sections all apply to bridge deck drainage, but are complicated by the structural and architectural requirements of bridges. The bridge deck inlets tend to be small to conform to structural requirements and, as such, tend to clog easily. Down-drain pipes can detract from the bridge aesthetics, and encased piping has serious maintenance considerations.

Wherever possible, do not design bridge deck profiles with sags or low points because small inlet sizes and potential for debris clogging make them difficult to drain.

Wherever possible, design bridges to meet roadway drainage criteria without the use of bridge deck inlets. Typically, bridges are built with uniform gutter geometry, as opposed to the more effective composite gutter section. Where required by criteria, on-grade inlet spacing may be determined both by allowable spread criteria and bridge pier spacing.

Roadway inlets should be placed up-gradient of bridges to reduce or eliminate runoff onto the bridge deck.

Roadway inlets should also be placed down-gradient of bridges to capture runoff from the bridge deck. This is especially critical where a curbed gutter section does not extend beyond the bridge abutment. Concentrated runoff from the bridge deck in these situations could precipitate erosion, which could cause damage to the abutment fill.

7.3.3.6 Recommended Methods

Design and evaluate the pavement drainage system performance according to the methods and procedures presented in HEC 22 *Urban Drainage Design Manual.* For bridge deck drainage design, HEC 21 *Design of Bridge Deck Drainage* is the recommended reference for information on detailed design methods and procedures.

7.3.3.7 Reporting

The design of a roadway drainage facility should be supported by documentation containing, at a minimum, the following information:

- Project identification
- Location of proposed installation
- Roadway gradient and applicable cross section
- Design discharge and frequency
- Gutter discharge and spread calculations
- Type and size of inlets
- Inlet efficiency calculations
- Data on intercepted and bypass flows

7.3.3.8 Plans

Design roadway drainage improvements to reflect the roadway gradient and cross sections given on the plans. For the location and design of inlets, prepare plans showing all details necessary to construct the improvements according to the hydraulic design, including the following:

- Location
- Type and size of inlets
- Special structure details, if any
- Drainage Summary Sheet

7.3.4 STORM DRAINS

A storm drain is the portion of the roadway drainage system that receives runoff from multiple inlets and conveys it through a series of pipes to an outfall. The design of storm drain systems includes selecting the proper hydrologic method and recurrence interval, sizing the pipe, locating access structures, determining energy losses, and computing the hydraulic gradeline to determine free surface flow versus pressure flow.

7.3.4.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HEC 22	FHWA HEC 22, *Urban Drainage Design Manual*
2.	AASHTO MDM Chap. 13	AASHTO Model Drainage Manual, Chapter 13 – *Storm Drainage Systems*
3.	AASHTO HDG Vol. IX	AASHTO Highway Drainage Guidelines, Volume IX – *Storm Drain Systems*
4.	AISI Sewer Design	American Iron and Steel Institute, *Modern Sewer Design*

7.3.4.2 Design Standards

7.3.4.2.1 Capacity Design

Design Flood

The following design flood standards apply to both High- and Low-Standard roadways. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

- On-Grade: 10-year flood
- Sumps: 50-year flood

Roadway sumps are defined as deep roadway sags that must have storm drain systems to outlet collected runoff and limit gutter depths.

7.3.4.3 Design Criteria

Design storm drains to flow full (i.e., no pressure) for the design event whenever possible.

7.3.4.3.1 Minimum Size

The minimum size for storm drain pipe is 15” [375 mm] or equivalent.

7.3.4.3.2 Minimum Slope

Design storm drains with slope sufficient to develop a self-cleaning velocity of 3 ft/s [0.9 m/s] when flowing full (reference Table 7-7 in HEC 22). Slope less than 0.5% should be avoided for constructability reasons.

7.3.4.3.3 Hydraulic Gradeline

Compute the hydraulic gradeline (HGL) over the full length of storm drains with four or more inlets connected in series.

In storm drain sections where the hydraulic gradeline for the design flood must exceed the pipe soffit (i.e., the pipe flows under pressure), the hydraulic gradeline for the design flood will remain below the ground elevation at all inlets and access structures, and watertight gaskets should be specified for the pipe joints.

7.3.4.3.4 Access Structures

Locate access structures to provide access for inspection and maintenance. Inlet structures are considered access structures and should be designed accordingly. Access structures are typically located based on maintenance requirements and at changes to the storm drain alignment or profile, including locations where:

- Two or more storm drains converge
- Pipe size changes
- Abrupt change in alignment occurs
- Abrupt change in slope occurs
- At intermediate points according to spacing given in Exhibit 7.3-A

Exhibit 7.3-A ACCESS STRUCTURE MAXIMUM SPACING

Pipe Size, in [mm]	Maximum Spacing, ft [m]
15 – 24 [375 – 600]	300 [90]
27 – 36 [675 – 900]	400 [120]
42 – 54 [1050 – 1350]	600 [180]
60 and up [1500 and up]	1000 [300]

7.3.4.3.5 Materials

Refer to Section 7.3.6 for standards and guidance regarding the selection of alternative materials. All proposed storm drain installations will meet the selected design criteria regardless of which alternative material is selected.

7.3.4.4 Design Guidance

7.3.4.4.1 Storm Drain Profile

Where practical, match the pipe soffit elevations (high point inside pipe) at all junctions, rather than the pipe invert elevation. Invert elevations for same size pipes should be offset to account for losses in access structures. This technique will help prevent backwater profiles from rising and upstream velocities from decreasing.

Where possible, the pipe size should not decrease in the downstream direction, even though the capacity of the smaller pipe may be greater due to a steep slope. Exceptions are to be considered when tying into an existing system.

The storm drain profile should be designed as close to the surface as possible, taking minimum cover depths and utility conflicts into consideration.

7.3.4.4.2 Hydraulic Gradeline

If the computed hydraulic gradeline is higher than allowed by criteria, energy losses can be reduced by increasing the pipe size or designing more hydraulically efficient access structures.

7.3.4.4.3 Outlet Treatment

Use standard headwall/wing wall outlet treatment where applicable. Storm drain outlets will be stable for the design discharge. Reference Section 7.3.5 for design of outlet protection, when required.

7.3.4.5 Recommended Methods

Design and evaluate the storm drain system performance according to the methods presented in HEC 22 *Urban Drainage Design Manual*, or approved equivalent.

7.3.4.6 Reporting

The design of the storm drain and evaluation of the hydraulic gradeline should be supported by documentation containing, at a minimum, the following information:

- Project identification
- Location of proposed installation
- Hydrologic design computations
- Hydraulic design calculations

7.3.4.7 Plans

For the location and design of storm drains, prepare plans showing all details necessary to construct the improvements according to the hydraulic design, including the following:

- Size
- Alignment
- Length
- Slope and inlet/outlet invert elevations
- Inlet, access structure locations
- Acceptable materials, including class, gauge, and any special coatings
- Joint gasket treatments, if any
- Outlet treatment

Information placed on the plans will include individual profile sheets showing design discharge, drainage area, hydraulic gradeline, and any special access structure details. Show maximum pipe cover, structure excavation, type of pipe (e.g., wall thickness, size, length), and acceptable alternative pipe materials on Drainage Summary Sheet. End Treatments, energy dissipators, or riprap must be shown. Include any necessary FLH Standard Drawings or special detail drawings.

7.3.5 OUTLET PROTECTION

Local scour at culvert, ditch, and storm drain outlets is a common occurrence. The natural runoff is usually confined to a lesser width and greater depth as it passes through a conveyance system. An increased velocity results with potentially erosive capabilities at the conveyance outlet. Turbulence and erosive eddies form also as the flow expands to conform to the natural channel. In addition to the hydraulic characteristics of the flow at the outlet, the erosive characteristics of the outlet channel bed and bank material, and the amount of sediment and other debris in the flow are contributing factors to scour potential.

For most small outlets, riprap protection is sufficient to protect the structure and adjacent property from being undermined by the scouring action of the expanding flow. The focus of this section is on the design requirements for riprap outlet protection. If riprap protection is not expected to contain the potential scour, or the outlet velocity is very high, an energy dissipator may be appropriate. Refer to Section 7.4.9 for guidance on energy dissipators.

7.3.5.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. HEC 14 — FHWA HEC 14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*

2. AASHTO HDG Vol. IV — AASHTO Highway Drainage Guidelines, Volume IV – *Hydraulic Design of Culverts*

7.3.5.2 Design Standard

7.3.5.2.1 Stability Design

Outlet protection will be designed to meet the appropriate stability standards for the structures they are intended to protect. Specific references to appropriate standards are provided below:

Culvert Outlets

Refer to Section 7.3.1.3.2.

Ditch Outlets

Refer to Section 7.3.2.2.2.

Storm Drain Outlets

Refer to Section 7.3.4.4.3.

7.3.5.3 Design Criteria

The general design criteria for riprap outlet protection are as follows:

Demonstrate that the riprap is reasonably expected to remain stable and to protect the facility under worst-case conditions up through the stability design flood throughout its intended service life.

Provide appropriate termination details to prevent undermining or flanking of the riprap by scour and erosion processes beyond the protection itself. Riprap intended to prevent local scour, for instance, must be protected from undermining by long-term degradation.

7.3.5.4 Design Guidance

In order to release storm water discharge to a stable outlet, there are several alternatives for outlet protection:

- no protection required (no scour potential or expected scour can be tolerated)
- riprap outlet protection (standard outlet treatment)
- minimal outlet protection with performance monitoring
- formal energy dissipator

Riprap protection at culvert, ditch, and storm drain outlets is appropriate where moderate outlet velocities exist. At some locations, the use of a roughened perimeter within the conveyance structure, upstream of the outlet, may alleviate the need for special outlet protection.

7.3.5.5 Recommended Methods

Design and evaluate the performance of energy dissipators according to the methods presented in HEC 14. HEC 14 also contains procedures for estimating scour hole dimensions at pipe outlets.

7.3.5.6 Reporting

The design of outlet protection for culvert, ditch, or storm drain outlets should be supported by documentation containing, at a minimum, the following information:

- Project identification
- Location of proposed installation
- Hydraulic design calculations

7.3.5.7 Plans

For the location and design of riprap outlet protection, prepare plans showing all details necessary to construct the improvements according to the hydraulic design, including the following:

- Location
- Dimensions and extent of riprap
- Gradation
- Bedding and Filter Material or Geotextile
- Grading or slope details

7.3.6 ALTERNATIVE PIPE MATERIALS

It is Federal Lands Highway policy to specify alternative drainage pipe materials on all projects where feasible and to comply with the provisions of 23 CFR 635.411. All suitable pipe materials, including reinforced concrete, steel, aluminum, and plastic will be considered as alternatives for all new cross culverts and storm drain pipes on Federal Lands Highway projects. Not all pipe materials are appropriate or applicable for all storm drain applications. The design of alternative drainage pipe materials should consider functionally equivalent performance in three areas: structural capacity, durability and service life, and hydraulic capacity. The service life and hydraulic capacity issues are addressed in this section.

7.3.6.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. 23 CFR 635.411 Title 23 CFR 635.411 in 23 CFR 635D, *General Material Requirements*

2.	FHWA-FLP-91-006	FHWA, *Durability of Special Coatings for Corrugated Steel Pipe*, FHWA FLP-91-006
3.	FHWA-RD-97-140	FHWA, *Durability Analysis of Aluminized Type 2 Corrugated Metal Pipe*, FHWA RD-97-140, 2000.
4.	AASHTO HDG Vol. IV	AASHTO Highway Drainage Guidelines, *Volume IV – Hydraulic Design of Culverts*
5.	AASHTO HDG Vol. XIV	AASHTO Highway Drainage Guidelines, *Volume XIV – Culvert Inspection and Rehabilitation*
6.	Caltrans Chapter 850	California Department of Transportation Highway Design Manual, Chapter 850 – *Physical Standards*

7.3.6.2 Design Standards

7.3.6.2.1 Service Life

Design cross culvert and storm drain pipes with a minimum maintenance-free service life of 50-years, regardless of pipe material selection. A shorter service life may be used for temporary installations, and a longer service life may be considered in unusual situations.

7.3.6.2.2 Minimum Pipe Classification

Use Class II as the minimum for all reinforced concrete pipes. Determine appropriate pipe class from FLH fill height FLH Standard Drawings.

Use a minimum wall thickness of 0.0625” [1.63 mm] for all steel and aluminum pipes. The appropriate minimum structural metal thickness will be determined from approved FLH fill height tables.

7.3.6.3 Design Guidance

7.3.6.3.1 Service Life

The durability and service life of a storm drain pipe is directly related to the environmental conditions encountered at the site and the type of materials and coatings from which the pipe was fabricated. The two primary causes of early failure in drainage pipe materials are corrosion and abrasion.

Corrosion gradually wears away at the pipe walls by chemical action, and can occur from both the soil and water sides of the pipe. Abrasion wears away at the interior pipe wall by friction from suspended or bed-load sediment.

7.3.6.3.2 Data Collection

Corrosion

Representative pH and resistivity determinations are required in order to specify pipe materials capable of providing a maintenance-free service life. Samples are taken in accordance with the procedures described in AASHTO T 288 and T 289. Samples should be taken from both the soil and water side environments to ensure that the most severe environmental conditions are selected for determining the service life of the drainage pipe. Soil samples should be representative of backfill material anticipated at the drainage site. Avoid taking water samples during flood flows or for two days following flood flows to ensure more typical readings. In locations where streams are dry much of the year, water samples may not be possible or necessary. In areas of known uniform pH and resistivity readings, a random sampling plan may be developed to obtain the needed information.

In corrosive soil conditions where water side corrosion is not a factor, consider specifying less corrosive backfill material to modify the soil side environment. The mitigating effect of the specified backfill should be taken into account in making alternative pipe materials selections in situations where the soil side conditions control the design.

Abrasion

An estimate of the potential for abrasion is required in order to determine the need for invert protection. Four levels of abrasion are referred to in this guidance and the following guidelines are established for each level:

- *Level 1*. Nonabrasive conditions exist in areas of no bed load and very low velocities. This is the condition assumed for the soil side of drainage pipes.
- *Level 2*. Low abrasive conditions exist in areas of minor bed loads of sand and velocities of 5 ft/s [1.5 m/s] or less.
- *Level 3*. Moderate abrasive conditions exist in areas of moderate bed loads of sand and gravel and velocities between 5 ft/s and 15 ft/s [1.5 m/s and 4.5 m/s].
- *Level 4*. Severe abrasive conditions exist in areas of heavy bed loads of sand, gravel, and rock and velocities exceeding 15 ft/s [4.5 m/s].

Abrasion levels are intended as guidance to help the engineer consider the impacts of bed-load wear on the invert of pipe materials. Sampling of the streambed materials is not required, but visual examination and documentation of the size of the materials in the stream bed and the average slope of the channel will give the designer guidance on the expected level of abrasion. Where existing culverts are in place in the same drainage, the conditions of inverts should also be used as guidance. The expected stream velocity should be based upon a typical flow (i.e., 2-year flow and less) and not a 10-or 50-year design flood.

7.3.6.3.3 Reinforced Concrete Pipe

Reinforced concrete pipe (AASHTO M 170M) is typically specified as an alternative whenever environmental conditions permit. The appropriate pipe class is determined from approved FLH fill height FLH Standard Drawings. If the following guidance on corrosion and abrasion limitations is used, reinforced concrete pipe can be assumed to have a minimum service life of 50 years.

Corrosion

Reinforced concrete pipe should not be specified for extremely corrosive conditions where the pH is less than 3.0 and the resistivity is less than 300 Ω-cm. Where the pH is less than 4.0, or the pipe is exposed to wetting and drying in a salt or brackish water environment, protective coatings (e.g., epoxy resin mortars, poly vinyl chloride sheets) should be used. When the sulfate concentration is greater than 0.2% in the soil or 2,000 parts per million in the water, Type V cement should be specified. When the sulfate concentration is greater than 1.5% in the soil or 15,000 parts per million in the water, Type V cement should be used with a sulfate resistant pozzolan. A higher cement ratio may also be used (e.g., AASHTO Class V pipe design).

Abrasion

On installations in severe abrasive environments, consider using seven or eight sack concrete or increasing the cover over the reinforcing steel.

7.3.6.3.4 Steel Pipe with Metallic Coatings

Steel pipe will typically be specified as an alternative when the environmental conditions permit. The appropriate minimum structural metal thickness is determined from approved FLH fill height tables. Federal Lands Highway design policy assumes that steel pipe will provide a useful, maintenance-free service life for a period of time beyond the point of first perforation. This assumes an acceptable risk for most Federal Lands Highway projects, but at locations with erodible soils, large traffic volumes, or high fills where replacement or repair would be unusually difficult or expensive, consider increasing the steel plate by one standard thickness. In unusual situations where very high fills and severe abrasion are combined, or where other environmental concerns would make replacement of a pipe culvert very costly or impractical, consider using a pipe one size larger in diameter to permit re-lining in the future by insertion of another pipe.

The following types of steel pipe with metallic coatings are considered as alternatives on Federal Lands Highway projects:

- Galvanized steel (AASHTO M 218)
- Aluminum coated steel (Type 2) (AASHTO M 274)

Corrosion

Under non-abrasive and low-abrasive conditions, the service life of steel pipe with metallic coatings may be determined based upon corrosion (i.e., pH and resistivity) factors determined from Exhibit 7.3-B, which shows the relationship between service life and corrosion for plain galvanized steel pipe. It has been adapted from the California Department of Transportation "Method for Estimating the Service Life of Steel Culverts," California Test 643. The curves have been modified to show the expected average service life of pipe with a steel thickness of 0.0625" [1.63 mm] assuming a useful, maintenance-free service life 25 percent longer than the number of years to first perforation. Under moderate and severe abrasive conditions, abrasion protection must also be considered.

Under nonabrasive and low abrasive conditions, the metal thickness of galvanized and aluminum coated steel (Type 2) alternatives should be determined from Exhibit 7.3-B based on the resistivity and pH of the site. The minimum metal thickness of steel pipe, as determined from FLH standard fill height tables, may have to be increased, or the additional life of a protective coating may have to be added, in order to provide a 50-year service life. The results included in FHWA-FLP-91-006 indicate that within the environmental range of 5.0 through 9.0 pH and resistivity equal to or greater than 1500 Ω-cm, aluminum coated steel (Type 2) can be expected to give a service life of twice that of plain galvanized pipe.

Exhibit 7.3-B can be used to determine various combinations of increased thicknesses, aluminum coated steel (Type 2), and protective coatings to achieve a 50-year service life, but in no case may the metal thickness specified by the structural requirements be reduced.

<u>Abrasion</u>

Under nonabrasive and low abrasive conditions, the metal thickness of the galvanized, galvalume, and aluminum coated steel alternatives, as determined from Exhibit 7.3-B, should be used.

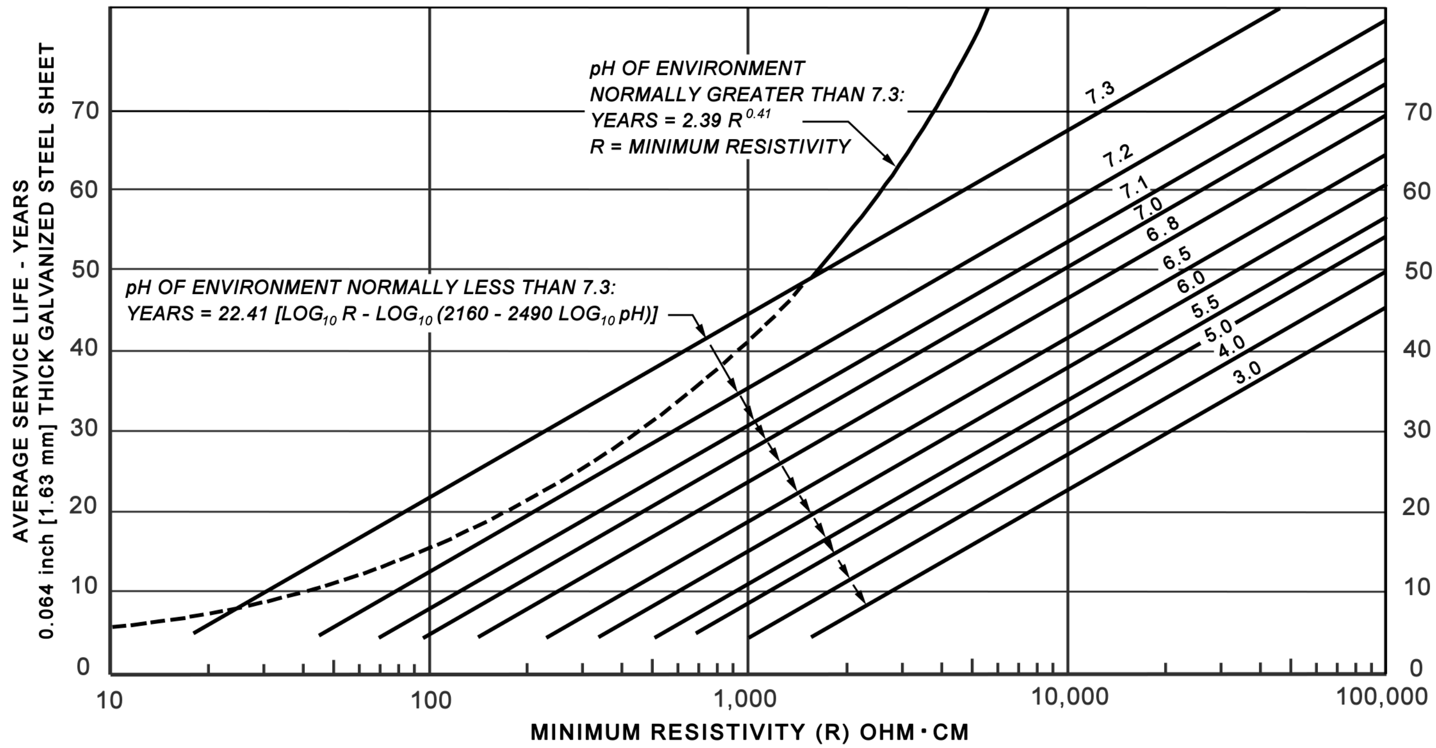
On installations in moderate abrasive environments where protective coatings are not required for corrosion protection, the thickness of the metal should be increased by one standard metal pipe thickness determined from the diagram for average service life of plain galvanized culverts (see Exhibit 7.3-B) or invert protection should be provided. Invert protection may consist of bituminous coating with invert paving with bituminous concrete, Portland cement concrete lining, installation of metal plates or rails, or velocity reduction structures.

On installations in severe abrasive environments where protective coatings are not required for corrosion protection, the thickness of the metal should be increased by one standard metal pipe thickness determined from the diagram for average service life of plain galvanized culverts (see Exhibit 7.3-B) and invert protection should be provided. Invert protection may consist of installation of metal plates or rails, or velocity reduction structures.

Protective coatings are not suitable for corrosion protection in moderate-abrasive and severe abrasive locations. Metal pipes should not be specified in moderate and severe abrasive environments where coatings are required to protect against water-side corrosion.

Exhibit 7.3-B ESTIMATING STEEL PIPE SERVICES LIFE

FEDERAL LANDS HIGHWAY MODIFIED CALIFORNIA METHOD CHART FOR ESTIMATING SERVICE LIFE OF PLAIN GALVANIZED STEEL CULVERTS



Service Life Estimation Chart for Average Service Life of Plain Galvanized Culverts

THICKNESS FACTORS

THICKNESS, inch	**0.052**	**0.064**	**0.079**	**0.109**	**0.138**	**0.168**
GAGE	**18**	**16**	**14**	**12**	**10**	**8**
THICKNESS, mm	**1.32**	**1.63**	**2.01**	**2.77**	**3.51**	**4.27**
FACTOR	**0.8**	**1.0**	**1.2**	**1.7**	**2.2**	**2.6**

Note: Multiply the average Service Life by the Thickness Factor

NOTES:

1. The curves in this Chart are based on the data in FHWA-FLP-91-006 which uses the factors in California Test 643, “Method for Estimating the Service Life of Steel Culverts”. These factors increased the estimated service life by 25% after first perforation.
2. The Chart has also been modified to reflect a minimum metal thickness of 0.064 inch or 16 gage [1.63 mm]
3. Under conditions with pH between 5 and 9, and above R ≥ 1500, the average service life determined for plain galvanized culverts should be multiplied by 2.0 for Aluminum coated steel, (Type 2).

7.3.6.3.5 Non-Metallic Protective Coatings for Steel Pipe

Protective coatings may be used to provide additional protection from corrosion or abrasion resulting in an extended service life. Coatings to protect against corrosion may only be used in non-abrasive and low abrasive environments.

The additional service life noted below in **bold** for each type of protective coating, for corrosion protection, are from Part V of FHWA-FLP-91-006. The added service is applicable only to non-abrasive and moderate abrasive conditions. All of the following types of steel pipe with non-metallic coatings are considered as alternatives on Federal Lands Highway projects:

Bituminous coating

Bituminous coatings (AASHTO M 190) can be expected to add **10 years** of service to the water side and **25 years** life to the soil side service life of pipe as determined from Exhibit 7.3-B. Bituminous-coated pipe should not be used in low abrasive environments.

Bituminous paving and coating

Bituminous paved invert with bituminous coatings (AASHTO M 190) can be expected to add **25 years** life to water side locations. Under moderate abrasive conditions, bituminous paved pipe may be used for invert protection where corrosion protection is not required.

Concrete lining

Concrete lining (ASTM A 849) can be expected to add **25 years** of service life. Due to the natural cracking of concrete, the concrete lining should be applied over an asphalt coating if corrosion protection is needed. Under moderate abrasive conditions, concrete lined pipe may be used for invert protection where corrosion protection is not required.

Polymer coating

Ethylene Acrylic Acid Film coatings (AASHTO M245 and M246) should provide an additional **30 years** service life with a 0.009” [0.25 mm] thickness.

Aramid fiber bonded coating

Only limited data is available for the service life of aramid fiber bonded coated (ASTM A 885) and epoxy coated pipes. No additional service life is currently credited with this policy.

7.3.6.3.6 Aluminum Alloy Pipe

Aluminum alloy pipe (AASHTO M 196M) will typically be specified as an alternative when environmental conditions permit. The appropriate minimum structural metal thickness is determined from approved FLH fill height tables. Within the following limits of corrosion and abrasion, aluminum alloy pipe can be assumed to have a service life of 50 years. Additional service life may be achieved where required by abrasion with the addition of protective coatings or additional metal thickness as discussed below:

Corrosion

An aluminum alloy should be allowed if the pH is between four and nine and the resistivity is greater than 500 Ω-cm. An aluminum alloy alternative can also be considered for use in salt and brackish environments when embedded in granular, free draining material.

Abrasion

On installations in non-abrasive and low-abrasive environments, abrasion protection is not required.

On installations in moderately abrasive environments, the thickness should be increased by one standard metal thickness or invert protection should be used. Invert protection may consist of bituminous coating and invert paving with bituminous concrete or Portland cement concrete, installation of metal plates or rails, or velocity reduction structures.

On installations in severe abrasive environments, the thickness of the metal should be increased by one standard metal pipe thickness from that determined for low-abrasive conditions and invert protection should be provided. Invert protection may consist of installation of metal plates or rails or velocity reduction structures.

7.3.6.3.7 Plastic Pipe

Polyethylene and polyvinyl chloride plastic pipe may be specified as alternatives for pipe diameters and minimum resin cell classifications shown in the AASHTO's *Standard Specifications for Highway Bridges*, Division I Design, Section 18, Soil Thermoplastic Pipe Interaction Systems. The thickness of the plastic alternatives must meet the structural requirements of AASHTO's *Standard Specifications*. The assumed service life of plastic pipe designed in accordance with AASHTO Section 18 is 50 years. The maximum allowable fill heights for pipe materials listed below is determined from approved FLH standard fill-height tables which include the following plastic pipe materials:

- Smooth wall polyethylene (ASTM F 714)
- Corrugated polyethylene (AASHTO M 294)
- Ribbed polyethylene (ASTM F 894)
- Smooth wall polyvinyl chloride (AASHTO M 278 and ASTM F 679)
- Ribbed polyvinyl chloride (AASHTO M304 and ASTM F 794)

Corrosion

Plastic alternatives may be specified without regard to the resistivity and pH of the site.

Abrasion

Under nonabrasive and low-abrasive conditions, polyethylene and polyvinyl chloride alternatives should be allowed. Plastic alternatives should not be used under moderate and severe abrasive conditions without invert protection.

Maximum Size

Limit the size of plastic pipe to 48” [1200 mm] under mainline roads.

The locations selected for use of plastic pipes should address partner agency concerns of possible damage due to fire, ultraviolet sunlight, and rodents.

7.3.6.4 Recommended Methods

Design and evaluate the design service life for galvanized steel culvert and storm drain pipes by the Modified California method presented in Exhibit 7.3B. Refer to FHWA-RD-97-140, *Durability Analysis of Aluminized Type 2 Corrugated Metal Pipe,* for design guidance on aluminized material.

7.3.6.5 Reporting

Documentation of the design service life of culvert and storm drain pipes should be included in the design reporting.

7.3.6.6 Plans

For culvert and storm drain pipes, include information on pipe material, size, class, gauge, and any special coatings in the Plan Drainage Summary.

7.4 RIVER HYDRAULICS

7.4.1 FLOODPLAIN ENCROACHMENTS

When a Federal Lands Highway project involves an encroachment on a base (100-year) floodplain, the location and design of the project must comply with FHWA Policy 23 CFR 650A, *Location and Design of Encroachments on Flood Plains*. This section identifies the standards and criteria arising from this policy and their applicability (see Section 7.4.1.2). It also provides guidelines for ensuring compliance.

Typically, one is referring to the standards and criteria of this section because of direction received from another section within this chapter that involves floodplain encroachments (e.g., bridges, culverts, etc.). Such direction is given when a proposed project includes a new or expanded encroachment on a base floodplain regulated by the Federal Emergency Management Agency (FEMA), or contains the potential for adversely impacting private property or insurable buildings on or near a base floodplain, as defined below.

7.4.1.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	23 CFR 650A	FHWA Policy 23 CFR 650 Subpart A, *Location and Design of Encroachments on Flood Plains*
2.	NS 23 CFR 650A	Federal-Aid Policy Guide, Non-regulatory Supplement to Title 23 CFR 650 Subpart A, Attachment 2, *Procedures for Coordinating Highway Encroachments on Floodplains with Federal Emergency Management Agency (FEMA)*
3.	44 CFR Subchapter B	Code of Federal Regulations, 44 CFR Sections 59 to 77, *National Flood Insurance Program (NFIP)*
4.	HEC 17	FHWA HEC 17, *The Design of Encroachments on Flood Plains using Risk Analysis*
5.	AASHTO MDM Chap. 2	AASHTO Model Drainage Manual, Chapter 2 - *Legal Aspects, Section 2.5 – National Flood Insurance Program*
6.	AASHTO HDG Vol. I	AASHTO Highway Drainage Guidelines, Volume I – *Hydraulic Considerations in Highway Planning and Location*

7.4.1.2 Standard Practices

If a proposed project includes a new or expanded encroachment on a FEMA regulated base floodplain, or contains the potential for adversely impacting private property or insurable buildings on or near the base floodplain, the design will comply with the FEMA standards and criteria used to administer the National Flood Insurance Program in accordance with 23 CFR 650A, Section 650.115(a)(5), in addition to the other applicable standards and criteria contained within this chapter. These standards and criteria apply as minimums, regardless of the hydraulic structure proposed or the encroachment type (i.e., transverse or longitudinal).

For the purposes of this chapter, adverse impacts to private property or insurable buildings will be defined, respectively, as follows:

- Damage to existing real or fixed private property, caused directly by the project during a 100-year flood, over the service life of the project
- Increased 100-year water-surface elevations that impact existing, insurable buildings

If a FEMA map revision request is anticipated, project management will be notified immediately to determine how the coordination process will be handled, and how a revision will be developed (e.g., development and evaluation of alternatives). The revision request will receive concurrence from Federal Lands Highway, the project partner, and the local floodplain administrator.

7.4.1.3 Design Standards

7.4.1.3.1 Capacity Design

Design Flood

Design the encroachment using the 100-year (base) flood.

Check Flood

Use the overtopping flood for evaluating encroachment impacts. If the overtopping flood is less than the base flood, or so large as to not be practicable, then use the greatest flood that may be reasonably estimated to pass through the structure, such as the 500-year flood, as the check flood.

7.4.1.3.2 Survey and Mapping

When survey is needed to quantify hydraulic impacts, refer to Chapter 5 for standards on survey for floodplain mapping.

7.4.1.4 Design Criteria

7.4.1.4.1 FEMA Regulated Base Floodplain

With Detailed Study (i.e., FIRM or FBFM map, report, and modeling information available)

- Floodway defined – Do not encroach upon floodway (bridge piers excepted)
- No Floodway defined – Do not exceed 1 ft [0.3 m] rise (or local standard if more strict)

No Detailed Study (i.e., FHBM map available)

- Do not exceed 1 ft [0.3 m] rise based on own pre- and post-project water-surface profile models

7.4.1.4.2 Unregulated Base Floodplain

Do not exceed 1 ft [0.3 m] rise based on own pre- and post-project water-surface profile models.

7.4.1.5 Design Guidance

7.4.1.5.1 Floodplains Identified on NFIP Maps

Where National Flood Insurance Program (NFIP) maps are available, their use is mandatory in determining whether the project will involve an encroachment upon a base floodplain. If a particular encroachment cannot be designed to meet FEMA standards and criteria, then coordination with FEMA is necessary, as described in the Non-Regulatory Supplement, Attachment 2 (NS 23 CFR 650A).

An encroachment upon a base floodplain identified on NFIP maps, for which a regulatory floodway has been established, will be considered consistent with NFIP standards and criteria if the highway and structure components are kept outside the regulatory floodway. An encroachment having components other than bridge piers within the regulatory floodway should be avoided wherever practicable.

If an encroachment upon a regulatory floodway cannot be avoided, it will be designed to cause no rise in the floodway profile. The floodplain administrator of each affected local community must be contacted and must concur that the project, as designed, will cause no rise in the base flood profile. An example of this is a project to replace an existing low-water crossing in a regulatory floodway with higher road profile and a bridge. Unless the new bridge is built with both abutments outside the floodway, then the higher-profile embankment leading to the bridge constitutes an encroachment upon the floodway.

An encroachment upon a base floodplain identified on NFIP maps, for which no regulatory floodway has been established, will be designed to cause no more than 1.0 ft [0.3 m] rise in the base flood profile, unless more strict local criteria are applicable and appropriate. Many states, counties, and municipalities have ordinances mandating more restrictive criteria than those listed above. It is imperative to determine the extent and nature of state, county and municipal floodplain regulations early in the reconnaissance and scoping phase of the project.

7.4.1.5.2 Coordination with FEMA

Coordination with FEMA is required when the project includes an encroachment upon a base floodplain identified by NFIP maps and the applicable standards and criteria cannot be satisfied. Typically, the coordination includes a map revision request in order to incorporate changes to the effective water-surface profile model; increases to the base flood profile, floodway profile, or base flood inundation limits; or to revise the regulatory floodway encroachment limits.

Whenever a project requires a physical map revision, a Conditional Letter of Map Revision (CLOMR) will be submitted to FEMA and their approval received prior to construction. Once the construction is completed, a survey may be required to verify that the project was constructed as represented in the CLOMR request, and a Letter of Map Revision (LOMR) will typically be requested.

When a project includes an encroachment upon a regulatory floodway and the no-rise criteria cannot be met, NFIP regulations mandate that a CLOMR request pursuant to 44 CFR Subchapter B Section 65.12 (*Revision of flood insurance rate maps to reflect base flood elevations caused by proposed encroachments*) be submitted to and approved by FEMA prior to construction of the project. When an encroachment meets FEMA/local standards and criteria on a base floodplain with a detailed regulatory study, FEMA, or the local floodplain administrator may request to obtain a copy of the updated water-surface profile model and study report.

Failure to comply with these regulations can lead to NFIP program sanctions against the affected local community.

7.4.1.5.3 Role of Community Floodplain Administrators

The responsibility for enforcing floodplain regulations lies with the local community (state, county, or municipality) having land use jurisdiction. This is true for floodplains identified by NFIP maps and those not included in the NFIP. The regulations of relevant local communities must be examined early in the reconnaissance and scoping phase of the project. Coordination with FEMA on a given project usually implies and includes coordination with the floodplain administrator of the local community. If a project requires revisions to the NFIP maps, for example, the revision request must be approved by the community floodplain administrator. It is important, therefore, to identify the names and contact information of the floodplain administrators of the communities affected by a project early, and to remain in frequent contact with the floodplain administrators as the project progresses.

7.4.1.6 Reporting

The reporting requirements for this section will be consistent with those applicable to the encroachment or structure type, as described in other sections of this chapter.

7.4.1.7 Plans

Show the following information in the project plans for encroachment structures:

- The magnitude, approximate probability of exceedance and, at appropriate locations, the water-surface elevations associated with the overtopping flood or the largest flood that may be reasonably estimated, such as the 500-year flood
- The magnitude and water-surface elevation of the base flood, if larger than the overtopping flood

7.4.2 SCOUR AND STREAM STABILITY

Any crossing of, or encroachment onto a natural river, stream or floodplain by a highway facility calls for an evaluation of the scour potential and the stability of the stream. This section identifies key technical references for assessment of scour and stream stability and provides some specific guidance for application to Federal Lands Highway projects.

7.4.2.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	T 5140.23	Technical Advisory T 5140.23, *Evaluating Scour at Bridges*, 1991
2.	HDS 6	FHWA HDS 6, *River Engineering for Highway Encroachments*, FHWA NHI-01-004, 2001
3.	HEC 18	FHWA HEC 18, *Evaluating Scour at Bridges*, FHWA HIF-12-003, 2012
4.	HEC 20	FHWA HEC 20, *Stream Stability at Highway Structures*, FHWA HIF-12-004, 2012
5.	HEC 23	FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*, FHWA NHI-09-111 and 112, 2009
6.	FHWA RD-86-126	FHWA Report Number RD-86-126, *Development of a Methodology for Estimating Embankment Damage Due to Flood Overtopping*, 1987
7.	NCHRP 533	NCHRP Report 533, *Handbook for Predicting Stream Meander Migration*, 2004

7.4.2.2 Standard Practices

The potential for scour and stream instability will be considered when designing highway facilities that interface with natural rivers, streams, or floodplains. Accordingly, an assessment or evaluation of the potential for scour and stream instability will be conducted at a level commensurate with the risk of damage to the facility. The design will protect the highway facility from stream instability and scour at an appropriate level, in accordance with the applicable sections of Chapter 7 for each type of drainage structure or facility.

7.4.2.3 Design Standards and Criteria

Select the design standards and criteria for stability against scour and stream instability in accordance with the applicable sections of Chapter 7, as referenced below:

- Bridge foundations, see Section 7.4.3
- Embankment stability in overtopping, see Section 7.4.3
- Longitudinal embankments, see Section 7.4.4
- Retaining walls, see Section 7.4.5
- Low water crossings, see Section 7.4.6
- Channel changes, see Section 7.4.7
- Scour and stream instability countermeasures, see Section 7.4.8

7.4.2.4 Design Guidance

7.4.2.4.1 General Approach to Stream Stability and Scour Analysis

HEC 20 describes the systematic analysis approach as having three levels, progressing from simple concepts and qualitative assessment to detailed numerical and physical modeling:

Level 1: Application of simple geomorphic concepts and other qualitative assessment methods.

Level 2: (if necessary after Level 1 assessment) Application of basic hydrologic, hydraulic, and sediment transport engineering concepts.

Level 3: (if necessary after Level 2 analysis) Application of detailed numerical or physical modeling studies.

In the majority of cases, the Level 2 analysis will provide a reliable, somewhat conservative evaluation of the potential threat from scour and stream instability. The design of the facility can then account for and protect against the threat. In such cases a Level 3 analysis is not required. Certain circumstances may justify a Level 3 study. Some examples are listed below:

- The hydraulics of the site are too complex for one-dimensional analysis and a two-dimensional model is required (see Section 7.4.3)
- The scour estimates are too conservative to be practicably accommodated in design and refined approaches are needed, such as:
  - ◊ Accounting for potential duration-limited scour

    ◊ Conducting physical modeling to represent site-specific conditions

- The scour will potentially be arrested or reduced by a scour-resistant horizon (e.g. bedrock, sandstone, shale, or stiff clay) and an assessment of the erodibility of the material is justified
- The degradation potential may be too complex for simple analysis and a sediment transport modeling study is justified

7.4.2.4.2 Scour Components

The analysis of scour potential at a bridge or other highway facility should consider several scour components, generalized as follows:

- Long-term bed elevation change
- General scour
- Contraction scour
- Local scour

Long-Term Bed Elevation Change

Aggradation and degradation are the vertical raising and lowering, respectively, of the streambed over relatively long distances and time frames. Such changes can be the result of both natural and man-induced changes in the watershed. Long-term bed change can occur in perennial streams that flow year round and in ephemeral desert arroyos. Its progression can take many forms, such as headcuts (vertical channel bed discontinuities) migrating upstream, progressive incision of a low-flow channel, or gradual lowering or raising across the streambed over time. Evaluation of the potential for long-term aggradation or degradation must consider the effects of a range of flow conditions over a long period of time, rather than focusing solely on the effect of a single event. HEC 20 provides extensive guidance on evaluating the potential for long-term bed change.

General Scour

General scour is a lowering of the channel bed elevation due to the natural downstream sediment transport capacity of a stream. Physical changes to the stream environment are not required to produce general scour. Common examples of general scour that occurs naturally are scour at the outside of a channel bend, scour at a confluence of two streams, and scour that occurs due to a change in stream gradient. For design purposes, general scour is usually evaluated on an event-specific basis, considering one or more flood conditions. Guidance on evaluating the potential for general scour is available in HDS 6, HEC 18, HEC 20, and HEC 23.

Contraction Scour

Contraction scour is a specific type of general scour that results when the flow area is constricted, for example when a bridged waterway has less flow area under the bridge than upstream. Its effects are usually localized in the vicinity of the constriction. Contraction scour is event-specific and is usually analyzed for one or more flood conditions (e.g. the stability design flood and check flood). HEC 18 provides detailed guidance on evaluating contraction scour.

Local Scour

The scour caused by, and in the immediate vicinity of an obstruction such as a bridge pier or abutment is referred to as local scour. Local scour can also be caused by other localized conditions, such as high-velocity flow impinging on a wall, sudden drops, or scour at the tip of a spur. Local scour is usually evaluated on an event-specific basis considering one or more flood conditions (e.g. the stability design flood and check flood). Local scour at bridges can be evaluated using the guidance of HEC 18. The evaluation of local scour in other contexts is aided by the guidance in HDS 6, HEC 20, and HEC 23.

7.4.2.4.3 Lateral Migration

Lateral migration of the stream channel is another potential long-term threat to highway facilities. Lateral migration can undermine bridge abutments, piers, embankments, retaining walls, and other facilities that were originally located at the top of the channel bank or set back from the channel. If lateral migration is a potential threat to a highway facility, the design should accommodate the channel migration by providing adequate foundation depth or should prevent the migration by the use of appropriate countermeasures. HEC 20 and NCHRP 533 provide guidance on evaluating and predicting meander migration. HEC 23 provides guidance on designing stream instability countermeasures.

7.4.2.4.4 Bridge Scour

Reference Elevations

Use the lowest channel bed elevation as the pier scour reference elevation for all main channel bridge piers, unless non-erodible material allows otherwise. Use the main channel hydraulic input variables and reference elevation for piers located outside but near the main channel, when the potential for channel migration exists. Use the lowest channel bed elevation as the abutment scour reference elevation for abutments located in or adjacent to the main channel, unless non-erodible material allows otherwise.

Debris at Piers

Consider the potential for debris to accumulate on the piers during a flood. If the potential is moderate to high, account for the debris by artificially increasing the pier width in the scour calculations or by some other rational approach.

Abutment Scour

If accommodating the computed local abutment scour depth in the foundation design is not practicable, consider using an abutment scour countermeasure to prevent the formation of the local scour. If a countermeasure is used, then design the abutment foundation to accommodate the sum of the estimated contraction scour and long-term degradation.

7.4.2.4.5 Incipient Motion

Chapter 5 of HEC 18 provides a critical velocity equation to determine whether the scour conditions are live-bed or clear-water. This equation is generally reliable for sand-bed channels. It is not always reliable for coarse bed material such as gravel or cobbles. To determine whether clear-water or live-bed conditions apply at a site with coarse bed material, consider developing a modified critical velocity equation using the detailed derivation data provided in Appendix C of HEC 18.

7.4.2.4.6 Sediment Transport Modeling

Sediment transport modeling (sediment routing analyses) is a Level 3 approach that is warranted only rarely. It is an appropriate approach when the Level 2 methods are producing results that are obviously too conservative. When sediment transport modeling is being considered, the context is usually a perceived threat of the long-term degradation component of total scour.

Commonly used sediment transport modeling programs include:

- BRI-STARS, available from the FHWA
- HEC-6, available from the U.S. Army Corps of Engineers

When undertaking sediment transport modeling, the engineer must take care to calibrate the model and should apply extensive engineering judgment to the interpretation and use of the results.

7.4.2.5 Recommended Methods

The methodologies described in HEC 18 and HEC 20 provide a systematic approach to evaluating scour potential and assessing stream instability and should be followed wherever practicable.

7.4.2.6 Reporting

In addition to the reporting requirements described in Section 7.1.11, the following items are required when scour evaluation, stream stability analysis, or sediment transport analysis have been performed.

- Sediment gradation curves
- Scour components investigated
- Scour equations/approach used
- Hydraulic input variable values (e.g. velocity, depth, and angle of attack) for scour calculations
- Sediment transport modeling assumptions, if applicable
- Calibration results

- Sediment sampling locations and frequencies, if sediment transport calculations were performed
- Sediment transport function used, if sediment transport calculations were performed
- Findings, conclusions, and recommendations

7.4.3 BRIDGED WATERWAYS

This section applies to the hydraulic design of waterway crossings involving bridges. For the purposes of this section, bridges are defined as structures that consist of a superstructure or deck supported by abutments, with or without piers, usually with an open bottom. This section typically does not apply to closed-bottom culverts even if their total span is greater than or equal to 20 ft [6.1 m].

7.4.3.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	23 CFR 650A	Code of Federal Regulations, Title 23, Part 650 Subpart A, *Location and Hydraulic Design of Encroachments on Flood Plains*
2.	NS 23 CFR 650A	Federal-Aid Policy Guide, Non-regulatory Supplement to Title 23 CFR 650 Subpart A, Attachment 2, *Procedures for Coordinating Highway Encroachments on Floodplains with Federal Emergency Management Agency (FEMA)*
3.	T 5140.23	Technical Advisory T 5140.23, *Evaluating Scour at Bridges*, 1991
4.	HDS 7	FHWA HDS 7, *Hydraulic Design of Safe Bridges*, 2012
5.	HEC 18	FHWA HEC 18, *Evaluating Scour at Bridges*
6.	HEC 20	FHWA HEC 20, *Stream Stability at Highway Structures*
7.	HEC 23	FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
8.	HEC-RAS	USACE HEC-RAS, *Hydraulic Reference Manual*
9.	AASHTO HDG Vol. VII	AASHTO Highway Drainage Guidelines, Volume VII – *Hydraulic Analysis for the Location and Design of Bridges*
10.	AASHTO HDG Vol. VIII	AASHTO Highway Drainage Guidelines, Volume VIII – *Hydraulic Aspects in Restoration and Upgrading of Highways*

11.	Guide to Bridge Hydraulics	Transportation Association of Canada, *Guide to Bridge Hydraulics*

7.4.3.2 Standard Practices

7.4.3.2.1 Floodplain Encroachments

If a waterway crossing constitutes a new or expanded encroachment on a base (100-year) floodplain that is regulated by FEMA or potentially creates an adverse impact to private property or insurable buildings, reference Section 7.4.1 for details on appropriate design policy, standards, and criteria, as well as guidance on FEMA coordination, if required.

7.4.3.2.2 Existing Bridges

Known Scour Problems

An appropriate scour analysis will be conducted on any existing bridge within the project limits that has known scour problems or concerns and has not had such an analysis conducted previously. This will be done regardless of the project type. The bridge owner will be informed of the results of the scour analysis and asked to update National Bridge Inventory, Item 113, accordingly.

Substantial Rehabilitation

To identify hydraulic consequences of proposed work, conduct full capacity and stability analyses on any bridge that is to be substantially rehabilitated. Substantial rehabilitation is defined as the addition or modification of a foundation element, any work that reduces the hydraulic opening of the bridge, or any work that changes the flow distribution at the crossing. Incorporate results of the analyses into the project, as necessary, to meet current standards. Scour countermeasures will be designed and installed as necessary to achieve the foundation stability design standard either before or as a part of the rehabilitation project. Existing bridge piers will be considered stable against scour if protected with a suitably designed countermeasure.

7.4.3.2.3 Scour Countermeasures

Scour countermeasures will not be used to protect or reduce scour at new bridge piers.

7.4.3.3 Design Standards

The hydraulic design of bridged waterways requires the definition of standards for capacity and foundation stability. The following standards apply to bridges on both High- and Low-Standard roadways. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

7.4.3.3.1 Capacity Design

Design Flood

Design bridges to convey the 50-year flood with appropriate freeboard. Freeboard is defined as the vertical clearance between the design-flood water surface and the low chord of the bridge. The required height of freeboard is defined in Section 7.4.3.4.

Check Flood

Use the greater of the 100-year flood or the overtopping flood as the standard check flood for water surface increase caused by the crossing.

The overtopping flood is defined as the discharge rate at which water would begin to flow over the top of the bridge deck or the approach roadways. If overtopping is not practicable then use the greatest flood that may be reasonably estimated to pass through the bridge, such as the 500-year flood.

Temporary Bridges

The capacity design standard for temporary bridges depends on the roadway classification. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

- *High-Standard Roadways:* Design temporary bridges to remain open to traffic during a 10-year flood.
- *Low-Standard Roadways:* Design temporary bridges to remain open to traffic during a 2-year flood.

7.4.3.3.2 Stability Design

Foundations

The stability design of a bridge foundation refers to its ability to withstand scour. Refer to Section 7.4.2 for guidance on evaluating scour at bridges.

- *Design Flood:* Design bridge foundations to withstand the estimated worst-case scour up through the 100-year flood.
- *Check Flood:* Use the 200-year event, as the check flood. Provide supporting documentation when using a flood magnitude less than 200-year for the check flood.
- *Scour Countermeasures:* When economically preferred, countermeasures can be used to protect bridge foundations from scour. Such countermeasures will be designed to withstand the estimated worst-case scour up through the 200-year flood. Scour countermeasures will not be used to provide foundation stability for new bridge piers.

When risk considerations, such as those described in Section 7.1.4, conclude that a flood standard other than the 50-year event should be used for capacity design; use Exhibit 7.4-A in conjunction with the selected capacity design flood standard to determine the minimum scour and scour countermeasure design standards, as applicable.

Exhibit 7.4-A CAPACITY DESIGN, SCOUR DESIGN, AND COUNTERMEASURE DESIGN STANDARDS FOR BRIDGES

Capacity Design Flood Frequency	Scour Design Flood Frequency	Scour Check Flood Frequency	Countermeasure Design Flood Frequency
Q_{10}	Q_{25}	Q_{50}	Q_{50}
Q_{25}	Q_{50}	Q_{100}	Q_{100}
Q_{50}	Q_{100}	Q_{200}	Q_{200}
Q_{100}	Q_{200}	Q_{500}	Q_{500}

Approach Embankments

Some bridged waterway crossings will be designed to allow overtopping of the approach embankments. In such cases design the embankment, with armoring if necessary, to remain stable in overtopping floods up through the 50-year event. Refer to Section 7.4.8 for guidance on the design of embankment protection measures.

Temporary Bridges

The stability design standard for temporary bridges depends on the roadway classification. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

- *High-Standard Roadways:* Design temporary bridges to remain stable in a 10-year flood.
- *Low-Standard Roadways:* Design temporary bridges to remain stable in a 2-year flood.

7.4.3.3.3 Survey and Mapping

When survey is needed to quantify hydraulic impacts, refer to Chapter 5 for standards on survey and mapping for bridged waterways.

7.4.3.4 Design Criteria

7.4.3.4.1 Capacity Design

Freeboard

- Design all bridges with a minimum freeboard of 2.0 ft [0.6 m]
- Design the bridge with 3.5 ft to 5.0 ft [1.0 m to 1.5 m] of freeboard when the potential for woody debris is significant

- Design the bridge with 5.0 ft to 10.0 ft [1.5 m to 3.0 m] of freeboard when the potential for ice flows during flood season is significant

Freeboard is defined as the vertical clearance between the design-flood water surface and the low chord of the bridge superstructure. Freeboard design provides a measure of protection to the bridge by reducing the chance of superstructure inundation and impact from floating debris.

The reference datum for measuring the freeboard is the computed water-surface elevation at the upstream face of the bridge. A bridge with a straight-grade profile will meet or exceed the freeboard criterion along its entire length. A bridge with an arched or vertical-curve profile will meet or exceed the freeboard criterion along at least half of its length.

The above freeboard criteria do not apply to temporary bridges.

7.4.3.4.2 Stability Design

Design Flood

Design bridge foundations to withstand the estimated total scour with normal geotechnical and structural safety factors. Assume that all streambed material above the total scour elevation has been removed and is not available for load bearing or lateral support.

Check Flood

Design bridge foundations to withstand the estimated total scour with geotechnical and structural safety factors of at least 1.0. Assume that all streambed material above the total scour elevation has been removed and is not available for load bearing or lateral support.

Countermeasures may be designed at abutments to prevent the formation of local scour. If a suitably designed countermeasure is used, design the abutment foundations to be stable with appropriate geotechnical and structural safety factors assuming the estimated contraction scour and any predicted degradation has occurred. Countermeasures will not be used at new bridge piers.

Refer to Section 7.4.2 for guidance on evaluating scour at bridges. Refer to Section 7.4.8 for references to standards, criteria, and guidance on the design of countermeasures.

7.4.3.5 Design Guidance

The hydraulic design of bridged waterways requires the investigation of numerous physical, operational, and regulatory elements during the data collection phase, which must then be applied, as appropriate, during project development. Examples of physical elements include geometrics (e.g. length, width, alignment, abutment type, pier type, deck profile, approach roadway profile); and hydraulic characteristics (e.g. freeboard, velocity, flow distribution, potential overtopping of approach roadways, scour potential, sediment transport, debris potential). Operational elements include inspection and maintenance requirements.

7.4.3.5.1 Bridge vs. Culvert

The typical channel or floodplain crossing will present an obvious need for either a culvert or a bridge based on the width of the channel or floodplain and the discharge to be conveyed. For some crossings it will be difficult to determine if a bridge or culvert is most suitable. Accordingly, the following general advantages of bridges and culverts are offered as guidance:

Bridges have the following advantages over culverts:

- Less susceptibility to clogging with sediment and debris
- The waterway increases with rising water surface until water begins to submerge the superstructure
- With properly designed foundations, the structure can accommodate streambed degradation
- Scour can potentially increase the bridge waterway capacity
- Bridge deck widening does not usually affect hydraulic capacity
- Substantially less fill volume may be required, especially for high-profile roadways

Culverts have the following advantages over bridges:

- Require less structural maintenance than bridges
- The capacity can sometimes be increased by installing improved inlets
- Usually easier and quicker to build than bridges
- Scour associated with the structure is localized and easier to control
- Upstream storage can be used to reduce peak discharge
- Profile-grade raises and widening projects sometimes can be accommodated by extending culvert ends

7.4.3.5.2 Bridge Rehabilitation

Most bridge rehabilitation projects cannot be cost-effectively designed to significantly improve the capacity of the bridge with regard to either freeboard or water-surface profile. Avoid to the extent practicable decreasing the freeboard or increasing the water-surface profile.

7.4.3.5.3 Approach Roadway Overtopping

It may be beneficial to design bridged waterway crossings to allow the flood to overtop the approach roadways. Allowing overtopping to occur at an elevation below the bridge low-chord often provides a high-capacity alternate flow path across the alignment, which leads to the following potential benefits:

- Reduces the probability of damaging pressure-flow and buoyancy conditions
- Reduces the peak velocity inside the bridge waterway
- Reduces the potential for scour to threaten the bridge foundations
- May preserve historic flow distributions
- May prevent excessive increase to the water-surface profile in large floods

The decision to allow overtopping of the approach roadways at a flood magnitude less than the 50-year should be supported by a risk assessment of the possible adverse consequences, which include:

- Loss of traffic serviceability during the overtopping period
- Loss of emergency vehicle access across the waterway during the overtopping period
- Possible loss of the road surface and embankment
- Potential damage to the bridge abutment by erosion of the adjacent approach embankment

If an overtopping condition is allowed, the road profile should be designed to keep the overtopping flow away from the bridge abutments.

7.4.3.5.4 Location of Bridge Abutments and Relief Openings

The bridge opening waterway should be designed so the velocity of water through the structure will not damage the highway facility or adjacent property. The acceptable velocities should be based on the characteristics of the individual site. These characteristics include the following:

- Natural stream velocities
- Bed materials
- Scour considerations (see Section 7.4.2)

Avoid placing abutments within the main channel of a natural stream or in other areas of relatively high natural flow concentration and velocity. Locate abutments and relief openings to preserve the natural flow distribution to the extent practicable Extensive guidance material can be found in the AASHTO HDG, Volume VII *Hydraulic Analysis for the Location and Design of Bridges*.

7.4.3.5.5 Pier Spacing, Shape and Orientation

Piers should be designed to minimize flow disruption and scour potential. The number of piers located in any channel should be limited to a practical minimum and piers should not be located in the main channel of small streams. Piers that are properly oriented with the flow do not significantly increase the water-surface profile. A solid pier will not collect as much debris as a pile bent or a multiple column bent. Rounding or streamlining the leading edges of piers helps to decrease the accumulation of debris and reduces local scour at the pier. Circular-shaped, single-column piers provide a benefit by eliminating the adverse effect of high attack angles.

7.4.3.5.6 Hydraulic Analysis and Modeling

The application of the standards, criteria, and guidance presented in this section requires a hydraulic analysis to determine the water-surface profile and flow distribution. It is necessary, at a minimum, to analyze a baseline (pre-project) condition and one or more proposed (post-project) conditions.

The most common and usually most appropriate approach to bridge hydraulic analysis is to compute a water-surface profile through 1-dimensional computer modeling. For guidance on applying 1-dimensional hydraulic models to bridged waterways, see the user documentation for HEC-RAS. Particularly useful is the HEC-RAS *Hydraulic Reference Manual*, Chapter 5 and Appendices B and D.

Some specific bridged waterway sites may not be suitable for 1-dimensional analysis. A key limitation in applying 1-dimensional models to bridge projects is the fact that flow contraction and expansion are often significant factors. The lateral components of velocity, which are ignored in 1-dimensional modeling, can be significant in the vicinity of the bridge. The water-surface elevation is assumed constant along a cross section in 1-dimensional modeling, when in reality the water surface can vary significantly along a cross section near the bridge, especially at skewed crossings.

Two-dimensional hydraulic models are formulated without the aforementioned limitations of 1-dimensional models. They are typically more difficult to develop and run, but can provide a far superior understanding of the hydraulics when the bridged waterway is complex.

7.4.3.6 Recommended Methods

7.4.3.6.1 One-Dimensional Computer Model

HEC-RAS is available from the U.S. Army Corps of Engineers (USACE).

7.4.3.6.2 Two-Dimensional Computer Model

FESWMS-FST2DH is available from the FHWA.

For efficient model development and post-processing, FESWMS-FST2DH should be used in conjunction with the graphical user interface SMS.

7.4.3.7 Reporting

Section 7.1.11 provides a general list of submittal requirements for hydraulic design projects. Specific deliverables for the analysis and design of bridged waterways will include at a minimum:

- Exhibit showing cross section locations and orientations
- A plot of the baseline water-surface profile compared to the proposed-condition water-surface profile resulting from the recommended design
- For the capacity design discharge: the water-surface elevation upstream of the bridge; the vertical clearance between the water surface and the lowest point on the low chord; and the percentage of the low chord length that meets the freeboard criterion
- The maximum velocity through the bridge opening for the capacity design discharge

- The predicted total scour depths and post-scour elevations at each substructure element (shown both graphically and in tabular form)
- Calculations for individual scour components
- Design calculations for any proposed scour countermeasures (i.e. riprap sizing calculations, etc.)
- Design sketches of any proposed scour countermeasures (i.e. abutment riprap, embankment protection, etc.)

7.4.3.8 Plans

Include the following information, as a minimum, in the bridge drawings:

- Location, geometry, and axis alignment of abutments
- Location, geometry, and axis alignment of piers
- Elevations of spread footing bases or pile tips for each abutment and pier
- Existing topography and grading contours in the plan drawing
- Water-surface elevation upstream of the bridge from the capacity design flood in the elevation drawing
- Waterway cross-section geometry in the elevation drawing
- Locations, dimensions, and details for any proposed scour countermeasures
- Magnitude, frequency, and water-surface elevation of overtopping flood or the check flood if overtopping is not possible
- Magnitude, frequency, and water-surface elevation for the 100-year flood if greater than the overtopping flood

7.4.4 LONGITUDINAL EMBANKMENTS

Hydraulic consideration is required when a longitudinal roadway encroachment on a 100-year floodplain is unavoidable. This section provides standards, criteria, and guidance for the hydraulic design of longitudinal embankments that encroach on base floodplains.

7.4.4.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HDS 6	FHWA HDS 6, *River Engineering for Highway Encroachments*
2.	HEC 11	FHWA HEC 11, *Design of Riprap Revetments*

3. HEC 20 FHWA HEC 20, *Stream Stability at Highway Structures*

4. HEC 23 FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*

7.4.4.2 Standard Practices

7.4.4.2.1 Floodplain Encroachments

Longitudinal floodplain encroachments on 100-year floodplains should be avoided wherever practicable. If a project requires an encroachment on a 100-year floodplain that is regulated by FEMA or potentially creates an adverse impact to private property or insurable buildings, reference Section 7.4.1 for details on appropriate design policy, standards, and criteria, as well as guidance on FEMA coordination, if required.

7.4.4.2.2 Use of Scour and Stream Instability Countermeasures

The stability standards presented in this section will usually be met by using a suitably designed countermeasure to prevent damage to the embankment. Refer to Section 7.4.8 for standards, criteria, and guidance on the design of countermeasures.

7.4.4.3 Design Standards

The standards presented here apply to longitudinal embankments, with or without retaining walls that support roadways for which the profile grade is controlled by riverine water-surface elevations.

7.4.4.3.1 Capacity Design

Design Flood

Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

- *High-Standard Roadways:* Design longitudinal embankments to provide adequate freeboard in the 50-year flood.
- *Low-Standard Roadways:* Design longitudinal embankments to provide adequate freeboard in the 25-year flood.

Freeboard is defined in Section 7.4.4.4.

Check Flood

Use the greater of the 100-year flood or the overtopping flood as the standard check flood for evaluating impacts to private property or insurable buildings. The overtopping flood is defined as the discharge rate at which water would begin to flow over the road surface.

7.4.4.3.2 Stability Design

Design Flood

Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

- *High-Standard Roadways:* Design longitudinally encroaching embankments with protection as needed to remain stable in the 50-year flood.
- *Low-Standard Roadways:* Design longitudinally encroaching embankments with protection as needed to remain stable in the 25-year flood.
- *Retaining Walls:* Refer to Section 7.4.5.

7.4.4.4 Design Criteria

The criteria presented here apply to longitudinal embankments, with or without retaining walls, that support roadways for which the profile grade is controlled by riverine water-surface elevations.

7.4.4.4.1 Capacity Design

Design longitudinal floodplain encroachments with a minimum freeboard of 2.0 ft [0.6 m]. Freeboard is defined as the vertical distance between the design water surface and the bottom of the aggregate base layer of the pavement structure.

7.4.4.4.2 Stability Design

Demonstrate that the embankment is reasonably expected to remain stable, with or without protection by countermeasures, up through the stability design flood throughout the intended service life of the embankment.

7.4.4.5 Design Guidance

7.4.4.5.1 Scour Mechanisms

Consider the following scour mechanisms in evaluating the potential scour threat to a longitudinal embankment within a 100-year floodplain:

- Long-term lateral instability in the form of channel migration
- Low-flow channel impingement, if the embankment will be located within a broad, sandy waterway that has a highly active low-flow channel meandering within it
- Bank erosion of an adjacent stream channel
- Contraction scour, if the longitudinal embankment will form a significant constriction to the waterway

- Local scour by impinging flow, if flood flows will impact the embankment at a significant angle
- Bendway scour, if the embankment will be located at the outside of a bend
- Outlet scour, if a cross drain or storm drain exits through the embankment
- Potential flanking or undermining of scour countermeasures intended to protect the embankment

7.4.4.6 Recommended Methods

Hydraulic analysis is necessary to determine the water-surface profile of the design flood for the purpose of establishing the profile grade that will provide adequate freeboard. Hydraulic analysis is also necessary to determine impacts to private property or insurable buildings. HEC-RAS modeling is an appropriate approach for most designs.

Refer to HEC 23 for approaches to estimating impinging-flow scour, bendway scour, and low-flow channel impingement scour. HEC 14 provides a method of estimating scour at cross drain and storm drain outlets.

7.4.4.7 Reporting

Section 7.1.11 provides a general list of submittal requirements for hydraulic design projects. Specific deliverables for the hydraulic analysis and design of longitudinal embankment encroachments will include at a minimum:

- A map or aerial photograph of the affected waterway reach showing the embankment location and hydraulic model cross section locations.
- A cross-section plot of the waterway showing the embankment, at the approximate point of maximum encroachment by the embankment
- A plot of the baseline water-surface profile compared to the proposed-condition water-surface profile resulting from the design alternatives
- The predicted total scour depths and post-scour elevations at intervals along the toe of the embankment
- Design calculations for any proposed embankment protection (i.e. riprap sizing calculations)
- Design sketches of any proposed embankment protection, showing longitudinal extent, required thickness of protection, and termination requirements (i.e. toe downs and end terminations)

7.4.4.8 Plans

If protection has been designed for the embankment, then the following must be included on the final design plans:

- Details and dimensions of any required protection

- Discharge rate and water-surface elevations at appropriate locations along the embankment profile for the capacity design flood and the 100-year flood

7.4.5 RETAINING WALLS

Some roadways include retaining walls to minimize fill quantities, longitudinal encroachments on adjacent floodplains or channels, and other environmental impacts. Hydraulic consideration is warranted when a proposed highway retaining wall is to be located within a 100-year floodplain, or if a cross drain or storm drain is designed to exit through a retaining wall. Scour at the retaining wall foundation must be prevented or the foundation must be designed for stability against the predicted scour. This section provides standards, criteria, and guidance for the hydraulic design and protection of retaining wall foundations.

7.4.5.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. HDS 6 — FHWA HDS 6, *River Engineering for Highway Encroachments*
2. HEC 14 — FHWA HEC 14, *Design of Energy Dissipators for Culverts and Channels*
3. HEC 20 — FHWA HEC 20, *Stream Stability at Highway Structures*
4. HEC 23 — FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*

7.4.5.2 Standard Practices

7.4.5.2.1 Floodplain Encroachment

Longitudinal floodplain encroachments on 100-year floodplains, with or without retaining walls, should be avoided wherever practicable. If a project requires an encroachment on a 100-year floodplain that is regulated by FEMA or potentially creates an adverse impact to private property or insurable buildings, reference Section 7.4.1 for details on appropriate design policy, standards, and criteria, as well as guidance on FEMA coordination, if required.

7.4.5.2.2 Use of Scour and Stream Instability Countermeasures

The stability standards presented in this section will be met by designing the retaining wall foundation to withstand the estimated scour associated with the stability design flood, or by using a suitably designed countermeasure to prevent the formation of all or a portion of the estimated scour. Refer to Section 7.4.8 for standards, criteria, and guidance on the design of countermeasures.

7.4.5.3 Design Standards

The design standards for the hydraulic design and protection of retaining wall foundations depend on the wall height and the roadway classification. Refer to the definition of High- and Low-Standard roadways in Section 7.1.6.

7.4.5.3.1 Stability Design

The hydraulic stability of a retaining wall foundation refers to its ability to withstand scour. Two different types of scour can potentially threaten a retaining wall foundation. First, flow along the wall from the channel or floodplain on which the wall is located (longitudinal flow) can cause scour potentially throughout the entire length of the wall foundation. Second, flow from cross drain or storm drain outlets penetrating the wall can cause local outlet scour. Each case has a set of stability standards presented below.

Longitudinal Flow

- *Wall Height > 6.5 ft [2 m]:* Design retaining wall foundations to withstand the estimated worst-case longitudinal scour up through the 100-year flood.
- *Wall Height 6.5 ft [2 m] or Less on High-Standard Roadways:* Design retaining wall foundations to withstand the estimated worst-case longitudinal scour up through the 50-year flood.
- *Wall Height 6.5 ft [2 m] or Less on Low-Standard Roadways:* Design retaining wall foundations to withstand the estimated worst-case longitudinal scour up through the 25-year flood.

Pipe Penetrations

Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

- *High-Standard Roadways:* Design retaining wall foundations to withstand the estimated worst-case outlet scour up through the 50-year flood.
- *Low-Standard Roadways:* Design retaining wall foundations to withstand the estimated worst-case outlet scour up through the 25-year flood.

7.4.5.4 Design Criteria

7.4.5.4.1 Stability Design

Longitudinal Flow

Design retaining wall foundations to withstand the estimated total scour (as defined in Section 7.4.2) from the stability design flood with normal structural and geotechnical safety factors. Assume that all streambed material above the total scour elevation has been removed and is not available for bearing or lateral support.

Pipe Penetrations

Design retaining wall foundations to withstand the estimated local outlet scour from the foundation-stability design flood with normal structural and geotechnical safety factors. Assume that all streambed material above the local scour elevation has been removed and is not available for bearing or lateral support.

7.4.5.5 Design Guidance

7.4.5.5.1 Scour Mechanisms

Consider the following scour mechanisms in evaluating the potential scour threat to a retaining wall segment. (See Section 7.4.2 for guidance.)

- Long-term degradation, if the wall is located within or immediately adjacent to a stream channel
- Long-term lateral instability in the form of channel migration
- Low-flow channel impingement, if the wall will be located within a broad, sandy waterway that has a highly active low-flow channel meandering within it
- Bank erosion
- Contraction scour, if the wall forms a significant constriction to the waterway
- Local scour by flow impinging on the wall, if flood flows will impact the wall at a significant angle
- Bendway scour, if the wall will be located at the outside of a bend
- Bed forms, if the wall is located within a sand-bed channel
- Outlet scour, if a cross drain or storm drain exits through the wall
- Potential flanking or undermining of scour countermeasures intended to protect the wall

7.4.5.5.2 Pipe Exit Configuration

Pipe exits from retaining walls that include drops (the invert of the exit pipe being above the toe of the wall) should be avoided whenever practicable. Such drops will be allowed, if required, as long as any additional scour potential caused by the drop is accommodated. The preferred horizontal alignment for pipes exiting a retaining wall is perpendicular to the wall.

7.4.5.6 Recommended Methods

Refer to HEC 23 for approaches to estimating impinging-flow scour, bendway scour, and low-flow channel impingement scour. HEC 14 provides a method of estimating scour at cross drain and storm drain outlets.

7.4.5.7 Reporting

Section 7.1.11 provides a general list of submittal requirements for hydraulic design projects. Specific deliverables for the hydraulic analysis and design of retaining wall encroachments will include at a minimum:

- The predicted total scour depths and post-scour elevations at intervals along the wall segment
- Design calculations for any proposed scour countermeasures (i.e. riprap sizing calculations)
- Design sketches of any proposed scour countermeasures

7.4.5.8 Plans

If scour calculations have been performed or countermeasures have been designed for the retaining wall, then the following must be included on the final design plans.

- Details and dimensions of any required scour countermeasures
- Stability design discharge with water-surface elevations at appropriate locations along the wall

7.4.6 LOW-WATER CROSSINGS

Low-water stream crossings can provide safe, cost-efficient alternatives to bridge and culvert crossings for certain low-volume roads, provided the streamflow and road-use conditions are suitable. This section provides standards, criteria, and guidance on the design of low-water crossings.

7.4.6.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	FHWA CFL-03-003	FHWA CFL-03-003, *Low Water Crossing Study*
2.	Low Volume Roads Engineering	U.S. Forest Service and U.S. Agency for International Development, *Low Volume Roads Engineering-Best Management Practices Field Guide*, 2003
3.	HDS 5	FHWA HDS 5, *Hydraulic Design of Highway Culverts*
4.	HDS 6	FHWA HDS 6, *River Engineering for Highway Encroachments*
5.	HDS 7	FHWA HDS 7, *Hydraulic Design of Safe Bridges*

6. HEC 20 FHWA HEC 20, *Stream Stability at Highway Structures*

7. HEC 23 FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*

7.4.6.2 Standard Practices

7.4.6.2.1 Allowable Uses

Low-water crossings will not be used on roadways with an ADT greater than 200, unless such crossing is a desirable, existing feature.

7.4.6.2.2 Classes and Applications

Two classes of low-water crossings are possible on Federal Lands Highway projects: vented crossings and unvented crossings. A vented crossing has a hydraulic opening beneath the road surface for low flows, while an unvented crossing has no opening beneath the road surface. The selection of the class to use for a particular project is dependent on the following:

- Vented Crossing:
  - ◊ Daily access required, AND
  - ◊ Crosses a perennial stream characterized by daily flows
- Unvented Crossing
  - ◊ Daily access not required, OR
  - ◊ Crosses an ephemeral stream with only intermittent, short-duration flows

7.4.6.2.3 Floodplain Encroachment

If a low-water crossing is in an NFIP floodplain or the potential exists for adversely impacting private property or insurable buildings, refer to Section 7.4.1 for relevant policy, standards, and criteria, as well as for guidance on FEMA coordination.

7.4.6.3 Design Standards

7.4.6.3.1 Capacity Design

<u>Vented</u>

Design vented low-water crossings to convey the 10-year flood beneath the road.

<u>Unvented</u>

Not applicable since all flow must pass over the roadway.

7.4.6.3.2 Stability Design

Design all low-water crossings to remain stable under worst-case scour conditions up through the 25-year flood.

7.4.6.4 Design Criteria

7.4.6.4.1 Capacity

Vented

No overtopping by the design flood.

Unvented

Not applicable since all flow must pass over the roadway.

7.4.6.4.2 Stability

Vented

Evaluate the foundation of any open-bottom structure for scour susceptibility according to guidance in Section 7.4.3.

Vented and Unvented

Design the crossing to remain stable under worst-case scour conditions up through the stability-design flood. Demonstrate that the embankment is expected to remain stable within the limits of protection. See Section 7.4.6.5 below for guidance on extent of embankment protection.

Design to withstand applicable scour components, e.g., drop scour, culvert outlet scour, and long-term degradation (refer to Section 7.4.2). The use of scour countermeasures is acceptable (refer to Section 7.4.8).

7.4.6.5 Design Guidance

Every low-water crossing should be posted with signs on both approaches instructing motorists to stay out of the crossing when it is flooded. The low-point of the roadway profile should be aligned with the channel thalweg.

7.4.6.5.1 Vented

Extent of Roadway / Embankment Protection

The recommended length of roadway/embankment to be protected from erosion and scour during overtopping is the water-surface width over the roadway during the stability design flood.

Hydraulic Operation

A vented low-water crossing will typically operate as a culvert for flows up to the capacity design flow and as a broad crested weir combined with a culvert for flows exceeding the capacity design flow.

Scour

If a hydraulic drop occurs from the upstream side to the downstream side of a vented crossing during overtopping, the potential exists for drop-scour on the downstream side of the embankment. Consequently, a vented low-water crossing will experience the potential for culvert-type outlet scour combined with drop-scour. The scour potential will be exacerbated if the downstream reach experiences degradation. The stability design must accommodate or prevent the formation of scour on the downstream side of the crossing.

Fish

Fish passage concerns may be a factor in the design of vented low-water crossings. Refer to Section 7.5.1 for guidance on designing crossings to prevent creating a barrier to fish passage.

7.4.6.5.2 Unvented

Extent of Roadway / Embankment Protection

The recommended length of roadway/embankment to be protected from erosion and scour during overtopping is the water-surface width over the roadway during the 2-year flood.

Maintenance

An unvented low-water crossing will typically be used in an arid or semi-arid setting and will be overtopped whenever the watershed produces runoff. The flow will often leave behind a deposit of sediment that may require clearing before reopening the road to traffic. Consider surfacing the low-water crossing with a hard surface to facilitate the quick removal of sediment deposits by heavy equipment without damage to the road.

Hydraulic Operation

An unvented low-water crossing will typically operate hydraulically as a broad-crested weir.

Scour

If a hydraulic drop occurs from the upstream side to the downstream side of an unvented crossing, the potential exists for drop-scour on the downstream side of the embankment. The scour potential will be exacerbated if the downstream reach experiences degradation. The stability design must accommodate or prevent the formation of scour on the downstream side of the crossing.

In addition to preventing or accommodating scour on the downstream side of the embankment, the road surface should be protected from erosion within the area wetted by the 2-year flood.

7.4.6.6 Recommended Methods

The U.S. Forest Service and U.S. Agency for International Development, *Low Volume Roads Engineering-Best Management Practices Field Guide* provides practical advice in developing the design of low-water crossings.

Chapter 5 of HDS 7 provides detailed guidance on the hydraulic analysis of roadway overtopping conditions. HDS 5 is an important reference in the analysis of the culvert-type flow through the openings of vented low-water crossings.

HEC 20 provides useful detailed guidance on evaluating the stability of the stream reach of interest. HEC 23 contains extensive guidance on the prediction of drop-scour and the design of countermeasures to prevent failure of the crossing from scour and stream instability.

If water-surface elevation impacts are a concern, it may be necessary to compute a water-surface profile through the affected stream reach.

7.4.6.7 Reporting

Section 7.1.11 provides a general list of submittal requirements for hydraulic design projects. Additional specific deliverables for hydraulic design of low-water crossings will include:

- The water-surface elevation upstream of the crossing for the capacity design discharge (vented crossings)
- The maximum velocity through the low-flow opening for the capacity design discharge (vented crossings)
- Calculations of applicable scour components and total scour
- Design calculations for the proposed scour countermeasures
- Design sketches of the crossing and the proposed scour countermeasures

7.4.6.8 Plans

Include the following information, as a minimum, in the drawings for the crossing:

- Locations of low-flow openings, if any
- Elevations of footings or piles if used as foundations
- Existing topography and grading contours in the plan drawing
- The water-surface elevation upstream of the crossing from the capacity design flood
- Magnitude and frequency of the capacity design flood
- Waterway cross-section geometry in the elevation drawing
- Extent of road surface protection
- Locations, dimensions, and details for the proposed scour countermeasures

7.4.7 CHANNEL CHANGES

Some projects require realignments of stream channels to avoid or to mitigate potential hydraulic problems at a highway crossing location. Properly designed channel changes can reduce the hazard of flood damage to a highway crossing by reducing skew and curvature, and sometimes by providing a larger main channel.

This section provides standards, criteria, and guidance related to the design of channel changes for those situations where they cannot be avoided. It addresses only the hydraulic aspects of channel relocation. For guidance on the environmental aspects of relocation (e.g., restoration of biological or ecological components), see Section 7.5.2.

7.4.7.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. HDS 6 — FHWA HDS 6, *River Engineering for Highway Encroachments*
2. HEC 11 — FHWA HEC 11, *Design of Riprap Revetment*
3. HEC 20 — FHWA HEC 20, *Stream Stability at Highway Structures*
4. HEC 23 — FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
5. AASHTO HDG Vol. I — AASHTO Highway Drainage Guidelines, Volume I – *Hydraulic Considerations in Highway Planning and Location*
6. AASHTO HDG Vol. VII — AASHTO Highway Drainage Guidelines, Volume VII – *Hydraulic Analysis for the Location and Design of Bridges*
7. AASHTO HDG Vol. X — AASHTO Highway Drainage Guidelines, Volume X – *Evaluating Highway Effects on Surface Water Environments*

7.4.7.2 Standard Practices

Alterations or relocations of existing stream channels will be avoided wherever practicable. Where channel changes cannot be avoided, close coordination with Environmental Office staff, resource agencies, and the partner agency will be initiated during the reconnaissance and scoping phase and continue throughout the design of the project.

The design of channel changes will consider the impacts to stream stability and to the riparian environment and will mitigate those impacts to the extent practicable.

If a channel change is proposed in a floodplain that is regulated by FEMA, or if it potentially creates an adverse impact to private property or insurable buildings, refer to Section 7.4.1 for details on appropriate design policy, standards, and criteria as well as guidance on FEMA coordination, if required.

7.4.7.3 Design Standards

7.4.7.3.1 Capacity Design

To the extent practicable, the channel change will duplicate the existing stream characteristics including:

- Stream capacity
- Width
- Depth
- Slope
- Sinuosity
- Bank cover
- Side slopes
- Flow and velocity distribution over the full range of discharges up to and including the 100-year flood

7.4.7.3.2 Stability Design

Where instability of a relocated stream channel may threaten the highway infrastructure, channel migration countermeasures will be provided. The design standard for the countermeasures depends on the classification of the roadway. Refer to the definition of High-Standard and Low-Standard roadways in Section 7.1.6.

- *High Standard:* Design channel migration countermeasures to withstand the worst conditions up through the 50-year flood.
- *Low Standard:* Design channel migration countermeasures to withstand the worst conditions up through the 25-year flood.

7.4.7.4 Design Criteria

7.4.7.4.1 Capacity Design

To minimize the potential biological and ecological impacts, avoid using prismatic channel geometries with neat grading lines wherever practicable.

7.4.7.4.2 Stability Design

Demonstrate stability in the horizontal and vertical dimensions, when required.

Bioengineering treatments for both vertical and lateral stability within the relocated reach of the channel may be used if the stability of the channel is not compromised relative to the standards and criteria presented in this section.

7.4.7.5 Design Guidance

Addressing potential impacts to the stability of the stream and to the riparian environment is a multi-disciplinary challenge involving the application of geomorphic analysis, hydraulic engineering, and stream habitat evaluation.

Geomorphic analysis is required to evaluate the range of potential responses of the stream to the proposed channel change, and to guide the design of the channel change to minimize the adverse responses. The basic types of potential response needing investigation include degradation, aggradation, or lateral instability. These responses can affect the channel upstream and downstream of the proposed channel change, as well as the relocated reach itself. An appropriate geomorphic analysis considers the initial state of the stream system and its degree of sensitivity to the channel change being considered. It makes use of established stream-response relationships as well as an understanding of geomorphic threshold conditions.

Refer to Section 7.4.2 for Standards, Criteria, and Guidance related to scour and stream instability. Refer to Section 7.4.8 for Standards, Criteria, and Guidance in the design of stream instability and countermeasures.

7.4.7.6 Recommended Methods

Chapters 4 and 6 of HEC 20, Chapter 5 of HDS 6 and Section 4 of the AASHTO Highway Drainage Guidelines, *Volume X* are good starting references for the geomorphic analysis.

The application of hydraulic engineering to channel change designs entails supplementing the geomorphic analysis with quantitative evaluations of the potential for stream instability and designing countermeasures against stream instability.

HEC 20, HEC 23, and HDS 6 contain recommended methods for hydraulic engineering applications to channel changes.

7.4.7.7 Reporting

Document through appropriate analysis, calculations, and judgment that the relocated channel, together with any associated channel stability protection measures, is reasonably expected to remain stable under worst-case conditions up to the design flood. Items to be documented include:

- Comparison of water-surface impact expected for each channel change alternative being considered
- Qualitative comparison of adverse impacts for each channel change alternative being considered

- Cross-section plots of the proposed relocated channel reach at key locations
- Design calculations for any proposed stream instability countermeasures (i.e. riprap sizing calculations, etc.)
- Design sketches of any proposed stream instability countermeasures

7.4.7.8 Plans

The project plans should include the following for any proposed channel change:

- Plan/layout drawing of the proposed channel relocation, including contour grading and showing the connection to the existing channel at the upstream and downstream ends of the channel change
- Cross section drawings at sufficient locations to allow adequate construction staking
- Details and dimensions of any proposed stream instability countermeasures

7.4.8 SCOUR AND STREAM INSTABILITY COUNTERMEASURES

This section provides standards, criteria, and guidance for designing countermeasures to protect Federal Lands Highway facilities from scour and stream instability.

7.4.8.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HDS 6	FHWA HDS 6, *River Engineering for Highway Encroachments*
2.	HEC 11	FHWA HEC 11, *Design of Riprap Revetment*
3.	HEC 14	FHWA HEC 14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*
4.	HEC 23	FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
5.	AASHTO HDG Vol. VII	AASHTO Highway Drainage Guidelines, Volume VII – *Hydraulic Analysis for the Location and Design of Bridges*
6.	AASHTO MDM Chap. 17	AASHTO Model Drainage Manual, Chapter 17 – *Bank Protection*

7.4.8.2 Standard Practices

The potential for scour and stream instability will be considered when designing highway facilities that interface with natural rivers, streams, or floodplains (see Section 7.4.2). Where it is impracticable or inappropriate to accommodate the estimated scour and stream instability in the design of the facility, countermeasures will be used to mitigate the potential for damage.

7.4.8.2.1 Bridge Piers

New piers will be designed so that they withstand the estimated total scour depth from the design flood without the need for countermeasures (see Section 7.4.3). The piers of bridges to be rehabilitated may be protected from scour by countermeasures as appropriate.

7.4.8.2.2 Floodplain Encroachments

Countermeasure installations themselves may encroach upon base floodplains and be subject to FHWA Policy 23 CFR 650A. If such an encroachment is in an NFIP mapped floodplain or if the encroachment produces potential adverse impacts to private property or insurable buildings, refer to Section 7.4.1 for related policy, standards, criteria, and guidance.

7.4.8.3 Design Standards

7.4.8.3.1 Stability Design

Scour and stream instability countermeasures will be designed to meet the appropriate stability standards for the structures they are intended to protect. Specific references to appropriate standards are provided below:

Culvert Outlets

Refer to Sections 7.3.1 and 7.4.9.

Foundations of Bridge Abutments and Existing Piers

Refer to Section 7.4.3.

Bridge Approach Embankments

Refer to Section 7.4.3.

Longitudinal Embankments

Refer to Section 7.4.4.

Protection of Retaining Wall Foundations

Refer to Section 7.4.5.

Low-Water Crossings

Refer to Section 7.4.6.

Channel Changes

Refer to Section 7.4.7.

Adjacent Streambanks

If the stream stability assessment indicates that streambank erosion or migration of a nearby channel may threaten the highway facility, install countermeasures to stabilize the channel banks. The design standards for protection of streambank countermeasures depend on the roadway classification. Refer to the definition of High- and Low-Standard roadways in Section 7.1.6.

- *High Standard:* Design the protection to withstand the worst scour conditions up through the 50-year flood.
- *Low Standard:* Design the protection to withstand the worst scour conditions up through the 25-year flood.

7.4.8.4 Design Criteria

The general design criteria for scour and stream instability countermeasures are as follows:

Demonstrate that the countermeasure is reasonably expected to remain stable and to protect the facility under worst-case conditions up through the stability design flood throughout its intended service life.

Provide appropriate termination details to prevent undermining or flanking of the countermeasure by scour and erosion processes not arrested by the countermeasure itself. A countermeasure intended to prevent local scour, for instance, must be protected from undermining by the sum of the estimated contraction scour and long-term degradation.

7.4.8.5 Design Guidance

7.4.8.5.1 Minimizing the Need for Countermeasures

Where practicable, it is usually preferable to design the facility so that countermeasures are not necessary. This can be accomplished by avoiding route locations through areas of high scour potential, or by designing the foundations of bridges and retaining walls to accommodate the estimated potential scour. Designing to avoid the need for countermeasures provides the following benefits:

- Avoids the additional cost associated with building countermeasures
- Avoids the considerable maintenance commitment usually associated with countermeasures

- Preserves the natural dynamics of the stream system
- Minimizes impacts to wetlands and riparian habitat
- Minimizes Section 404 wetlands permit requirements

7.4.8.5.2 Selection

Many different types of countermeasures, and variations of each type, have been used to protect highway facilities. At a minimum, the selection should consider:

- A verified need for the countermeasure (make sure the countermeasure is needed and that the design can't practicably be modified to avoid the need)
- The function of the countermeasure to address the need
- The compatibility of the countermeasure with the geomorphology of the stream channel
- The acceptability of any environmental impacts associated with the countermeasure, or the potential to mitigate the impacts
- The capital cost of the countermeasure
- The maintenance and inspection requirements of the countermeasure

7.4.8.5.3 Inspection and Maintenance

Most countermeasure installations for protection of highway facilities are designed with the expectation of some maintenance requirements. A typical riprap revetment, for example, needs regular inspection to verify its continuing functionality. A long-term maintenance commitment is needed to ensure the continued performance of a countermeasure through the expected service life of the highway facility.

7.4.8.6 Recommended Methods

The design of protection for structures, streambanks, and longitudinal embankments can be aided by the procedures found in several references, including:

1. HDS 6 — FHWA HDS 6, *River Engineering for Highway Encroachments*
2. HEC 11 — FHWA HEC 11, *Design of Riprap Revetment*
3. HEC 14 — FHWA HEC 14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*
4. HEC 23 — FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
5. AASHTO MDM Chap. 17 — AASHTO Model Drainage Manual, Chapter 17 – *Bank Protection*

6. Caltrans Chap. 870		California Department of Transportation Highway Design Manual, Chapter 870 – *Channel and Shore Protection-Erosion Control*
7. EM 1110-2-1601		U.S. Army Corps of Engineers EM 1110-2-1601, *Hydraulic Design of Flood Control Channels*, 1994.
8. Denver USDCM		Denver Urban Drainage and Flood Control District, *Urban Storm Drainage Criteria Manual*, Volume 2 (particularly useful for the design of grade control structures)

7.4.8.7 Reporting

The reporting requirements listed below should be integrated with those for the specific types of facilities that the countermeasures are designed to protect. The reporting items listed below are the minimum expected for countermeasure design.

- Description of need and countermeasure alternatives considered
- Description of selection criteria
- Documentation demonstrating the suitability and stability of the proposed countermeasure design, including calculations
- Design sketches of the proposed scour countermeasures

7.4.8.8 Plans

Include the following information, as a minimum, in the project drawings:

- Locations, dimensions, and details of any proposed scour and stream instability countermeasures

7.4.9 ENERGY DISSIPATORS

Local scour at culvert, storm drain, and channel outlets is a common occurrence. The natural runoff is usually confined to a lesser width and greater depth as it passes through a conveyance system. An increased velocity results with potentially erosive capabilities at the conveyance outlet. Turbulence and erosive eddies form also as the flow expands to conform to the natural channel. In addition to the hydraulic characteristics of the flow at the outlet, the erosive characteristics of the outlet channel bed and bank material, and the amount of sediment and other debris in the flow are contributing factors to scour potential.

Where the local scour potential exceeds the protective capabilities of standard outlet treatments, an energy dissipator design is typically required. The focus of this section is on the special design requirements for energy dissipators.

7.4.9.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HEC 14	FHWA HEC 14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*
2.	AASHTO HDG Vol. IV	AASHTO Highway Drainage Guidelines, Volume IV – *Hydraulic Design of Culverts*

7.4.9.2 Design Standard

Evaluate the performance of energy dissipators (i.e. velocity reduction) over a range of discharges. The range of discharges will include the lowest discharge for which scour is a concern to the design of the applicable conveyance system. Select the dissipator that provides acceptable performance over this range of discharges.

7.4.9.3 Design Criteria

Discharge outflow to the downstream channel at velocities that are compatible with the erosion characteristics of the outlet channel bed and bank material. If the outlet channel is stable, the natural channel velocities would be an appropriate dissipation target. If the outlet channel is unstable, the concern becomes a stream stability problem that may or may not include local energy dissipation as a solution. Refer to Section 7.4.2 for guidance on evaluating stream stability.

7.4.9.4 Design Guidance

There are many situations where standard riprap outlet structures are impractical even at low to moderate flow conditions. Energy dissipators can be designed easily and are suitable for a wide variety of site conditions. In some cases, concrete structures are more economical than large riprap basins, particularly where long-term costs are considered. Also, preformed scour holes (approximating the configuration of naturally formed holes) can dissipate energy while providing a protective lining to the streambed. Various types of energy dissipation structures are identified in HEC 14.

7.4.9.5 Recommended Methods

Design and evaluate the performance of energy dissipators according to the methods presented in HEC 14. HEC 14 also contains procedures for estimating scour hole dimensions at pipe outlets.

7.4.9.6 Reporting

The design of the energy dissipators for culvert, pipe, or channel outlets should be supported by documentation containing, at a minimum, the following information:

- Project identification
- Location of proposed installation
- Hydraulic design calculations

7.4.9.7 Plans

For the location and design of energy dissipators, prepare plans showing all details necessary to construct the improvements according to the hydraulic and structural design, including the following:

- Location
- Structural Details
- Dimensions and extent of auxiliary channel riprap
- Gradation of required riprap
- Bedding and Filter Material or Geotextile
- Grading or slope details

7.5 ENVIRONMENTAL HYDRAULICS

The topics included in this section on environmental hydraulics all require interdisciplinary design or analysis. Early and frequent coordination with the local Federal Lands Environmental Office, resource agencies, regulatory agencies, and the partner agency is often required. The role of the hydraulics engineer will vary from analysis and design to support, such as that required for permit application and acquisition, and review of deliverables from specialty contractors, as requested.

7.5.1 AQUATIC ORGANISM PASSAGE

The necessity to protect aquatic organism (e.g. fish) life and provide for their passage can affect many decisions regarding bridge, culvert, channel change, riprap design, and construction requirements. Because of their relatively small size, the ability of culverts to accommodate migrating aquatic organisms is an important design consideration. Consult state and local fish and wildlife resource agencies early in the roadway planning process when aquatic organism passage issues are anticipated. For existing culverts that obstruct aquatic organism passage, modifications can be used to improve passage criteria. Aquatic organism passage will be accommodated when need is verified by project scoping studies.

7.5.1.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	23 CFR 650A	Code of Federal Regulations, Title 23, Part 650 Subpart A, *Location and Hydraulic Design of Encroachments on Flood Plains*
2.	HDS 5	FHWA HDS 5, *Hydraulic Design of Highway Culverts*
3.	HEC 26	FHWA HEC 26, *Culvert Design for Aquatic Organism Passage*, FHWA HIF-11-008, October 2010.
4.	AASHTO MDM Chap. 9	AASHTO Model Drainage Manual, Chapter 9 – *Culverts*
5.	AASHTO HDG Vol. IV	AASHTO Highway Drainage Guidelines, Volume IV – *Hydraulic Design of Culverts*

7.5.1.2 Design Standards and Criteria

Roadway crossing structures needed to accommodate aquatic organism passage will comply with the applicable standards and criteria of this chapter. The selected design will be reasonable in terms of satisfying social, environmental, and economic constraints.

7.5.1.3 Design Guidance

7.5.1.3.1 Culverts

Because aquatic organism passage needs are particularly acute and frequent at culvert locations, many fish and wildlife agencies have established design standards and criteria for their passage through culverts. Design considerations include discharge, maximum allowable velocity, minimum water depth, substrate characteristics, maximum culvert length and gradient, type of structure, and construction scheduling. Final designs should consider these standards and criteria as well as those of this chapter.

New vs. Retrofit

The design of new or replacement culverts that must provide aquatic organism passage should seek to replicate the natural stream hydraulics and processes, such as sediment transport characteristics, over a range of discharges up to and including the roadway design flood. The design should concentrate low flows to provide adequate passage depth and provide high-flow velocities that are comparable to those in the natural channel upstream and downstream of the crossing.

For highway rehabilitation or restoration projects, where an existing culvert has been identified as an aquatic organism passage barrier, the engineer should consider alternatives for retrofitting the existing structure to meet passage requirements. It is possible that the addition of baffles inside the culvert, weirs downstream of the culvert, or other treatments can meet the criteria for local aquatic organism passage and design storm conveyance.

Oversized or Depressed Culverts

To improve aquatic organism passage success, culverts typically require a natural alluvial bottom. To provide this, the designer may use an oversized culvert, with the invert buried below the channel invert elevations and a portion of the culvert bottom filled with alluvial material. When conditions allow, this is the preferred method for providing a natural bottom. Consult HEC 26 for specific design guidance.

Open-Bottom Culverts

Open-bottom culverts, either concrete or metal, are sometimes designed for aquatic organism passage, environmental, aesthetics or economic reasons. These structures typically have a natural bottom and must be supported on both sides by a scour-resistant foundation. Because of the likelihood of local scour, evaluate and design the foundations using bridge criteria, unless they can be founded on bedrock. Refer to Sections 7.4.2 and 7.4.3 for information on foundation design in areas where scour is a potential.

Culverts with Baffles

Many baffle configurations have been shown to decrease the velocity or increase water depth through the culvert. Baffles may be used for making existing culverts aquatic organism passable in retrofit situations. The addition of baffles may cause culverts to flow in outlet control at relatively low discharge rates. Neglecting the culvert area occupied by the baffles may not adequately account for the energy losses from turbulence generated by the baffles.

Downstream Weirs

Weirs may also be useful in retrofit applications. They are typically constructed downstream of the culvert to increase tailwater and increase flow depths through the culvert. Weirs must be designed for stability during high flows and also provide for aquatic organism passage. This may require means for aquatic organisms to bypass the weir.

Special Treatment

In wide, shallow streams where sediment deposition is not a concern, one barrel of a multiple barrel culvert installation can be depressed slightly to concentrate low-flows, thus improving aquatic organism passage.

7.5.1.3.2 Bridges (reserved)

7.5.1.4 Recommended Methods

Analyze, design, and evaluate culverts for aquatic organism passage according to the methods and procedures presented in HEC 26, *Culvert Design for Aquatic Organism Passage*.

Use local or regional guidance, methods, or procedures, as available and applicable. Examples include:

- Federal resources agency procedures (e.g., USFS, USFWS, NMFS)
- State DOT Memorandums of Agreement with resource agencies (e.g., Alaska, Maine)
- State procedures (e.g., California, Oregon)

7.5.2 STREAM RESTORATION AND REHABILITATION

7.5.2.1 Standard Practice

Stream restoration/rehabilitation is a highly interdisciplinary task requiring close coordination with the Environmental Office, resource agencies, and the partner agency. This task may be undertaken as part of needed channel relocation work or as an independent environmental mitigation or habitat enhancement effort. The role of hydraulics is to provide:

- Appropriate protection for the roadway
- Compatibility with geomorphic and biological factors at the site
- Cost-effective design

For detailed guidance on the stability aspects of stream restoration or rehabilitation work, reference Sections 7.4.2, 7.4.7, and 7.4.8.

7.5.2.2 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	23 CFR 650A	Code of Federal Regulations, Title 23, Part 650 Subpart A, *Location and Hydraulic Design of Encroachments on Flood Plains*
2.	HDS 6	FHWA HDS 6, *River Engineering for Highway Encroachments*
3.	HEC 20	FHWA HEC 20, *Stream Stability at Highway Structures*
4.	HEC 23	FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
5.	AASHTO MDM Chap. 15	AASHTO Model Drainage Manual, Chapter 15 – *Surface Water Environment*
6.	AASHTO HDG Vol. X	AASHTO Highway Drainage Guidelines, Volume X – *Evaluating Highway Effects on Surface Water Environments*
7.	Stream Corridor Restoration	Federal Interagency Stream Restoration Working Group, *Stream Corridor Restoration: Principles, Processes, and Practices*

7.5.2.3 Design Standards and Criteria

The design standards and criteria applied to stream restoration and rehabilitation design will comply with the applicable standards and criteria of this chapter. The selected design will be reasonable in terms of satisfying social, environmental, and economic constraints.

7.5.2.3.1 Plan Form and Geometry

Replicate the historical plan form and channel geometries, if known. Where historical geometries are unknown, use the appropriate dominant discharge (2- to 10-year discharge) and regime theory to establish appropriate plan form and channel geometries.

7.5.2.3.2 Stability Checks

Conduct stability checks of plan form and channel geometry over a range of discharges up to and including the 50-year flood.

7.5.2.4 Design Guidance

In the process of restoration and rehabilitation of streams and aquatic habitat, the goal is not a static, immovable channel. Rather, the goal is to restore the stream to a reasonably stable, naturalistic system that exhibits a state of dynamic equilibrium.

7.5.2.5 Recommended Methods

Design and evaluate the hydraulic engineering aspects of stream restoration and rehabilitation according to the methods and procedures presented in Chapter 7 of HEC 20, HEC 23, and the Federal Interagency Stream Restoration Working Group, *Stream Corridor Restoration Principles, Processes, and Practices.*

7.5.3 WETLANDS

7.5.3.1 Standard Practice

Road construction and roadway operation can have numerous impacts on wetland chemistry, biology, surface hydrology, and groundwater hydrology. Wetland design and analysis is a highly interdisciplinary task requiring close coordination with the Environmental Office, resource agencies, and the partner agency. The primary role of the hydraulics engineer is for support and review of deliverables from specialty contractors, as requested.

7.5.3.2 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HDS 2	FHWA HDS 2, *Highway Hydrology*
2.	23 CFR 771	23 CFR 771, *Environmental Impact and Related Procedures*
3.	23 CFR 777	23 CFR 777, *Mitigation of Environmental Impacts to Privately Owned Wetlands*
4.	AASHTO MDM Chap. 15	AASHTO Model Drainage Manual, Chapter 15 – *Surface Water Environment*

5. AASHTO HDG Vol. X — AASHTO Highway Drainage Guidelines, Volume X – *Evaluating Highway Effects on Surface Water Environments*

7.5.3.3 Design Standards and Criteria

The design standards and criteria applied to wetland design will comply with the applicable standards and criteria of this chapter. The selected design will be reasonable in terms of satisfying social, environmental, and economic constraints.

7.5.3.4 Design Guidance

The design of wetlands should be performed by specialists. The primary role of the hydraulics engineer is for support and review as requested.

7.5.4 STORMWATER MANAGEMENT

7.5.4.1 Standard Practice

Where required by federal, state, or local storm water management policies, standards, and criteria, both permanent and temporary storm water controls will be incorporated into Federal Lands Highway projects. Controls on both water quantity and quality are typical. Best Management Practices (BMPs) that reduce storm water runoff during construction and prevent erosion at the inlets and outlets of conveyance features should be designed and incorporated into the project Storm Water Pollution Prevention Plan (SWPPP).

7.5.4.2 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. HEC 22 — FHWA HEC 22, *Urban Drainage Design Manual*
2. AASHTO MDM Chap. 12 — AASHTO Model Drainage Manual, Chapter 12 – *Storage Facilities*
3. AASHTO HDG Vol. IX — AASHTO Highway Drainage Guidelines, Volume IX – *Guidelines for Storm Drain Systems*
4. NPDES Regulations
5. State and Local Stormwater Management Manuals

6. FHWA PD-96-032 — FHWA PD-96-032, *Evaluation and Management of Highway Runoff Water Quality*

7. FHWA EP-00-002 — FHWA EP-00-002, *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring*

7.5.4.3 Design Standards and Criteria

Conduct project-specific hydrologic/hydraulic analyses, and design necessary facilities to support compliance with federal, state, and local stormwater management requirements, standards, and criteria.

The design standards and criteria applied to stormwater management design will comply with the applicable standards and criteria of this chapter. The selected design will be reasonable in terms of satisfying social, environmental, and economic constraints.

7.5.4.4 Recommended Methods

Federal, state, and local requirements often govern the design of stormwater management facilities. Where applicable, those design methods should be used and supplemented with the analysis and design methods recommended in this chapter.

Methods specific to storage routing analysis and outlet structure design for retention/detention basins are provided in Chapter 8 of HEC 22.

7.6 COASTAL HYDRAULICS

7.6.1 GENERAL

Tidal waterways and coastal shorelines present special challenges to the design of highway facilities. This section provides references, standards, criteria, and guidance specific to the design of highway facilities in coastal areas.

Certain elements of analysis and design in coastal areas require technical knowledge specific to the field of coastal engineering. The design of critical facilities in coastal areas, therefore, will usually require attention from a qualified coastal engineer.

7.6.1.1 Tide Levels and Wave Heights

The hydrology and hydraulics of coastal shorelines and tidal waterways are dominated by factors that are typically nonexistent or of little consequence in inland streams. The most significant factors distinguishing tidal waters from inland streams are the effects of the tides and wind-generated waves. Tidal water elevations and wave heights are, therefore, the two key elements of coastal hydraulic analysis that define design water surface elevations. Hydraulic design of roadway facilities along coastlines or crossing tidal waterways will consider the effects of tidal water elevations and their cyclical fluctuations, along with storm surges and wave heights, as appropriate. Refer to FHWA HEC 25, *Highways in the Coastal Environment*, for definitions of terminology specific to tidal waterways and coastal areas.

7.6.1.2 Vertical Datum Reconciliation

Published tide heights are usually referenced to the Mean Lower Low Water (MLLW). The relationship between MLLW and any fixed vertical datum such as the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29, often simply termed Mean Sea Level) varies widely depending on location along the coast. Resources are available that quantify the relationship between MLLW and NAVD 88, which can then be converted for NGVD 29. Chapter 6 of HEC 25 explains how to find and use these resources.

7.6.2 HYDROLOGY

Hydrologic analysis for projects along shorelines or crossing tidal waterways primarily involves the prediction of tidal water elevations and wave heights (i.e., design water surfaces). These predictions may be required for normal conditions unaffected by storms, for conditions resulting from severe storms or both. The appropriate recurrence interval or level of severity to be analyzed will depend upon the design standards presented later in this section.

7.6.2.1 References

The following references provided source information for the development of the guidance of this subsection (most recent editions apply):

1.	HEC 25	FHWA HEC 25, *Highways in the Coastal Environment*, FHWA NHI-07-096, 2008
2.	EM 1110-2-1100	U.S. Army Corps of Engineers EM 1110-2-1100, *Coastal Engineering Manual*

7.6.2.2 Standard Practices

7.6.2.2.1 Roadway Facilities Along Shorelines

The hydrologic analysis of a project along a shoreline of an ocean or bay will predict the following elements for astronomic and storm events of appropriate severity:

- Peak tidal elevations
- Wind-generated wave heights

7.6.2.2.2 Roadway Facilities Crossing Inlets, Tidal Channels and Bays

The hydrologic analysis of a project crossing an inlet, other tidally dominated channel, or bay, will predict the following elements for astronomic and storm events of appropriate severity:

- Water-level hydrograph at the project location resulting from combined astronomic tides and storm-surge conditions
- Discharge hydrograph at the project location resulting from combined astronomic tides and storm-surge conditions
- Wind-generated wave heights

7.6.2.2.3 Roadway Facilities Crossing Estuaries

The hydrologic analysis of a project crossing an estuary (a tidally affected reach at the mouth of a river or stream) will predict the following elements for astronomic and storm events of appropriate severity:

- Peak discharge rates for riverine floods along with approximate riverine flood duration and time-to-peak estimate
- Water-level hydrograph at the project location resulting from combined astronomic tides and storm-surge conditions
- Discharge hydrograph at the project location resulting from combined astronomic tides and storm-surge conditions
- Wind-generated wave heights

The hydrologic analysis of estuaries requires an investigation of the probability of a severe flood coinciding with an extreme astronomic tide or storm-surge condition.

7.6.2.3 Design Guidance

The hydrologic determinations called for above require analysis methods that are usually not relevant to inland rivers and streams. Essentially the design processes involve:

- Estimating the magnitude and timing of the ocean's rise and fall for the event or condition of interest
- Estimating the discharge hydrograph or the peak discharge rate at the location of interest in response to the tidal rise and fall
- If appropriate, combining the tidal discharge information with the riverine flow
- Estimating the water-surface elevation associated with the peak discharge
- Developing an appropriate design wave height prediction, usually a function of the wind speed, the fetch, and the depth of the waterway

7.6.2.4 Recommended Methods

The processes described above can be achieved by simple or complex analysis methods, depending on project needs. Chapters 2 through 4 of HEC 25 describe various available methods and their appropriate application.

A common approach for developing wave height predictions is to assume a hurricane-force wind and use the U.S. Army Corps of Engineers EM 1110-2-1100, *Coastal Engineering Manual* to determine the "significant wave height."

7.6.2.5 Reporting

Section 7.6.2.2 describes the hydrologic elements that are to be predicted depending on the project situation. Those elements must be reported and must be supported by appropriate documentation, which will include, at a minimum:

- Data and data sources
- Reference for methods used
- Assumptions
- Conclusions
- Recommendations

7.6.3 FLOODPLAIN ENCROACHMENTS

The National Flood Insurance Program has designated special flood hazard areas for coastal shorelines and tidal waterways. As with inland floodplains, coastal flood hazard areas are delineated for base flood (100-year) conditions. Consequently, the requirements of Section 7.4.1 also apply to projects encroaching on FEMA regulated coastal floodplains. The impacts of roadway projects encroaching on coastal floodplains are typically less critical than on riverine floodplains. Unlike riverine floodplains, the base flood elevations of coastal floodplains other than estuaries are not typically affected by roadway encroachments. The flood elevations of non-estuary coastal floodplains are set by the effects of astronomic tides, storm surges, and waves, which are not sensitive to the presence of roadway encroachments.

7.6.3.1 References

The following references provided source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. 23 CFR 650A — Code of Federal Regulations, Title 23, Part 650 Subpart A, *Location and Hydraulic Design of Encroachments on Flood Plains*

2. NS 23 CFR 650A — Federal-Aid Policy Guide, Non-regulatory Supplement to Title 23 CFR 650 Subpart A, Attachment 2, *Procedures for Coordinating Highway Encroachments on Floodplains with Federal Emergency Management Agency (FEMA)*

3. FEMA Appendix D — FEMA Guidelines and Specifications for Floodplain Mapping Partners – Appendix D, *Guidance for Coastal Flooding Analyses and Mapping*

7.6.3.2 Standard Practices

Refer to Section 7.4.1.2.

7.6.3.3 Design Standards

Refer to Section 7.4.1.3.

7.6.3.4 Design Criteria

Refer to Section 7.4.1.4. Note that encroachments on coastal floodplains other than estuaries rarely cause any rise to the base flood elevations.

7.6.3.5 Design Guidance

Because coastal flood levels are driven by tides, storm surges, and waves, they are typically not affected by highway encroachments. Water-surface-elevation impact studies are usually not required, therefore, for projects encroaching on the floodplains of shorelines, bays, or inlets. Projects encroaching on estuary floodplains may cause an adverse impact, depending on the importance of riverine flooding compared to coastal flooding at the location of interest. Refer to

Section 7.4.1.5 for more comprehensive guidance on the design of floodplain encroachments and coordination with floodplain administration officials (FEMA, state, and local).

7.6.3.6 Reporting

Refer to Section 7.4.1.6.

7.6.3.7 Plans

Refer to Section 7.4.1.7. The magnitude (discharge rate) of the flood will not be applicable except in the case of estuaries.

7.6.4 SCOUR AND STREAM STABILITY

Scour and stream instability present potential threats to highway facilities in coastal areas, just as in the riverine context. This section provides standards, criteria, and guidance related to scour and stream instability specifically in coastal areas.

7.6.4.1 References

The following references provided source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	T 5140.23	Technical Advisory T 5140.23, *Evaluating Scour at Bridges*, 1991
2.	HDS 6	FHWA HDS 6, *River Engineering for Highway Encroachments*
3.	HEC 18	FHWA HEC 18, *Evaluating Scour at Bridges*
4.	HEC 20	FHWA HEC 20, *Stream Stability at Highway Structures*
5.	HEC 23	FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
6.	HEC 25	FHWA HEC 25, *Highways in the Coastal Environment*
7.	FHWA RD-86-126	FHWA Report Number RD-86-126, *Development of a Methodology for Estimating Embankment Damage Due to Flood Overtopping*
8.	AASHTO HDG Vol. XI	AASHTO Highway Drainage Guidelines, *Volume XI – Highways Along Coastal Zones and Lakeshores*
9.	EM 1110-2-1100	U.S. Army Corps of Engineers EM 1110-2-1100, *Coastal Engineering Manual*

7.6.4.2 Standard Practices

The potential for scour and stream instability will be considered when designing highway facilities that interface with shorelines and tidal waterways. Accordingly, an assessment or evaluation of the potential for scour and stream instability will be conducted at a level commensurate with the risk of damage to the facility. The design will protect the highway facility from stream instability and scour at an appropriate level, in accordance with the applicable sections of Chapter 7 for each type of drainage structure or facility.

7.6.4.3 Design Standards and Criteria

Select the design standards and criteria for stability against scour and stream instability in accordance with the applicable sections referenced below:

- Bridge foundations, see Section 7.6.5
- Roadway embankments, see Section 7.6.6
- Scour and stream instability countermeasures, see Section 7.6.7

7.6.4.4 Design Guidance

Refer to Section 7.4.2.4 and consider additional guidance related specifically to scour and stream instability in coastal areas.

Even though the standards and criteria associated with scour and stream instability are often the same for inland-area and coastal-area projects, the processes causing scour can be quite different.

7.6.4.4.1 Wave Attack Considerations

Wave attack can cause scour at facilities located along shorelines. Embankment side slopes, for instance, can be destroyed by waves through impact, run-up, or rebound, unless protected.

7.6.4.4.2 Causes of Degradation

Degradation in an inlet is usually caused by a sediment imbalance in the tidal flows through the inlet. The degradational trend can be initiated by construction of coastal protection works that stop or impede the littoral drift of sediment from reaching the inlet, or by another nearby inlet to the same bay becoming closed.

7.6.4.4.3 Flow Reversal

Since the flow reverses directions in a tidal waterway the contraction scour and local scour potential often must be determined for flow in both directions, and the worst case used for design.

7.6.4.4.4 Short Duration of High Discharge and Velocity

If the scour potential is being estimated for a short-duration event, such as a hurricane storm surge condition, consider the possibility that the scour-causing flows will not last long enough to develop the full equilibrium scour potential. Contraction-scour calculations can be modified to account for the time-rate of scour (see HEC 25, Chapter 5).

7.6.4.4.5 Riverine vs. Tidal Scour Conditions

For bridges that could be subject to scour from both extreme riverine floods and extreme tidal storm events, it may be necessary to analyze the scour for both conditions and design for the worst case.

7.6.4.5 Recommended Methods

HEC 25 provides a description of Level 1, Level 2, and Level 3 analysis approaches for tidal waterways. It also gives detailed guidance analyzing tide levels, hydraulics, and scour potential in tidal waterways.

For estimates of wave scour, refer to the U.S. Army Corps of Engineers EM 1110-2-1100. This manual provides guidance on wave height prediction as a function of wind speed, wind duration, the fetch of the water body, and the water depth within the fetch.

7.6.4.6 Reporting

Refer to Section 7.4.2.6.

7.6.5 BRIDGED WATERWAYS

This section provides standards, criteria, and guidance specific to bridges over tidal waterways.

7.6.5.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. 23 CFR 650A — Code of Federal Regulations, Title 23, Part 650 Subpart A, *Location and Hydraulic Design of Encroachments on Flood Plains*
2. T 5140.23 — Technical Advisory T 5140.23, *Evaluating Scour at Bridges*, 1991
3. HEC 18 — FHWA HEC 18, *Evaluating Scour at Bridges*

4.	HEC 20	FHWA HEC 20, *Stream Stability at Highway Structures*
5.	HEC 23	FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
6.	HEC 25	FHWA HEC 25, *Highways in the Coastal Environment*
7.	HEC-RAS	USACE HEC-RAS, *Hydraulic Reference Manual*
8.	AASHTO HDG Vol. VII	AASHTO Highway Drainage Guidelines, Volume VII – *Hydraulic Analysis for the Location and Design of Bridges*
9.	AASHTO HDG Vol. VIII	AASHTO Highway Drainage Guidelines, Volume VIII – *Hydraulic Aspects in Restoration and Upgrading of Highways*
10.	AASHTO HDG Vol. XI	AASHTO Highway Drainage Guidelines, Volume XI – *Highways Along Coastal Zones and Lakeshores*

7.6.5.2 Standard Practices

7.6.5.2.1 Floodplain Encroachments

New or expanded encroachments on 100-year coastal floodplains should be avoided wherever practicable. If a project requires an encroachment on a 100-year coastal floodplain that is regulated by FEMA or potentially creates an adverse impact to private property or insurable buildings along estuaries, reference Sections 7.6.3 and 7.4.1 for appropriate design policy, standards, and criteria, as well as guidance on FEMA coordination, if required.

7.6.5.3 Design Standards

The following standards apply to bridges on both High- and Low-Standard roadways. Refer to the definitions of High- and Low-Standard roadways in Section 7.1.6.

7.6.5.3.1 Capacity Design

Design bridges to provide the appropriate freeboard above the 50-year storm-tide elevation plus the 50-year wave height.

Temporary Bridges

- *High-Standard Roadways:* Design temporary bridges to remain open to traffic while experiencing the highest astronomic tide plus the 10-year wave height.
- *Low-Standard Roadways:* Design temporary bridges to remain open to traffic while experiencing the highest astronomic tide plus the 2-year wave height.

7.6.5.3.2 Stability Design

The stability design of a bridge foundation refers to its ability to withstand scour.

Design Flood

Use the worst-case scour-producing event up through the 100-year event as the design flood. See HEC 25 for an expanded description of the stability design event.

Check Flood

Use a more severe storm, on the order of a 500-year event, as the check flood. Provide supporting documentation when using an event frequency other than 500-year for the check flood.

Temporary Bridges

- *High-Standard Roadways:* Design temporary bridges to remain stable while experiencing the highest astronomic tide and the 10-year wave height.
- L*ow-Standard Roadways:* Design temporary bridges to remain stable while experiencing the highest astronomic tide and the 2-year wave height.

7.6.5.4 Design Criteria

Refer to Section 7.4.3.4. Those criteria apply here, with the following modification to the capacity design criteria:

The reference datum for measuring freeboard is the design storm tide elevation plus the design wave height at the bridge location, on whichever side of the bridge this reference elevation is highest.

7.6.5.5 Design Guidance

Refer to Section 7.4.3.5 for general guidance related to bridge design.

7.6.5.6 Recommended Methods

HEC 25 provides recommended methods for hydraulic and scour analysis of bridges over tidal waterways.

7.6.5.7 Reporting

Section 7.1.11 provides a general list of submittal requirements for hydraulic design projects. Specific additional deliverables for the analysis and design of bridged tidal waterways will include at a minimum:

- For the capacity design event: the water-surface elevation at the bridge; the vertical clearance between the design water surface (storm tide elevation plus wave height) and the lowest point on the low chord; and the percentage of the low chord length that meets the freeboard criterion
- The maximum discharge through the bridge opening for the foundation stability design event
- The maximum velocity through the bridge opening for the foundation stability design event
- The predicted total scour depths and post-scour elevations at each substructure element (shown both graphically and in tabular form)
- Calculations for individual scour components
- Design calculations for any proposed scour countermeasures (i.e. riprap sizing calculations, etc.)
- Design sketches of any proposed scour countermeasures (i.e. abutment riprap, embankment protection, etc.)

7.6.5.8 Plans

Include the following information, as a minimum, in the bridge drawings:

- Location, geometry, and axis alignment of abutments
- Location, geometry, and axis alignment of piers
- Elevations of spread footing bases or pile tips for each abutment and pier
- Existing topography and grading contours in the plan drawing
- The capacity-design water-surface elevation (storm tide elevation plus wave height) in the elevation drawing
- Waterway cross-section geometry in the elevation drawing
- Locations, dimensions, and details for any proposed scour countermeasures
- Magnitude, frequency, and water-surface elevation of overtopping flood or the check flood if overtopping is not possible
- Magnitude, frequency, and water-surface elevation for the 100-year flood if greater than the overtopping flood

7.6.6 ROADWAY EMBANKMENTS

This section provides standards, criteria, and guidance related to the design of roadway embankments parallel and adjacent to coastal shorelines.

7.6.6.1 References

The following references provided source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1.	HDS 6	FHWA HDS 6, *River Engineering for Highway Encroachments*
2.	HEC 11	FHWA HEC 11, *Design of Riprap Revetment*
3.	HEC 20	FHWA HEC 20, *Stream Stability at Highway Structures*
4.	HEC 23	FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
5.	HEC 25	FHWA HEC 25, *Highways in the Coastal Environment*
6.	AASHTO HDG Vol. XI	AASHTO Highway Drainage Guidelines, Volume XI – *Highways Along Coastal Zones and Lakeshores*
7.	EM 1110-2-1100	U.S. Army Corps of Engineers EM 1110-2-1100, *Coastal Engineering Manual*

7.6.6.2 Standard Practices

7.6.6.2.1 Floodplain Encroachments

Roadway encroachments on 100-year coastal floodplains should be avoided wherever practicable. If a project requires an encroachment on a 100-year coastal floodplain that is regulated by FEMA or potentially creates an adverse impact to private property or insurable buildings along estuaries, reference Sections 7.6.3 and 7.4.1 for appropriate design policy, standards, and criteria, as well as guidance on FEMA coordination, if required.

7.6.6.2.2 Use of Scour and Stream Instability Countermeasures

The stability standards presented in this section will usually be met by using a suitably designed countermeasure to prevent damage to the embankment. Refer to Sections 7.6.7 and 7.4.8 for standards, criteria, and guidance on the design of countermeasures.

7.6.6.3 Design Standards

The standards presented here apply to coastal roadway embankments, with or without retaining walls, for which the profile grade is controlled by tidal water levels and wave heights. Refer to the definition of High- and Low-Standard roadways in Section 7.1.6.

7.6.6.3.1 Capacity Design

- *High-Standard Roadways:* Design coastal roadway embankments to provide adequate freeboard above the 50-year storm-tide elevation plus the 50-year wave height. Freeboard is defined in Section 7.6.6.4.
- *Low-Standard Roadways:* Design coastal roadway embankments with the profile grade above the highest astronomic tide plus the 25-year wave height.

7.6.6.3.2 Stability Design

- *High-Standard Roadways:* Design coastal roadway embankments with protection as needed to remain stable against the 50-year storm surge and 50-year wave attack.
- *Low-Standard Roadways:* Design coastal roadway embankments with protection as needed to remain stable against the 25-year wave attack.

7.6.6.4 Design Criteria

The criteria presented here apply to coastal roadway embankments, with or without retaining walls, for which the profile grade is controlled by tidal water levels and wave heights.

7.6.6.4.1 Capacity Design

- *High-Standard Roadways:* Design coastal roadway embankments with a minimum freeboard of 2.0 ft [0.6 m]. Freeboard is defined as the vertical distance between the design water surface and the bottom of the aggregate base layer of the pavement structure.
- *Low-Standard Roadways:* No freeboard required since overtopping is a desired and cost-effective mechanism for providing hydraulic relief.

7.6.6.4.2 Stability Design

Demonstrate that the embankment is reasonably expected to remain stable, with or without protection by countermeasures, up through the stability design standard throughout the intended service life of the embankment.

7.6.6.5 Design Guidance

Prominent concerns in the design of coastal highway embankments are:

- Preventing an unacceptable frequency of service interruption by high water (e.g. storm surges) and waves
- Protecting the roadway embankment from destruction by wave attack up through the stability design event.
- Protecting the roadway embankment from scour by adjacent parallel or impinging currents.

It is necessary, therefore, to determine the peak storm tide elevation, the expected significant wave height and the peak velocity of any adjacent parallel or impinging current associated with the design recurrence interval. In some cases it may be necessary to analyze numerous types of events to develop the design parameters. In some locations, for instance, the highest storm tide with a 50-year recurrence interval may be generated by an extratropical storm, such as a Nor'easter, while the 50-year currents and waves may come from a hurricane.

The appropriate level of study to determine the design wave height depends upon several factors, including: the location of the facility; the orientation of the water body with respect to the facility; the straight-line length of the fetch along the anticipated wind direction; the depth of water along the fetch; and the anticipated speed and duration of sustained winds.

7.6.6.6 Recommended Methods

HEC 25 gives detailed guidance for analyzing tide levels, hydraulics, and scour potential in tidal waterways.

U.S. Army Corps of Engineers Manual EM 1110-2-1100 provides guidance on wave height prediction. The methods in EM 1110-2-1100 should generally be used in locations that are not subject to attack from large waves. Examples of appropriate locations include small bays or channels protected by barrier islands, and inland reaches of estuaries. At locations subject to attack by large waves, such as the open ocean coastline, the wave height determination should employ more extensive coastal engineering approaches, including numerical wave modeling.

7.6.6.7 Reporting

Section 7.1.11 provides a general list of submittal requirements for hydraulic design projects. Specific additional deliverables for the analysis and design of coastal roadway embankments will include at a minimum:

- A map or aerial photograph of the affected coastal area showing the embankment location
- If a detailed tidal hydraulic analysis was developed, a map showing the model limits, boundary condition locations, and cross section locations
- A profile drawing showing the design storm tide level and wave height along the embankment
- The predicted total scour depths and post-scour elevations at intervals along the toe of the embankment
- Design calculations for any proposed embankment protection (i.e. riprap sizing calculations)
- Design sketches of any proposed embankment protection, showing longitudinal extent, required thickness of protection, and termination requirements (i.e. toe downs and end terminations)

7.6.6.8 Plans

If protection has been designed for the embankment, then the following must be included on the final design plans:

- Details and dimensions of any required protection
- A profile drawing showing the design storm tide level and wave height along the embankment

7.6.7 SCOUR AND STREAM INSTABILITY COUNTERMEASURES

This section provides standards, criteria, and guidance for the design of countermeasures in coastal areas.

7.6.7.1 References

The following references provide source information for the development of the standards, criteria, and guidance of this subsection (most recent editions apply):

1. HDS 6 — FHWA HDS 6, *River Engineering for Highway Encroachments*
2. HEC 11 — FHWA HEC 11, *Design of Riprap Revetment*
3. HEC 23 — FHWA HEC 23, *Bridge Scour and Stream Instability Countermeasures*
4. HEC 25 — FHWA HEC 25, *Highways in the Coastal Environment*
5. AASHTO HDG Vol. VII — AASHTO Highway Drainage Guidelines, Volume VII – *Hydraulic Analysis for the Location and Design of Bridges*
6. AASHTO HDG Vol. XI — AASHTO Highway Drainage Guidelines, Volume XI – *Highways Along Coastal Zones and Lakeshores*
7. AASHTO MDM Chap. 17 — AASHTO Model Drainage Manual, Chapter 17 – *Bank Protection*
8. Caltrans Chap. 870 — California Department of Transportation Highway Design Manual, Chapter 870 – *Channel and Shore Protection-Erosion Control*
9. EM 1110-2-1100 — U.S. Army Corps of Engineers EM 1110-2-1100, *Coastal Engineering Manual*

7.6.7.2 Standard Practices

The potential for scour and stream instability will be considered when designing highway facilities that interface with shorelines and tidal waterways (see Section 7.6.4). Where it is impracticable or inappropriate to accommodate the estimated scour or stream instability in the design of the facility, countermeasures will be used to mitigate the potential for damage.

7.6.7.2.1 Bridge Piers

New piers will be designed so that they withstand the estimated total scour depth from the design flood or event without the need for countermeasures (see Section 7.4.3). The piers of bridges to be rehabilitated may be protected from scour by countermeasures as appropriate.

7.6.7.3 Design Standards

7.6.7.3.1 Stability Design

Scour and stream instability countermeasures will be designed to meet the appropriate stability standards for the structures they are intended to protect. Specific references to appropriate standards are provided below:

Foundations of Bridge Abutments and Existing Piers

Refer to Section 7.6.5.

Roadway Embankments

Refer to Section 7.6.6.

7.6.7.4 Design Criteria

Refer to Section 7.4.8.4.

7.6.7.5 Design Guidance

Refer to Section 7.4.8.5 and consider additional guidance related specifically to the design of scour and stream instability countermeasures in coastal areas.

7.6.7.5.1 Wave Attack

When designing countermeasure installations in coastal environments that will be subject to wave attack, consider the potential for the countermeasure to be destroyed or compromised by wave attack. The riprap size required to resist wave attack is often larger than that required to withstand the computed current velocity.

7.6.7.5.2 Filter Requirements

Designing riprap countermeasures in tidal waterways can be particularly challenging with respect to filtering, because of the very fine bed sediments that often exist in tidal waterways. The problem is compounded by the relentless pumping action cause by wave impacts. Unless the design adequately prevents the migration of fine sediment through the revetment section, the countermeasure may settle or unravel, thus becoming ineffective. Take special care to provide an adequate filter based on site-specific bed sediment characteristics.

7.6.7.6 Recommended Methods

HEC 25 and the U.S. Army Corps of Engineers' EM 1110-2-1100 provide methods and procedures for determining wave heights and designing countermeasures to withstand wave attack.

7.6.7.7 Reporting

Refer to Section 7.4.8.7.

7.6.7.8 Plans

Refer to Section 7.4.8.8.

Chapter 8 – SAFETY AND TRAFFIC DESIGN

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CHAPTER 8

SAFETY AND TRAFFIC DESIGN

8.1 GENERAL

The purpose of this chapter is to provide guidance for evaluating and developing highway safety alternatives to be incorporated into roadway and structural designs. This includes providing for the safe accommodation of traffic through construction work zones. The safety guidelines of any highway facility are primarily a reflection of the attitude of the administration responsible for the facility and the priority placed on the use of available funds. While the overall objective is maximum highway safety, environmental and economical restraints may prohibit achieving this goal. The designer must, therefore, ensure that the design provides the maximum safety enhancements for each dollar spent.

Agreements have been negotiated with most of the Federal agencies with significant public road mileage, and they have active programs to meet the applicable guidelines. These interagency agreements are described in Chapter 2. The FLH Divisions provide technical guidance to many of these agencies in the design and construction of their roads. In addition, they work to ensure that objectives of the *Highway Safety Guidelines* are accomplished.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

8.1.1 SAFETY PHILOSOPHY

In support of the national goals set forth within the US Department of Transportation and the Federal Highway Administration, FLH is equally committed to reducing the number of deaths and serious injuries and improving the overall safety of transportation on Federal and Indian lands. Building on FLH's strong history in leading context sensitive engineering solutions, FLH will continue to evaluate individual projects and their appropriate functional classification to balance the FHWA transportation and safety mission with the land management and resource protection mission of the Federal Lands Managing Agencies (FLMAs). Appropriate safety applications are to be incorporated while respecting the resource impacts, historic and cultural values of the associated facility. This is to be achieved through a collaborative and cooperative effort between the FLH and the FLMAs. This includes:

- Collection and reporting of accurate and timely crash data,
- Implementation of Safety Management Systems and principles,
- Early consideration of safety in all highway programs and projects,
- The identification and investigation of impacted hazardous locations and features and establishing countermeasures and priorities to address the identified or potential hazards,
- Incorporating appropriate safety improvements in all FLH projects, and

- Systematic upgrading of roadside features and elements will be designed to meet current nationally accepted standards for crashworthiness.

It is FLH's conviction that the respective statutory missions of FLH and partner agencies relating to enhancing safety are compatible. The FLH Vision is ''Creating the best transportation system in balance with the values of Federal and Tribal lands.'' This requires a unique effort to build a harmonic blend of the transportation access and environmental and resource protection elements of the respective agency missions. FLH is confident that its efforts in providing partnership, dedicated to addressing public safety concerns and historic and cultural issues, compliment the unique setting of the projects. The overall goal is to work cooperatively to integrate safety as a basic business principle in all activities jointly undertaken by the FLH and FLMAs.

Also refer to Section 9.1.5 for additional information on the FLH highway design philosophy and Context Sensitive Solutions.

8.1.2 SAFETY DESIGN POLICY

New construction and reconstruction involves the application of appropriate policies, standards, and criteria in the design and construction of the facility as described in Section 4.4. The application of those guidelines virtually ensures a reasonable level of geometrics and safety. Even with their use, however, operational or roadside safety problems may still exist that will not be identified unless a safety analysis is performed.

The design policy applicable for RRR projects is the same as for new construction and reconstruction, unless a separate FHWA approved State or local RRR design policy is applicable to the project. However, because of the limited scope of RRR projects, reconstruction to meet full standards may not be possible and is generally not intended. When this occurs, the designer must identify the substandard features and analyze their potential effect on highway safety. The analysis and proposed mitigation are to be documented as discussed in Section 9.1.3.

8.1.3 ROADWAY SAFETY

A crash is seldom the result of a single cause. Typically, several influences affect the situation at any given time. These influences can be separated into three elements:

- The human,
- The vehicle, and
- The environment.

The environmental element includes the roadway and its surroundings. The designer can only control roadway elements and must make a judicious selection of the roadway geometrics, drainage, surface type and other related items to lessen the potential for crashes and/or reduce the severity should they occur. The ideal design applies appropriate guidelines over a section of roadway.

The designer should avoid discontinuities in the highway environment. Some examples include:

- Abrupt changes in design speeds;
- Short transitions in roadway cross section;
- Short radius curves in a series of longer radius curves or at the end of a long tangent;
- Changes from full to partial access control;
- Roadway width constrictions (e.g., narrow bridges, other structures);
- Intersections and pullouts with inadequate sight distances;
- Hidden sag vertical curves and inadequate sight distance at crest vertical curves; and/or
- Other inconsistencies in the roadway design.

Standardizing highway design features and traffic control devices reduces driver confusion and makes the task of driving easier. Through the use of these standard features, the driver learns what conditions to expect on a certain type of highway. The goal, if possible, is to design a highway so that a driver needs to make only one decision at a time. Multiple decisions confuse and distract a driver.

8.1.4 ROADSIDE SAFETY

When a vehicle leaves the roadway, any object in or near its path may become a contributing factor to the severity of the crash. The basic concept of a forgiving roadside is that of providing a clear recovery area where an errant vehicle can be redirected back to the roadway, stop safely or slow enough to mitigate the effects of the crash.

Consult the AASHTO *A Policy on Geometric Design of Highways and Streets* (*Green Book*) and the AASHTO *Roadside Design Guide* for guidance on appropriate clear recovery areas.

The designer must evaluate these requirements in conjunction with environmental, contextual and economic constraints to determine the acceptable clear zone for the traffic, speed and terrain of the project.

Potentially hazardous features located within the identified clear zone should be treated with one of the following options, which are listed in order of preference:

1. Remove the hazard.
2. Redesign the hazard so it can be traversed safely.
3. Relocate the hazard to a point where it is less likely to be struck, preferably outside the clear zone.
4. When a potential hazard remains in the clear zone, reduce the impact severity by using an appropriate breakaway device.
5. If the feature is potentially more hazardous than a barrier system that could shield it, consider installing a barrier system, a crash cushion or both.

6. If it is not feasible or practical to shield the hazard, delineate it.

8.2 GUIDANCE AND REFERENCES

The publications listed in this section provided much of the fundamental source information used in the development of this chapter. While this list is not all-inclusive, the publications listed will provide a designer with additional information to supplement this manual:

1.	RDG	*Roadside Design Guide*, AASHTO, Current Edition.
2.	MUTCD	*Manual on Uniform Traffic Control Devices for Streets and Highways*, FHWA, Current Edition, with approved revisions.
3.	SHS	*Standard Highway Signs*, FHWA, Current Edition.
4.	Traffic Engineering Handbook	*Traffic Engineering Handbook*, Institute of Transportation Engineers, Current Edition.
5.	Traffic Control Devices Handbook	*Traffic Control Devices Handbook*, Institute of Transportation Engineers, Current Edition.
6.	HCM	*Highway Capacity Manual*, Transportation Research Board, Current Edition.
7.	AASHTO SR-3	*Highway Safety Design and Operations Guide*, AASHTO, 1997.
8.	FHWA SA-93-001	*Roadway Delineation Practices Handbook*, Report No. FHWA SA-93-001, 1994.
9.	NPS UniGuide Standards	*UniGuide Standards Manual*, US Department of the Interior, National Park Service, June 2002.
10.	Forest Service Sign Manual	*Signs and Poster Guidelines for the Forest Service*, USDA Forest Service, EM-7100-15.
11.	Special Report 214	*Designing Safer Roads*, Special Report 214, Transportation Research Board, 1987.
12.	Safety Effectiveness of Highway Design Features	Safety Effectiveness of Highway Design Features, Vol. I: *Access Control* (FHWA-RD-91-044), Vol. II: *Alignment* (FHWA-RD-91-045), Vol. III: *Cross-Sections* (FHWA-RD-91-046) Vol. IV: *Interchanges* (FHWA-RD-91-047) Vol. V: *Intersections* (FHWA-RD-91-048) Vol. VI: *Pedestrians and Bicyclists* (FHWA-RD-91-049) Federal Highway Administration, Washington, D.C., 1992.
13.	NCHRP 350	*Recommended Procedures for the Safety Performance Evaluation of Highway Features*, NCHRP Report No. 350, National Cooperative Highway Research Program, 1993.

14.	Roadside Hardware	Roadside Hardware web site, FHWA Office of Safety
15.	FHWA SA-90-017	*A Users' Guide to Positive Guidance*, Report No. FHWA SA-90-017, September 1990.
16.	FHWA-SA-07-010	*Railroad-Highway Grade Crossing Handbook*, Report No. FHWA-SA-07-010, FWHA, Revised 2nd edition, March 2008.
17.	NCHRP Report 148	*Roadside Safety Improvement Programs on Freeways — A Cost Effectiveness Approach*, Glennon, J.C., NCHRP 148, 1974.
18.	AASHTO GL-6	*Roadway Lighting Design Guide,* AASHTO, 2005.
19.	FLH Barrier Guide	*Barrier Guide for Low Volume and Low Speed Roads*, FLH, 2005
20.	AASHTO Green Book	*A Policy on Geometric Design of Highways and Streets*, AASHTO, current ed.
21.	FP-XX	*Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects*, FHWA, current ed.

8.3 INVESTIGATION PROCESS

The investigation process begins with the initial consideration and priority given to candidate projects for safety improvements. FLH Program projects involve the preservation or improvement of the facility and the enhancement of roadway safety.

The majority of FLH projects involve existing roadways. On existing highways, historical information relating to the highway's operation or safety should be analyzed. State DOT's generally have operational and safety records for the Federal system. Respective agencies frequently have data for routes on their systems. Unfortunately, on off-system county roads, the available data may be scarce. This is often due to the low-volume rural nature of the facility. As a result, many crashes on these facilities go unreported. Information retrieval systems may also be less developed for these roads. Good sources of information are law enforcement officials, local maintenance personnel, property owners, local businesses, mail carriers, school bus companies, etc. A drive through of the project, with a keen eye towards operational or safety problems, or potential problems, will often detect areas requiring special attention during design.

8.3.1 CRASH DATA

Many State highway agencies maintain computerized crash files. They can provide statistics regarding statewide rates for fatal, injury and property damage crashes as well as rates on specific routes. By comparing statistical trends in a given area of the State, the designer may detect clues to the basic causes or problems that should be addressed during design. For example, if a proposed FLH Program project were located in a portion of a State that has a higher than normal run-off-the-road crash rate, further analysis of the types of crashes (e.g., skidding) may be warranted.

The designer should review available crash reports to determine if any engineering features may have contributed to the problem. Law enforcement agencies can usually provide available crash reports. In the case of the National Park Service (NPS), each park maintains its own crash reports and in a central Service-wide Traffic Crash Reporting System (STARS). Forest highway crash data can be obtained through Forest Rangers and sometimes even through State crash data systems. Contact the Highway Safety Engineer for more information on crash data sources.

8.3.2 TRAFFIC SAFETY STUDIES

Traffic safety studies, when available, provide excellent references for evaluating safety and operational characteristics. The NPS has had traffic safety studies performed in many of their larger parks. The States or other agencies may also have such information available on their systems. While the content and form of traffic safety studies vary widely, they usually include an introduction that describes the goals and purpose of the study and defines the study area and project specifics.

8.4 SAFETY ANALYSIS

The extent of appropriate safety enhancements on all projects can be determined by performing a safety analysis. A safety analysis consists of analyzing potentially hazardous features and locations; both the project's crash history and the list of potentially hazardous locations and features should be used during the project development process. At a minimum, review this information on each project where a design exception is requested. The project files should contain documentation of the safety analysis performed and any improvements or mitigations taken to enhance safety.

8.4.1 CRASH ANALYSIS

The amount of data available for analysis will vary from project-to-project as well as the level of detail and accuracy of the data. Therefore, the designer must determine on a case-by-case basis whether the data furnished for safety analysis purposes is satisfactory.

In some cases, the circumstances may indicate the need to evaluate crash reconstruction. This involves drawing inferences concerning the interactions of speed, position on the road, driver reaction, comprehension and obedience to traffic control devices and evasive tactics. Crash reconstruction uses basic engineering knowledge of vehicle motion analysis, force analysis and mechanical energy.

8.4.1.1 Crash History

The crash history for the project should be developed and analyzed to determine possible causes and to select appropriate safety enhancements. Where practical, crashes should be summarized by location, type, severity, contributing circumstances, environmental conditions and time period. This will help identify high accident locations (HAL) and may indicate some spot safety deficiencies.

Depending on how crash information is filed, it may be necessary to record the information first and then group all crashes occurring at specific locations. This serves to identify HALs. Analysis of the types of crashes can suggest appropriate corrective action. The use of computer spread sheet programs will enhance the ability to evaluate this data.

Limited crash data are common on rural two-lane highways with low to moderate traffic volumes. Data generated from a small sampling can be misleading because they can be significantly influenced by small variances. The limited amount of this type of data often makes traditional methods of analysis difficult.

Crash or fatality rates are calculated by a formula consisting of the number of crashes or fatalities, the time over which the crashes or fatalities occurred, the traffic volume, and the length of the segment. Crash rates are traditionally shown in crashes per million vehicle miles [kilometers] traveled (VMT [VkmT]), while fatality rates are shown in fatals per hundred million vehicle miles [kilometers] traveled.

The equation for calculating a crash rate is shown below.

$$\text{Crash Rate} = \frac{\text{Crashes in Period}}{\text{Exposure in Same Period}} = \frac{\text{Crash Frequency}}{\text{Exposure per Unit of Time}}$$

Exposure is usually based on traffic volume; which explains why the crash rate for a road may have many values depending on the analyzed segment (and its associated traffic volume). Rates from different roads or segments should be compared under similar traffic volume conditions for a more accurate comparison.

In addition to crash data analysis, a Road Safety Audit may be a more appropriate tool to use because it relies on an examination of an existing facility as well as reviewing crash data collected in the past. The procedure for performing this audit is described in Section 8.4.6, Roadway Safety Audits.

Special consideration should be given to analyzing crash data on RRR projects. To more fully understand the safety issues, analysis of RRR projects may often require the following special efforts:

- A study of individual crash reports including those just beyond the project termini,
- A review to relate crash data with field conditions, and
- Interviews with maintenance and/or police personnel. These interviews may reveal areas where operational problems or minor crashes occur, but are not documented.

Crash analysis study procedures involve determining the significance of the crash history and developing summaries of the crash characteristics. The project's crash rates and summaries are used to detect abnormal crash trends or patterns and to distinguish between correctable and non-correctable crashes. Analyses of these summaries are used to identify possible safety deficiencies of the existing facility.

When summarizing crash data for analysis purposes, adhere to the following criteria:

1. **Time Period.** Select a time period for the collection of the crash data (e.g., five years). The time period chosen should contain reasonably current information on traffic volumes, pavement condition and other site-related data. Past changes in the character of the facility (e.g., physical changes, roadside development) are accounted for when evaluating the crash activity.
2. **Direction of Traffic.** Examine crash data with respect to the direction the vehicles were traveling.
3. **Location.** Examine crash data with respect to location. Crashes occurring within an intersection area should be separated from those occurring outside the area of influence of the intersection. In addition, similar crash types occurring in differing situations should be recorded separately. For example, left-turn crashes into a driveway should not be

included with left-turn crashes at an intersection. Collision diagrams may be useful in the analysis.

4. **Project Termini.** Examine the number of crashes and the crash rates within the project termini. A comparison of this data with statewide norms for similar facilities should provide a reasonable indication of the relative safety of the existing roadway.

5. **Compare Crash Statistics.** Summarize the crash data and compare it to typical statistics on similar facilities. A specific crash type categorizes patterns. The identification of crash-type patterns may be used to suggest possible causes. Consider the severity patterns to determine if particular roadway or roadside features have contributed to the overall severity of the crashes that have occurred.

6. **Contributing Circumstances.** Summarize the contributing circumstances portion of the crash report. This identifies possible crash causes noted by the investigating police officer. Contributing circumstances are categorized by:

   - Human (driver) factors,
   - Vehicle related factors, and
   - Environmental factors.

   The contributing circumstances information is used to verify, add or delete possible causes developed by the crash summary by type procedure.

7. **Correctable Versus Non-Correctable Crashes**. The contributing circumstance data can be used to separate correctable and non-correctable crashes. In separating the crashes by these classifications, careful consideration should be made to ensure that the crashes are indeed non-correctable. Exhibit 8.4–A lists the contributing circumstances found on most crash reports and indicates if they are generally correctable or non-correctable through highway improvements.

8. **Environmental Conditions**. Summarize crashes by environmental conditions. This procedure identifies possible causes of safety deficiencies related to the existing condition of the roadway environment at the time of the crash. Typical classifications used in the analysis include lighting condition (i.e., daylight, dusk, dawn, dark) and roadway surface condition (i.e., dry, wet, snowy, icy, unknown). These summaries are compared to average or expected values for similar locations or areas to determine whether the occurrence of a specific environmental characteristic is greater or less than the expected value at the location.

8.4.1.2 Probable Causes and Safety Enhancement

Probable crash causes need to be defined once the crash patterns are identified. On-site or photolog reviews of field conditions of crash sites are used to reduce the list of possible causes identified on the crash history to the most probable causes. The probable causes identified can then be used as a basis for selecting appropriate safety enhancements to alleviate the safety deficiency. Exhibit 8.4–B is a listing of probable crash causes and possible safety enhancements. This list is not all-inclusive; however, it does provide a general list of possible crash causes as a function of crash patterns and appropriate safety enhancements.

Exhibit 8.4–A CONTRIBUTING CIRCUMSTANCES

Driver-Related	
Unsafe speed	Sick
Failed to yield right-of way	Fell asleep
Following too close	Lost consciousness
Improper passing	Driver inattention
Disregard traffic controls	Distraction
Turning improperly	Physical disability
Alcohol involvement	Drug involvement
Vehicle-Related	
Brakes defective	Tow hitch defective
Headlights defective	Overload or improper loaded
Other lighting defects	Oversize load on vehicle
Steering failure	Tire failure/inadequate
Environment-Related	
Animal on roadway	Holes/deep ruts/bump
Glare	Road under construction/maintenance
View obstructed/limited	Improperly marked vehicle(s)
Debris in roadway	Fixed objects
Improper/nonworking traffic controls	Slippery surface
Shoulders defective	Water ponding
Roadside hazards	

8.4.2 EXISTING SITE CONDITIONS ANALYSIS

Hazardous locations or features on existing roadways may or may not be HALs. Many locations with narrow bridges, slippery pavement, rigid roadside obstacles or other potentially hazardous conditions have crash potential but may not yet have a crash history. Therefore, it is important to identify potentially hazardous locations or features in the development of projects. When crash history is not available, a project listing of potentially hazardous features and locations may be used to determine the need for safety enhancements.

Exhibit 8.4–B GENERAL CRASH PATTERNS

Crash Pattern	Probable Cause	Safety Enhancement
Run-off roadway	Slippery pavement	Improve skid resistance Provide adequate drainage Groove existing pavement
	Roadway design inadequate for traffic conditions	Widen lane/shoulders Relocate islands Provide proper superelevation Install/improve traffic barriers Improve alignment/grade Flatten slopes/ditches Provide escape ramp
	Poor delineation	Improve/install pavement markings Install roadside delineators Install advance warning signs
	Poor visibility	Improve roadway lighting Increase sign size
	Inadequate shoulder	Upgrade roadway shoulder
	Poor or confusing channelization	Improve channelization
Bridges	Alignment	Realign bridge/roadway Install advance warning signs Improve delineation/markings
	Narrow roadway	Widen structure Improve delineation/markings Install signing/signals
	Visibility	Remove obstruction Install advance warning signs Improve delineation and markings
	Vertical clearance	Rebuild structure/adjust roadway grade Install advance warning signs Improve delineation and markings Provide height restriction/warning
	Slippery surface (wet/icy)	Resurface deck Improve skid resistance Provide adequate drainage Provide special signing
	Rough surface	Resurface deck Rehabilitate joints Regrade approaches

Exhibit 8.4–B GENERAL CRASH PATTERNS
(Continued)

Crash Pattern	Probable Cause	Safety Enhancement
Bridges (cont.)	Inadequate barrier system	Upgrade bridge rail Upgrade approach rail/terminals Upgrade bridge - approach rail connections Remove hazardous curb Improve delineation and markings
Overturn	Roadside features	Flatten slopes and ditches Relocate drainage facilities Extend culverts Provide traversable culvert end treatments Install/improve traffic barriers
	Inadequate shoulder	Widen shoulder Upgrade shoulder surface Remove curbing/obstructions
	Pavement feature	Eliminate edge drop-off Improve superelevation/crown
Parked vehicles	Inadequate road design	Widen shoulders
Fixed object	Obstructions in or too close to roadway	Remove/relocate obstacles Make drainage headwalls flush with side slope Install breakaway features to light poles, signposts, etc. Protect objects with guardrail Delineation/reflectorized safety hardware
	Inadequate lighting	Improve roadway lighting
	Inadequate pavement markings, signs, delineators, and guardrail	Install reflectorized pavement lines/raised markers Install reflectorized paint and/or reflectors on the obstruction Add special signing Upgrade barrier system
	Inadequate road design	Improve alignment/grade Provide proper superelevation Install warning signs/delineators Provide wider lanes
	Slippery surface	Improve skid resistance Provide adequate drainage Groove existing pavement

Exhibit 8.4–B GENERAL CRASH PATTERNS
(Continued)

Crash Pattern	Probable Cause	Safety Enhancement
Sideswipe or head-on	Inadequate road design	Provide wider lanes Improve alignment/grade Provide passing lanes Provide roadside delineators Sign and mark unsafe passing areas
	Inadequate shoulders	Improve shoulders
	Excessive vehicle speed	Install median devices
	Inadequate pavement markings	Install/improve centerline, lane lines and edge lines Install reflectorized markers
	Inadequate channelization	Install acceleration and deceleration lanes Improve/install channelization Provide turning bays
	Inadequate signing	Provide advance direction and warning signs Add illuminated signs
Access-related	Left-turning vehicles	Install median devices Install-two-way left-turn lanes
	Improperly located driveway	Move driveway to side street Install curbing to define driveway locations Consolidate adjacent driveways
	Right-turning vehicles	Provide right-turn lanes Increase width of driveways Widen through lanes Increase curb radii
	Large volume of through traffic	Move driveway to side street Construct a local service road
	Large volume of driveway traffic	Signalize driveway Provide acceleration and deceleration lanes Channelize driveway
	Restricted sight distance	Remove obstructions
	Inadequate lighting	Improve street lighting

Exhibit 8.4–B GENERAL CRASH PATTERNS
(Continued)

Crash Pattern	Probable Cause	Safety Enhancement
Intersection (signalized/ unsignalized) left turn, head-on, right angle, rear end	Large volume of left/right turns	Widen road Channelize intersection Install STOP signs Provide signal Increase curb radii
	Restricted sight distance	Remove sight obstruction Provide adequate channelization Provide left/right-turn lanes Install warning signs Install STOP signs Install signal Install advance markings to supplement signs Install STOP bars
	Slippery surface	Improve skid resistance Provide adequate drainage Groove pavement
	Large numbers of turning vehicles	Provide left- or right-turn lanes Increase curb radii Install signal
	Inadequate lighting	Improve roadway lighting
	Lack of adequate gaps	Provide signal Provide STOP signs
	Crossing pedestrians	Install/improve signing or marking of pedestrians crosswalks Install signal
	Large total intersection volume	Install signal Add traffic lane
	Excessive speed on approaches	Install rumble strips in travel lane
	Inadequate traffic control devices	Upgrade traffic control devices
	Poor visibility of signals	Install/improve advance warning signs Install overhead signals Install 12 in [300 mm] LED signal lenses Install visors/back plates Relocate signals Remove sight obstructions Add illuminated/retroreflectorized signs

Exhibit 8.4–B GENERAL CRASH PATTERNS
(Continued)

Crash Pattern	Probable Cause	Safety Enhancement
Intersection (cont.)	Unwarranted signals	Remove signals
	Inadequate signal timing	Upgrade signal system timing/phasing
Nighttime	Poor visibility or lighting	Install/improve street lighting Install/improve delineation/markings Install/improve warning signs
	Poor sign quality	Upgrade signing Provide illuminated/retroreflectorized signs
	Inadequate channelization or delineation	Install pavement markings Improve channelization/delineation
Wet pavement	Slippery pavement	Improve skid resistance Groove existing pavement
	Inadequate drainage	Provide adequate drainage
	Inadequate pavement markings	Install raised/reflectorized pavement markings
Pedestrian/bicycle	Limited sight distance	Remove sight obstructions Install/improve pedestrian crossing signs and markings
	Inadequate protection	Add pedestrian refuge islands
	Inadequate signals/signs	Install/upgrade signals/signs
	Mid-block crossings	Install warning signs/markings
	Inadequate pavement markings	Supplement markings with signing Upgrade pavement markings
	Lack of crossing opportunity	Install traffic/pedestrian signals Install pedestrian crosswalk and signs
	Inadequate lighting	Improve lighting
	Excessive vehicle speed	Install proper warning signs
	Pedestrians/bicycles on roadway	Install sidewalks Install bike lanes/path Eliminate roadside obstructions Install curb ramps
	Long distance to nearest crosswalk	Install pedestrian crosswalk If warranted, install pedestrian actuated signals

Exhibit 8.4–B GENERAL CRASH PATTERNS
(Continued)

Crash Pattern	Probable Cause	Safety Enhancement
Railroad crossings	Restricted sight distance	Remove sight obstructions Reduce grade Install active warning devices Install advance warning signs
	Poor visibility	Improve roadway lighting Increase size of signs Install advance markings to supplement signs
	Inadequate pavement markings	Install STOP bars Install/improve pavement markings
	Rough crossing surface	Improve crossing surface
	Sharp crossing angle	Rebuild crossing with proper angle or offset

8.4.2.1 Potential Roadside Hazards Review

Conduct a site investigation of the roadway project. Document all potential roadside hazards that are outwardly visible, and include those documented in previous reports that still exist in the field. Exhibit 8.4–C presents an example of a roadside hazard review.

Document not only those elements that appear to be a potential hazard, but identify all of the site elements that point to past problems or items that required maintenance. Some examples include:

- Locations of skid and tire marks, indicating where abrupt turns or stops were required;
- Damaged guardrail sections;
- Recently replaced signs, poles and barriers (indicating that something may have struck the previous feature);
- Dips or bumps in the pavement;
- Scars in the pavement (showing locations either rocks/debris have fallen, or where hitches/bumpers have scraped due to poor vertical alignment, grade or cross slope); and/or
- Visible signs of impacts to the bottoms of bridges or overhead structures (showing a lack of vertical clearance for the vehicles using the roadway).

Exhibit 8.4–C SAMPLE ROADSIDE HAZARD REVIEW

Page 1 of 1

State: **Montana** Prepared by: **Paul Schneider**
County: **Flathead** Date: **May 19, 1996**

National Forest/Park: **Glacier National Park**

Highway Route: **US Route 2** Limits: **193+116 to 202+128** Length: **9.0 km**

General Location: **Beginning 1 km south of Camas and extending north to top of graveyard hill at Essex.**

Item	Hazard Location		Description of Hazard	Action	Cost	Remarks
	Station	Offset (m)				
1	193+438	6.0 Rt	100×100 wood sign post	Yes	$ 90	Relocate to backslope
2	194+082	4.9 Rt	100×100 wood sign post	Yes	$ 90	Relocate to backslope
3	194+243	5.5 Lt	Concrete culvert headwall	Yes	$ 500	Replace existing culvert
4	194+323	4.9 Rt	Concrete culvert headwall	Yes	$ 600	Replace existing culvert
5	194+564	3.7 Lt	Mailbox in no-passing zone	Widen	$1000	Provide mailbox turnout
6	194+886	4.3 Rt	Two 100×150 wood sign posts (not drilled)	Yes	$ 50	Drill posts
7	195+530	4.9 Lt	Abrupt culvert ends	Yes	$ 250	Lengthen culvert – provide metal end sections
8	196+013	4.6 Lt	Mailbox - good sight Distance	No	-	Tight right-of-way
9	196+013	5.5 Lt	Abrupt approach road Culvert	Yes	$ 600	Extend approach culvert and flatten slope to 1:10
10	196+174 to 196+656	6.7 Rt	Steep fill slope	None	-	Not cost effective Guardrail
11	197+300	6.0 Lt	Concrete culvert headwall	Yes	$ 500	Replace and extend
12	198+105	5.5 Rt	Abrupt approach road Culvert	Yes	$ 600	Extend culvert and flatten slope to 1:10
13	200+680	4.3 Rt	Concrete culvert headwall	Yes	$ 500	Replace existing culvert
14	201+645	3.7 Lt	Mailboxes (4)	Widen	$2500	Provide mailbox turnout

8.4.2.2 Two-Way Travel on Narrow, Single Lane Facilities

While not desirable, two-way travel on a narrow roadway cannot always be avoided, especially if widening the roadway would significantly interfere with the context of the adjacent landscape. When reviewing these facilities, document in particular where sight distance needs are critical issues. Rather than widening the entire roadway, perhaps only widening through the curves is necessary, especially if there is a low history of crashes on the facility.

8.4.2.3 Access Evaluation

Access management seeks to improve traffic distribution, reduce vehicle conflicts and reduce crashes by providing better access control. Better access control can be achieved by combining, reducing and improving safety elements of access points. The result is a roadway that functions safely and efficiently for its useful life, and creates a more attractive corridor. A good access management plan can offer a great combination among operation, geometric design and safety.

8.4.2.4 Turning Movements, Intersection Sight Distance

Evaluation of existing site turning movements, whether into a driveway, within a site facility (i.e. an entry station, parking lot, bus pullout, etc.), or at an intersection, includes a review of the geometry to make the turn and the ability to see oncoming traffic to safely make the turning movement. Evidence that either of these conditions is not adequately available is the existence of tire marks over a curb, heavy wear either on or beyond the shoulder, or skid marks leading to the intersection.

Evaluation of the sight distance at intersections includes the geometry of the intersection, the traffic control at the intersection, and driver behavior. Sight distance is affected by sight obstructions. Examples of sight obstructions at intersections include:

- Buildings
- Parked or Turning Vehicles
- Landscaping and Trees
- Intersection Signing Panels and Light Poles
- Fences
- Retaining Walls
- Graded Slopes too close to the Mainline
- Vertical Grades of Approaching Roadways

Intersection sight distance (ISD) is the minimum sight distance required for drivers to safely negotiate intersections, including intersections with or without stop controls or traffic signals. Refer to Section 9.3.7.5 for more information.

Decision sight distance (DSD) is the length of road a driver needs to receive and interpret information, select an appropriate speed and path and begin and complete an action in a safe maneuver. This distance is greater than the distance needed to simply bring a vehicle to a stop, and provides for a reasonable continuity of traffic flow. Use DSD for the approach to intersections if it is greater than the ISD. Refer to Section 9.3.7.3 for more information.

The speed at which vehicles approach and move through an intersection, along with the design vehicle used, are the primary factors which influence the minimum dimensions of intersection design. Features such as minimum sight distance, curve radii, and lengths of turning and storage lanes, directly relate to the design speed and design vehicle. Refer to Section 9.3.14 for geometry guidelines at an intersection.

8.4.2.5 Adequate Facility Capacity

Capacity is a term that indicates the ability of a specific facility to fulfill a specific function. For roadways, it generally means the amount of traffic that can pass by a specific point on a roadway or through an intersection. For evaluating these situations, the *Highway Capacity Manual* (*HCM*) is the document of choice. There are also many facilities that can restrict traffic from moving, resulting in vehicles queuing on the mainline. Queuing of traffic on the mainline that results from restricted access off of the main roadway, queuing at a toll/fee facility, and/or vehicles stopping and accumulating at an overwhelmed intersection typically requires analysis developed for that particular activity, and may require individual traffic studies that are unique for a given application.

If the mainline traffic is routinely restricted, evaluate the site to see if sufficient warnings are in place to alert the driver of the potential restriction. This is particularly important if the facility or the queued traffic is in any way hidden from the oncoming mainline traffic (i.e., located around a bend or curve). If the mainline traffic is not supposed to be delayed, such as traffic leaving the mainline to enter a facility through a driveway or intersection, evaluate whether a separate turning lane is necessary. Such a facility should provide enough storage to allow the queued vehicles to get off of the mainline and not obstruct the through traffic.

When evaluating facility capacity, also review the site for adequate storage and operation of pedestrian facilities as well. This is particularly important around trailheads and visitor facilities where parking may be on one side of a roadway or access, and the attraction on the other. Similar to queued traffic, pedestrians will only be delayed for a limited period of time before they decide to reduce their necessary decision sight distance.

8.4.2.6 Appropriate, Visible Signing and Marking

Provide appropriate, visible signing and marking in accordance with the MUTCD in plans, specifications and estimates (PS&E). **Design all PS&Es using the current edition of the *MUTCD*.**

Evaluation of existing signing and markings is not only a review of the appropriate placement of these elements, but a review of their functionality and condition with respect to their current location. For evaluating proper application signing and markings, refer to the *MUTCD*, which discusses signs, including Regulatory, Warning, Guide, Specific Service, Tourist Oriented Direction Signs, Recreational and Cultural Interest, and Emergency signs. The *MUTCD* also discusses pavement markings on all types of facilities. It is used as a standard so that all drivers can understand the consistent use, meaning and purpose of every traffic control device. The FHWA *Standard Highway Sign Guide* (*SHS*), the *NPS UniGuide Standards*, and other documents (e.g., USFS, State, etc.) should also be used for additional guidance when evaluating individual signs. Upgrading pavement markings and signing to MUTCD requirements can reduce crashes and help guide motorists. This is especially important when motorists are unfamiliar with the roadway.

The retroreflective sheeting on sign panels gradually deteriorates over time making signs less visible at night. The *MUTCD* requires that traffic signs be illuminated or retroreflective to enhance nighttime visibility. Sign sheeting does not have a life expectancy that matches typical project design life. Therefore, replace all permanent regulatory (black on white / white on red), warning (black on yellow), and destination and directional guide (white on green / white on brown) signs with new panels conforming to the *MUTCD*. Although all signs are required to be retroreflective and maintained, the following signs may be excluded from the above retroreflectivity replacement policy and should be evaluated on a project by project basis to determine the need for replacement:

- Parking, Standing, Stopping signs,
- Walking/Hitchhiking signs,
- Adopt-A-Highway signs,
- Blue/brown background information signs, including educational plaques and recreational and cultural interest area symbol signs, and
- Bikeway signs for exclusive use by pedestrians/bicyclists.

Projects can be exempted from this sign replacement policy if there are already plans for another agency to replace the signs in the very near future.

In addition to review of the appropriate application of these elements, also review the following:

- Visibility/location of signs/markings. It is important that the motorist can see the sign or pavement marking, so that it can be clearly seen and reacted to (such as a warning sign placed an adequate distance from the safety condition, such as a Stop Ahead sign in advance of a Stop sign). Advance warning sign distances as well as other appropriate information are discussed in the *MUTCD*.
- Size of text/font on signs appropriate for posted speed. Similar to visibility, the text/font must be appropriate for the driver to read while moving at the design speed. The *MUTCD, SHS* and the *NPS UniGuide Standards* should be used for evaluating text/fonts.
- Light screening. Visitor facilities, especially those with heavy pedestrian use, will incorporate site lighting. Occasionally, the projection of the lighting can interfere with the driver's ability to see. Lighting at athletic facilities in particular can blind a driver if they look directly at these fixtures. If the site has extensive use of specialty or flood lights, evaluate their location and projection at night to see if these facilities impair a driver's ability to see the road, signing, markings, and pedestrians. Occasionally, screening is warranted to block the lighting from obstructing the driver's view.

8.4.2.7 Evaluation of Lighting and Traffic Signal Warrants

A careful analysis of traffic operations, pedestrian and bicyclist needs, and other factors at a large number of signalized and unsignalized locations, coupled with engineering judgment, has provided a series of signal warrants, described in Chapter 4C of the *MUTCD*, that define the minimum conditions under which installing traffic control signals might be justified.

Highway lighting is discussed in Section 8.7.3, and in AASHTO's *Roadway Lighting Design Guide*, which includes a similar discussion on lighting warrants.

8.4.3 EXISTING GEOMETRIC CONTROLLING FEATURES ANALYSIS

Refer to Section 4.4 for determination of current design standards and controls that are applicable to the project.

Many existing highways do not meet current design standards and have safety deficiencies when compared to the current design standards of the AASHTO *Green Book*. The amount of upgrading necessary to bring an existing facility to current design standards has been a continuing concern. This concern was recognized in the 1982 *Surface Transportation Assistance Act*, Section 101(a), which emphasized safety by stating that RRR projects "shall be constructed in accordance with standards that preserve and extend the service life of the highways and enhance highway safety." Although the primary objective of RRR projects is to restore the structural integrity of the existing roadway, both the safety and capacity of the facility should be reviewed and enhanced, when required.

To properly review an existing roadway for conformance to current and acceptable design criteria, the following factors should be evaluated. If the feature is within the current design guidelines, no changes are necessary. If the feature does not meet the current standards, it should either be improved or documented to warrant a design exception. Economics, anticipated growth, crash history, program schedules, time, manpower, etc., may have some bearing prior to final determination.

8.4.3.1 Horizontal and Vertical Stopping Sight Distance

As-built plans are normally the best source of data available for evaluation of existing horizontal curves and vertical profile alignments. In some instances, hard copy maps or other survey information may be available in the absence of as-built plans. Once the existing alignment has been determined, the AASHTO *Green Book* can be utilized to determine the theoretical adequacy of the existing horizontal alignment and the vertical profile. Refer to Section 9.3.7.2 for more information on Stopping Sight Distance (SSD).

Stopping sight distance on horizontal curves is an important feature that should be closely observed during the initial field review. During the drive through the project, features that would appear to restrict horizontal and vertical sight distance (e.g., narrow cut ditches, trees, outcroppings) should be observed. Measurements can be taken during the field visit to determine if restrictions do exist or additional data can be requested as needed.

8.4.3.2 Cross Section

Lane width and shoulder width on an existing roadway can be determined by researching the as-built plans or by actual field measurement. During the field reviews, lane and shoulder widths should be observed and verified as necessary to determine how the existing widths compare with AASHTO guidelines. Refer to Section 9.3.8 for more information.

8.4.3.3 Existing Superelevation

While the horizontal curvature shown on as-built plans is generally very reliable, the superelevation data cannot be relied upon because revisions to superelevation during construction may not have been well documented. Also, subsequent overlay projects and maintenance work may have changed the original superelevation.

Since as-built superelevation data may not be reliable, other means of reviewing superelevation are needed. It is not the intent to field survey each curve to determine actual values; however, the following actions should be performed during the initial field review:

- Observe the comfort level of the existing curves as they are driven through at the posted speeds.
- Arrange to review any particular problem areas in more detail (e.g. discuss with the maintenance foreman responsible for the area).

8.4.3.4 Roadway Cross Slope

AASHTO has established guidelines for ranges of cross slopes for various roadway classifications. See Section 9.3.8.4.1 for the FLH standard practice regarding cross slope. The primary consideration on cross slope is to provide adequate pavement drainage. This item should be addressed by visual observation during the site visit. Also, agency maintenance representatives should be asked to provide any historical information in regard to problems with cross slope, ponding on the pavement or irregular shape of the cross section.

In some instances, the existing pavement cross section may have become distorted due to several overlays and/or maintenance treatment. If this is the case, the new pavement design should consider alternatives (e.g., additional removal, milling, total reconstruction) for the pavement section. This should be coordinated closely with the materials team and should be included as part of their pavement evaluation process.

8.4.3.5 Intersection Stopping Sight Distance/Decision Sight Distance

The at-grade intersections of the through facility with intersecting roads should be reviewed for adequacy of sight distance during the initial field review for the project. If there appears to be a potential problem with sight distance, the sight distance may need to be determined on site.

Consideration should be given to modifications of obstructions occurring within the sight triangle. The location of the intersection on the vertical alignment is also an important factor. See Section 9.3.7 for more information on sight distance requirements.

8.4.3.6 Vertical Grades

The existing profile on a route can be determined by a review of the as-built plans. The review of the vertical alignment and stopping sight distance will provide some indication of grades that may need further evaluation. In general, AASHTO has established guidelines for suggested maximum grades for various roadway classifications.

8.4.3.7 Vertical Clearance

Underpass clearances at bridge structures should be verified through a review of the bridge inspection or maintenance reports. Existing clearances can then be compared with the AASHTO recommended clearances. Whenever a change in the existing profile grade on an existing route is being contemplated, the vertical clearances at existing structures should be reviewed to determine how the proposed changes in profile (e.g., overlay, mill) affect the clearance. AASHTO provides recommended vertical clearances for various roadway classifications.

8.4.3.8 Structural and Functional Sufficiency

Bridge width is defined as the minimum clear roadway width on the bridge as listed under the column heading "Curb to Curb" of the Bridge Record. For all existing bridges contained within the project limits, the bridge width should be compared with the AASHTO guidelines. AASHTO provides bridge width criteria for the various functional roadway classifications.

Structural sufficiency is determined in part by the maintaining agency, but is generally desirable to achieve an HS20 [MS-18] load rating, regardless of the functional classification of the roadway. AASHTO provides structural capacity criteria for the various roadway functional classifications. Refer to Chapter 10 for guidance on rating structural capacity.

Functional sufficiency is the adequacy of the bridge to carry the traffic volume and speed from an operational and capacity standpoint. Refer to the *Green Book* for guidance on the overall clear roadway width and design speed recommended for the particular functional classification and design traffic volume.

And finally, the bridge barrier type and sufficiency should be evaluated. For information regarding bridge barrier and off-bridge transition features (e.g., barrier curbs, walkways and roadside barriers) refer to the *RDG*.

8.4.4 EVALUATION OF PEDESTRIAN/MULTI-MODAL FACILITIES

When evaluating the existing conditions, make a separate evaluation of the site from the perspective of pedestrians, bicyclists, handicapped persons and those using alternative forms of transportation (e.g., horseback, snowmobiles, ATVs). Clear delineation of the path these users are intended to follow, supplemented with adequate signing and information placards, is another important safety evaluation element of the roadway. Also refer to Section 9.3.16 and Section 9.3.17.

8.4.4.1 Accessibility Requirements

Refer to the *ADA Accessibility Guidelines for Buildings and Facilities* (*ADAAG*) for design guidelines.

8.4.4.2 Path Width/Accessibility

Where pedestrians are present, verify that the path for the pedestrian is clearly delineated. In addition, observe the paths that pedestrians choose to take and review the safety of the alternative routes. If any of these conditions are determined to be unsafe, positive pedestrian barriers such as railings may be necessary to ensure safe pedestrian crossings and keep them from crossing the roadway at hazardous locations.

The size of pedestrian facilities is volume dependent. The National Park Service uses many useful resources for estimating visitor traffic. These should be reviewed when sizing the sidewalk and pathway facilities.

8.4.4.3 Parking/Trails access from Roadways/Bridges

Pedestrians will generally use the shortest path of least resistance to reach their destination. If their destination is visible, and a “short-cut” can be seen that will significantly reduce their walking distance, given no other means of restriction, they may attempt to use the short-cut. Ingress/egress from trails, comfort stations, parking facilities and buildings must be coordinated with crosswalks and sidewalks.

If a sidewalk is not provided, the visitor may become resourceful and use other transportation facilities to view or access their desired destination. For example, if a bridge crosses a beautiful canyon and provides a unique photo opportunity, but does not have a sidewalk, most people will simply walk on the roadway. While some environmental and historic restrictions could prevent the structure from having a sidewalk, the designer must address how keep the pedestrian and vehicular traffic separated. This will likely require discussions with the resource agencies, but could reduce future safety implications if these concerns are addressed early in the design.

8.4.5 SAFETY EVALUATION COMPUTER PROGRAMS

Several computer programs are available to aide in the evaluation of the safety of an existing roadway. While these programs work as a great tool, they should not be used as a replacement of site evaluation and professional assessment.

8.4.5.1 Interactive Highway Safety Design Model (IHSDM)

The IHSDM is a suite of software analysis tools for explicit, quantitative evaluation of safety and operational effects of geometric design decisions during the highway design process. It culminates a multiyear research and development effort conducted by the Federal Highway Administration.

The IHSDM is intended for use throughout the highway design process from preliminary planning and engineering through detailed design to final review for two-lane rural roads. It may be used both for projects to improve existing roadways and for projects to construct new roadways. The 2006 release of IHSDM has six evaluation modules:

- Policy review,
- Crash prediction,
- Design consistency,
- Driver/Vehicle
- Intersection review, and
- Traffic analysis.

Additional capabilities including evaluations of multilane rural highways are planned for future releases.

8.4.5.2 Roadside Safety Analysis Program (RSAP)

Highways are designed to provide motorists with reasonable levels of protection against serious run-off-the-road crashes. When hazards cannot be removed or relocated within the clear zone, a determination needs to be made if a safety device is warranted to protect motorists from the roadside obstacle. RSAP uses the concept of incremental benefit/cost analysis to weigh the risk of death or injury to the motoring public against the initial cost of installing and maintaining the safety improvement. Appendix A of the *Roadside Design Guide* provides a cost-effective selection procedure for comparing alternative solutions to problem locations and instructions for operating the Roadside Safety Analysis Program (RSAP) computer software. The annual cost of each alternative is computed over a given period of time, taking into consideration initial costs, maintenance costs and crash costs. Crash costs incurred by the motorist, including vehicle damage and personal injury, are considered together with crash costs incurred by the highway department or agency. The alternative with the least total cost is normally selected, except when environmental or aesthetic considerations dictate otherwise.

The ability to easily vary input data allows the designer to explore various areas of sensitivity of the analysis at a given location. The effects of current traffic and future traffic can be explored to evaluate cost effectiveness over the design life of a project. Although most of the data collected through research pertains to high-speed situations, the designer can analyze how sensitive the cost effectiveness is with respect to the severity index. However, a correlation can be made provided the designer recognizes that lower design/running speeds would lessen severity. Use of this tool has been successful in persuading agencies to recognize the cost effectiveness of selected safety feature applications.

This program accesses research information by Kennedy-Hutcheson for high-volume roads and Glennon for low-volume roads with roadway widths less than 28 ft [8.5 m]. The program shows both annual cost comparison and present worth. Generally, the annual cost is used to facilitate comparison of different alternatives with varying design life.

Refer to NCHRP Report 492, the RSAP Engineer's Manual, for more information.

8.4.5.3 Resurfacing Safety Resource Allocation Program (RSRAP)

Highway agencies face a dilemma in determining the appropriate balance of resurfacing and safety improvement in their programs to maintain the structural integrity and ride quality of highway pavement. RSRAP uses an optimization process based on integer programming to determine the most cost-effective set of safety enhancements that achieve the optimal benefits for a specified set of candidate resurfacing projects. In this way, RSRAP can maximize the system wide safety benefits for a given set of resurfacing projects as a whole, rather than maximizing the benefits at any particular site. RSRAP incorporates the best available estimates of the safety effectiveness of specific geometric design and safety improvements.

8.4.6 ROAD SAFETY AUDITS

A Road Safety Audit (RSA) is a formal safety performance examination of an existing or future road or intersection by an independent audit team. They can be performed during any stage of project development from planning through construction and throughout the operation of the completed facility. RSAs can also be used on any size project, from minor maintenance assessments to major new program expansions. Typical improvements suggested include:

- Removal of sight distance obstructions,
- Addition/design changes to turn lanes,
- Improvement to acceleration/deceleration lane design,
- Illumination,
- Median barrier placement,
- Consideration of pedestrian's ability to cross a street,
- Improvements to superelevation,
- Drainage improvements,
- Roadway shoulder and lane width modifications,
- Access management/consideration of driveways,
- Realignment of intersection approaches, and
- Improvements to signing and pavement marking.

The recommended procedure for conducting an RSA is as follows:

1. **Audit Team**. Following identification of a project or roadway that is to be evaluated, select an interdisciplinary audit team to conduct the review. The team should consist of three to five people from various design and operations disciplines including highway design, traffic safety, traffic engineering, planning, geometric design, construction, maintenance, human factors and enforcement.

2. **Pre-Audit Meeting**. Conduct a pre-audit meeting with the interdisciplinary team and the Project Owner/Design Team to review available project drawings and site information, including traffic and crash data.
3. **Field Review**. Consider field reviews under various conditions like during peak travel times or at night. The team should have the willingness to investigate new ideas outside the traditional scope of work.
4. **Audit Analysis**. Analyze collisions, geometrics, operations, traffic conflicts, and human factors and identify deficiencies. Select countermeasures and prepare a report listing the team's findings and recommendations.
5. **Report Audit Findings**. Present report and audit findings to the Project Owner/Design Team.
6. **Prepare Formal Response**. The Project Owner/Design Team prepares a formal response, incorporating the findings into the project when appropriate.

RSAs are different from traditional safety reviews because these multi-discipline team reviews tend to be more proactive, considering all of the various types of road users that may be using the facility and all of the factors that contribute to a crash. These reviews include day and night field reviews by independent teams. The synergy created by these teams has resulted in more safety implementation recommendations being recommended than in the past when only one safety individual was responsible for the review.

8.4.7 SAFETY EVALUATION REPORT

After the accumulation of available data, this information and all observations must be consolidated and documented in a Safety Evaluation Report. The results of the crash analysis and the list of potential roadside hazards provide the input for this evaluation. From these two sources, the designer should develop a composite list that locates and describes the identified safety problems.

Alternatives for correcting the safety problems should be developed and evaluated for effectiveness, cost and environmental impact. Alternatives may range from site-specific improvements to total reconstruction. The evaluations, alternatives and the action selected should be documented in the project files.

8.5 SAFETY DESIGN

8.5.1 DESIGN EXCEPTIONS

Although often viewed as dictating a set of national standards, the AASHTO *Green Book* is actually a series of guidelines on geometric design within which the designer has a range of flexibility. As stated in the forward to this document:

> *"The intent of this policy is to provide guidance to the designer by referencing a recommended range of values for critical dimensions. Sufficient flexibility is permitted to encourage independent designs tailored to particular situations."*

While it provides guidance on the geometric dimensions of the roadway (e.g., travel lanes, medians, shoulders, horizontal clearance, etc.), there are many aspects of design that are not directly addressed in the *Green Book*. Despite the range of flexibility that exists with respect to virtually all the major road design features, there are situations in which the application of even the minimum criteria would result in unacceptably high costs or major impact on the adjacent environment. For these instances, the design exception process allows for the use of criteria lower than those specified as minimum acceptable values in the *Green Book*.

For a full discussion on the elements that must be addressed in a design exception, refer to Section 9.1.3.

8.5.2 DEFINING THE CLEAR ZONE

A clear zone (L_c) is defined as the roadside border area (starting at the edge of the traveled way) that is available for safe use by errant vehicles. The width of the clear zone is influenced by the type and volume of traffic, speed, horizontal alignment and side slopes. Slopes steeper than 1V:4H are non-recoverable and most vehicles will be unable to stop or return to the road easily. See Exhibit 4.3-B as an example. Slopes steeper than 1V:3H are considered critical since a vehicle is more likely to overturn. The need for traffic barriers as discussed in Section 8.5.3 should be evaluated when slopes within the clear zone are in these ranges.

Determine clear zone widths for all roadway sections by using Table 3.1 or Figure 3.1 of the AASHTO *Roadside Design Guide* or by using the *FLH Barrier Guide*. Where feasible and environmentally acceptable, the clear zone width should be a minimum of 10 ft [3 m]. On rural collectors and local roads and streets with a design speed of less than 40 mph [60 km/h] or an ADT less than 750, the clear zone width may be determined and documented on a project-by-project basis.

Note that many publications (*RDG* and the *Green Book*) consider a foreslope to include the entire sideslope(s) from the outside edge of the roadway shoulder down to the bottom of the ditch or fill/embankment section.

8.5.3 TRAFFIC BARRIERS

For all projects, FLH standard practice is to establish an appropriate clear zone and design the roadside accordingly. When clear zone requirements cannot be met, the designer should give special attention to the roadside hazards. Obstacles located within the clear zone should be removed, redesigned, relocated or made breakaway. If this is not feasible, then guardrail or some other type of roadside barrier should be considered, provided that the roadside barrier offers the least hazard potential. If it is determined that a traffic barrier is not needed, consider delineating the hazard.

While the following sections provide policy and direction for installing traffic barriers, the designer should also review the *FLH Barrier Guide* for a more comprehensive review of available barriers, their applications and their installation requirements.

8.5.3.1 Identifying Needs

Roadside obstacles may be classified as non-traversable hazards or fixed objects.

The following are examples of non-traversable hazards that may warrant roadside barriers:

- Steep embankments (slopes steeper than 1V:3H),
- Rock cuts,
- Large boulders,
- Ditches,
- Culvert openings,
- Permanent bodies of water over 2 ft [0.6 m] in depth,
- Large trees over 4 in [100 mm] diameter, and/or
- Shoulder edge drop-offs steeper than 1V:1H and depth greater than 2 ft [0.6 m].

A ditch section is safe or hazardous depending upon the type of sideslopes and widths. The *Roadside Design Guide* contains examples of a variety of ditch configurations. Frequently, limited right-of-way, environmental factors and terrain will preclude the designer from being able to develop these preferred ditch sections. Preferred ditch sections should receive greater consideration on high-speed, high-volume facilities. Medians on divided roadways also deserve special attention.

The following are examples of fixed objects that may warrant roadside barriers:

- Bridge piers, abutments, parapets or railings;
- Retaining walls;
- Fixed sign bridges and non-breakaway sign supports;
- Trees over 4 in [100 mm] in diameter;
- Headwalls of box culverts or pipe culverts;
- Culvert end sections with diameters larger than 36 in [900 mm]; and/or

- Utility appurtenances.

The unprotected end of a bridge rail or parapet is considered a hazard. In most designs, an approach roadside barrier with a smooth transition to the bridge barrier is warranted. Exceptions to this policy may include structures designed for use on low-volume, low-speed highways. Refer to Section 8.5.3.4 and the *Roadside Design Guide* for more discussions on bridge rails and transition barriers.

Crashes involving roadside hazards represent a problem inherent to any existing highway facility. Even on new or reconstructed projects, the complete elimination of all roadside hazards may not be feasible or practical.

When determining the need for traffic barriers, consider cost, feasibility, and environmental impacts when evaluating the following four alternatives:

1. **Remove or Reduce Hazard.** Remove a hazard in it's entirety or by relocating it. Reduce the degree of the hazard through a redesign of the object or use of breakaway devices.

2. **Install a Barrier.** With regard to installing a barrier, RSAP (see Section 8.4.5.2) allows the designer to evaluate any number of barriers that can be used to shield the hazard. Through this method, the following can be evaluated:

   - The effects of average daily traffic,
   - Offset of barrier or hazard,
   - Size of barrier or hazard, and
   - The relative severity of the barrier or the hazard.

   For low-volume, low-speed roads, strict adherence to the guardrail warrants shown in the *Roadside Design Guide* are frequently not practical or cost-effective. See the *FLH Barrier Guide* for more information.

   Characteristics that affect barrier needs include the following:

   - Roads closed in winter and during periods of hazardous climatic conditions,
   - Roads closed at dark,
   - Vehicle speed,
   - Length or other vehicle restrictions, and
   - Roads with access limited to passenger-carrying vehicles.

   Another consideration affecting the use of barriers is for areas that have unusual environmental sensitivity (e.g., endangered plants and animals, major historic and scenic resources).

   Always remember that a barrier is itself a significant hazard and is more likely to be hit than the hazard it is intended to protect. Therefore, the relative severity, costs and frequency of crashes must be considered.

   Although the warrants cover a wide range of roadside conditions, special cases or conditions will arise for which there is no clear choice. These cases must be evaluated on an individual basis, and, in the final analysis, must usually be solved by engineering judgment.

3. **Sign or Delineate Hazard**. Signing or delineating a hazard is typically cost-effective on low-volume and/or low-speed facilities, or where the probability of crashes is low.

4. **Do Nothing**. Use this option only after determining that other alternatives are not cost-effective in reducing the risk of crashes.

8.5.3.2 Type Selection

Once it has been determined that a barrier is needed, type selection will be made. While the most predominant type of roadside barrier used on Federal Lands' projects is metal W-beam guardrail, the designer needs to be cognizant of various selection criteria for roadside barriers. Exhibit 8.5–A lists the various criteria that should be considered.

Exhibit 8.5–A SELECTION CRITERIA FOR ROADSIDE BARRIERS

Characteristic	**Considerations**
Deflection	Space available behind barrier must be adequate to permit dynamic deflection of barriers.
Strength and Safety	System should contain and redirect vehicle at design conditions. System should be as safe as possible considering costs and other considerations.
Maintenance	Collision maintenance. Routine maintenance. Environmental conditions. Inventory of spare parts.
Compatibility	Can system be transitioned to other barriers? Can system be terminated properly?
Costs	Initial costs. Maintenance costs. Crash cost to motorist.
Field Experience	Documented evidence of barrier's performance in the field.
Aesthetics	Barrier should have a pleasing appearance.
Promising New Designs	It may be desirable to install new systems on an experimental basis.

Refer to the *Roadside Design Guide* and the FHWA Roadside Hardware website for design criteria of the various systems.

The FLH has conducted crash tests using the National Cooperative Highway Research Reports (NCHRP) 230 and 350 criteria to evaluate aesthetic barrier systems. Research efforts are in progress to identify and crash-test other systems for possible use on FLH Program projects.

The owner agency generally selects the type of roadside barrier. It is the designer's responsibility to ensure that the selected barrier has been tested and approved for use and designed to function where installed.

The FLH policy requiring barrier systems to meet the requirements of NCHRP-350 is provided below:

1. **Routes on the NHS**. The following applies:

   - *State and local routes*. **As required by FHWA, it is the policy of the FLH to use only roadside safety hardware that meets NCHRP 350 criteria. No exceptions are permitted, except for specific hardware items receiving delays or temporary waivers granted by the FHWA, Office of Safety Design (HSA-10).**

   - *National Park Service (NPS) routes.* **It is also the policy of the FLH that all roadside safety hardware shall meet NCHRP 350 criteria on NPS routes.**

   A request for acceptance of aesthetic barrier systems previously accepted under NCHRP 230 may be submitted to the Office of Safety Design for consideration. The Office of Safety Design may determine that the barrier is acceptable under NCHRP 350 criteria without retesting if the test result data under NCHRP 230, or results from similar systems tested under NCHRP 350, indicate the system is likely to meet NCHRP 350 criteria.

2. **Routes not on the NHS**. The FLH should comply with the owning agency's policies on roadside safety hardware on non-NHS routes. The owning agency's policies will be referenced as the reasons for permitting barrier systems that do not meet NCHRP 350 criteria. **However, no barrier systems shall be used that have not passed NCHRP 230 criteria. If the agency has no policy, FLH shall specify roadside safety hardware that meets NCHRP 350 criteria.** Although there is no regulatory requirement, the FHWA strongly encourages safety hardware used on non-NHS routes to meet NCHRP 350 criteria.

   - *State and local routes*. Due to particular issues (e.g., maintenance of barrier systems), State or local agencies may require barrier systems that do not meet NCHRP 350 criteria. **The FLH Divisions shall ensure the owning agencies are aware that proposed systems do not meet NCHRP 350 criteria before complying with the owning agencies' requests. The decision and reasons for specifying barrier systems that do not meet NCHRP 350 criteria must be documented as a formal design exception.**

   - *NPS routes*. **All barrier systems shall meet NCHRP 350 criteria. The decision to use barrier systems that do not meet NCHRP 350 criteria must be documented as a formal design exception.**

Roadside safety hardware meeting NCHRP 350 criteria are currently being accepted by the Office of Safety Design following a review of data submitted by the vendor or the developer of the system. Updated lists of approved barrier systems are maintained by the FHWA. If no acceptable non-proprietary barrier terminal systems and transitions are available that meet the project needs, at least three acceptable proprietary systems (if available) shall be permitted as options in the contract.

8.5.3.3 Design Procedures

Once the need for barrier has been determined, the designer must determine the length and location for the barrier. The following discussion outlines the significant elements for locating and designing roadside barriers. However, the designer should refer to the *Roadside Design Guide* for specific details and limiting criteria for layout and use of the barrier selected, along with the *FLH Barrier Guide* for low volume and low speed road applications.

8.5.3.3.1 Length of Barrier

The length of need is equal to the length of the area of concern parallel to the roadway, plus the length of the approach barrier on the upstream side (and downstream side, if needed), plus a safety end treatment. Exhibit 8.5–B depicts approach barrier layouts for both adjacent traffic and opposing traffic. Refer to the *RDG* for descriptions of the variables shown in these layouts.

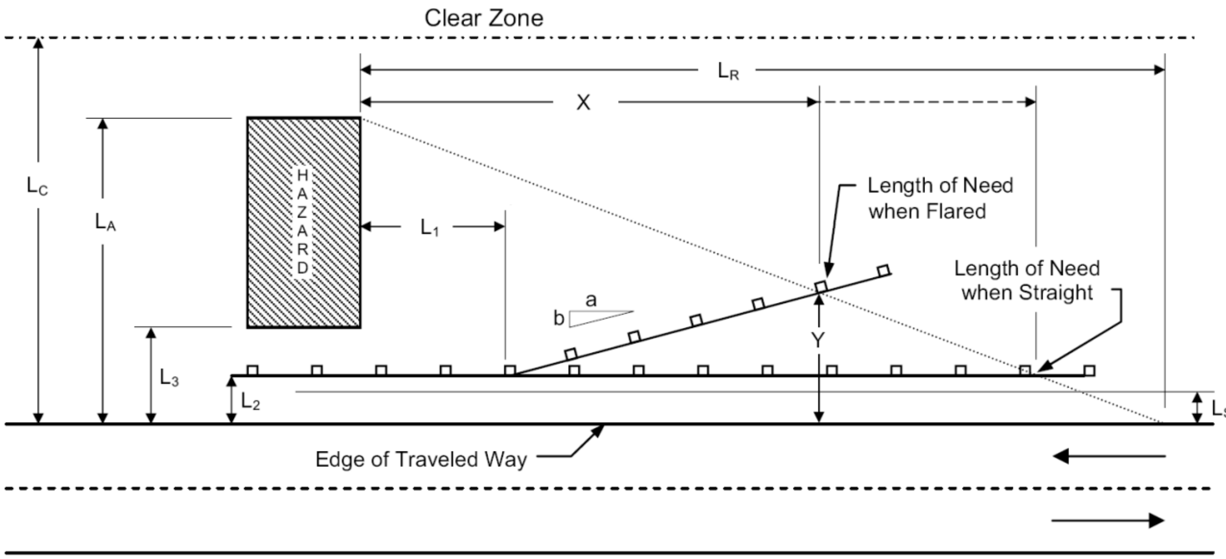
Where slopes outside of the graded shoulder are flat enough, the barrier approach should be flared or the guardrail installation should be located outside of the graded shoulder to minimize the length of need. More commonly, where slopes are steeper, the barrier will run along the shoulder.

8.5.3.3.2 Location of Barrier

The location of a barrier may be one of the following:

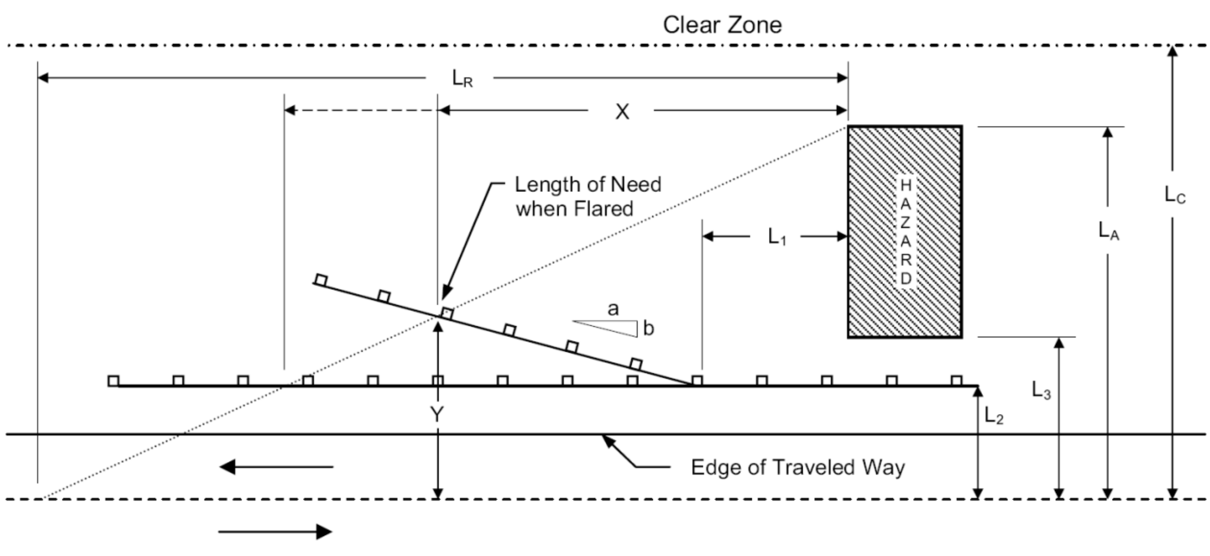
1. **Adjacent to the Graded Shoulder**. Designers should be aware that barrier installations require widening of the shoulder to provide adequate soil support. In addition, special attention is required at barrier terminals to ensure that widened areas are graded correctly so that the terminal will function properly.
2. **Back of the Graded Shoulder**. Where barriers are located in back of the graded shoulder or when barriers are flared back of the shoulder edge, slopes in front of the barrier shall be 1V:10H or flatter. Also, the algebraic difference between the shoulder slope and the slope in front of the guardrail should not be greater than 8 percent.
3. **Adjacent to a Retaining Wall Face**. When barriers are located near the edge of a retaining wall, there may not be adequate support behind the barrier for the embedded posts to properly sustain the impact loading and may require project-specific design. For example, the supports may need to be founded in a cantilever-spread footing and require a special structural design. For these situations, both the structural and highway safety engineers need to review the proposed installation.

Exhibit 8.5–B GUARDRAIL LENGTH REQUIREMENTS



Approach Barrier Layout for Adjacent Traffic

Note: For a description of the layout features and the associated equations to design these installations, refer to the Roadside Design Guide.



Approach Barrier Layout for Opposing Traffic

8.5.3.3.3 Barrier/Curb Combinations

The following briefly describes barrier/curb combinations:

1. **All Barrier/Curb Combinations**. Concrete curb and gutter, header curb or other rigid-type curb used in combination with a barrier should be avoided whenever possible.

Curbs should not be used in front of barriers unless the combination has been successfully crash-tested.

2. **Guardrail/Curb Combinations**. Where there are no other feasible alternatives to guardrail/curb combinations, the face-of-curb should be located behind or flush with the face of guardrail. However, crash tests have shown some guardrail/curb combinations with curbs located flush with the face of the guardrail can cause vaulting due to deflection of the rail. Therefore, curbs higher than 4 in [100 mm] should not be used with guardrail unless:

   - The guardrail/curb combination has been successfully crash-tested, or
   - The rail is adequately reinforced (stiffened) to reduce its deflection.

   On low-speed roads, use of a reinforced rail may not be cost-effective. These locations are best analyzed on a case-by-case basis, taking actual or anticipated operating speeds into account and considering the consequences of vehicular penetration.

The *Roadside Design Guide* and the *FLH Barrier Guide* contain additional information on curb and barrier/curb combinations.

8.5.3.3.4 Shy Distance

Barriers are themselves items that must be avoided. Placed at the edge of the roadway, most drivers will provide an extra cushion of separation from the barrier to ensure that neither their vehicle nor the barrier is damaged. This separation is called the shy distance and it varies with respect to speed and the size of the obstacle. It is defined as the distance from the edge of the traveled way beyond which the typical driver will not perceive a roadside object as an immediate obstacle. Placed any closer to the edge of the roadway, the driver may feel compelled to either change the vehicle's placement or reduce its speed.

As a rule of thumb, barrier should be placed an additional 2 ft [0.6 m] beyond the edge of the prevailing shoulder to retain the driver's perception of a constant width roadway. A more detailed discussion is available in the AASHTO *Roadside Design Guide*, Section 5.6, which provides additional information on what the suggested shy distance should be, based on various design speeds and obstacle offsets.

8.5.3.3.5 Transitions

Once a barrier is selected for a site application, use that type of barrier to protect the motorist throughout the length of the hazard. Occasionally, there is a need to transition from one type of barrier to another. This condition is typical at bridge locations, where the roadway barrier may be a flexible W-Beam system and the bridge incorporating a rigid concrete barrier. The key concern in changing from one type of barrier to another is the possible impact at the transition point. Review Section 8.5.3.4 to ensure the design addresses pocketing concerns. Transition sections should provide gradually increasing lateral stiffness to properly join two different barrier materials.

8.5.3.4 Bridge Railings

Selection of the appropriate barrier both on and approaching the bridge structure requires cooperation between the bridge and roadway disciplines. In addition, attention to aesthetics, maintenance, and its ability to deflect an errant vehicle must all be evaluated before the type of railing is selected. While the selection of the barrier used on the structure itself is generally determined by the Structural Engineer following the design guidelines provided in Section 10.4.4, the type of transition used between the bridge barrier and the roadway barrier approaching the structure can vary.

Barriers on bridge structures must be rigid enough to deflect the errant vehicle without leaving the edge of the bridge deck. To provide this rigidity on the structure, the barrier system on the bridge deck may be anchored to cast-in-place concrete barriers located at or beyond the abutments. These anchors serve as a transition as they provide an attachment point between the bridge railing and the approach roadway barrier transition terminal. One example of this transition is the thrie-to-W-beam transition which is used on many bridge rail retrofit jobs. Currently there is no standard drawing/detail for these installations; however, they are very common throughout FLH with details available from suppliers and many DOT sites.

On many projects, existing bridges have inadequate bridge or transition railings. When replacing structurally obsolete bridges, railing replacement should meet current standards. When bridge railings are structurally adequate but functionally obsolete, engineering analysis should be performed to determine the recommended action on a case-by-case basis.

Special attention should be given to the proper attachment of the transition railing with the bridge railing or parapet. The railing connection should develop the full tensile strength of the rail element and be designed to prevent possible pocketing or snagging of a vehicle on the end of the bridge parapet. The bridge plans should generally include special drawings of these connection details. Transition guardrail should satisfy the minimum length of need to develop its full tensile strength capacity. Besides the FHWA Roadside Hardware website, a resource that is recommended for information on various guardrail transitions is FHWA Technical Advisory T 5040.34, which provides some sample designs for attachment to modified and unmodified concrete safety shape bridge rails, wingwalls or parapets.

The terminal end should extend outside the lateral clear zone or be provided with a crash worthy terminal, protected by a crash cushion or buried in a cut slope. In rare occasions, there are site constraints that don't provide enough room in advance of the bridge barrier to construct the necessary approach barrier, or the standard flexible to rigid barrier transition. Examples could include parking lots and turnouts located immediately adjacent to the bridge abutment. In these locations, the designer should consider extending the rigid barrier beyond the bridge and terminating the barrier properly outside the clear zone within the parking lot or turnout, or consider providing a crash cushion or impact attenuator in advance of the bridge barrier. Wrapping a standard flexible barrier around an approach without the necessary rigid transition will allow the errant vehicle to deflect the face of the flexible barrier, resulting in the vehicle directly impacting the bridge barrier with results similar to having no approach protection at all. There are guidelines for installing curved guardrails that have been crash tested, see the Standard Drawings and the *RDG* for more information.

8.5.4 CRASH CUSHIONS AND END TREATMENTS

Crash cushions shield errant vehicles from impacting fixed rigid hazards (e.g., an intersection of bridge parapets at a gore area) by smoothly decelerating the vehicle to a stop condition when hit head on. Also, it is desirable for the crash cushion to redirect a vehicle when hit from the side by functioning in a manner similar to a longitudinal barrier.

End treatments are devices that are designed to treat the end of a longitudinal barrier. The end treatment may function by:

- Decelerating a vehicle to a safe stop in a relatively short distance,
- Permitting controlled penetration of the vehicle behind the device,
- Containing and redirecting the vehicle, or
- A combination of any of the above.

These devices may be located in roadway medians, gore areas or along the roadside. These devices have been developed for specific applications (e.g., limited shoulder width, temporary construction installations, high frequency impact sites, the protection of wide hazards, and the protection of fixed features that protrude into the clear zone).

8.5.4.1 Determination of Need

As with longitudinal barriers, the first consideration with regard to a rigid object or a hazardous condition is to evaluate the feasibility of removing the obstruction, relocating it or making it breakaway. When these options are not feasible, the next step is to determine whether or not some type of barrier is warranted by analyzing the cost effectiveness as described in Section 8.4.5.2. The cost-effective procedure can be used to evaluate both longitudinal barriers as well as crash cushions.

8.5.4.2 Types of Treatments

The *Roadside Design Guide* presents several approved crash cushions and end treatments. Updated lists of approved crash cushions and end treatments are maintained by the FHWA. Crash test criteria can be found in NCHRP Report 350.

8.5.4.3 Design Procedures

Standard Drawings or manufacturer's designs, or both, should be followed when crash cushions or end treatments are needed. The road cross-section design must take into account the width, offset, and flare of the end treatment or crash cushion.

8.5.5 TRAFFIC CALMING

Travelers are often concerned about excessive traffic volumes and speeds on local streets. Local streets are intended to serve the adjacent land use at slow speeds, yet they are often designed so that high-speed travel is accommodated. Traffic calming measures are sometimes considered, primarily in residential neighborhoods, to address demonstrated safety problems caused by excessive vehicle speeds and conflicts with pedestrians, bicyclists, and school children. Well designed traffic calming devices effectively reduce traffic speeds and volumes while maintaining local access to adjacent facilities and turnouts. Refer to Section 9.3.1.13.3 for more information and guidance.

Public involvement is needed for residents, businesses, planners and engineers to understand the issues and agree with the proposed changes. The benefits of traffic calming, especially for pedestrians and bicyclists include:

- Reduced traffic speeds and volumes allow bicyclists to share the road with vehicles;
- Quieter streets and increased ease of crossing enhance the pedestrian environment;
- Lower traffic speeds increase safety (high speeds are responsible for many pedestrian fatalities); and
- In park and forest settings, lower traffic speeds enhance the visitor experience in a natural setting.

8.5.5.1 Managing Speeds

Managing traffic speeds can be accomplished through physical constraints on the roadway or by creating an "illusion of less space." Motorists typically drive at a speed they perceive as safe; this is usually related to the road design, especially available width. Refer to Section 9.3.1.14 for self-explaining, self-enforcing road concepts.

One way to achieve the lower speed is to provide various physical constraints. The following are some examples:

1. **Narrow Streets or Travel Lanes**. Narrow (minimum) cross sections can effectively reduce speeds, as most drivers adjust their speed to the available lane width. Narrow streets also reduce construction and maintenance costs. See the AASHTO *Guide for Achieving Flexibility* for information about lane width issues and mitigation.
2. **Speed Humps** (not speed bumps). If well designed, speed humps allow a vehicle to proceed over the hump at the intended speed with minimal discomfort, but driving over the hump at higher speeds will rock the vehicle. The hump is designed with a reversing curve at each end, and a level area in the middle long enough to accommodate most wheelbases.
3. **Chokers** (i.e, curb extensions, bulb-outs, neckdowns). Chokers constrict the street width and reduce the pedestrian crossing distance.

Another means to reduce speeds is to provide the illusion of limited space. Examples of this technique include:

1. **Creating Vertical Lines**. By forcing some natural or barrier elements closer to the roadway edge, the roadway will appear narrower than it is. This can be accomplished with longitudinal barriers, curbs, or trees and landscaping.
2. **Coloring or Texturing Bike Lanes**. Drivers see only the travel lanes as available road space, so the roadway appears narrower than it is. Painting the road surface is expensive; lower-cost methods include:
   - Paving travel lanes with concrete and bike lanes with asphalt, or the reverse;
   - Slurry-sealing or chip-sealing the roadway and not the bike lanes; and
   - Incorporating dyes into concrete or asphalt.
3. **Chicanes**. By alternating on-street parking, landscaping or other physical features from one side of the road to the other, the driver does not see an uninterrupted stretch of road. The roadway width remains adequate for two cars to travel.

8.5.5.2 Roundabouts

Roundabouts are a common form of intersection control used throughout the world. Until recently, many State and local agencies throughout the United States have been hesitant to recommend and install roundabouts due to a lack of objective nationwide guidelines on planning, performance and design of roundabouts. The FHWA publication *Roundabouts: An Informational Guide*, explains some principles of good design and indicates potential tradeoffs of roundabouts, along with addressing the following topics:

- Definition of a roundabout and what distinguishes roundabouts from traffic circles;
- Methodology for identifying appropriate sites for roundabouts and the range of conditions for which roundabouts offer optimal performance;
- Methodology for estimating roundabout capacity and delay;
- Design principles and standards to which roundabouts should conform, including applicable national standards (e.g., the AASHTO *Policy on Geometric Design of Highways and Streets*, the *Manual on Uniform Traffic Control Devices)*;
- Consideration for all modes, including heavy vehicles, buses, fixed route transit, bicycles, pedestrians and emergency vehicles;
- Guidelines for operational features (e.g., signing, pavement markings, illumination, landscaping); and
- Public acceptance and legal issues associated with roundabouts.

8.5.6 EVALUATION OF THE DESIGN FOR WEATHER CONDITIONS

Most of the time, a roadway surface is dry and will allow a vehicle to respond in a predictable manner while the driver is negotiating stops, curves and lane changes. The engineer should also take into account what will happen to the roadway surface during inclement weather activities as well, especially if these activities recur every season. Vehicles traveling on impaired road surfaces often lose traction. With a loss of traction comes a loss of control of the vehicle. The problem is exacerbated when out-of-control vehicles on impaired roads frequently end up crossing the centerline and colliding head-on with oncoming vehicles. The oncoming vehicle has limited defensive capabilities as their tire friction and opportunity to respond is also impaired.

The following sections discuss recurring activities and some precautions that should be considered as the design is developed.

8.5.6.1 Skid Resistance

During field reviews of the road, if any patch of slick or damaged asphalt is observed, this will prohibit proper friction between the vehicles tires and the roadway during inclement weather. The surface should be repaired and covered with a friction course or wearing course.

For information regarding skid resistance on unpaved roads, see the design guidelines in the AASHTO *Guidelines for Geometric Design of Very Low-Volume Local Roads*.

8.5.6.2 Black Ice

Black ice is typically formed due to snow melt running across the roadway surface during the day, and freezing on the roadway or bridge surface at night. Some of this can only be mitigated with proper snow maintenance activities (e.g., plows pushing the snow completely off of the roadway surface and into a ditch). As a designer, there are elements of design that can minimize the occurrence of snowmelt from crossing the roadway. These include:

- In areas where there is no ditch, consider the installation of concrete barriers to prevent runoff from reaching the roadway surface.
- Clear trees sufficiently away from the roadway, ensuring no shadows are present on the pavement that would retain ice on the roadway in spots rather than melting and draining away.
- Avoid abrupt horizontal curves in areas where ice may form, especially on bridge decks, as these surfaces stay frozen the longest.

8.5.6.3 Snowpack and Snow Storage

To prevent black ice from occurring, there must be adequate storage for plowed snow to be contained off of the roadway prism while it melts. The designer must consider not only the capacity to handle the melted water in the runoff, but the area required to contain the snow mass while it melts. Finally, if the slopes adjacent to these storage areas can be cleared sufficiently to allow late-day sun, the site would benefit from quicker melting times.

8.5.6.4 Fog

When fog occurs on the roadway, visibility distance is hindered. This in turn impacts traffic flow through reduced travel speed, which leads to increased speed variance between drivers, delayed travel time and ultimately increased collision risk. The operational impacts of fog hinge on driver capabilities/behavior, road treatment strategy, access control, and speed limit control. Specific mitigation measures for fog are not readily available. Some possible methods of dealing with low visibility conditions include:

- Advisory strategies to provide information on predicted and prevailing conditions. Such systems typically involve the installation of low visibility warning systems that use computer systems to predict foggy conditions. The system can alert traffic managers for deployment of additional safety forces to the roadway, turn off overhead lighting to reduce glare, and warn motorists of the conditions and to drive appropriately.
- Control strategies to regulate traffic flow and roadway capacity. Examples could be to close or reduce capacity of roadways frequently experiencing foggy conditions.
- Treatment strategies to provide roadway elements to mitigate weather impacts. Examples can include installation of raised or recessed pavement markers, rumble strips, or profiled pavement markings to better define the roadway limits and direction to the driver.

The benefits of road weather management strategies include improved safety due to reduced crash risk, increased mobility due to restored capacity, reduced delays, and more uniform traffic flow. Other benefits include increased productivity due to reduced labor, treatment material, and equipment costs.

8.5.6.5 Bridge Conditions

One of the most challenging elements to consider as part of bridge design is the force of nature, specifically the weather. Rain, ice, and wind can each have a substantial influence on the stability of a structure. Bridge designs have evolved to improve upon experienced failures of the past. Iron has replaced wood; steel has replaced iron; and pre-stressed concrete has replaced steel in many locations. Each new material or design technique builds off the lessons from the past. Weather-related problems, however, have yet to be completely eliminated. Cases of weather-related failure on bridges far outnumber those of design-related failures. To this day, there is no specific construction material or bridge design that can completely eliminate or mitigate these effects. When evaluating an existing bridge site, consider the site elements that will not likely exist during the inspection period, such as the following:

- Runoff: With respect to rainfall and runoff, the best solution involves diverting all runoff before it can access the bridge structure. For water that is captured on the bridge deck, ensure the water can be diverted off of the deck without causing ponding or more than allowable spread on the travel way. In some rural areas on low volume roads, runoff may be allowed to sheet flow directly off of the structure and into the drainageway or water body that is being crossed (confirm this is acceptable with the environmental agencies). This solution ensures no ponding can occur on the deck at any point. If the water must be conveyed off the structure, ensure no sags or “birdbaths” exist on the deck that could capture the runoff. Finally, with very long structures, if the runoff must be captured within a drainage system, the pipes must not only have the capacity to carry the runoff from the structure, they must also be maintainable and free from obstructions during all types of weather. The pipes should be accessible to have sediments and debris removed, and insulated against possible freezing if located in colder climates (as this is very difficult and expensive, these systems are typically not used in colder climates).

- Hazardous Spills: With inclement weather, the possibility of hazardous or undesirable materials being drained into sensitive waters is another bridge concern. Depending on the local environmental requirements, two mitigation measures may be required for this condition: (1) the runoff must be routed into a drainage structure that can filter out the first flush contaminants (using a absorbent filter for example); or (2) diverting the runoff from the bridge into a containment basin that can retain spills and runoff before entering a protected waterway.
- Snow and Ice: In cold climates, bridges typically are the first segments of the roadway surface that will freeze up. In these climates, structures should be designed to be straight with minimal grades. If they must incorporate horizontal curves, it is best that the curve be started in advance of the bridge, with the full superelevation developed in advance of the structure. Sag vertical curves must be avoided as the runoff will typically freeze and accumulate at the low point. As noted above, conveying drainage runoff through a pipe system during snow conditions usually results in frozen pipes that clog. Some pipes freeze solid and expand, slitting the pipe material and making it useless once the snow melts.
- Debris: Bridges and drainage facilities alike are designed to convey a design volume through a given opening. Over time, debris can accumulate at the entrance of the structure, reducing the capacity of the structure. Similar to a drainage inlet, the opening to the structure must be free of debris, and free from materials that may trap debris.

8.5.6.6 Barrier and Bridge Rail Considerations

Roadside and bridge barriers are typically designed independent of drainage systems. When the site gets inundated with rain or snow, the interrelation between these two design elements becomes more apparent. Evaluate the impacts of snow and rain on the barriers in the following scenarios:

- Permeable vs. non-permeable barrier designs in snow areas: When snow is removed from the roadway surface and placed behind the barrier, will the runoff from the stored snow cross through the barrier (i.e., on superelevated roadway sections with W-Beam rail sections), or be directed behind the rail to swales or other conveyance facilities. Of primary concern is that if the snow removed in the early morning is piled behind the barrier, will it melt during the day only to create a patch of black ice when it freezes again in the evening?
- Plow conditions: Will the maintenance equipment for the roadway have the ability to push snow along or through the barrier, or throw snow over the barrier? If materials can only be pushed, there must be opportunities to dispose of the snow in open areas, or the shoulders will be used for snow storage.

8.6 TRAFFIC ANALYSIS

A traffic analysis is an evaluation of the roadway's projected demand and the effects of that demand on the capacity of either the existing or proposed facility.

The analysis of the traffic on a transportation facility is a fundamental concern of transportation engineering. There are essentially two components of traffic analysis:

1. **Demand**. The traffic load that will use the facility (projected traffic volumes).
2. **Supply**. The ability of the roadway to handle the traffic load or the roadway's capacity.

8.6.1 TRAFFIC DEMAND

One of the real complexities of the transportation problem is the inability to accurately predict and control the level of demand for the system or the service. Transportation demand is generally related to social and economic influences. Transportation demand generally relates to commuters or visitors that result in other activities that may eventually lead to a physical load (e.g., the passage of vehicles over a section of roadway or a street).

A multitude of factors can contribute to the level of transportation demand, and are summarized in the following sections.

8.6.1.1 Average Annual Daily Traffic (AADT)

The foundation of demand is based on the current traffic counts of a facility. The measurement of traffic is generally considered to be in terms of the flow of vehicles. The flow is typically expressed in terms of vehicles per unit of time.

Some commonly used units of measurement for traffic flow are vehicles per day, vehicles per hour, passengers per day, etc. The common measurements of traffic flow are vehicles per day (veh/day) or vehicles per hour (veh/hr). A good reliable indicator of the general level of traffic activity on a street or a roadway is the Average Annual Daily Traffic (AADT). This is the total annual traffic at a highway location divided by the number of days of the year. If the facility is not open all year long, then traffic volumes will only be described in seasonal averages.

8.6.1.2 Seasonal Variations

Many facilities have varying traffic volumes throughout the year. These seasonal fluctuations can vary greatly, but they are generally very predictable. Seasonal peaks are particularly important to recreational facilities. To make adequate projections, traffic counts must be acquired throughout the year at regular intervals. These counts will generate a pattern that can be used to project the Average Daily Traffic (ADT) for any given season.

8.6.1.3 Peak Hour/Design Volumes

Average daily traffic counts (collected for continuous 24-hr periods) are the typical source of traffic volume information. Designing the facility to meet the average daily traffic can result in significant delays during the higher use periods. The highest hourly volume that occurs in a given day is called the Peak Hourly Volume (PHV). The Design Hourly Volume (DHV) is the standard for estimating the peak traffic loads during the day for design. It is based on the 30th highest PHV of the year. This volume can be determined using Equation 8.6(1):

$$DHV = AADT \times K \qquad \text{Equation 8.6(1)}$$

Where:

DHV = Design Hourly Volume in the design year

AADT = Average Annual Daily Traffic (vehicles per day) in the design year; see Section 8.6.1.1

K = Design Hour Factor (the proportion of daily traffic traveling during the design hour expressed as a decimal); see Section 8.6.1.6

8.6.1.4 Trends (Past and Projected)

To determine trends affecting transportation facilities, it is important to review past and recent history to have a reasonable idea of what to expect in the future. The more historical information that can be provided and evaluated, the better and more accurate the projection will be. In addition to volumes, it is also important to determine where patrons are coming from, be they local, statewide, regional, national, international, or a mix.

Local Growth / Population Trends. For most county and state facilities, the respective DOT keeps historic records of traffic counts for various types of roadways. If no major developments are to occur that would change the trends to the traffic numbers, simply plotting the historic rates will produce a growth factor that can be used for estimating future traffic volumes. If the roadway being improved is to serve a new facility, or if the existing facility will be experiencing significant development improvements, these historic rates may need to be increased. Discussions with local planners at both the County and State transportation jurisdictions can usually provide insights to such matters. Typical values range from 1.5% to 3% while values as high as 4% are only experienced in areas with significant new development or unusually high growth.

Park Visitor Attendance History/Projections. For all national park facilities, the NPS keeps records of both visitor and traffic counts that can be used to evaluate trends and form a basis for projections.

Intersection Turning Movement Projections. At some entrance or intersection locations, it is also essential to evaluate where patrons are arriving from (directional), so determining origin and destination is also important. To determine the adequacy of an intersection, AM, PM, or weekend peak hour turning movements may be needed to evaluate the efficiency of an intersection. This information is not typically available from an existing database, but must be gathered by counting the traffic at a given intersection. Once this information is determined, the same growth rate used to project the future, overall traffic needs of the roadway can be applied to the turning movements at the intersection.

8.6.1.5 Classifications

Transportation demand certainly varies between different types of roadways. Roadways are characterized by determining their functional classification. The functional classification of a particular roadway establishes a range of design speeds and also defines a range of design parameters. Classification is normally determined during the planning and programming phase, and it is verified with consideration of additional data as part of the conceptual engineering studies. Refer to Section 9.3.1.2 for guidance on functional classification, as well as FHWA Functional Classification Guidelines.

8.6.1.6 Traffic Factors (K, D, T)

Several factors are used to evaluate the traffic flow. The three most common factors provided include the Design Hour Factor (K), the Directional Split Factor (D) and the Heavy Vehicle Factor (T). These factors are usually determined on the basis of regional or route-specific characteristics.

K Factor: The Design Hour Volume is typically the 30th highest hourly volume experienced in a year. The factor used to express this volume as a percentage of the annual average daily traffic is defined as the K-Factor [Design Hour Volume = AADT × (K-Factor)]. If no specific information is provided, the typical K factor for a rural facility is 12 to 15 percent, and 10 to 12 percent for an urban facility.

D Factor: This factor accounts for the directional distribution of the traffic. Values generally range from 0.54 to 0.59 and are used to convert average daily traffic to directional peak hour traffic. If this factor is unknown or cannot be easily determined, a default D-factor of 55 percent may be used (expressed as 0.55). Note that for one-way streets, the D-factor becomes 1.0 since 100 percent of the traffic is traveling in the same direction.

T Factor: Roadway capacity is reduced as the number of large trucks, recreation vehicles, and buses increase. The T-Factor (Heavy Vehicle Factor) is used in calculating the level of service (LOS) of a roadway based on the percentage of heavy vehicles. If the relative proportions of RVs, trucks and buses are not known, the heavy vehicles can be considered trucks when determining passenger-car equivalents. If this factor is unknown or cannot be easily determined, a default T-factor of 5 percent may be used in urban areas and 10 percent in rural areas.

8.6.1.7 Turning Movements

In order to determine if an intersection or interchange will work at a given Level of Service (LOS, see Section 8.6.2.1), it is necessary to utilize peak hour turning traffic volumes at the specific site to be analyzed. These turning traffic volumes (typically AM and PM peak hours) are usually based on actual volume counts made at the existing intersection, and can be projected for the future using the same growth rates used in traffic projections (typically, 20 years out). Traffic at intersections is generally divided into left-turn, through, and right-turn traffic volumes. The designer can then use these traffic volumes to perform a capacity analysis and resulting LOS to determine how many left-turn, through, or right-turning traffic lanes (or combined left-turn and through lanes, or combined through and right-turn lanes) are needed.

If traffic counts are collected to determine the effectiveness of current or proposed geometry, the traffic counts should be done in 15 minute increments in both the morning and afternoon heavy use periods. In that way, a Peak Hour Factor can be established and used to determine the intersection LOS. The Peak Hour Factor (PHF) is the ratio of hourly demand to four times the peak 15-minute demand [Highest sum of 4 consecutive 15-minute periods / (4 × highest 15-minute flow rate)]. This ratio typically ranges from 0.75 to 0.95. The higher values tend to occur as demand approaches capacity on the facility. Default values of 0.88 for rural areas and 0.92 for urban areas may be used in the absence of local data.

8.6.1.8 Speed and Delay Data

Speed and Delay can be measured or calculated to help determine Level of Service (LOS, see Section 8.6.2.1). Free-flowing roadways (such as freeways) are impacted by increasing traffic volumes and density, with reduced speeds typically resulting as traffic volumes increase. Traffic speeds can be determined by using speed measuring devices (such as radar or surface instruments) or by the “floating car” method. The floating car method involves driving at the general speed of most traffic and making several passes (at least 3) on the segment of roadway being measured. In that manner, a representative example of current traffic speeds can be obtained.

Intersections that are controlled by traffic control devices (such as a traffic signal or a Stop sign) are not free flowing facilities, so the LOS is determined by average traffic delays (and not average speeds). Traffic delays can be measured by several different approaches, including stop watches, video tape, traffic detectors, etc. Traffic delay can be measured in two different manners, stopped-delay and control-delay. Stopped delay is the time a vehicle is actually stopped due to a traffic control device. Control device includes the time of slowing, stopping, and accelerating to normal speeds, and typically is approximately 30% higher than just the stopped delay (at a traffic signal).

8.6.1.9 Conflict Study Data

Conflicts are traffic events involving two or more vehicles where one or both take evasive action to avoid a collision. Conflicts can be identified as a potential conflict, where the paths of two cars cross and a collision "may" occur, such as a left-turning vehicle in one direction crossing the path of an opposing through traffic vehicle at an intersection.

Conflicts can also be measured to determine how many actual conflicts occur over a given period of time at an intersection. Traffic conflict studies provide an effective way to measure traffic safety, supplement crash studies in estimating the potential for accidents at a given intersection, and can measure the effectiveness of a given geometry or traffic control device.

Conflicts can also be considered at vehicle interactions which "may" lead to crashes. For a conflict to occur, traffic must be on a collision course (attempting to occupy the same space/same time). The action of the first user places the secondary user on a collision course unless corrective action is taken. If corrective action is not taken, or inadequate or inappropriate action is taken, the result would be a near-miss or an accident, resulting in a "conflict."

Conflict studies typically involve using trained observers or devices such as video taping to be able to methodically identify and catalog traffic conflicts.

8.6.1.10 Presentation of Traffic Data (Data required for Highway Design Standards Form)

The complexity of the traffic data collected varies by the site and project requirements. For every project, there is a minimum amount of traffic data that is desired for every project. This information is typically collected at the onset of the project development process, and summarized in the Highway Design Standards Form (see Section 9.1.3). This information is generally presented in a tabular format similar to Exhibit 8.6–A.

8.6.2 HIGHWAY CAPACITY

The method used for describing and determining capacity and traffic operating conditions is outlined in the *Highway Capacity Manual* (HCM).

8.6.2.1 Level of Service

Level of Service (LOS) is defined as a qualitative measure of operational conditions within a traffic stream and the perception by motorists. Six levels of service, LOS A through LOS F, are used to designate different operating conditions in terms of such factors as speed, travel time, freedom to maneuver, traffic interruptions, comfort, and convenience. Safety is not included in the measures that establish service levels.

There are several analytical methods presented in the HCM to determine the LOS of a roadway or intersection.

Most design or planning efforts typically strive for service flow rates of LOS C in rural areas, and LOS D in urban areas in the design year.

Exhibit 8.6–A HIGHWAY DESIGN STANDARDS FORM TRAFFIC DATA

		ADT				
TRAFFIC	**YEAR**	**AVERAGE**	**SEASONAL**	**DHV**	**PERCENT TRUCKS**	**D**
Current	(1)	(3)	(5)	(7)	(8)	(9)
Design	(2)	(4)	(6)			

Note: The procedures for determining the data within each of the fields listed above are summarized as follows:

1. Current Year: This is the current year, the year the design development is occurring.
2. Design Year: This is typically a projection that is 20 years from the anticipated completion of construction.
3. Current Year ADT: Current Year Average Daily Traffic. The value is typically provided by the land manager. For example, current and historic traffic data is available for all NPS roads from the Eastern Federal Lands web site. Values for forest and county roads are typically available from State or County transportation departments. Some minor facilities may not have frequent traffic counts, and estimates or site counts are required to determine the current traffic volumes.
4. Design Year ADT: Estimate the volume of traffic in the design year by determining the average annual growth that will occur for the facility (as discussed in Section 8.6.1.4), and applying a standard annual growth formula to determine the future traffic demands [i.e., Design Year ADT = (Current Year ADT) × (1+ Annual Growth in decimal percent)^(number of years between current and design year)]
5. If the facility has heavy seasonal shifts in visitor traffic, determine the SADT per Section 8.6.1.2.
6. Similar to (4) above, extend the current seasonal values into the future by the anticipated growth rate.
7. The design hourly volume (DHV) is described in Section 8.6.1.3, and is equal to the AADT × K-Factor.
8. Determine the percentage of heavy vehicles such as trucks, RVs and buses, as noted in Section 8.6.1.6.
9. Determine the directional split factor, as noted in Section 8.6.1.6.

8.7 TRAFFIC DESIGN

The safe and efficient movement of traffic through the highway project necessitates that designers review the proposed design from a traffic operations standpoint. The designer needs to be alert for situations that involve alterations in the driver's behavior or changes in driver attention. During the design phase, the designer should attempt to perceive the final roadway as it will appear to the motorist anticipating the necessary traffic control devices. Traffic control devices are intended to provide the user with sufficient advance information so the highway can be driven safely. Through the proper application of design standards, the number of motorist decision points will be minimized. There will, however, always be a need for appropriate permanent traffic control devices to inform, regulate and/or warn the motorist. A review of the safety analysis will generally identify areas of existing operational problems.

Field reviews during construction are encouraged to substantiate if the original perceived operational characteristics of the project were germane and to provide timely adjustments during construction should they be warranted. After construction is completed and the project is opened to traffic, an evaluation should be made of the traffic control devices to determine their adequacy and if they are functioning as planned.

See Section 9.3 for traffic design topics not covered in the following sections.

8.7.1 SIGNING AND DELINEATION

The *Manual on Uniform Traffic Control Devices (MUTCD*) is the national standard for signing, signalization, channelization and pavement markings for all public roads in the United States. The Standard Highway Sign (*SHS*) book, the *NPS UniGuide Standards*, the *Forest Service Sign Manual*, and state DOT manuals provide additional design criteria, methods and charts for design.

All traffic control devices shall be in accordance with the MUTCD. Compliance with the requirements of the MUTCD for all traffic control devices is mandatory and includes the following:

- Use;
- Placement;
- Uniformity;
- Maintenance;
- Color;
- Size;
- Shape;
- Legend;
- Retroreflectivity; and
- Removal, when not applicable.

The main message of the MUTCD is the importance of uniformity. Substantial adherence to the *MUTCD* is required on all public roads. However, some owner agencies have supplements or have developed similar manuals (e.g., the NPS Sign Manual), that must also be considered when designing and constructing roads under their jurisdiction. The ITE *Traffic Control Devices Handbook* supplements the MUTCD by providing basic information and criteria to address most questions that are relative to traffic control devices and their applications.

Highway users are dependent on traffic-control devices (i.e., signs, markings, signals) for information, warning and guidance. Uniform, high-quality devices are important for the safe, efficient use and public acceptance of any road regardless of the width, alignment and structural design.

Any traffic control device should meet five basic requirements:

- Fulfill a need;
- Command attention;
- Convey a clear, simple meaning;
- Command respect from road users; and
- Give adequate time for proper response.

The following aspects should be carefully considered in order to maximize the ability of the traffic control device to meet the five requirements listed above:

- Design,
- Placement and operation,
- Maintenance, and
- Uniformity.

Consideration should be given to these requirements and aspects during the design stage to ensure that the required number of devices can be minimized and properly placed. In addition, local variations in laws and ordinances must be complied with when installing traffic control devices (i.e., all regulatory traffic control devices shall be supported by laws, ordinances, or regulations).

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

8.7.1.1 Signing

The above cited references provide the designer with the information required to properly select the appropriate signing.

The authority for regulatory signing rests with the maintaining/regulating agency. Likewise, the client agency may have specific concerns regarding warning or informational signs. The designer's responsibility is to identify all signs required and review them with the appropriate agencies during project development.

Some owner agencies may have established sign plans for particular routes or regions; these plans should be requested and reviewed during project development. For example, the NPS Director's Order 52C, *Park Signs*, requires each park to have an established sign plan. These plans should be reviewed together with crash statistics and any available safety studies to ensure continued appropriateness whenever additional construction work takes place.

8.7.1.1.1 Sign Supports

Sign supports should be designed in accordance with the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*. Owner agency practice, in accordance with the above standards, may dictate the types of materials to be used. **Sign supports and luminaires left unprotected by a barrier system and located within the clear zone shall be breakaway or yielding and meet the requirements of NCHRP 350.** See the FHWA lists of breakaway hardware for approved designs.

8.7.1.1.2 Sign Design

Any site-specific signs that are developed must be evaluated to ensure the lettering is large enough to be both visible and legible at the distance and speed that the user is traveling. Lettering sizes varies with the design speed. This information is found in the *MUTCD*, *SHS*, *NPS UniGuide Standards*, or other owner agency documents.

The MUTCD requires that traffic signs be illuminated or retroreflective to enhance nighttime visibility. The retroreflective sheeting on sign panels gradually deterioerates over time making signs less visible. Within the project limits, signs must be evaluated for appropriate levels of retroreflectivity (See MUTCD 2A.08). It is recommended that all permanent regulatory (black on white/ white on red), warning (black on yellow), and destination and directional guide (white on green or brown) be replaced with new panels conforming to the MUTCD. All other signs (e.g., parking, trails, information, etc.) should be evaluated on a project by project basis to determine the need for replacement.

8.7.1.2 Pavement Markings

Pavement markings have definite and important functions to perform in a proper scheme of traffic control. In some cases, they are used to supplement the regulations or warnings of other devices (e.g., traffic signs, signals). In other instances, they are used alone and produce results that cannot be obtained by the use of any other device. In these cases, they serve as a very effective means of conveying certain regulations and warnings that could not otherwise be made clearly understandable.

Pavement markings have definite limitations. They can be obliterated by snow, may not be clearly visible when wet and may not be very durable when subjected to heavy traffic. In spite of these limitations, they have the advantage, under favorable conditions, of conveying warnings or information to the driver without diverting the driver's attention from the roadway.

8.7.1.2.1 General Application

Each standard marking shall be used only to convey the meaning prescribed for it in the *MUTCD*. Before any newly paved highway, surfaced detour or temporary route is opened to traffic all necessary markings must be in place.

Remove or obliterate markings no longer applicable, or which may create confusion for the motorist, as soon as practicable. Painting over markings is not an acceptable method of obliteration. Markings must be retroreflective.

All markings shall be placed in accordance with the *MUTCD*.

8.7.1.2.2 Pavement Marking Materials

The standard material used for pavement markings is a conventional or waterborne paint with retroreflective beads. All other pavement-marking materials are considered to be upgraded materials. To upgrade, consideration must be given to material performance, material cost, traffic volume and type, climatic conditions, availability of materials and installation equipment (both for initial installation and maintenance). Only when an upgraded material is established to be more cost-effective than the standard material can the upgraded material be used. The following guidelines may be used for upgrading the striping material in lieu of an economic evaluation:

1. **Epoxy and Polyester Materials**. Epoxy thermoplastic (ETP), epoxy and polyester materials may be specified for centerlines, lane lines and edge lines under any of following conditions:
   - The average daily lane volume is in excess of 1000;
   - Because of environmental, traffic or climatic conditions, it is necessary to restripe with paint two or more times a year, or epoxy every two years; or
   - The location is not proposed or scheduled for sealing or resurfacing within the next three years.
2. **Thermoplastic and Preformed Plastic Materials**. Thermoplastic and preformed plastic type materials may be allowed for centerlines, lane lines and edge lines when one of the following conditions are met:
   - The average daily lane volume is in excess of 5000;
   - The location is not proposed or scheduled for sealing or resurfacing within the next five years; or
   - The pavement markings are considered critical (e.g., intersections, lane drops).

These upgraded materials may be specified under lower traffic conditions where directed by the owning agency or where there is a need to emphasize transitions, channelization or special markings (e.g., stop lines and crosswalks). Before specifying these materials, additional consideration should be given to justify the added costs of these materials if it will be less than three years before the pavement is scheduled for sealing or resurfacing.

8.7.1.3 Raised Pavement Markers

Raised pavement markers (RPMs) are intended to be used as a positioning guide or to supplement or substitute for pavement markings. RPMs can be retroreflectorized or nonretroreflectorized, and they may be mounted on the pavement surface or recessed. The color of the RPMs shall conform to the color of the pavement markings for which they supplement or substitute.

The appropriate type of RPMs and/or snow-plowable recessed low profile markers should be considered for the following:

- Intersection channelization,
- Directional left-turn lanes,
- High hazard/crash locations,
- Areas of frequent inclement weather, and
- Gore areas and approaches to deceleration lanes.

Retroreflective RPMs have one or more retroreflective lenses and a base. They may be used in conjunction with, or as a substitute for, pavement markings. Nonretroreflective RPMs should not be used alone, but can supplement pavement markings or retroreflective RPMs.

8.7.1.4 Rumble Strips

Roadway departure fatalities account for almost half of all traffic fatalities and include run-off-road (ROR) and head-on fatalities. The main causes of these crashes are driver inattention, drowsiness, and carelessness. Noise and vibration produced by rumble strips are effective alarms for drivers who are leaving the roadway. They are also helpful in areas where motorists battle rain, fog, snow or dust.

Rumble strips are raised (by using RPMs) or grooved patterns on the roadway that provide both an audible warning (rumbling sound) and a physical vibration to alert drivers that they are leaving the driving lane. In addition to warning inattentive drivers, rumble strips help drivers stay on the road during inclement weather when visibility is poor. Some States paint stripes over the rumble strips (i.e., rumble stripes) to make them visible.

There are three types of rumble strips. The most common type is the continuous shoulder rumble strip (CSRS). These are located on the road shoulder to prevent roadway departure crashes on expressways, interstates, parkways and two-lane rural roadways that have high numbers of single-vehicle crashes. Centerline rumble strips are used on some two-lane rural highways to prevent head-on and sideswipe type collisions. Transverse rumble strips are installed on approaches to intersections, toll plazas, horizontal curves, and work zones.

See the FHWA Rumble Strips website for more information on rumble strips.

8.7.2 TRAFFIC SIGNALS

Traffic control signals are devices that control vehicular and pedestrian traffic by assigning the right-of-way to various movements for certain pre-timed or traffic-actuated intervals of time. Traffic control signals are one of the key elements in the function of many urban streets and of some rural intersections. The planned signal system for a facility should be integrated with the design to achieve optimum safety, operation, capacity and efficiency. Careful consideration should be given in plan development to intersection and access locations, horizontal and vertical curvature, pedestrian requirements and geometric schematics to ensure the best possible signal progression, speeds and phasing. In addition to the initial installation, future needs should also be evaluated.

The design of traffic signal devices and warrants for their use are covered in the *MUTCD*. Consult additional reference sources when designing signalized intersections and other traffic control systems not covered by the *MUTCD*. The ITE *Traffic Control Devices Handbook* provides the fundamental procedures for proper analysis and design of traffic control systems as well as the *Highway Capacity Manual*.

Owner agencies or State highway agencies are good sources for design assistance, particularly in the area of equipment compatibility and electrical design.

8.7.3 ILLUMINATION

Highway illumination helps promote safe and orderly movement of traffic at night, and reduces the probability of crashes due to insufficient visibility. Roadway lighting design is complex enough that computer software analysis tools are generally needed in order to take into consideration roadway geometry (horizontal and vertical), the impact of one illumination source upon another, and the various illumination results caused by varying the type of lighting source and the vertical and horizontal aspects of lighting caused by the height and location of the illumination source(s). Also, the impacts of lighting pollution needs to be taken into consideration, as residential areas and the ability to see the night sky can be impacted by the design of highway illumination.

Intersection illumination is generally provided to improve night-time safety conditions for drivers, pedestrians and bicyclists.

Sign illumination is used to ensure legibility of overhead signs during night-time conditions. A sign may be illuminated externally or internally.

Tunnel lighting requires a great deal of attention and analysis. The greatest impacts to drivers in tunnels occur during the daytime and impact drivers greater than during night-time conditions, as the eye must adapt from bright to dark and then to bright again.

The steps in lighting design generally include:

- Familiarity with the project and design requirements.
- Selection of general types of fixtures and poles to be used.
- Locating the fixtures.
- Performing computations to assure compliance with design criteria.

The computational aspects of lighting design typically involve these criteria:

- Luminance (cd/m^2) – indicates the relative brightness of a roadway after considering the amount reflected from the pavement by a given light source

- Illuminance (Lux) – is the measurement of light incident on the roadway from a given light source.
- Small Target Visibility – is affected by the luminance of the target, the background, the adjacent surroundings, and glare.
- Lighting Pollution – or uplighting, is the amount of light that is directed upwards rather than down towards the roadway, and is affected by the inclusion of cutoff or semi-cutoff lighting fixtures which limits the amount of uplighting.
- Light Trespass – is the amount of unwanted lighting in areas such as residential neighborhoods.

Practitioners have various documents that they can utilize when designing highway lighting, AASHTO's *Roadway Lighting Design Guide* (2005) being one of the more popular. This guide contains recommended warrants for lighting and various lighting design criteria which can be used as a guide when conducting lighting analysis and preparing lighting designs.

8.7.4 HIGHWAY-RAIL GRADE CROSSINGS

The function of traffic control at highway-rail grade crossings is to permit reasonably safe and efficient operation of both rail and highway traffic at highway-rail grade crossings. See Part 8 of the *MUTCD* for more information on traffic control for these types of intersections. For guidance on the geometric design of railroad-highway grade crossings refer to Section 9.3.15.

The appropriate traffic control system used to provide crossing protection at a highway-rail grade crossing should be determined by an engineering study involving both the road agency and the railroad company. Crossing protection is either passive or active, as described in the following sections.

8.7.4.1 Passive Crossing Protection

Passive crossing protection includes signing, pavement markings and, if applicable, grade crossing illumination. Signing used at railroad grade crossings should include the following:

- A railroad crossing sign commonly identified as the Crossbuck sign (R15-1). The Crossbuck sign shall have a strip of retroreflective white material on the back of each blade, except where Crossbucks have been installed back-to-back. The Crossbuck sign post shall also have a retroreflective strip on both sides, facing traffic. The railroad is typically responsible for placement and maintenance of Crossbuck signs. Improvements may need to be made as part of the highway project.
- An auxiliary railroad crossing sign (R15-2) of an inverted T-shape mounted below the Crossbuck sign to show the number of tracks when two or more tracks are between the signs.
- An advance railroad warning sign (W10 series).

- An exempt railroad crossing sign (R15-3) as a supplemental sign (when authorized by law or regulation) mounted below the Crossbuck. The railroad advance warning signs may also be supplemented with an exempt sign (W10-1a).
- A DO NOT STOP ON TRACKS sign (R8-8).

Pavement markings placed in advance of a grade crossing on all paved approaches must consist of railroad pavement markings, NO PASSING markings for two-lane roads and stop lines, if needed.

If an engineering study is conducted and determines that better nighttime visibility of the crossing is needed, consider installing illumination at and adjacent to the Highway-rail grade crossing. Consider lighting where train speeds are low, where crossings become blocked for long periods, or where crash history shows that motorists experience difficulty in seeing the crossing, trains or control devices during hours of darkness.

8.7.4.2 Active Crossing Protection

Active crossing protection consists of post-mounted and/or cantilever flashing light signals and, where warranted, the addition of automatic gates. Bells or other audible warning devices may be included in the assembly.

There is no single standard system of active traffic control devices universally applicable for grade crossings. Perform an engineering study to determine the type of active traffic control system that is appropriate to consider. Refer to State standards for the level of crossing protection needed. If State standards do not apply, Exhibit 8.7–A may be used to help determine the level of crossing protection to provide.

Use the signals shown in the current edition of the *MUTCD* and the *Railroad-Highway Grade Crossing Handbook (FHWA-SA-07-010)* for active crossing signal installations. The locations of signals and automatic gates are shown in the *MUTCD.* A railroad signal may be a point hazard that warrants the use of a traffic barrier or a crash cushion. Install all traffic barriers (see Section 8.5.3) or crash cushions (see Section 8.5.4) outside the minimum railroad clearance as shown in the MUTCD.

Exhibit 8.7–A GUIDELINES FOR RAILROAD CROSSING PROTECTION

Type of Highway	Exposure Factor[1]	Type of Railroad Facility	
		Non-Mainline	Mainline
Two Lane	Under 1500 1500 to 5000 5000 to 50 000 Over 50 000	Retroreflective Signs Flashing Lights Automatic Gates[2] Separation	Flashing Lights Flashing Lights Automatic Gates[2] Separation
Multilane	Under 50 000 Over 50 000	Automatic Gates Separation	Automatic Gates Separation
All Fully Controlled Access	In all cases	Separation	Separation

Notes:

1. Exposure Factor = Trains per day x vehicle ADT.
2. Automatic Gates to be used in urban areas and flashing lights in rural areas, unless conditions warrant otherwise.

8.7.5 INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

Intelligent Transportation Systems (ITS) are wired or wireless communication based information and electronics technologies that relieve traffic congestion and improve roadway safety. ITS generally includes one or more of the following types of systems (with examples):

- Arterial Management
  - ◊ Coordination of traffic signals
  - ◊ Signal preemption for emergency vehicles
  - ◊ Adaptive or advanced signal systems (real-time)
  - ◊ Special event capabilities
  - ◊ Reversible lanes
  - ◊ Dynamic message signs
- Freeway Management
  - ◊ Ramp meters
  - ◊ Dynamic message signs
  - ◊ Vehicle detection
  - ◊ CCTV cameras
  - ◊ HOV
  - ◊ Special events, emergencies
  - ◊ Identify detour routes (electronic trailblazers)

- Traffic Management or Operations Centers (TMC or TOC)
    - ◊ Central facilities for ITS system operations
    - ◊ Electronic wall maps
    - ◊ CCTV images
    - ◊ Computer operator stations
    - ◊ Coordination with police and emergency responders
- Transit Management
    - ◊ Surveillance
    - ◊ Signal Priority
    - ◊ Dynamic Routing
    - ◊ Information Dissemination
- Incident Management
    - ◊ Surveillance and Detection
    - ◊ Mobilization and Response
    - ◊ Information Dissemination
    - ◊ Clearance/Recovery
- Emergency Management
    - ◊ Hazmat Management
    - ◊ Emergency Medical
    - ◊ Response and Recovery
- Electronic Payment
    - ◊ Tolls
    - ◊ Transit
    - ◊ Parking
    - ◊ Multi-use
- Traveler Information
    - ◊ Pre-trip (Web, Kiosks, other)
    - ◊ En-Route (511, In-Vehicle, Other)
    - ◊ Tourism and Events
- Information Management
    - ◊ Archiving Data (for planning, operations, research, administration)
- Crash Prevention
    - ◊ Road Geometry Warning (Ramp Rollover)
    - ◊ Highway-Rail Crossings
    - ◊ Intersection, pedestrian, bicycle, animal warning systems
- Roadway Operations
    - ◊ Construction/Maintenance Information (web and DMS's)
    - ◊ Asset Management
    - ◊ Work Zone Management

- Road Weather
  - ◊ Surveillance and Prediction
  - ◊ Response and Treatment
  - ◊ Traffic Control
  - ◊ Information Dissemination
- Commercial Vehicle Operations
  - ◊ Tracking
  - ◊ Terminal/Border Crossings
- Intelligent Vehicles
  - ◊ Collision Avoidance
  - ◊ Collision Notification
  - ◊ Driver Assistance

ITS analysis involves utilizing the National ITS Architecture which is a common framework for planning, project definition, and integration of ITS systems. The ITS Architecture is a basis for defining the required functions, physical entities, or information flows required to operate and integrate the various ITS systems.

8.8 TEMPORARY TRAFFIC CONTROL (TTC)

Construction activity presents many traffic control problems that must be addressed by the designer. Regardless of whether the project is open or closed to public traffic, some form of construction traffic control will be required. A plan directed to the safe and expeditious movement of traffic through construction and to the safety of the work force performing those operations is defined as a TTC Plan.

It is FLH policy that a TTC plan be designed and incorporated into all projects.

8.8.1 TEMPORARY TRAFFIC CONTROL (TTC) PLAN DEVELOPMENT

The purpose of the TTC plan is to anticipate and describe those traffic control measures that will be necessary during project construction and to outline coordination needs with owner agencies and the public.

TTC plans will vary in scope and complexity depending upon the type and volume of traffic and the nature of the construction project. At an early stage in the project development, the development of the TTC plan should begin and a determination made of the nature and volume of current and predicted traffic. All interested agencies should be involved throughout the development of the TTC plan. For projects with low-traffic volumes or that otherwise have few traffic hazards or conflicts, the TTC plan may be quite simple.

For projects that have one or more of the following characteristics, the TTC plan will normally be more complex:

- High-volume or high-speed traffic;
- Rush hour or seasonal traffic patterns;
- Heavy use by bicycles, pedestrians or disabled persons;
- Changing work conditions or other conditions that would be confusing to the traveling public;
- Hazards due to nighttime operations;
- Detours or complex traffic patterns; and/or
- Closely spaced intersections, interchanges or other decision points.

In developing the TTC plan, consider the items in Exhibit 8.8–A as needed. These items may be used as a checklist in either developing or reviewing the adequacy of traffic control plans.

All TTC plan features, which are obligations on the part of the contractor, shall be included in the plans and specifications. When necessary, appropriate project-specific or standard typical traffic schemes shall be included in the plans.

Exhibit 8.8–A TEMPORARY TRAFFIC CONTROL PLAN CHECKLIST

Temporary Traffic Control Plan Items	
1.	Estimated traffic volumes, vehicle types, and direction of travel
2.	Traffic speeds
3.	Required number of travel lanes
4.	Traffic control layouts including signing, markings, channelization devices, traffic signals, traffic delineators, barriers, and detour schemes
5.	Restrictions on work periods such as rush hours, holidays, special events, nights, and weekends
6.	Characteristics of adjacent highway segments
7.	Requirements for partial completion and opening sections to traffic
8.	Maneuvering space available for traffic (public and work equipment)
9.	Requirements for installing, maintaining, moving, or removing traffic control devices
10.	Turns or cross movements required by traffic
11.	Restrictions on contractor hauling or moving materials
12.	Provisions for accommodating adjacent businesses or residential areas
13.	Any special requirements for the contractor's traffic safety coordinator
14.	Requirements for after hours surveillance or on-call personnel
15.	Special requirements for nighttime operations
16.	Restrictions on parking vehicles, storing materials, and the contractor's equipment
17.	Special provisions on pedestrian or bicycle movements
18.	Provision for accommodating regularly scheduled services such as postal vehicles and school buses.
19.	Maximum delays (time, queue length, etc.)

The *MUTCD* must be used as a standard for signs, striping and other traffic control devices. Because of the general nature of the MUTCD, it will usually be necessary to use supplemental information.

The contract PS&E must include the minimum requirements for controlling traffic through the construction work zones. The TTC plan as contained in the contract must be adopted by the contractor unless an alternate TTC plan is developed by the contractor and approved by the engineer prior to beginning construction operations.

Include traffic control provisions in the PS&E distribution made to other offices and agencies for review before advertising in order that these other parties may have an opportunity to review the provisions for adequacy and coordination.

Payment for TTC plan activities will usually be made by individual bid items for services, traffic control devices, signing, etc. For projects with only light traffic where traffic control procedures are minimal, payment may be incidental to other items of work, or paid for on a lump-sum basis.

There may be certain traffic control information that is of value to the project engineer but should not be included in the contract. In this case, this type of information should be documented and copies provided to the appropriate construction project engineer as described in Section 9.6.6. This information may include the following:

- The need for public relations (e.g., notifications to the local news media);
- Any special agreements reached with other agencies relating to traffic control or traffic management;
- Crash reporting requirements; and
- Any special guidance on traffic management for the project engineer.

8.8.2 TEMPORARY TRAFFIC CONTROL (TTC) PAVEMENT MARKINGS

The TTC plan should reflect FLH policy that pavement markings conforming to full *MUTCD* standards shall be installed as quickly as practical in the construction process. Special standards described below are available to accommodate the periods of time before installation of permanent markings is practical.

8.8.2.1 Definitions

1. **Temporary Pavement Markings**. Either interim or standard markings installed prior to the installation of permanent markings.
2. **Interim Markings**. Interim markings are special, reduced dimension, temporary centerline and lane line markings, which are permitted by *MUTCD* Section 6F.72 or raised pavement markers permitted by Section 6F.73. Interim markings are permitted on new pavement lifts when additional pavement lifts or standard markings are to be installed within two weeks. Interim markings must conform to the color and retroreflective requirements of the *MUTCD*.
3. **Standard Markings**. Standard markings are centerline, lane line, and no-passing zone markings that comply fully with the dimensional, color and retroreflective requirements of

the *MUTCD*. Standard markings may be either temporary or permanent, although permanent markings typically have additional contractual requirements.

4. **Vehicle Positioning Guides**. Temporary raised pavement markers, installed on centerline and lane lines immediately after paving but prior to the installation of temporary or permanent pavement markings. See *MUTCD* Section 6F.73 and the *FP-XX* for more information.

5. **Severe Curvature**. Roads with a design speed of 35 mph [55 km/h] or less, or curves with speeds of at least 10 mph [15 km/h] less than the design speed for the remainder of the road.

8.8.2.2 Unmarked Pavement

Section 6F.72 of the *MUTCD* permits a limited period of unmarked pavement prior to the required installation of temporary or permanent markings. The traffic volume as outlined in Section 8.8.2.4 and Section 8.8.2.5 defines the time limitations. During this period, it is recommended that adequate delineation and signing be provided as follows:

- Vehicle positioning guides shall be installed on centerline and lane lines at a maximum spacing of N (N = cycle length, usually 40 ft [12 m]) in combination with appropriate signs, channelizing devices and other delineation. Spacing should be reduced to 0.5 N in severe curvature situations.
- A W8-12 “NO CENTER STRIPE” sign shall be placed at the beginning of each unmarked section, and after each major intersection or entrance ramp. In addition, an R4-1 “DO NOT PASS” sign shall be installed at the beginning of the project and approximately every mile [1.6 km] thereafter. At the end of each zone, an R4-2 “PASS WITH CARE” sign shall be used.
- The R4-1 sign at the beginning of each zone may be supplemented by a W14-3 “NO PASSING ZONE” sign.

8.8.2.3 Marked Pavement

Temporary markings are required if the time limitations as described for unmarked pavement are exceeded and it remains impractical to install permanent markings. Temporary markings should be standard markings, unless the specific time limitations of temporary markings can be met. The following are special standards for temporary markings:

1. **Centerlines and Lane Lines**. *MUTCD* Section 6F.72 requires interim broken-line pavement markings to be 2 ft [0.6 m] stripes on 40 ft [12 m] cycles or 2 ft [0.6 m] stripes on 20 ft [6 m] cycles in severe curves. When 30 percent or more of the road is designated as meeting the criterion for severe curvature, the entire road may be striped on a 20 ft [6 m] cycle. Temporary raised pavement markers may be substituted for broken line segments, and solid lines, in accordance with spacing described in the *FP-XX*.

2. **Edge Lines**. Temporary edge lines are not required, except in the case of a winter shutdown or extended delay of six weeks or more in the completion of paving and

installation of permanent markings. Temporary edge lines meeting the requirements of the *MUTCD* must be installed on those roads where edge lines were present prior to construction and permanent edge lines are specified in the contract.

8.8.2.4 Time Limitations — Roads with the ADT < 1000

Where average daily traffic does not exceed 1000 veh/day, and where the installation of permanent markings is not practical or possible immediately prior to opening the road to traffic, the following applies:

- For a scheduled duration of not more than two weeks after opening of a new lift of pavement, the minimum requirements of Section 8.8.2.2 apply.
- As an option to unmarked pavement during the same two-week time frame, temporary centerline markings meeting the standards of interim markings as defined in Section 8.8.2.3 are permitted.
- For a scheduled duration of more than two weeks after the opening of a new lift of pavement, the minimum requirements of standard markings as defined in Section 8.8.2.1 apply; as well as the requirements for edge lines in Section 8.8.2.3.

8.8.2.5 Time Limitations — Roads with the ADT > 1000

Where the average daily traffic exceeds 1000 veh/day, and where the installation of permanent pavement markings is not practical immediately prior to opening the road to traffic, the following applies:

- For a scheduled duration of not more than three days after the opening of a new lift of pavement, the minimum requirements of Section 8.8.2.2 apply.
- For a scheduled duration of not more than two weeks after opening a new lift of pavement, the minimum requirements of interim markings as defined in Section 8.8.2.1.
- For scheduled duration of more than two weeks after opening a new lift of pavement, the minimum requirements of standard markings as defined in Section 8.8.2.1 as well as the requirements for edge lines in Section 8.8.2.3 apply.

8.8.2.6 No Existing Markings

Where the existing road, prior to construction, has no markings, then temporary markings are not required prior to completion of the work. However, if the construction is nearly complete, including one or more lifts of pavement materials, and has upgraded the geometrics and increased prevailing speeds, temporary markings are required in accordance with Section 8.8.2.3.

8.8.2.7 One-Lane Paving

Where only one lane of a two-lane road is being paved during construction and the second lane is paved the following day (permitted by the *FP-XX* depending on lift thicknesses), the paving must be offset so that the existing markings are not obscured or temporary markings must be installed on the one lane mat prior to opening it to traffic. In addition, a W8-11 “UNEVEN LANES” sign should be used in this situation.

8.8.2.8 Special Pavement Markings

The need for temporary school zone, railroad, cross walk, stop line and other special pavement markings must be evaluated on a case-by-case basis during the design process. Markings that are deemed warranted must be included in the contract. Bicycle and pedestrian traffic, limited sight distance and other potential hazards should also be considered during the design process as well as traffic volume and the duration of construction.

8.8.2.9 Diversions and Detours

Paved temporary roads and detours that carry other than low-volume traffic, or are to be used in excess of two weeks, must receive the standard markings in accordance with the *MUTCD*. When two-way traffic is detoured onto what would ordinarily be a one-way road, or what may appear to be a one-way road, signing must be supplemented with W6-3 “TWO-WAY TRAFFIC” signs at maximum intervals of 1 mile [1.6 km].

8.8.2.10 State Standards

Designers should be cognizant of prevailing State standards (i.e., more stringent standards) and make adjustments to FLH requirements, wherever appropriate.

8.8.2.11 Contract Items

Contract requirements and contract items should be structured to assure safety while not subsidizing or encouraging delays, inefficiencies and excessive use of temporary markings and related traffic control.

Vehicle positioning guides are not considered centerline markings. They may be paid for as vehicle positioning guides or considered a subsidiary obligation. Additional signing and/or channelization devices necessary during periods of unmarked pavement should be anticipated and included in the TTC plan.

Because the *FP-XX* prohibits painted temporary markings on the final lift of pavement, it may be appropriate to include a contract item for temporary markings for lifts other than the final lift, but not for the final lift. This will minimize the cost of the temporary markings item and encourage the contractor to schedule permanent markings on the final lift in a timely manner.

8.8.2.12 Contract Provisions

It is important to structure contracts so that major overruns and unnecessary government liability for short-term markings will not occur if the contractor elects to perform the paving and marking differently than the designer assumed. The following are general guidelines that must be reevaluated on a case-by-case basis:

- There should be sufficient quantities of temporary markings to accommodate each lift of paving materials anticipated during construction.
- The contractor should be given the option of furnishing painted markings, reflective tape or temporary raised pavement markers. The bid item should include removal when required. Generally, painted short-term markings are cheapest and are appropriate immediately behind the paving operation on intermediate lifts. The temporary raised pavement markers are more practical on final lifts since they are easily removable prior to installing permanent markings, and are usually less expensive than reflective tape on roads with extensive no-passing zones.
- The Government is not obligated to pay for two systems on the same lift. If the time limit for temporary interim markings expires due to poor scheduling, and the contractor has to install temporary standard markings, then the upgrade should be at the contractor's expense.
- For large projects, it is intended that the time limitations on temporary interim markings will force the contractor to complete manageable sections of the project through permanent striping, rather than have the entire project partially complete for an unacceptably long period of time.

8.8.3 TEMPORARY TRAFFIC CONTROL (TTC) CHANNELIZING DEVICES

The preferred channelizing device for any application involving both day and night usage is the drum. If clearance or width problems preclude the use of drums, other devices (e.g., vertical panels, barricades, tubular markers) may be substituted. All devices must meet current crashworthiness standards.

The TTC plan should address and contain appropriate standards defining the expected condition of the traveled way and the needs of the public through the duration of the project. Specific situations that should be addressed through the use of appropriate signing and channelizing devices in each TTC plan include the following:

1. **Delineating Isolated Hazards**. Delineate hazards such as partially completed guardrail, catch basins, and major dropoffs.
2. **Protecting Workers**. Protect workers by separating traffic from an active work site.
3. **Separating Opposing Lanes.** Separate opposing lanes of traffic in confined or detour situations.
4. **Tapers and Transitions.** Tapers and transitions guide traffic from one lane to another, on or off a detour, facilitate a merge, lane narrowing or a one-lane flagging situation.
5. **Delineating Continuous Hazards.** Delineate continuous hazards such as shoulder dropoffs.
6. **Delineating the Traveled Way.** Delineate the traveled way through a work zone when no specific hazards are present. This is often appropriate for low-volume roads where

no detour or temporary pavement surface is provided, and traffic must be routed through the work zone. Once the permanent channelizing cues (e.g., delineators or pavement markings) are removed, temporary delineation must be provided, especially for nighttime traffic.

7. **Portable Changeable Message Signs**. Provide current information on the current or future work, any work-related delays or detours, and how to maneuver through the construction site. Portable Changeable Message Signs (PCMS) used for TTC are also called variable message signs (VMS) and should be used as a supplement to and not as a substitute for conventional signs and pavement markings. See *MUTCD* 6F.55 for more information.

   In an age where the motorist feels that they are entitled to as much advance notice of any interruptions to their travel plans, these devices have become very supportive as an outreach device, as well as a safety device.

8. **Temporary Traffic Signals**. Control road user (public and project-related) movements through TCC zones for extended periods of time instead using of a flagging operation. Temporary traffic control signals are typically used in situations such as temporary haul road crossings, one-way operations on roads or bridges, and intersections.

   Temporary signals can be installed using embedded poles, with overhead steel cables providing the support of the signal heads, or there can be mobile traffic signals delivered to the site, complete with controllers and interconnects. These compact units are transported similar to PCMS, and are placed on opposing corners of the intersection or at either end of a one-way operation, and some models provide both side and overhead signal heads. See *MUTCD* 6F.80 for more information.

8.8.4 TEMPORARY TRAFFIC CONTROL (TTC) BARRIERS/END TREATMENTS

Depending on traffic volume, speed, duration of condition, geometrics and related risk assessment factors, Items in Section 8.8.3 may warrant the use of a temporary concrete barrier. In high-risk situations, such as retaining wall construction or large culvert installations, channelizing devices should not be used alone where a positive barrier is warranted.

8.8.5 TRAFFIC DELAYS

Since many FLH projects are constructed in congested tourist locations, addressing the delays to the traveler in the TTC plan is almost as important as the TTC devices themselves. Between the plans and the SCRs, the designer must work with the land management agency and local emergency services personnel to establish desirable and acceptable delays to the public during construction. If only short (15-minute) closures are anticipated, they must still be agreed to with the resource agencies in advance of the advertisement, and clearly conveyed to the contractor through the construction documents.

The TTC plan should clearly identify all restrictions to traffic closures. These restrictions should address activities on holidays or weekends or perhaps between noon on Friday through Sunday night through an entire summer season. Coordination with the FLH construction personnel on holiday and other shut-downs should also be addressed. If extended public closures will be necessary, consider specifying closures during low-usage times such as midday, evenings, or just before/after a road may be closed for the winter. On some projects, the use of incentives or lane rental is an appropriate consideration to limit the impacts from delays.

Occasionally, it is not the time that is the critical factor of a closure, but the impacts of the queued traffic that must be addressed. On some roads, only a few cars will be stopped over a 30-minute closure, while other highways experience delays that impact thousands. Working closely with the resource agency over the many variations in the construction restrictions will ensure that confusion and conflicts will be minimized during the construction itself.

8.8.6 EMERGENCY RESPONSE CONSIDERATIONS

Delays to the traveling public may be unavoidable in order to complete the construction of a project. Delays to emergency services personnel could have severe consequences if these restrictions are not discussed and resolved in advance of the construction activities. Include with the development of the TTC plan and construction sequencing plan a discussion with local emergency response personnel. Their concerns may be resolved with simple advance notification of any closed traffic operations. In some areas, they may need to mobilize response crews on both sides of the closed roadway to maintain adequate service.

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CHAPTER 9

HIGHWAY DESIGN

9.1 GENERAL

This chapter provides policies, standards, standard practices, criteria, guidance and references for developing and documenting the highway design. This includes development of the final geometric design and the preparation of plans, specifications and estimates (PS&E) and related information to support highway construction and subsequent facility operations. The highway design policies and standards are applicable to new highway construction and reconstruction, as well as Resurfacing, Restoration and Rehabilitation (RRR) improvements. Section 1.1.1 provides policy definitions, standards, standard practices, criteria, and guidance. FLH Policy statements are shown in **bold type**. Statements regarding FLH Standard Practice are so indicated. Information on how to perform basic design procedures and fundamental steps for performing the design work are typically incorporated by references to other documents.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.1.1 ROLE OF THE DESIGNER

The role and responsibility of the highway designer is to gather and incorporate all of the interdisciplinary engineering and environmental input required to develop the highway design, and to provide a complete and acceptable PS&E assembly with all appropriate supporting documentation. The highway design and the PS&E package represents the final product of a collaborative, interdisciplinary and interagency design effort and depicts all the various decisions and commitments made during the planning, programming and project development processes.

The designer is responsible for participating in an interdisciplinary (e.g., cross-functional) team approach, led by the Project Manager, for evaluating design issues and developing design solutions for the project delivery. The designer is responsible for interpreting and applying guidance from each chapter in the *PDDM* as applicable to highway design development and PS&E compilation. The designer is also responsible for directly incorporating certain engineering data, plans, specifications and estimates produced by the other engineering disciplines into the PS&E and assuring that these products properly interrelate within the final PS&E assembly. The following briefly summarizes the designer's role and responsibility for development of the geometric design and PS&E, in relation to other disciplines described in the respective chapters of the *PDDM*.

- **Chapter 1 – Introduction.** Incorporate the philosophy, technical policies, and general approach to risk while developing the highway design and preparation of the PS&E.
- **Chapter 2 – Planning and Programming.** Designers should use information developed during the planning and programming phases including interagency agreements, planning and inventory data, program information and other general data developed on the scope, schedule and funding amount for the project being designed.

- **Chapter 3 – Environmental Stewardship.** Incorporate information regarding environmental requirements and public involvement. Environmental documents include the decisions and commitments made for mitigation of project impacts and concerns. Review all environmental documents for decisions, mitigation measures and commitments made during the conceptual studies and preliminary design phase that affect development and construction of the project or operation of the highway following construction. Coordinate any proposed deviation from the decisions, mitigation measures and commitments with the Environmental Section and affected resource agencies.

- **Chapter 4 – Conceptual Studies and Preliminary Design.** During the 30 percent design stage develop the recommended roadway location, design concepts and the basic design criteria for the facility. These engineering studies and preliminary designs are developed in conjunction with the environmental process using an interdisciplinary and interagency team approach, led by the Project Manager. Conceptual studies and preliminary design development include significant input from the highway owner agency, Federal land management agency, project stakeholders, the public and other interested parties, which is incorporated into the final design and PS&E.

- **Chapter 5 – Survey and Mapping.** The Survey and mapping unit provides information on the field survey, datum, coordinate system, property ties, right-of-way and utility locations and related data. The data collected is used to provide topographic maps, site maps, aerial imagery, right-of-way exhibits, land boundary and ownership information, utility maps and control information for developing the design.

  Closely coordinate the survey and mapping with the design and other engineering discipline activities to determine the type and limits of the survey and mapping required to complete the project delivery, and to share available information. Coordinate closely with the survey and mapping section to identify any additional information needs for developing the design and establishing controls for the construction process, and to use the available survey and mapping information most efficiently and effectively. When field reviews specifically for this coordination purpose are not possible, it is especially important for the designer and survey and mapping specialists to discuss the field information required. Use knowledge of the anticipated processes for design and construction, including new construction, reconstruction and RRR projects, to maximize the effectiveness of the survey and mapping activities performed to support the design and construction engineering.

  As needed, provide the appropriate information to the survey unit to stake the project design data in the field. This may include design data and notes to establish centerline, and to set slope stakes, clearing limits, reference points or hubs, grade stakes or hubs, right-of-way, and other control points necessary to complete the work. Keep the design files organized such that information provided for survey stakeout is current, correct and reflects the design criteria established for the project. It is the designer's responsibility to verify and confirm all design data and notes provided for field use to prevent the possibility of staking incorrect data.

- **Chapter 6 – Geotechnical.** Incorporate the geotechnical information necessary to develop the highway design. The Geotechnical Unit provides subsurface data and recommendations for earthwork, slopes, materials, conditions, and geotechnical design. As applicable, the geotechnical investigations and report recommendations also include foundation designs for bridges, retaining walls and other structures, as well as information and recommendations regarding rock slopes and rock fall mitigation, geotechnical hazards, landslides and subsurface water.
- **Chapter 7 – Hydrology/Hydraulics.** Incorporate the hydrology/hydraulic data needed in developing the highway design. Develop culverts, ditches and other minor hydraulic features using the established standards and guidance described in the chapter. The Hydraulics Unit provides methodology and sources of runoff data, and recommendations for developing the roadside drainage design, provides data and recommendations to the Structural Design Unit for major drainage structures, and provides conceptual designs or design recommendations, and if necessary final designs, for major hydraulic structures and special water resource features for incorporation in the PS&E.
- **Chapter 8 – Safety and Traffic Operations.** Closely coordinate geometric design development, safety-related design features and PS&E compilation with the necessary information on roadway safety, roadside safety and traffic engineering data needed for highway design. The Safety and Traffic specialists provide guidance on evaluation of safety deficiencies, provision of safety features, and evaluation of traffic operations data.

  The crash history and safety performance should be analyzed for all projects. In addition, potentially hazardous features and locations should be identified to determine appropriate safety enhancements. A crash study analysis of the location, type, severity, contributing circumstances, environmental conditions and time periods may suggest possible safety deficiencies that need improvement or mitigation as part of the project. The chapter provides details on data collection, crash investigation and analysis. Also refer to Chapter 4 for additional information on incorporating the necessary traffic and crash data into highway design solutions.
- **Chapter 10 – Structural Design.** Coordinate the development of the geometric design and PS&E with the necessary information on structural design and bridges. The Structural Unit designs bridges, major retaining structures and special structural elements. The Structural Unit will provide complete structural plans, specifications and an estimate of cost for incorporation into the PS&E package.
- **Chapter 11 – Pavements.** Coordinate the development of the typical surfacing cross section and related highway design features with information and recommendations for the pavement or other type roadway surfacing. The Pavements Unit normally provides the roadway surfacing data and recommendations for pavement structure materials and thickness. Incorporate the recommendations for pavement materials and thickness provided by the Pavements Unit.
- **Chapter 12 – Right-of-Way and Utilities.** Coordinate closely with Right-of-Way and Utilities units to identify the proposed right-of-way acquisition needs and utility accommodation, adjustments or relocations, and to provide the design information and proposed impacts of construction activities to property and utilities. As applicable, the

Right-of-Way, Survey, Mapping, or the Design Unit may provide information on the existing right-of-way and utility deeds, plats, agreements and related data. The right-of-way and utility data provides the basis for development of proposed right-of-way and utility plans, descriptions, agreements and other documents for clearance of right-of-way and utilities for construction. Coordinate design efforts to minimize the needs for proposed right-of-way and utility adjustments.

- **Chapter 13 – Design Follow-up.** The designer is responsible for obtaining feedback and follow-up information from post construction reviews, evaluating the effectiveness of the constructed design, and incorporating the information as an input for improving the design and development of future FLH projects.

9.1.2 DESIGN REQUIREMENTS AND STANDARDS

Refer to Section 4.4 for determination of applicable design standards and selection of design criteria to be used for the development of the geometric design and PS&E. For all projects, document the applicable design standards and criteria using the Highway Design Standards Form and show in the PS&E on the title sheet and typical section plans sheets. The applicable design standards and criteria should be documented during the conceptual studies and preliminary design (prior to 30 percent design stage).

Design standards determination also applies to Resurfacing, Restoration and Rehabilitation (RRR) projects; however, the overall approach to the design process is treated differently, since it is generally not intended or feasible for all substandard design elements to be reconstructed to fully meet the current design standards on RRR programmed projects. The RRR design process accommodates existing conditions or existing elements to remain included as part of the project rather than be reconstructed to the current standards of design. This is done using a safety-conscious design approach including risk analysis, which often requires design exceptions. For RRR projects, the approach to safety-related elements is similar to reconstruction projects in that any substandard safety conditions or controlling criteria are identified, and addressed on an individual, case-by-case basis.

Within this chapter many of the geometric design requirements, FLH standard practices, and guidance refer primarily to the design of new construction or reconstruction projects, and may not be appropriate for RRR projects or other projects with a very limited scope of improvement. Refer to Section 9.4 for guidance specifically applicable to RRR projects.

9.1.3 EXCEPTIONS TO DESIGN STANDARDS

It is acknowledged that designers are challenged with balancing a multitude of needs and expectations in selecting design criteria and geometry for highway facilities. The exception to standards outlined in *FLHM 3-C-2* permits the FLH Division Engineer to approve exceptions to design standards that are proposed for incorporation into the project. In addition to the design exception process, FLH policy includes flexibility to consider and approve alternative design criteria for individual projects, when necessary and appropriate.

When exceptions to the standards are necessary, document these exceptions with the risk to the traveling public, or the client, or the maintaining agency, or combination thereof appropriately noted. Inform the client and the maintaining agency, if different, of the risk and the consequences; document the risk and consequences of its acceptance, and provide alternatives to waiving the engineering standards. If the risk is acceptable to the client and the maintaining agency (if different), document this acceptance.

When evaluating the need for a design exception the design standards are not devalued; rather, in-depth understanding of the standards including the underlying theories and basis for derivation of the standard values, and the margins of substantive safety and operational performance that the standards provide, is used to add value to a unique situation by applying flexibility.

For all projects, document the selection of applicable design criteria from approved standards, and when approved standards are not attained, document all exceptions. Refer to *FLHM 3-C-2*. There are 13 principle design elements that are considered controlling criteria, and 4 supplemental standards, that require formal approval and documentation each time they are not attained. The 13 principle controlling criteria are:

- Design speed,
- Lane width,
- Shoulder width,
- Bridge clear roadway width,
- Horizontal curvature,
- Vertical curvature,
- Gradient,
- Stopping sight distance,
- Normal travel lane cross slopes (crown),
- Superelevation,
- Structural capacity,
- Horizontal clearance to structures (tunnels and bridge underpasses), and
- Vertical clearance.

The 4 supplemental standards are:

- Clear zone,
- Barrier crashworthiness,
- Design flood, and
- Pavement design service life.

In addition to these 13 controlling criteria and 4 supplemental standards requiring formal approval, the designer should receive concurrence and document in some manner any other elements of the highway design relating to safety, operational performance or functionality that do not meet applicable FLH standards. Refer to Division Supplements for guidance on documenting other highway design elements not meeting applicable FLH standards. Deviations from FLH standards for critical elements of other technical functions described in other *PDDM* chapters should also be approved and documented, as applicable for the technical function. The client and highway owning/maintaining agency should be informed of and concur in deviations from FLH standards and standard practices, as well as the consequences and risks of such decisions.

Any existing substandard elements that will remain after completion of the project must be identified, evaluated and documented in the same way as new design features.

There are basically two different approaches for evaluating and documenting design standard exceptions:

- A project-wide, or corridor design exception; and
- A site-specific design exception.

A project-wide or corridor design exception may be advantageous for design consistency, maintaining driver expectancy, and to coordinate geometric design features within the corridor (albeit using lower design criteria), but may be disadvantageous if the necessity for the lower design criteria is not a prevailing condition throughout the corridor. A corridor design exception is best reserved for those elements (e.g., roadway width) that are not functions of the design speed. A design speed exception relates to either 1) the minimum design speed applicable to the functional classification and terrain, or 2) individual design elements that are based on design speed and addressed on an individual basis. The design speed is not necessarily constant within the corridor if there are distinct zones that are appropriate to change both design speed and posted speed. A design exception to apply a lower design speed than the posted speed should not be recommended, especially if it is feasible to design a majority of the corridor or zone to meet criteria for the posted speed. It will potentially result in the unnecessary reduction of all of the speed-related design criteria rather than just the one or two features that led to the need for the exception. Refer to Section 9.3.1.13 for additional guidance on design speed and posted speed.

A site-specific design exception acknowledges the necessity for using lower geometric design criteria for a specific feature while providing higher design criteria for the prevailing conditions along the corridor, and the exception will usually affect only a single element of the geometric design criteria (e.g., a horizontal curve radius, a vertical curve length) and other elements are not compromised.

> *Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information including applicable Highway Design Standards form for use within each FLH Division.*

9.1.3.1 Need for Design Exception

Before an exception is recommended, there must be compelling and demonstrated reasons why the approved standard criteria should not be used.

Describe and explain the conditions that preclude conformance to the applicable design standard. A preliminary estimate of the additional construction cost to conform to the applicable standard may be required, as compared with the proposed design exception.

The need for a design exception should be identified, evaluated and decided as soon as possible in the design and decision-making process. The key milestone for identification and evaluation of design exceptions is at the completion of the preliminary design (30 percent) stage.

9.1.3.2 Design Exception Consequences and Risk Assessment

When considering project elements that may require design exceptions to the applicable standards, the resultant safety and operational risk aspects must be 1) understood by the designer, and 2) properly communicated to project stakeholders.

Identify and describe the estimated operational and safety effects and potential risks of the design exception, and its compatibility with adjacent sections of roadway within the project. Safety enhancement is an essential element of any project design, therefore, a design exception should not be recommended if it would decrease the relative safety performance of the roadway in the affected area. Functional classification of the road, the amount and character of the traffic, the type of project (i.e., new construction, reconstruction, RRR) and the crash history should be considered in the risk assessment. The cost of attaining full standards and the resultant impacts on scenic, historic or other environmental features, as well as whether other future improvements are programmed, should also be taken into consideration. As a minimum, the following issues should be considered in the risk assessment:

- What is the degree to which a standard is being reduced?
- Will the exception affect other standards or projects?
- Are additional features being included in the project (e.g., improved roadway geometry, signing, delineation, roadside safety) that would adequately mitigate the safety and operational effects of the deviation?

The interdisciplinary project team should describe the context of the design exception and provide input for consideration. The designer should consider the context and the basis of the design standard, describe the safety effects or risks of the design exception, and provide a professional recommendation about alternatives to consider.

Refer to the sections on geometric design controls for considerations and guidance on risk assessment and mitigation of specific geometric design elements. The Interactive Highway Safety Design Model (IHSDM) should be used to help identify potential safety consequences and risks of geometric design elements.

Refer to Section 1.1.3 and Section 4.4.6 for general guidance on risk assessment. Refer to various sections elsewhere in this chapter for guidance on evaluation of the geometric design and operational effects, risk assessment and mitigation related to specific geometric design elements and features.

9.1.3.3 Mitigating Design Exceptions

Describe the mitigating measures proposed to maximize operation and safety of the facility in the affected area. Refer to the sections on geometric design controls for specific considerations and guidance on mitigation. If the mitigation for a design exception cannot be resolved at the preliminary design stage, it should be resolved at the intermediate design (50 percent) stage. For more information see FHWA-SA-07-011, *Mitigation Strategies for Design Exceptions*.

9.1.3.4 Documenting Design Exceptions

Documentation for all design exceptions should follow the guidelines in this manual, FHWA procedure from the *Federal-Aid program Guide (FAPG) Subchapter G-Engineering and Traffic Operations, Part 625-Design Standards for Highways, Non-Regulatory Supplement for Part 625, No. 8. Design Exceptions*, and relevant FHWA Policy and Engineering Directives.

Refer to the format in the Division Supplements for documenting design exceptions on a project.

Tort liability is a major concern of the government. The designer must ensure that the design process is in compliance with all applicable standards, and that decisions regarding design exceptions are properly documented. Documentation of the design exception should include the applicable controlling criteria and standard for which a design exception is requested, the background information, need, consequences, risks, and mitigation described in the preceding sections.

The documentation supporting the design exception decision should be prepared at the earliest possible point in the design process, and must become a part of the PS&E package presented to the owner agency. Any design exceptions should be identified, evaluated and documented during development of the conceptual studies and preliminary design (30 percent stage of project development). However, it may not be possible to finally resolve and document the approval of design exceptions until later in the final design process.

Refer to Chapter 4 of the AASHTO publication *A Guide for Achieving Flexibility in Highway Design* for additional information about concerns regarding tort liability and documenting design exceptions.

9.1.3.5 Monitoring Design Exceptions

Design exceptions should be collected and periodically reviewed in order that the managers in the Division offices remain fully informed on the nature and extent of design exceptions being approved for given categories of projects.

The safety and operational performance of the roadways that are constructed with design exceptions should be monitored, using performance management systems, to assist in future analysis and decision-making. Refer to Section 2.4 for information on system-wide planning and performance management.

9.1.4 VARIANCES TO FLH STANDARD PRACTICE AND GUIDANCE

Variations from the highway design standard practice and guidance will be necessary for special or unusual conditions, or to provide the proper balance among diverse user needs, environmental concerns, and fiscal restraints. Consequently, the provision of standard practice and guidance in this Chapter is not intended to preclude the exercise of discretion and engineering judgment in response to site-specific conditions, or achievement of appropriate flexibility in the highway design. Rather, such discretion and judgment is encouraged where it is appropriate and there is a clear need and a rational basis for deviation. However, it is equally important to promote consistency in the application of the standard practice and guidance, to regularly match the highway design with the needs, conditions and context of the facility and its users.

To fulfill these objectives, obtain endorsement and document the rationale for variances from FLH highway design standard practice in the project design file. The extent of documentation may depend on the specific nature of the variation and its potential effect (if any) on safety performance, traffic operations, or serviceability. The terms "consider" and "should" denote suggested guidance only and do not designate a standard practice or a design requirement; but convey an expectation for the highway designer to evaluate the situation before proceeding. Differences from the suggested guidance do not require documentation; however considerations for selecting special or unusual design parameters should be noted in the project design file. Procedures for documenting variations from highway design standard practice may be described in applicable Division Supplements.

9.1.5 DESIGN PHILOSOPHY AND CONTEXT SENSITIVE SOLUTIONS

The Federal land management agencies, and FLH, have long recognized the need to modify traditional approaches to the planning, design and construction of roads on such sensitive and protected lands. This has resulted in a philosophy for design of roads to exercise sensitivity and care in application of the established design requirements and standards described in Section 9.1.2. The FLH design philosophy is evident in the following design policy references:

The Foreword to the *Green Book* states:

> *"Highway engineers, as designers, strive to meet the needs of highway users while maintaining the integrity of the environment. Unique combinations of design controls and constraints that are often conflicting call for unique design solutions."*

The *Park Road Standards* state:

> *"The fundamental purpose of national parks–-bringing humankind and the environment into closer harmony–-dictates that the quality of the park experience must be our primary concern. Full enjoyment of a national park visit depends on its being a safe and leisurely experience. The distinctive character of park roads*

plays a basic role in setting this essential unhurried pace. Consequently, park roads are designed with extreme care and sensitivity with respect to the terrain and environment through which they pass–-they are laid lightly onto the land."

The highway design must carefully balance the user's safety needs, desires, expectations, comfort, and convenience within the context of many constraints and considerations including terrain, land use, roadside and community effects, environmental effects, aesthetics and cost. To balance the user's needs with the values of the Federal land management agencies, while exercising stewardship and oversight, a specialized design philosophy has evolved. The FLH design approach is to actively engage the project stakeholders in applying the design policies, standards, criteria, best practices, guidance and engineering judgment to achieve an outstanding solution. Designers must represent the design policies and understand their engineering basis; and also must understand and respond to the values, concerns and constraints of each situation with flexibility and creative solutions. In applying flexibility the goal is not to lower, but to raise the performance level of the facility by optimizing the design criteria to exactly fit each situation using expert tools, information and communication.

The FLH and the Federal land management agencies share a legacy of working together on the planning, design and construction of roads. As a result, long-standing relationships and collaborative processes have evolved for successfully delivering the work, which actively engage the Federal land management agencies, State and local road-owning agencies, resource agencies and the public. These processes are essentially similar to the process described for achieving Context Sensitive Solutions (CSS). NCHRP Report 480, *A Guide to Best Practices for Achieving Context Sensitive Solutions*, provides guidance that is also closely aligned with the design approach used by FLH. CSS represents a collaborative, interdisciplinary approach to roadway planning, design and construction, which involves all partners, stakeholders and the public to ensure that transportation projects are in harmony with communities and that projects preserve environmental, scenic, aesthetic and historic resources. The effective application of CSS techniques can achieve these goals while maintaining safety and mobility.

Evaluating diverse needs and contextual issues, to balance and optimize the level of enhancement, may require collection and analysis of more data and project-specific information than for a non-CSS type approach. Fully understanding the context, and the true needs of the users, requires comprehensive data and personal interaction. Facilitating the collaborative interdisciplinary approach, effectively engaging stakeholders and the public with enhanced communication and decision-making tools and processes, risk assessment, and management endorsement requires planning and technical information. Ensuring that safe and technically sound solutions result from this exercise of flexibility in design requires expert thinking and analysis. To closely fit the design within the physical site constraints requires accurate survey and mapping, and iterative design to reach the optimum solution. The facility may need to deliver excellent operational performance to equally meet transportation demands and contextual enhancement goals. In addition to design, the construction techniques, materials, drainage and safety appurtenances may need to provide superior performance to accomplish the goals of CSS. The final cost of the resultant solution may not be any more than a non-CSS approach, but the level of data collection, analysis, engineering and construction may require higher thinking, performance and quality than may be the norm elsewhere in the highway industry.

Within FLH design policy, the products of the design philosophy will vary between projects that are executed by different interdisciplinary teams and designers, despite that precisely the same design standards are used. The differing emphasis for diverse goals, the unique context of each location, the technical knowledge of the designer and the amount of input from stakeholders in shaping the design, will result in unique solutions.

The remaining sections of this chapter describe the requirements and factors that influence the highway design and PS&E process, and guidance that should be considered by designers. These include the geometric design, types of projects and their approach, other highway design elements, the PS&E development and design documentation, including Division Supplements.

Also refer to Section 4.4.5 for guidance on applying flexibility in the design and Section 4.6.1 for guidance on achieving Context Sensitive Solutions.

9.2 GUIDANCE AND REFERENCES

The publications listed in this section provided much of the fundamental source information used in the development of this chapter. While this list is not all-inclusive, the publications listed will provide the designer with additional information to supplement this manual.

Abbreviations and definitions are described in Section 1.4.

9.2.1 STANDARDS OF PRACTICE

1.	Green Book	*A Policy on Geometric Design of Highways and Streets*, AASHTO, current edition (specific references in this chapter are to the 2011 edition).
2.	Park Road Standards	*Park Road Standards*, US Department of the Interior, National Park Service, 1984.
3.	FP-XX	*Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects*, FHWA, current edition.
4.	MUTCD	*Manual on Uniform Traffic Control Devices*, FHWA, current edition.
5.	RDG	*Roadside Design Guide*, AASHTO, current edition.
6.	VLVLR	*Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤400)*, AASHTO, 2004
7.	DS-Interstate	*A Policy on Design Standards-Interstate System*, AASHTO, current edition.
8.	FLHM 3-C-2	Federal Lands Highway Manual Policy Guide, Chapter 3, Section C, Subsection 2, *Exception to Minimum Engineering Standards - Risk Factors*
9.	ADAAG	*Americans with Disabilities Act Accessibility Guidelines*, Architectural and Transportation Barriers Compliance Board, current edition
10.	PROWAC	*Guidelines for Accessible Public Rights-of-Way*, current edition
11.	23 CFR 650 Subpart B	*Erosion and Sediment Control on Highway Construction Projects*, 1994
12.	E380-93	*Standard Practice for Use of the International System of Units (SI), The Modernized Metric System*, ASTM, 1993.

13.	FAR	*Federal Acquisition Regulations*
14.	Specification Writer's Guide	*Specification Writer's Guide for Federal Lands Highway*, FHWA-CFL/TD-08-001, 2008.

9.2.2 GUIDANCE

1.	AASHTO Flexibility Guide	*A Guide for Achieving Flexibility in Highway Design*, AASHTO, 2004,
2.	IHSDM	*Interactive Highway Safety Design Model* (IHSDM), FHWA, current edition.
3.	NCHRP Report 480	*A Guide to Best Practices for Achieving Context Sensitive Solutions*, TRB, 2004.
4.	AASHTO SR	*Highway Safety Design and Operations Guide*, AASHTO, 1997.
5.	T 5040.28	Technical Advisory 5040.28, *Developing Geometric Design Criteria and Processes for Non-Freeway RRR Projects*, FHWA, October 17, 1988.
6.	Special Report 214	TRB Special Report No. 214, *Designing Safer Roads*, Transportation Research Board, 1987.
7.	HCM	*Highway Capacity Manual*, Transportation Research Board, current edition.
8.	FHWA-RD-00-67	*Roundabouts: An Informational Guide*, FHWA-RD-00-67, 2000.
9.	NCHRP Report 502	*Geometric Design Consistency on High-Speed Rural Two-Lane Roadways*, TRB, 2003.
10.	NCHRP Report 504	NCHRP Report 504, *Design Speed, Operating Speed, and Posted Speed Practices*, TRB, 2003
11.	FHWA-RD-99-207	*Prediction of the Expected Safety Performance of Rural Two-Lane Highways*, FHWA-RD-99-207, FHWA, 2000.
12.	FHWA-RD-94-034	*Horizontal Alignment Design Consistency for Rural Two-Lane Highways*, FHWA-RD-94-034, FHWA, 1995.
13.	FHWA-RD-01-103	*Highway Design Handbook for Older Drivers and Pedestrians*, FHWA-RD-01-103, 2001

14.	AASHTO GPF	*Guide for the Planning, Design and Operation of Pedestrian Facilities*, AASHTO, 2004.
15.	AASHTO GBF	*Guide for Development of Bicycle Facilities*, AASHTO, 2012.
16.	Access Management Manual	*Access Management Manual*, Transportation Research Board, 2002.
17.	ITE Driveway Guidelines	*Guidelines for Driveway Location and Design*, Institute of Traffic Engineers (ITE), 1987.
18.	Practical Highway Esthetics	*Practical Highway Esthetics*, ASCE, 1977.
19.	Trail Design Manual	*Trail Design Manual, "Trails for the Twenty-First Century," Planning, Design, and Management Manual for Multi-use Trails*, Rails to Trails Conservancy, 1993.
20.	FHWA-FLP-91-001	*Design Risk Analysis* (Volume I and II), FHWA-FLP-91-001, FHWA, 1991.
21.	FHWA-SA-07-001	*Good Practices: Incorporating Safety into Resurfacing and Restoration Projects*, FHWA-SA-07-001, December 2006
22.	FHWA-SA-07-010	*Railroad-Highway Grade Crossing Handbook*, FHWA-SA-07-010, Revised 2nd edition, March 2008.
23.	FHWA-SA-07-011	*Mitigation Strategies for Design Exceptions*, FHWA-SA-07-011, July 2007
24.	NCHRP Report 279	*Intersection Channelization Design Guide*, 1985.
25.	FHWA-HRT-05-139	*Evaluation of Safety, Design, and Operation of Shared-Use Paths*, FHWA, 2006
26.	AASHTO GL-6	*Roadway Lighting Design Guide*, AASHTO, 2005.
27.	NCHRP Synthesis 430	*Cost-Effective and Sustainable Road Slope Stabilization and Erosion Control*, TRB, 2012.
28.	FHWA-FLP-94-005	*Best Management Practices for Erosion and Sediment Control*, FHWA, 1995.
29.	AASHTO MDM	Model Drainage Manual, AASHTO, Chapter 16, *"Erosion and Sediment Control."*

30. AASHTO HDG Highway Drainage Guidelines, AASHTO Volume III, *"Erosion and Sediment Control in Highway Construction."*

31. FAPG 23 CFR 630B *Guidelines for Preparation of Plans, Specifications, and Estimates*, FHWA Non- Regulatory Supplement for 23 CFR, Part 630, Subpart B, 1991

32. AASHTO HLED *A Guide for Transportation Landscape and Environmental Design*, AASHTO, 1991

33. FLH Specifications Procedures

34. FLH Safety Philosophy

35. FLH Context Sensitive Solutions Philosophy

9.3 GEOMETRIC DESIGN

Before beginning detailed design activities see Chapter 4 for standards and guidance on conceptual studies, project scoping, background data, and development of the preliminary design.

The over-arching considerations for geometric design are:

- Design the highway geometry with regard to the function, use, context and the environment in which the facility operates, and
- Provide consistency in the quality, appearance and operational performance of the roadway.

The following sections describe specific considerations and elements for geometric design.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.3.1 GEOMETRIC DESIGN CONTROLS

Identify design constraints early and optimize the vertical and horizontal geometry for compatibility. The geometric design controls should normally be established during the project scoping, see Section 4.3. Determination of geometric design controls should take into account the FLH Safety Philosophy and the FLH Context Sensitive Solutions Philosophy. Balance the user's needs with provisions for automobiles, trucks, motorcycles, pedestrians, bicyclists, and transit. In making these determinations, consider that routinely selecting only the minimum recommended values may not result in the optimum design for all users from a safety, operational or cost-effectiveness perspective. Also consider that other controls such as environmental requirements, structural design requirements, and supplemental standards for safety elements, design flood and pavement design may affect certain geometric design elements and their cost and scope. Refer to the respective Chapters for such controls and requirements. The following sections address the various geometric design controls.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.3.1.1 Roadway Context

Consider the roadway context as a critical factor in determining geometric design elements such as alignment and cross section, and in selecting design features such as curb type and traffic barrier, and in selecting construction materials and aesthetic treatments. Identify roadway design controls that are sensitive to, and respectful of, the surrounding context to facilitate the project success. It is essential that all transportation facilities be designed as part of the total environment. Traditionally, the highway design process has focused first on a project's transportation elements and design controls, particularly those associated with motor vehicle travel. A context-sensitive approach for identification of design controls begins with analysis of the contextual elements, such as environmental and community resources, of the area through which the roadway passes. After there is a thorough understanding of the area surrounding the road, the road's users, the affected non-users, constraints, and enhancement opportunities, then the transportation controls of the roadway, its function within the regional transportation system, and the appropriate level of speed, mobility and access may be considered. Three primary concepts should be considered in establishing the roadway's contextual design controls:

- The character and level of sensitivity of the surrounding natural and built environment,
- The roadway function in terms of providing regional mobility versus local access, and
- The level of access management, i.e., separation versus connectivity, between the roadway and the adjacent land use.

Also refer to Section 9.5.10 for consideration of design elements for environmental protection and enhancements.

9.3.1.2 Functional Classification

The AASHTO *Green Book* establishes a relationship between functional classification and design criteria (refer to *Green Book* Section 1.3). Also refer to FHWA functional classification guidelines. The functional classification of a particular highway establishes a range of design speeds, and together with the selected design speed further defines a range of parameters associated with horizontal and vertical alignment, lane width, shoulder type and width, median area type and width, and other major design features.

The functional classification of the project will normally be determined during the planning and programming phase, and it is verified with consideration of additional data as part of the conceptual engineering studies. Determine the functional classification from a statewide perspective not simply a "forest," "county" or tribal reservation point of view. For NPS projects refer to Section 9.3.1.2.5. Some Forest Highways and IRR roads may fulfill a relatively high function within their respective area; however, the functional classification should be from the point of view of all roads within the State. Many State DOTs maintain maps indicating the functional classification of all roads in that State.

Grade separations and interchange ramps may be associated with highways having any functional classification or design speed. Refer to *Green Book* Chapter 10 for design of grade separations and interchanges.

9.3.1.2.1 Local Roads

Local roads primarily provide access to adjacent land with little through movement. Very few FLH projects are located on routes with local road functional classification. Some Refuge Road projects, IRR projects and ERFO projects are located on local roads.

Green Book Section 5.5 references the VLVLR for design of certain very low-volume local roads (ADT ≤ 400). The VLVLR may be used in lieu of the *Green Book* for designing FLH projects on local roads that fit the criteria. The VLVLR is applicable for local roads that are 1) primarily used by familiar drivers, and 2) design average daily traffic volume of 400 or less. Verify with the

Branch Chief responsible for Highway Design that the VLVLR is appropriate for the specific project.

The VLVLR Exhibits 3, 4, 5, 6, and 7 are based on side friction factors provided in the 2001 edition of the *Green Book*. The values for maximum side friction factor, f_{max}, in these exhibits should be revised using the values provided in the current edition of the *Green Book*. The corresponding values for minimum radius, R_{min}, in these exhibits should be revised using Equation (2) of the VLVLR. FLH standard practice for using the VLVLR is to apply the revised limiting values of f_{max} and R_{min} with Exhibits 3 and 4 for horizontal curve design of the designated roadways. *Green Book* Tables 3-7 and 3-13 may be substituted for the VLVLR Exhibits 3 and 4, respectively to obtain these values. In especially constrained situations, as described in the VLVLR, the revised limiting values of f_{max}, and R_{min} and the reductions in design speed shown in Exhibits 5, 6, and 7 may be used for horizontal curve design of the designated roadways, if endorsed and documented as a variance from FLH highway design standard practice.

9.3.1.2.2 Collectors

Collectors provide a medium level of service at moderate speed for intermediate distances by collecting traffic from local roads and connecting them with arterials. Many FLH Forest Highway and Public Lands projects are located on routes with collector classification.

9.3.1.2.3 Arterials

Arterial roads provide a high level of service at high speeds for relatively long distances, with little interruption and with some degree of access control. Some FLH program projects, and a number of FLH special projects, are located on routes with arterial classification.

9.3.1.2.4 Freeways

Freeways are a type of arterial road that provide full access control, accommodate the highest speeds with no traffic interruption. A few FLH special projects are located on routes with freeway classification.

9.3.1.2.5 National Park Service Roads

The National Park Service, in its 1984 *Park Road Standards*, has established its own system of functional classification. The assignment of a functional classification to a park road is not based on traffic volumes or design speed, but on the intended use or function of the particular route.

The fundamental considerations in park road design are distinct from most other State and local highway systems. The design controls and criteria, design elements, and roadway features may share some theoretical similarities with corresponding AASHTO design criteria, however the purpose of park roads and associated design values are different. Where the source of design criteria is noted as compiled from the 1984 AASHTO *Green Book* (e.g. vehicle dimensions, turning paths, grades, vertical curves, radius, sight distance tables and figures), instead use the corresponding values from the current edition of the *Green Book*. If design criteria and standards for certain elements are not addressed by the *Park Road Standards*, use appropriate values recommended by the *Green Book*.

9.3.1.2.6 Special Routes

When applicable, consider the requirements for special routes designated to serve specific purposes as described below:

- **National Highway System (NHS).** The NHS is separate and distinct from the functional classification system.
- **Strategic Highway Corridor Network (STRAHNET).** The STRAHNET includes highways which are important to support an emergency military defense deployment. The minimum vertical clearance on these routes is 16 ft [4.9 m].
- **Bicycle Routes.** Bicycle routes are designated and signed as preferred routes through high bicycle travel demand corridors. Roadway widths and surfacing are important to assure their usability as discussed in Section 9.3.17.

9.3.1.3 Terrain

The type of terrain has an influence on design speed, maximum grade, and the alignment. Section 3.4.1 of the AASHTO *Green Book* separates terrain into three classifications:

- Level,
- Rolling, or
- Mountainous.

Terrain classifications pertain to the general character of a specific route corridor. For example, routes in mountain valleys and in mountain passes that have all the characteristics of level or rolling terrain should be classified as such. The terrain classification determines the maximum allowable grades in relation to design speed.

9.3.1.3.1 Level Terrain

Level terrain is generally sloping at 1V:20H or less. Sight distances, as provided by horizontal and vertical geometry, are generally long or can be made so without construction difficulty, major expense, or undue adverse effects. Trucks and passenger cars can operate at similar, consistent speeds.

9.3.1.3.2 Rolling Terrain

Rolling terrain is generally sloping between 1V:20H and 1V:3H. Natural slopes repeatedly rise above and fall below the road grade, and occasional steep excavation and embankment slopes restrict or control the horizontal and vertical alignment. The terrain generates steeper grades than in flat terrain, causing trucks to often operate at speeds below those of passenger cars.

9.3.1.3.3 Mountainous Terrain

Mountainous terrain is frequently sloping over 1V:3H. Changes in terrain elevation with respect to the roadway cross section and profile are abrupt. Benched side-hill excavation and limited locations for embankments are typical restrictions that control the horizontal and vertical alignment. The terrain generates steep grades causing some trucks to operate at substantially slower speeds than passenger cars.

The AASHTO *Green Book* recognizes the unique difficulty and expense of road construction in mountainous terrain, and for some geometric design elements, it suggests reduced values in the criteria than for other terrain.

9.3.1.4 Location

Refer to *Green Book* Section 1.3.1 for guidance on determining the applicable location, for determining design criteria. A highway located within the corporate limits of a city does not necessarily determine if it should have an urban cross-section. Consider the development density and land use adjacent to the highway corridor. Presence of several of the following typically indicates urban character:

- Sidewalks or frequent pedestrian travel
- Bicycle usage
- Curbing
- Closed drainage systems
- Cross street frequency 8 or more per mile [5 or more per km]
- Driveway frequency 25 or more per mile [15 or more per km]
- Minor commercial driveway frequency 10 or more per mile [6 or more per km]
- Multiple major commercial driveways per mile [km]
- Numerous right of way constraints

For design of certain cross-section elements, urban roadways may be further categorized as lower-speed urban (40 mph [60 km/h] or less posted or regulatory speed), transitional (45 mph [70 km/h]), and high-speed urban (50 mph [80 km/h] or more).

9.3.1.5 Traffic Volume

Daily, peak hour, and patterns of motor vehicle traffic are key design controls for the roadway facility. Daily traffic estimates are also used in making design decisions related to the total user benefit of a proposed improvement. For example the benefit of highway safety roadside improvements is directly related to the crash exposure (expressed in ADT) on the road. Refer to *Green Book* Section 2.3.2 for guidance on determination of traffic volume.

9.3.1.5.1 Traffic Volume Measures

Refer to Section 4.3.2.3 for a description of traffic volume measures in establishing design controls. Automatic traffic recorder/vehicle classification counts are generally needed for determining the design criteria and for analyzing capacity and delay conditions. Turning movement counts are generally needed for the design of critical or high volume vehicle turning movements at intersections.

9.3.1.5.2 Volume Classifications

For determining design criteria, the *Green Book* classifies traffic volume as < 250, < 400, < 1500, < 2000 or > 2000 average daily traffic (ADT).

9.3.1.5.3 Design Hourly Volumes

Consider the design hourly volume (DHV), or daily peak-hour traffic, in the design of travel lanes and shoulder width, intersection layout, and consideration for level of service to be provided. Refer to the paragraph on “Peak-Hour Traffic” in *Green Book* Section 2.3.2 for guidance on determining the DHV for the project.

9.3.1.5.4 Future Traffic Projections

Projects that are developed should serve a useful function for some time into the future. Projects that involve significant capital investment are generally assumed to have a long functional lifetime, while projects of lesser investment are generally assumed to have a shorter functional lifetime. This requires anticipation of the future transportation demands and resultant safety and operational conditions, at a future period commensurate with the level of capital investment, with and without the project to assess its effectiveness at meeting the transportation needs.

Traffic projections are typically forecast for a period 20 years ahead of the anticipated completion of the construction project. Some metropolitan planning organizations have developed traffic projections on various routes for a specific planning horizon year, based on region-wide traffic modeling systems. To determine the future traffic projection, consider the recent and projected traffic growth rates for other highways in the vicinity, the statewide and national traffic growth rates for similar type of highways, the recent and anticipated population growth rate of the area including areas of trip origin and destination, visitation growth rate, land use planning data, and other available information. Also consider the effects of improvement of the route on trip generation and travel routing, especially if proposed improvements include significant reduction of travel time or significant change in the type of surfacing. Base future traffic projections using a growth rate factor applied to the current traffic volume, including adjustment if applicable for induced traffic growth.

Forecasts of future activity levels should include estimates of pedestrian and bicycle activity. Exercise care when forecasting pedestrian and bicycle volumes to consider latent demand above presently observed pedestrian and bicycle volumes because the facilities do not yet exist in the project area, are substandard, or do not provide complete connectivity to destinations.

9.3.1.6 Level of Service and Mobility

When applicable, determine the level of service (LOS) criteria as a design control to characterize the quality of movement through a transportation network, such as for urban or rural arterials, or urban collector functional classifications. Guidelines applicable for selection of the design LOS are provided in *Green Book* Table 2-5. A variety of analytical methodologies and computer software packages are available to estimate LOS for facility users. The desired level of service should be determined through input of the affected community and the facility stakeholders; therefore ensure that the project participants have a thorough understanding of the resulting level of service from the design so that the expectations can be met, or objectives modified. Generally, for the design year LOS C or better is desired and LOS D is the recommended minimum.

Refer to Section 8.6.2 for guidance on determining appropriate level of service. Refer to *Green Book* Section 2.4 for information on capacity characteristics, levels of service and design flow rates. Also refer to the *Highway Capacity Manual* and the FHWA Traffic Analysis Tools. When applicable in urban areas, determine the level of service for pedestrians, bicyclists, or transit; see NCHRP Report 616, *Multimodal Level of Service Analysis for Urban Streets*.

9.3.1.7 Level of Access and Management

Determine the level of access control and management to maintain safe and efficient roadway operations for all users. Consider the management of driveway locations, approach roads, median treatments, turn lanes, curbs, barriers, and other access management features. The degree of access management is influenced by both the function of the roadway and the roadway context. Consider more stringent access control on arterials than on collectors and local roads, reflecting the mobility and land access functions of these roadways. Consider the existing access points along the roadway and the possibility for changes in access that are consistent with the project's objectives, and need for future access to developing areas. For example, it may be possible to relocate, redesign, or consolidate some driveways along an existing roadway to improve sight distances and safety.

The *Access Management Manual*, TRB, 2003 provides guidance on the application of access management techniques for both existing and new roadways. Also refer to *Green Book* Section 2.5.

9.3.1.8 Cross Section and Multi-modal Accommodation

Determine the design controls that will influence the overall roadway width, and components of the cross section that will accommodate the various users. Approach the formulation of needed cross section components beginning from the right-of-way or construction limits edge to edge then inward, rather than the more traditional approach of beginning from the centerline outward. Through this approach, the accommodation of pedestrians and bicyclists should be positively encouraged and safely enhanced, and contextual elements considered from the outset.

Determine the level of multi-modal accommodation within the cross section for pedestrians, bicyclists and motor vehicles, i.e., whether separate accommodation of travel for all type users must be provided (e.g., sidewalk, bike lane, shoulder, travel lane) or whether some form of shared use may be acceptable within the roadway. If a public transit system exists or is anticipated, determine the level of separate accommodation needed. Consider the operating speed of motor vehicles, and the relative volumes of pedestrians, or bicyclists, or both, the vehicular needs for usable shoulders, roadside or on street parking, and environmental or right-of-way constraints in establishing the level of multi-modal separation or shared-use cross section relationships.

Consider the overall roadside including the criteria for slopes, clear zones, ditch sections, curbs, barrier systems, auxiliary lanes and medians as these elements typically contribute greater influence and impact on the overall cross section than the range of travel lane and shoulder widths considered. Also consider the needs for snow storage, maintenance, placement of utilities (poles and buried conduit), roadside signage, fencing, and other appurtenances for inclusion as cross section design controls.

Determine the various factors that control the range of travel lanes and shoulders that should be considered, (i.e., to meet the highway function, traffic volume, speed and mix of motor vehicles and drivers that are anticipated to use the facility). These factors are discussed in the previous and following sections.

Once the level of multi-modal accommodation, roadside design criteria, and roadway cross section design controls are determined, the dimensions for each cross-sectional element can be identified and assembled. Consider a variety of alternative arrangements that can be combined for the various cross section elements, which optimizes the mobility and safety for all users, within the environmental and right-of-way constraints.

9.3.1.9 Design Vehicle

The design vehicle is the controlling vehicle constraint for design of the project. This can be represented as a standard passenger car, motor home, single-unit truck, bus or semi-trailer. *Green Book* Section 2.1 describes representative design vehicles parameters. Selection of an appropriate design vehicle should be made with knowledge of the existing and anticipated type-of-use, the tradeoffs involved with design and spatial impact, and with input from stakeholders and the public. The largest class of vehicle that uses the facility on a regular basis should be selected as the design vehicle. It should represent a cost-effective choice for the project and be appropriate for its context. The use of the facility by the design vehicle should be a measurable (i.e. over 0.5 percent) and reasonably predictable percentage of the average daily traffic.

9.3.1.9.1 Selection of Design Vehicle

In comparison to some major State highways, FLH Program projects are typically designed with a need to accommodate relatively high-use by recreational vehicles (motor home or passenger car with trailer) or intercity tour buses, and relatively low-use by large semi-trailer trucks.

The AASHTO classification parameters represent all vehicles within a particular classification and therefore the dimensions are larger than most vehicles of that class. Considerations for selection of a design vehicle are summarized in the following:

1. **Passenger Car (P) and Trailers (P/T)**. A passenger car may be selected as the design vehicle when the main traffic generator is parking lot or series of parking lots. A combination of passenger car and boat trailer or camper trailer should be considered when the parking facilities include such recreational uses.
2. **Motor Home (MH) and Boat Trailer (MH/B)**. A motor home may be selected when the main traffic generator is a recreational facility. A combination of MH and boat trailer should be considered when the recreational facility includes such use.
3. **Single Unit Truck (SU)**. A single unit truck may be used for intersection design of major residential streets, and is generally recommended for local roads, collectors and park or forest roads that serve visitor concession facilities. Generally for FLH projects the SU-30 [SU-9] is used rather than the SU-40 [SU-12]
4. **Buses**.
    a. An intercity bus (BUS-45 [BUS-14]) may be used for collector roads and minor arterials, and park roads, serving intercity bus routes, tourism destinations, visitor lodging and interpretive facilities, etc.
    b. A city transit bus (CITY-BUS) may be used for intersections of urban highways and city streets that are designated city bus routes, and otherwise have relatively few large trucks using them.
    c. The large (S-BUS-40 [S-BUS-12]), or conventional (S-BUS-36 [S-BUS-11]), school bus may be used for intersections of highways with low-volume county highways or very low-volume local roads and for residential subdivision major street intersections.
5. **Semi-trailers (WB)**.
    a. The intermediate semi-trailer WB-40 [WB-12] may be used for local or collector roads and minor arterials that serve some level of commercial truck traffic.
    b. The interstate semi-trailer WB-62 [WB-19] or WB-67 [WB-20] should be used for intersections of arterial roads and for other intersections on highways and industrialized streets or industrialized local roads that carry either high volumes of traffic or that provides local access for large trucks.
    c. For Forest Highways and other Forest access roads consider the wheelbase requirements of logging trucks, which are typically less than WB-40 [WB-12] semi-trailers.

9.3.1.9.2 Encroachments and Oversized Vehicles

Using the largest vehicle expected to use the facility on a less frequent basis, as design vehicle can result in a conflict of design objectives (e.g. designing for the larger vehicle results in larger corner radii which increases pedestrian crossing distances and paved areas). Design the facility for use by the largest legal vehicle, or the largest oversized vehicle anticipated, with an allowable encroachment. The allowable encroachment should not extend beyond the paved shoulders or encroach on sidewalks, but may include the opposing travel direction if sufficient sight distance is available for the maneuver and it is permitted by the state's vehicle code. In order to provide a balanced design, encroachments are generally acceptable for:

- Shoulders at intersections,
- Intersections along low-speed urban streets,
- Intersections along low-volume rural roads,
- Single left turns that use two receiving travel lanes in the same direction, and
- Double left or double right turn lanes that cannot accommodate side-by-side operation of the design vehicles, however designs should accommodate a passenger car alongside the design vehicle.

The WB-67 [WB-20] is commonly the largest legal vehicle in many states, and the WB-40 [WB-12] is the most common vehicle to transport commercial products in rural areas. In some areas the maximum oversized vehicle may be a modular home unit on a WB-67 [WB-20] trailer. The dimensions of this trailer may be assumed to be a maximum of 16 ft [4.9 m] high including the trailer, 16 ft [4.9 m] wide, and 56 ft to 80 ft [17 m to 24 m] long. When oversized vehicles encroach beyond the traveled way, consider:

- Wider shoulders,
- Full-depth surfaced shoulders,
- Sloping curb in lieu of vertical curb,
- Stabilized areas behind curbing,
- Relocation of signs, poles, appurtenances,
- Removable signs and appurtenances, and
- Removal of trees and shrubs.

As an alternative to a site-specific evaluation and design for the largest oversize vehicle, consider an alternate routing to bypass the particular site.

Commercially available computer software (e.g., AutoTurn) may be used for verifying vehicle tracking paths at intersections, in parking lots, sharp curves, etc., and for developing templates for special design vehicles.

9.3.1.10 User Characteristics

A fundamental expectation in roadway design is that all users will be accommodated safely. Virtually all roadways serve a variety of users including pedestrians, bicyclists, motor vehicle drivers and their passengers. Determine the composition of users anticipated for the facility, and account their needs. Consider the needs of pedestrians and bicyclists as an initial design control, not as an afterthought later in the design development. When human and vehicular factors are properly accommodated, the safety and effectiveness of the highway is greatly enhanced.

Driver performance and human factors are integral to the determination of highway design criteria. *Green Book* Section 2.2 provides guidance on consideration of user characteristics.

For application of design criteria and design of countermeasures, consider the presence, characteristics and special needs (i.e., information, time, visibility) of the following types of users:

- Pedestrians,
- Bicyclists, and
- Motor vehicle drivers (e.g., inexperienced, aging, unfamiliar, familiar).

Consider a wide variety of pedestrian users and abilities, including children, older adults, and people with various disabilities in the design. Design the facility to accommodate a wide range of pedestrians' physical, cognitive, and sensory abilities, including aids such as wheelchairs and power chairs. Accommodate pedestrian crossing needs at all intersections where sidewalks or pathways exist. Refer to Section 9.3.16 for pedestrian considerations and facilities. Refer to the *Highway Capacity Manual* for definitions of pedestrian level of service based on spatial and delay measurements.

Provide designs that will accommodate and encourage bicycle use. Typically design for bicyclists with moderate skills, which will encompass the needs of most riders. In the vicinity of schools, recreational areas and neighborhood streets consider special accommodation of young, inexperienced bicyclists. An operating space of 4 ft [1.2 m] should be used as the minimum width for one-way bicycle travel. Where motor vehicle traffic volumes, truck and bus volumes, or speeds are high, a more comfortable operating space of 5 to 6 ft [1.5 to 1.8 m] is desirable. Also, adjacent to on-street parking, 5 to 6 ft [1.5 to 1.8 m] is desirable to provide space for the opening of car doors into the travel lane or shoulder. Refer to Section 9.3.17 for bicycle considerations and facilities.

Also refer to Section 9.3.4.1 for discussion of the relationship of human factors and driver performance to the geometric design.

9.3.1.11 Maximum and Minimum Superelevation Rate

FLH standard practice includes the following:

- Establish a maximum superelevation value, e_{max} of 4, 6, or 8 percent, depending on the considerations described below, and
- The minimum superelevation rate, also referred as reverse crown, is equal to the normal crown rate for the type of pavement or surfacing.

Design criteria for e_{max} may be established by individual FLH Division practice, with values selected for the specific project. Establish the e_{max} for the project, with consideration for:

- Climatic conditions during travel seasons (frequency and amount of rain, snow, ice),
- Functional classification,
- Rural or urban location,
- Design speed,
- Frequency of slower-moving vehicles (e.g. trucks, traffic congestion, farm equipment),
- Environment (terrain conditions, elevation, adjacent land use),
- Constructability, and

- Road maintenance.

Higher e_{max} should be used for higher design speeds or friction demands. An e_{max} of 8 percent is typically recommended for higher design speeds, equal to or greater than 50 mph [80 km/h]. In rural areas the e_{max} should typically be either 6 or 8 percent. In urban areas the e_{max} should typically be either 4 or 6 percent, due to the constraints imposed by adjacent development (e.g., intersecting curbs, sidewalks, driveways and streets). In low-speed urban areas, less than 50 mph [80 km/h], the typical e_{max} rates of 4 or 6 percent may be undesired or impractical, and in such cases AASHTO Method 2 may be used for design of curves to minimize superelevation. In such cases the roadway may remain normal crown in curves so long as the resultant side friction demand is less than the allowable side friction factor, *f,* for design (see *Green Book* Figure 3-6).

An e_{max} of 6 percent is typically recommended where snow or icy conditions routinely occur during winter. An e_{max} of 4 percent may be appropriate for locations where the predominant traffic use operates in snow-packed or icy conditions (e.g., primarily serves winter recreation and ski areas). In selecting e_{max} consider combinations of longitudinal grade and cross slope such that the vector components of the curve design superelevation rate, *e* and the longitudinal grade, G should not exceed 10 percent where snow or icy conditions routinely occur during winter, which is expressed by the following:

$$(e\%)^2 + (G\%)^2 \leq 100$$

Green Book Section 3.3.3 provides guidance on selection of e_{max}. See *Green Book* Table 3-19 for maximum limiting superelevation rates for design speeds.

9.3.1.12 Speed Characteristics

Speed is a key design control for the alignment, lane and shoulder width, and the width of the roadside recovery clear zones for errant vehicles. Speed characteristics should meet the user's expectations, and also be consistent with the community's goals and objectives for the facility. Consider the various measures and characteristics of speed for design control, as described in the following sections. Refer to *Green Book* Section 2.3.6 for additional guidance.

9.3.1.12.1 Operating Speed

Operating speed is the speed at which drivers are observed operating their vehicles in typically good weather and surface conditions during off-peak free-flow conditions (not following). Operating speed is measured at discrete points along a roadway. Use the 85th percentile of the distribution of observed speeds to characterize the operating speed associated with a particular location or geometric feature. The operating speed is affected by the roadway features such as curves, grades, topography, width, access to adjacent properties, presence of pedestrians and bicyclists, parking, traffic control devices, lighting, etc.

The 50th percentile (mean) speed is also used for certain operational analyses. The average speed is the summation of the instantaneous or spot-measured speeds, at a specific location, of the free-flowing vehicles divided by the number of vehicles observed.

The pace speed is the highest speed within a specific range of speeds that represents more vehicles than in any other like range of speed. The range of speeds typically used is 10 mph [16 km/h].

A target speed (recommended speed) is the desired operating speed along a roadway, under optimal conditions. The purpose of a target speed is to define an operating environment that provides cues to the driver to conform to the intended speed. An appropriate target speed should be determined early in the project development process and should consider:

- The roadway context (i.e. character of the surrounding area, function of the roadway, and level of access management);
- The roadway geometry including alignment, sight distance, superelevation;
- Other physical conditions such as narrow lanes, roadside development, steep grades;
- The volume and mix of traffic, expectations of facility users, and expected safety performance;
- The anticipated driver characteristics, workload, and level of familiarity with the route; and
- The current range of operating speeds along the route.

The target speed is operating speed rather than desired average running speed. Consider that predicted 85th percentile operating speeds may be significantly higher in many locations along the route than average running speed, and that the actual operating speeds upon completion of the project will differ from what is intended or desired. The target speed should be considered as a factor in the selection of an appropriate design speed as discussed in Section 9.3.1.13.

9.3.1.12.2 Running Speed

Refer to the section on "Running Speed" in *Green Book* Section 2.3.6 for guidance on determination of the running speed for a section of the project.

Average running speed is typically used to characterize conditions on a roadway for analytical (planning, route selection, air quality) purposes rather than for the design of roadway geometry.

9.3.1.12.3 Posted Speed

The posted speed is the signed and legally enforceable speed limit established by the entity with responsibility for the highway. The regulatory speed is the speed limit applicable to the highway in the absence of a posted speed limit, and is typically established by state or local statute, local ordinances or other regulations. The *MUTCD* typically references the posted speed, or the measured 85th percentile operating speed if greater, for design of traffic control devices. Numerous studies have indicated that drivers will not significantly alter what they consider to be a safe operating speed, regardless of the posted speed limit, unless there is continuous enforcement.

9.3.1.12.4 Design Speed

Refer to the section on "Design Speed" in *Green Book* Section 2.3.6. PDDM Section 9.3.1.13 describes considerations for selection of the design speed.

Design traffic control devices (e.g., warning signs, no-passing zones) based on either the overall measured 85th percentile operating speed, or the posted or regulatory speed limit, rather than the design speed.

9.3.1.13 Selecting an Appropriate Design Speed

It is FHWA policy that the design speed should equal or exceed the posted or regulatory speed limit of the completed facility.

Where an established geometric design standard for the posted or regulatory speed cannot be met, and lesser values are proposed, the condition must be treated as a formal design exception as outlined in Section 9.1.3.

To encourage a "self-explaining, self-enforcing" roadway (see Section 9.3.1.14) it is FLH standard practice to select a design speed that:

- Is logical and recognizable to the driver (i.e. the reason for the speed is evident);
- Reinforces the driver's expectations and behavior with respect to the purpose and function of the highway, its location, topography, adjacent land use and intended speed;
- Is appropriate for the topography, adjacent land use, and type of highway; and
- Is consistent with other geometric and roadside design features (e.g., lane and shoulder widths, cross section elements).

The selection of an appropriate design speed involves consideration of many additional factors including the functional classification, expected volume and composition of traffic, usage, operating speeds, access, topography, contextual characteristics, and impacts. The section on "Design Speed" in *Green Book* Section 2.3.6 explains the philosophy of design speed and its relationship to operating speed and running speed. A discussion of design speed is covered in pages 12-13 of the *Park Road Standards*. Recent research on design speed, operating speed and posted speed practices is provided in *NCHRP Report 504* and *Transportation Research Record (TRR) 1796*, 2002.

Typically, a higher functional classification prescribes a higher range of design speeds. Refer to *Green Book* Table 6-1 for recommended design speeds for rural collector roads. For rural arterial roads the *Green Book* recommends design speeds in the range of 40 to 75 mph [60 to 120 km/h]. Also refer to Table 1 of the *Park Road Standards* for typical design speeds.

When either 1) the minimum design speed applicable to the functional classification and terrain, or 2) individual design elements that are based on design speed and addressed on an individual basis, cannot be achieved, address the situation as a formal design exception. The design exception can cover a single location on the project, multiple locations, or the entire project corridor. A lower design speed for an isolated segment of a project should not be proposed as a design exception, due to the importance of relating all geometric features of the highway. A reduction in the design speed in one area may be unlikely to affect overall operating speeds. It may potentially result in the unnecessary reduction of all of the speed-related design criteria in the area rather than just the one or two features that led to the need for the exception. The acceptable alternative approach to such a design speed exception is to evaluate each geometric feature individually, addressing the design exceptions for each feature, and applicable mitigation, within the context of the appropriate design speed.

The design speed is not necessarily constant within the corridor if there are distinct, recognizable zones (e.g. terrain, land use) that are appropriate to change both design speed and posted speed.

Consider the inter-relationship between speed and roadway geometry in design. The selection of design speed influences the geometrics of the roadway. Consequently, the geometrics of the roadway are important determinants of the operating speeds that result on the constructed facility. Current best practice for the selection of a design speed is through an iterative process:

- Develop a preliminary design,
- Estimate the overall 85^{th} percentile operating speeds along the alignment,
- Check for large differences between the 85^{th} percentile speeds on successive curves, and
- Revise the proposed alignment to reduce these differences to acceptable levels.

Where revision of the proposed alignment is not feasible, then effective mitigation to address the speed differences should be provided.

9.3.1.13.1 Coordination of Design Speed, Operating Speed, and Posted Speed

Occasionally projects (e.g. RRR projects) retain geometric elements, such as tight curves, superelevation, or restricted sight distances that, overall, are applicable for a speed lower than the posted speed for the corridor. This may be due to terrain, adjacent land use, or environmental or historic constraints. In these cases, the designer should recommend a posted speed consistent with the overall geometric features. In most instances, the owner agency has the authority to establish the posted speed for the facility. When necessary, the establishment of speed limits, and guidance in setting posted speeds that are consistent with the design of the highway, should be recommended to the owner-agency. However, when system-wide regulatory speed limits prevail they mandate the posted speed.

In order to provide overall design consistency, and to minimize the use of design exceptions, all possible effort should be made to coordinate the proposed design with current standards for the regulatory or posted speed limit through one of the following methods:

- By obtaining agreement with the owning/maintaining agency to establish a posted speed limit that is most consistent with the proposed design, or

- By reconstruction of deficient features to meet the regulatory or posted speed design standards, or
- By a combination of these approaches.

Current best practice for speed management is to establish the posted speed limit with strong consideration for the overall measured 85^{th} percentile operating speed. Higher posted speeds impose greater challenges and constraints on the design. Difficult or constrained conditions may lead to consideration of a lower design speed for an element or portion of the highway. Designs based on artificially low speeds can result in inappropriate geometric features that violate driver expectations and degrade the safety of the highway. Posting a speed limit and setting the design speed significantly lower than the overall 85^{th} percentile operating speed may not adequately address substantive safety needs. It has been found that reducing the posted speed limit (e.g., matching with too low of a design speed) will likely have little or no effect on the overall 85^{th} percentile operating speed without adequate enforcement. Inconsistencies and safety risks inherent in the geometric design cannot be corrected or masked simply by lowering the posted speed limit, even though the number of formal design exceptions, legal liabilities and need for mitigation of safety risks may be perceived as reduced. Instead, emphasize consistency of design so as not to surprise the driver with unexpected features. Where the measured 85^{th} percentile operating speed is significantly higher overall than the posted speed limit (e.g., 10 mph [16 km/h] or more), it is recommended to use a design speed that is higher than the posted speed limit.

9.3.1.13.2 Considerations of Speed

Design speed selection should seek to balance the benefits of high speed for mobility, efficiency and long-distance regional travel with environmental, community, right-of-way, and construction-cost constraints. The longer the trip, the greater the driver’s desire to use higher speeds, therefore knowledge of users’ travel distance from trip origin to destination is important. Except for local streets, park roads and other recreational roads where higher speeds are not needed or desired, every effort should be made in the design to minimize the time of travel and to use as high a design speed as practical. On rural highways, a greater percentage of vehicles are usually able to travel at the limiting speed that is governed by the geometric design, so the selection and relationship of the geometric design elements affecting speed are especially important to optimize. On rural arterials, the driver expectation is to safely operate at higher speeds than for collector and local roads.

Occasionally a project’s existing geometric elements, including horizontal and vertical curvature, sight distance, lane and shoulder width, are generally suitable for speeds significantly higher overall (more than 10 mph [16 km/h]) than the posted speed for the corridor. This may be due to gentle terrain, or the prevalence of design values that are several times greater than the minimum for the posted speed. In these cases, the designer should evaluate the inferred design speed, which is the maximum speed for which all critical design-speed related criteria are met for a particular length of the highway. The inferred design speed for a horizontal curve radius-superelevation design is the maximum speed for which the limiting-speed side friction value, f_{max}, is not exceeded for the design superelevation rate. The inferred design speed for a vertical curve is the maximum speed for which the limiting-speed stopping sight distance is not exceeded. An inferred design speed that is significantly higher than the posted speed may result in operating speeds that are substantially higher than anticipated. In these cases the design speed for the project should be selected with strong consideration of the inferred design speed, as well as the posted speed and operating speed. Where applicable, consider speed reduction techniques for transitions to lower-speed environments.

9.3.1.13.3 Considerations of Calming and Low-speed Environment

In selecting a design speed consider appropriate elements to maintain the safety of pedestrians, bicyclists, and anticipated mix of slower traffic (e.g. local farm vehicles, local residential and commercial vehicles), and include transitional elements at locations necessitating lower operating speeds. Traffic calming measures may be considered, primarily in residential neighborhoods, to address demonstrated safety problems caused by excessive vehicle speeds and conflicts with pedestrians, bicyclists, and school children.

Where conflicts exist between higher-speed and lower-speed users, pedestrians, bicyclists, wildlife, recreational uses, residential activity, business activity and complex traffic situations, it may be beneficial to provide lower design speed criteria, features and traffic calming measures for reduced speeds, as appropriate. Speed can be reduced by inducing curvature into the alignment, with greater accumulated curvature deflection of the alignment having greater affect. A curvilinear alignment consisting of a series of low-speed curves, with a gradual change in radius between the successive curves, will reinforce the desired low-speed operation. Sudden unexpected changes in the alignment, profile, cross section or roadside elements are not recommended; however, gradual changes over a transition section that is apparent to the driver can be effective to introduce a low-speed operating environment.

Traffic calming measures include features added to the roadway to create horizontal or vertical deflections, narrowing the real or apparent roadway width and more constrained cross section, signing, noise, humps or vibration to increase the driver's awareness of speed, and devices increasing the driver's attentiveness to the presence of pedestrians. A description of traffic calming techniques is available at Traffic Calming from FHWA and from Traffic Calming for Communities from ITE. Additional guidance on traffic calming is provided in Section 8.5.5 and TrafficCalming.org.

9.3.1.13.4 Managing Variations in Operating Speed

Many vehicles operate at speeds higher than the design speed on long tangents and flatter curves. These vehicles have to slow to the design speed in order to safely and comfortably negotiate the sharpest curves. In areas of sharp curves, the radius and the superelevation of adjacent curves should be designed to limit the difference in operating speed between the curves to a maximum of 15 mph [20 km/h], and preferably, to less than 5 mph [10 km/h]. If the maximum differential is exceeded, the plans must include advance curve and advisory speed signs for the lower speed curves. Additional delineation of the lower speed curvature should be considered on a case-by-case basis (e.g., delineators, raised pavement markers, chevrons).

The IHSDM and its associated references provide methodology to determine the predicted operating speeds for a particular design and horizontal alignment. Application of the IHSDM is described in Section 8.4.5.1

Alternatively, the variation in operating speed may be roughly predicted by determining the inferred design speed of the geometry at various locations based on a comparison with the horizontal and vertical design criteria prescribed by the *Green Book* for the various design speeds, and by a correlation of the inferred design speed with observed operating speeds. The speed correlations are described in *NCHRP Report 504*.

Except for a controlled intersection, design of the roadway geometry for less than 20 mph [30 km/h] is not recommended. For design speeds of 60 mph [100 km/h] or greater, strive to provide a design having highly consistent geometry that facilitates vehicle operation at a uniform speed. Exhibit 9.3-A describes recommended maximum variations in operating speed for design consistency.

Exhibit 9.3-A MAXIMUM VARIATIONS IN OPERATING SPEED BETWEEN SUCCESSIVE CURVES, AND BETWEEN LONG TANGENTS AND CURVES, FOR DESIGN CONSISTENCY

Condition Status	US Customary			Metric		
	Design Speed (mph)			Design Speed (km/h)		
	< 35	35 to 55	> 55	< 60	60 to 90	> 90
Unacceptable	15	20	15	25	30	25
Undesired	10	15	10	15	20	15
Typical	5	< 10	5	10	< 10	5
Desired	5	5	0	5	5	0

For recommended maximum variations of operating speeds between the main roadway and interchange ramps, refer to *Green Book* Section 10.9.6. For weaving sections see *Green Book* Section 2.4, 10.9.3 (subsection entitled “Cloverleafs”), and 10.9.5.

Also refer to Section 9.3.4.2 for additional guidance on the concepts of design consistency.

For high-speed roads, a reduction in operating speeds in the area of a major intersection may be beneficial. For high-speed roadway segments approaching a major intersection, consider the need for a speed reduction treatment within a transition area of sufficient length for comfortable deceleration in advance of the intersection. Refer to NCHRP Report 613, *Guidelines for Selection of Speed Reduction Treatments at High-Speed Intersections*.

9.3.1.14 Self-explaining, Self-enforcing Road Concepts

Incorporate self-explaining, self-enforcing road concepts into the design, as appropriate. The concept of the self-explaining, self-enforcing road is that the road (both the roadway and the roadside) is specifically and completely designed for a particular, commonly recognizable, purpose or function. This concept, or philosophy, relies on the physical roadway design attributes to passively "enforce" or reinforce intended operating speeds and other driver behaviors, rather than relying primarily on signs, directives and active enforcement. Conflicting road attributes (e.g., a high-speed cross section combined with a low-speed alignment) are removed, and agreeing design attributes are substituted, which maintain safety and desired operations. This philosophy is considered a speed management and behavioral design approach in which the objective is not necessarily to restrict speed, but to plan and design a roadway where the appropriate speed and operational safety naturally result, and a "self-explaining" look and feel is achieved for the particular type of highway facility.

Implement this concept by including in the design various roadway design features and treatments, including aesthetic enhancements, which are commonly associated with a recognizable "standardized" road category, to communicate to the driver the sense of its function type and the facility context. Special treatments should be provided at the transition zones between differing road functions or speed categories, to serve as "gateways" that overtly emphasize and accentuate those attributes that define the new road function and its intended speed. Design the new road function (and its intended speed) to be readily recognized and understood by the driver. Design a recognizable speed-reduction treatment to transition between a high-speed rural countryside and a low-speed suburban community. Also, design a recognizable speed-reduction treatment to transition between a high-speed arterial highway and a low-speed interpretive park road. The criteria and guidelines described in Section 9.3.1.13.4 may be applicable to these transitions. In addition to emphasizing the transition zones, fully provide the design and safety features appropriate for the differing road function or speed categories. For additional description of the concepts and philosophy of a self-explaining, self-enforcing road design, see *Geometric Design Practices for European Roads* (FHWA, June 2001).

9.3.2 AESTHETIC CONSIDERATIONS

FLH standard practice is to:

- Emphasize curvilinear alignment, generally defined as having an equal or greater proportion of the alignment in curves than on tangents, and
- Apply the general considerations, general design controls, and alignment coordination found in *Green Book* Section 3.5.

Also strive to accomplish the following:

- Provide curvilinear alignment through scenic terrain.
- Avoid short, abrupt horizontal and vertical curves, especially if the central angle or change in grade is small and a substantial length of both tangents is visible.
- Designate sufficient right-of-way area on the inside of curves, and at the ends of long tangents, to facilitate adequate control of vegetation or setback of potential future development that could impair sight distance, and tangential views, especially in scenic terrain.

Broken-back vertical curves are visually unpleasing and undesired, and should be substituted with a single overall vertical curve when practical.

From an aesthetic standpoint, the geometric design for bridges should blend in with curvilinear alignment. Design superelevation to avoid or minimize unsightly kinks, humps or dips in bridge railing or curbs. Coordinate the vertical alignment closely with the bridge location. Consider that bridges placed on conspicuous sag vertical curves can have an unfavorable appearance.

Coordinate the clearing, slope design, and vegetation management in vista areas to provide a visual buffer, frame views, define spaces or to provide visual context for the roadway. Consider aesthetic treatment of curbs, culvert headwalls, retaining walls, traffic barriers, and structures to blend and de-emphasize new features and enhance prominent vistas. Consider the location and type of signing, posts, fencing and other appurtenances to minimize blockage of views.

The ultimate test for an aesthetically pleasing facility is whether it complements the area through which it passes and enhances the user's appreciation of its context. The designer should strive to achieve this goal.

9.3.3 HORIZONTAL AND VERTICAL ALIGNMENT RELATIONSHIPS

Apply the general controls and guidelines for coordination of line and grade described in *Green Book* Section 3.5.2, and also refer to *Green Book* Figure 3-46 for recommended alignment and profile relationships in roadway design.

Horizontal and vertical alignments should not be designed independently. Horizontal and vertical alignments are mutually related and their interrelationship can have a significant effect on the operational and safety characteristics of the roadway. What applies to one is generally applicable to the other. The highway designer should visualize the completed facility in a three-dimensional mode to ensure that the horizontal and vertical alignments complement each other and enhance the beneficial features of both. Excellence in a coordinated design will maximize the sight distance and safety of the highway, encourage uniform speed and make a positive contribution to the visual character of the road.

9.3.4 COMBINATIONS OF DESIGN ELEMENTS AND FEATURES

Consider design criteria and elements in combination with all the various elements and features that interplay at any given location, and in sequence, along the highway, rather than each in isolation. Specific considerations are described in the following sections.

9.3.4.1 Human Factors and Driver Performance

In developing the highway design, consider human factors with the intent to minimize driver error. Refer to *Green Book* Section 2.2 for information on the driving task, guidance tasks, roadway information handling, and driver error. Also refer to the *Highway Design Handbook for Older Drivers and Pedestrians*, FHWA-RD-01-103, which provide recommendations for improving the highway design beneficial to all users.

9.3.4.2 Design Consistency

Provide geometric design elements and operational features consistent with driver expectancy and the driving tasks required. Provide a highway design that minimizes:

- Changes in predicted 85th percentile operating speed,
- Changes in predicted roadway safety,
- Improper lane positioning,
- Complexity of traffic control devices, and
- Driver workload.

Consistency with respect to these measures can help minimize the potential for driver error.

At locations where the highway characteristics change, provide adequate visibility or notice of the changed condition, and provide the safest environment possible.

Design consistency also relates to using consistent design speeds for the design of the various individual geometric elements present along the corridor and consistent application of criteria for various design elements. If design speed for a horizontal alignment is increased (e.g., to match the posted speed limit), all design criteria must meet the standards for the increased speed.

Alignment consistency refers to the design of successive geometric design elements to minimize large variations in operating speed, using curvilinear alignment design to avoid long tangent lengths and designing sequences of horizontal and vertical alignment elements which follow one another within acceptable ranges for variation in operating speed. Designs that generally conform to the terrain contours (i.e., “laying lightly” on the landscape) will generally result in a curvilinear alignment; however, variability in the alignment consistency can be expected to increase as the severity of the terrain, or other alignment controls, increases.

It is especially important to consider successive curve radii in transitions from long tangents or flat curves to those of minimal radius, since actual operating speeds typically exceed design speeds on tangents and flat curves (radius greater than 1,500 ft [450 m]). In evaluating alignment consistency the designer may assume 85th percentile operating speeds of 60 mph [100 km/h] approaching curves following tangents or flat curves with radius greater than 1,500 ft [450 m], for distances traveled in 30 seconds or more at the design speed, on rural two-lane highways. See Section 9.3.1.13.4 for guidance on managing variations in operating speed between successive curves.

Refer to NCHRP Report 502, *Geometric Design Consistency on High-Speed Rural Two-lane Roadways* for additional information on design consistency.

9.3.4.3 Combinations of Design Elements with Intersections and Bridges

Combinations of alignment and cross section design elements, together with such features as intersections and bridge structures, must be carefully considered during design. The complex traffic operations at intersections are sometimes difficult to predict, and may be exacerbated by unforeseen traffic peaks and future operational conditions. The design of bridge structures may far outlast the life of the original roadway alignment or cross section, and may in the future experience greater traffic volumes and speeds than originally envisioned for the roadway. Avoid using minimum design criteria at these types of locations, especially the combination of minimal design criteria for multiple design elements (e.g., horizontal and vertical alignment, lane and shoulder width, sight distance).

Where possible, locate bridge structures entirely on tangents, curves, or superelevation transitions, but not on combinations of these. This may require minor adjustments in horizontal alignment to avoid or minimize these types of combinations. Wherever possible, avoid the introduction of new cross section elements (widening, additional lanes or shoulders) on the bridge, but introduce the cross section element ahead of the bridge and carry the element across the bridge structure.

9.3.4.4 Additive Design Risk Assessment

Safety and operational risks increase substantially as combinations of critical design elements are added. Combinations of minimal horizontal curve geometry, minimal vertical curve geometry, minimal roadway width and cross section elements, steep grades, limited sight distance, presence of intersections and driveways, structures and barriers each add a greater level of risk to the situation. While using minimum design criteria for a single design element may not pose a great risk, the combination of minimum design criteria, or below-minimum design criteria, or both, for several design elements at the same location may result in unacceptably high levels of safety or operational risk. When using minimum design criteria is proposed, the combinations of other roadway and design elements and features should also be considered.

Consider the combinations of volume, speed and type of traffic that is exposed to the risk, in evaluating the site-specific conditions (e.g., nighttime versus daytime traffic volume and speed) to factor into design risk decisions.

9.3.5 HORIZONTAL ALIGNMENT

Refer to *Green Book* Section 3.3.13 for general guidelines applicable to the design of all horizontal alignment.

The horizontal alignment design should provide for safe and continuous operation at a uniform design speed for substantial lengths of highway. Use an iterative geometric design process consisting of sufficient analysis to determine the predicted operating speeds on tangents and curves, and a feedback loop to adjust the horizontal alignment design. The design speed, minimum radius, superelevation, and transitions are the primary criteria in horizontal alignment design. These design elements are related by the laws of mechanics and also involve side friction factors, centripetal force, gravity, etc. that are discussed in detail in the following subsections.

In addition to the above general criteria, apply the following considerations in all horizontal alignment design:

- Safety,
- Functional classification,
- Topography,
- Compatibility between existing and proposed conditions (contextual controls)
- Tangent to curve transitions
- Vertical alignment,
- Compatibility with the roadway cross section,
- Design vehicle characteristics,
- Driver characteristics, driver expectancy and workload,
- Lines of sight,
- Drainage considerations,
- Construction cost,
- Environmental protection,
- Cultural development, and
- Aesthetics.

These factors, when properly balanced, should produce an alignment that is safe, economical and in harmony with the natural contour of the land and the environment.

9.3.5.1 Horizontal Curves

Horizontal alignment design focuses on the design of horizontal curves, as they are the primary controlling feature. The following sections address the elements for design.

9.3.5.1.1 Speed

Speed prediction is an essential element that should be considered in the development of the geometric design and especially for design of horizontal alignment and curves. Refer to Section 9.3.1.12 for a description of speed characteristics relating to highway design.

9.3.5.1.2 Side Friction Factor

FLH standard practice is to use the *Green Book* values of side friction factor for curve design. Refer to *Green Book* Figure 3-6 and Table 3-7 for side friction factors assumed for design.

For unpaved roads, the designer may establish an appropriate value for side friction factor that is less than the values provided in the *Green Book*. VLVLR Exhibit 17 lists ranges of traction coefficients used by the Forest Service in design of unpaved or snow-packed roads

(ADT ≤ 400), and recommends using a side friction factor that is 0.2 less than the listed traction coefficients as a basis for establishing minimum radius.

9.3.5.1.3 Superelevation

FLH standard practice is to use AASHTO Method 5 for determination of design superelevation rates for the various curve radii of a horizontal alignment. Refer to *Green Book* Figure 3-8 for a description of the Method 5 procedure for superelevation distribution.

Superelevation may be minimized in low-speed urban areas, 45 mph [70 km/h] or less, by using AASHTO Method 2 for design of curves. In such cases the roadway cross slopes may remain normal crown in curves so long as the resultant side friction demand is less than the allowable side friction factor, *f,* for design (*Green Book* Figure 3-6). Refer to *Green Book* Table 3-13 for minimum radii and superelevation in low-speed urban areas, in cases where the typical superelevation rates using AASHTO Method 5 are either undesired or impractical. See *Green Book* Section 3.3.6 for additional guidance in such cases.

Very flat horizontal curves need no superelevation because the side friction needed to sustain the lateral acceleration developed by vehicles, even at high speeds, is minimal. The minimum curve radii for a section with normal crown (NC) are designated in the *Green Book* superelevation tables (Tables 3-8 to 3-12). See *Green Book* Section 3.3.5 for more information.

9.3.5.1.4 Curve Radius

Refer to *Green Book* Section 3.3.5 for guidance on selection of the minimum curve radius. Select a curve radius that fits the terrain and other controls, and that meets, and preferably exceeds, the minimum criteria for the design speed. Strongly consider adjacent curves to minimize excessive variations in operating speed and to promote design consistency. Refer to Section 9.3.1.13.4 for guidance in managing variations in operating speed.

9.3.5.1.5 Reversals in Alignment

Avoid abrupt reversals in alignment by providing enough room between curves for superelevation runoff or for spirals. See Section 9.3.5.2 for information on horizontal curve and superelevation transitions. Design the tangent distance between reversing curves to either be sufficiently long to establish a normal crown (tangential) driving mode, or a lesser length to provide a flowing reversal of the superelevation with a continuous transition between the reversing curves.

For simple, reversing curves with intervening normal crown template, design the tangent distance to preferably exceed 6 to 7 seconds duration, at the design speed. For a continuous, merged transition between the reversing curves, preferably design the tangent length to be approximately 3 to 4 seconds duration. For simple curves, tangent lengths of 5 seconds duration at the design speed may cause conflicts with the desired superelevation transitions.

9.3.5.1.6 Broken Back Curves

Broken-back curves (i.e., adjacent curves in the same direction with short intervening tangents) violate drivers' expectations. When broken-back curves are visible for some distance ahead, they present an unpleasing appearance, even with tangents as long as 1,300 ft [400 m]. It is desirable to introduce a slight reverse curve between them to eliminate the broken-back effect. Broken back curves with intervening tangent lengths of 200 ft to 400 ft [60 m to 120 m] are especially undesirable. However, broken-back curves may be necessary in difficult terrain or due to sever alignment controls. In some cases, a single long curve or compound curves may be preferred to replace the broken-back curve.

9.3.5.1.7 Compound Curves

Avoid compound curves if practical because drivers do not expect, or readily discern, changes in the rate of curvature within a curve and will tend to drift outside of their travel lane. However, compound curves may be necessary in difficult terrain or due to severe alignment controls, to eliminate excessive cuts or fills, encroachments into rivers or creation of broken-back curves. A single curve, in cases of minimal additional impact, is always preferable to a compound curve.

Because neither compound nor broken-back curves are desirable, involve senior design experience and judgment to determine which to use in an unavoidable situation.

When designing for compounding curves, the radius of the flatter curve should not be more than one-and-a-half times that of the sharper curve. If this is impractical, design a partial spiral or a curve of intermediate radius between the main curves. The rate of change in radius of a partial connecting spiral should be approximately equal to the average for the normal spirals used on the curves. Intermediate connecting curves should have a length not less than the runoff length for the flatter main curve as obtained from the superelevation runoff tables as shown in the *Green Book*.

The arc length of compound curves should be designed to provide at least 3 seconds, and preferably 5 seconds, of driving time on each main curve, excluding transitions.

9.3.5.1.8 Small Deflection Angles

Small alignment angle deflections (less than 5 degrees) should have relatively long curves to avoid the appearance of a kink. The minimum curve length should provide at least 3 seconds, and preferably 4 seconds, of driving time on the curve.

Avoid very small angle deflections (less than 1 degree) if practical by substituting a single tangent. Angle deflections of 15 minutes and less may become undetected and thus can create computational problems with design or surveying software data, and should not be used in the design. When very small deflections of between 15 and 40 minutes are required (e.g., to connect with a previously established tangent construction), they do not necessarily require using a curve, but it is preferable to locate changes in grade with vertical curves at these angle points to mitigate the visible effect to the road user.

Ensure tangency at all connections of tangents with curves or spiral curve transitions, and at compound curves. In no case provide an angle point at these locations.

9.3.5.1.9 Curvature on Through-Fills

Use only very flat curvature on long, high through-fills, unless guardrail, or other measures (e.g., delineators, guardrail retro-reflectors), or both, are used to delineate the edge of the roadway.

9.3.5.2 Horizontal Curve and Superelevation Transitions

The design of horizontal curve transitions includes the transition of the roadway cross slope as well as the possible incorporation of a spiral or compound transition curve in the alignment geometry. Refer to *Green Book* Section 3.3.8 for general guidance on horizontal curve and superelevation transitions.

The following sections provide guidance on specific design considerations for superelevation transitions.

9.3.5.2.1 Attainment of Superelevation on Tangent and Curve

The following FLH superelevation transition standards apply:

- Provide at least the minimum superelevation runoff length (L_r) determined by *Green Book* Equation 3-23,
- For determining the maximum superelevation runoff length, provide a relative gradient that is at least 70 percent of the maximum relative gradient values in *Green Book* Table 3-15, and
- Proportion the superelevation runoff on the tangent and curve within the allowable ranges, as described below.

FLH standard practice is to design the tangent runout distance (L_t) based on the same relative gradient as the superelevation runoff, as shown in Exhibit 9.3-B:

$$L_t = e_{ncr} \times L_r / e_d$$

where:
e_{ncr} = normal crown rate (%)
e_d = design superelevation rate
L_r = Superelevation runoff length

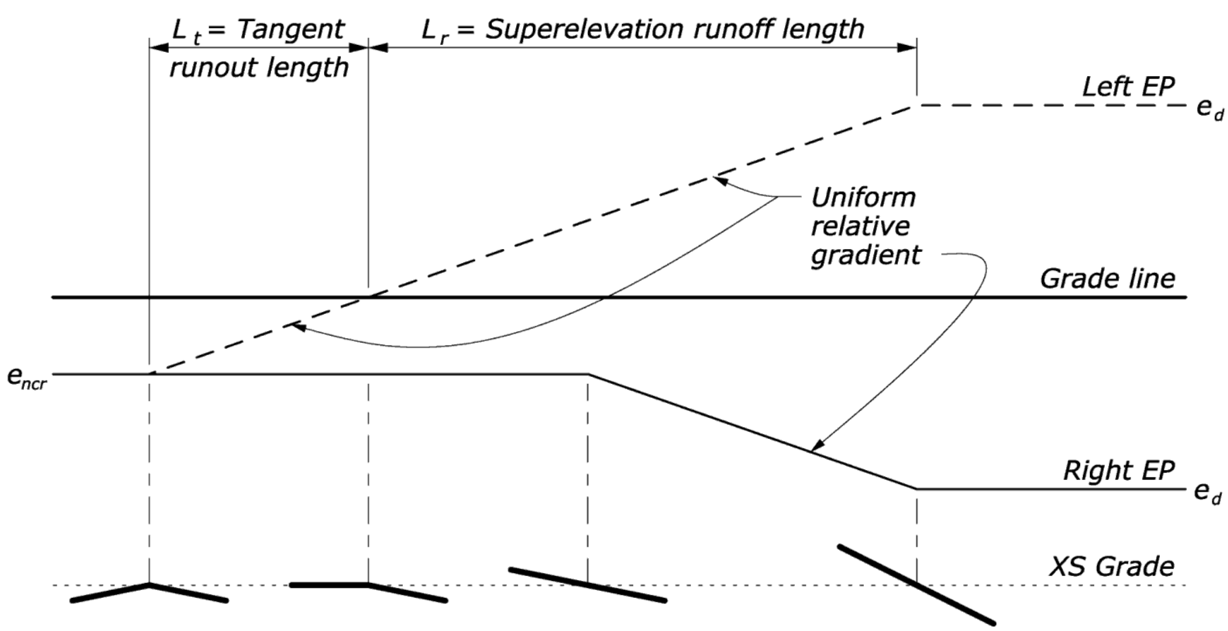
FLH standard practice is follow the *Green Book* recommended values for location of the superelevation runoff, with inclusion of the additional criteria described herein. *Green Book* Table 3-18 provides recommendations for allocation of the superelevation runoff between the tangent and curve to minimize vehicle lateral shifts, based on theoretical considerations.

To resolve the transition conflicts caused by a short tangent distance between curves, FLH standard practice includes the following:

- Up to 50 percent of the runoff length may be located on the curve and 50 percent on the tangent, if it is impractical to provide sufficient tangent length to accommodate the standard allocation of superelevation runoff; however,
- At least 60 percent of the superelevation runoff length on the tangent is the minimum desired, and 80 percent on the tangent is the maximum desired, for two-lane roadways; and
- For certain situations such as a short curve length, or if necessary to accommodate reversing curves with merged transitions, up to 90 percent of the superelevation runoff length may be located on the tangent.

Where there is insufficient tangent length to accommodate the minimum superelevation runoff length or allocation criteria between curves, redesign the curves to provide the minimum runoff length, or address the situation as a formal design exception. If the portion of superelevation runoff located on the tangent is not within the range of 50 to 90 percent, a formal design exception is required for the superelevation transition.

Exhibit 9.3-B SUPERELEVATION ATTAINMENT BETWEEN TANGENT AND CURVE



9.3.5.2.2 Reverse Curve Transitions

FLH standard practice for reverse curve transitions includes the following:

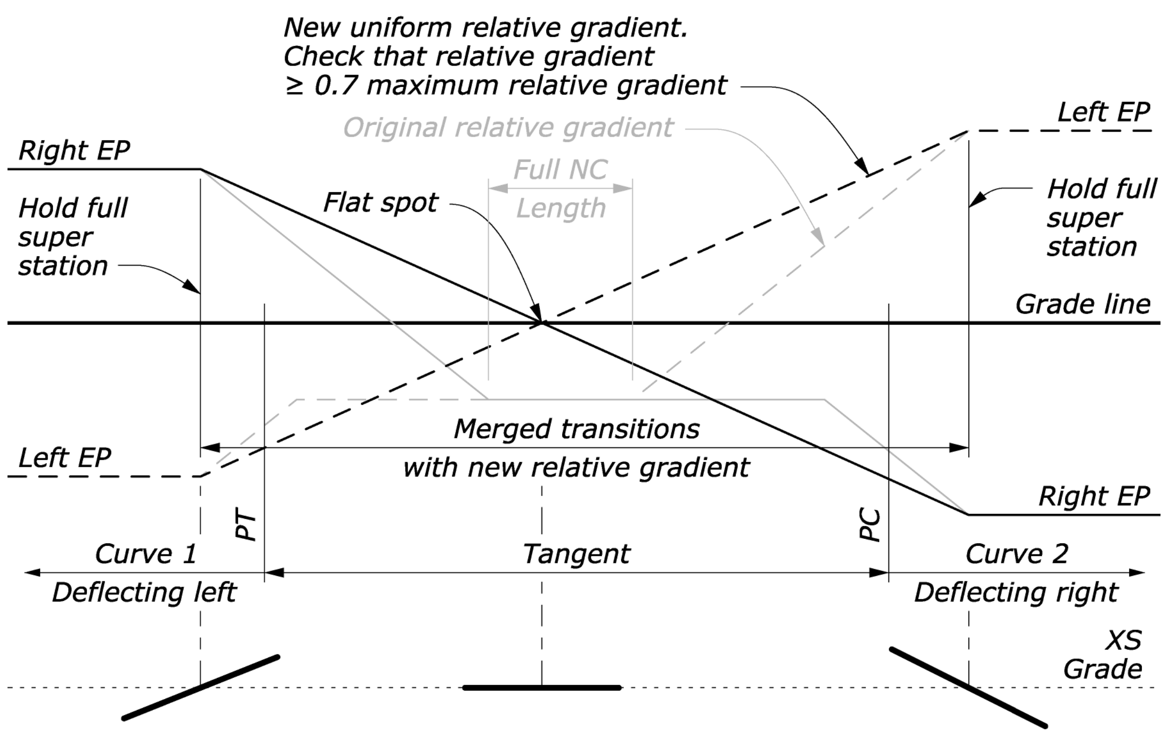
- The minimum length of normal crown section between reverse curves is 100 ft [30 m],
- The desired length of normal crown section is at least 200 ft [60 m], or 3 seconds travel time at the design speed whichever is greater, and
- In no case let tangent runouts overlap.

Provide superelevation runoff between the minimum and maximum lengths, and proportion the superelevation runoff on the tangent and curve within the allowable range, as described in Section 9.3.5.2.1. Otherwise, treat the situation as a formal design exception.

If the initially designed length of normal crown section is less than 1½ times the normal cross section interval, and less than 75 ft [30 m], FLH standard practice to resolve the situation includes the following, (as shown in Exhibit 9.3-C):

- Combine (merge) the two transitions as a supercritical case; and
- If the resultant relative gradient is within the maximum and minimum values, use the same uniform relative gradient for each transition, with the zero percent positioning determined by the original designed (unadjusted) full super (FS) stations; or
- If the relative gradient is not within maximum and minimum values, locate the zero percent position at a distance ratio based on the superelevation rate (*e*) of each curve, and use the average of the two original designed relative gradients, that it is within the maximum and minimum values.

Exhibit 9.3-C TREATMENT OF REVERSE CURVES: SUPERCRITICAL CASE

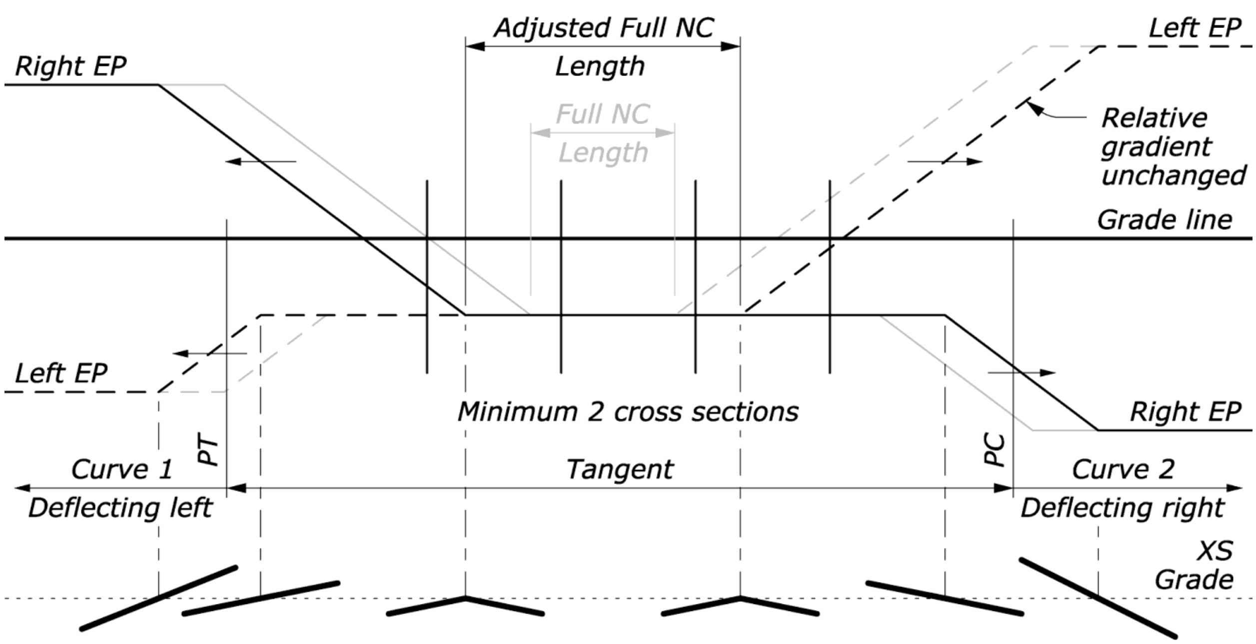


If the initially designed length of normal crown section is between 1½ and 2 times the normal cross section interval, or between 75 ft and 100 ft [30 m and 40 m] either adjust the full super stations to provide the necessary length of normal crown section, or provide an intervening section of minimum super rate (reverse crown).

To resolve a superelevation transition conflict (critical case) and provide the minimum normal crown section of at least 100 ft [30 m], the necessary length of normal crown section may be provided by adjusting the locations of the superelevation runoff relative to the ends of each curve (PT and PC) as shown in Exhibit 9.3-D, or by increasing the relative gradient (i.e., reducing the superelevation runoff length), or by a combination of both of these solutions. FLH standard practice in this case is to hold the original designed relative gradients and adjust the FS stations, if necessary, to provide the minimum length of normal crown section, within the following parameters:

- The portion of the superelevation runoff lengths located on each curve may be increased, providing that the portion of the superelevation runoff located on the curve does not exceed 50 percent.
- The original designed superelevation runoff length may be decreased, providing that the minimum superelevation runoff length (L_r) determined by *Green Book* Equation 3-23 is provided.

Exhibit 9.3-D TREATMENT OF REVERSE CURVES: CRITICAL CASE

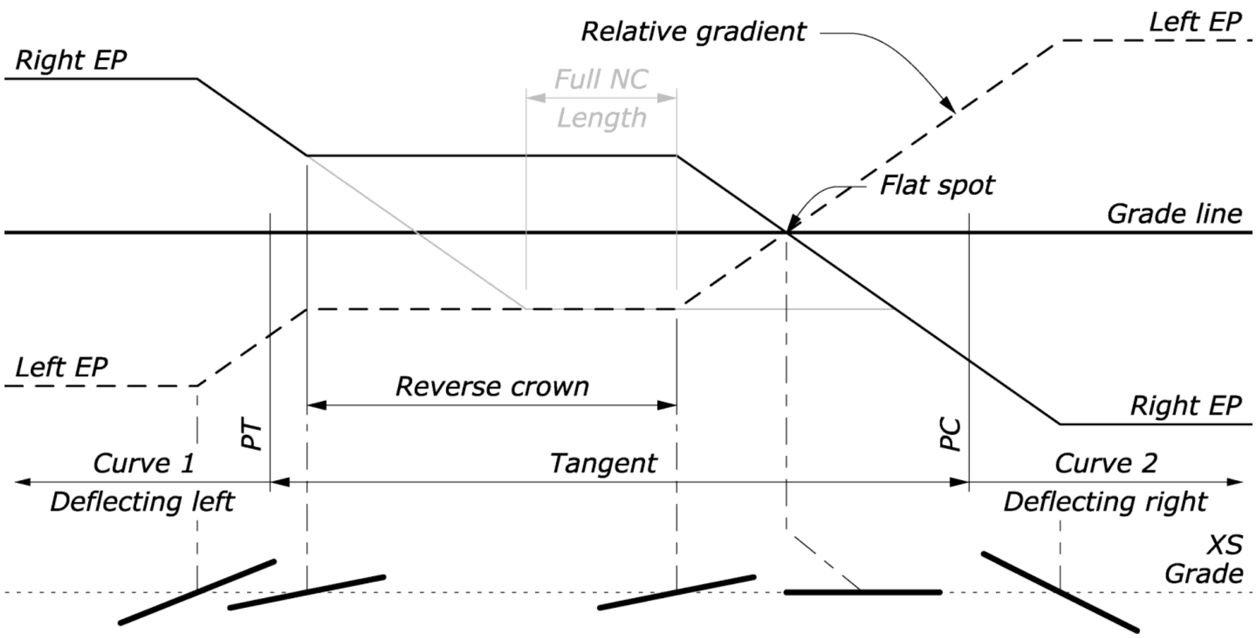


For intermediate tangent lengths between reversing curves, when the initially designed tangent length is insufficient to develop a minimum normal crown section of at least 100 ft [30 m], and desirably 200 ft [60 m] or 3 seconds of travel time at the design speed, yet is too long to merge the transitions comfortably between the curves with either the desired relative gradient, or desired allocation of superelevation runoff on the curve, or both, a section of minimum super rate (reverse crown) may be provided within the transition. FLH standard practice in this case includes the following as shown in Exhibit 9.3-E:

- The transition from full super to minimum super (reverse crown) passing through zero percent may be associated with either curve, depending on the geometric or pavement drainage considerations,
- Provide a minimum length of reverse crown section of at least 50 ft [20 m], or 1 second of travel time at the design speed whichever is greater, and

- Design the resultant superelevation transitions to provide the same relative gradient for each curve transition, within the maximum relative gradient recommended in *Green Book* Table 3-15, with approximately one-third of the theoretical superelevation runoff for each transition located on the curve and two-thirds on the tangent.

Exhibit 9.3-E TREATMENT OF REVERSE CURVES: USE OF REVERSE CROWN



9.3.5.2.3 Compound Curve Transitions

FLH standard practice is that the relative gradient of the superelevation transition must not exceed the maximum relative gradient values in *Green Book* Table 3-15, and should not be less than 70 percent of these values.

There are two primary considerations for designing superelevation transitions for compound curves:

1. Transition length
2. Position with respect to the PCC (allocation percentage on each curve)

FLH standard practice includes the following:

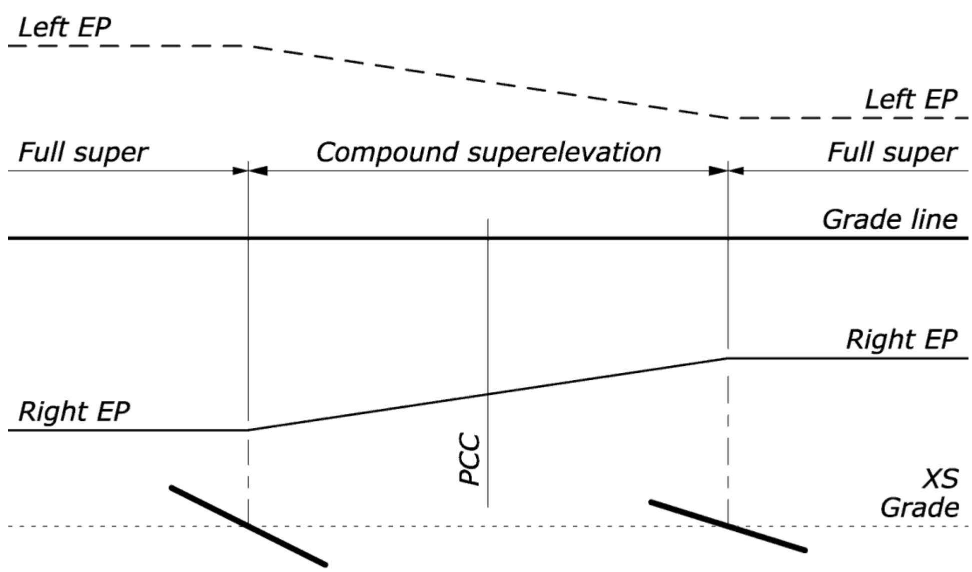
- Determine the relative gradient(s) appropriate for each curve, based on the design of a theoretical tangent transition for each curve;
- Determine the compound curve transition length, L_{cc}, based on *Green Book* Equation 3-23 by substituting L_{cc} for L_r, and substituting the difference in the design superelevation rates of both curves for e_d, and the average theoretical relative gradient of both curves for Δ;
- Determine the distribution percentages based on a ratio of the design superelevation rate (e_d) of each curve, divided by their sum:

$$\frac{e_d(curve1)}{e_d(curve1)+e_d(curve2)} \text{ and, } \frac{e_d(curve2)}{e_d(curve1)+e_d(curve2)};$$

- Allocate the lesser percentage of the compound curve transition length on the sharper curve, and the greater percentage length on the flatter curve, to establish the position of the full super stations with respect to the PCC.

Refer to Exhibit 9.3-F.

Exhibit 9.3-F COMPOUND CURVE TRANSITION



9.3.5.2.4 Broken Back Curve Transitions

FLH standard practice is that the minimum length of normal crown section between broken back curves is 200 ft [60 m], or 3 seconds of travel time at the design speed whichever is greater.

Broken back curve transitions may be categorized as one of three treatments:

1. Short intervening tangent treated as a compound curve
2. Intermediate intervening tangent with a minimum super rate (reverse crown) section
3. Long intervening tangent with a normal crown section

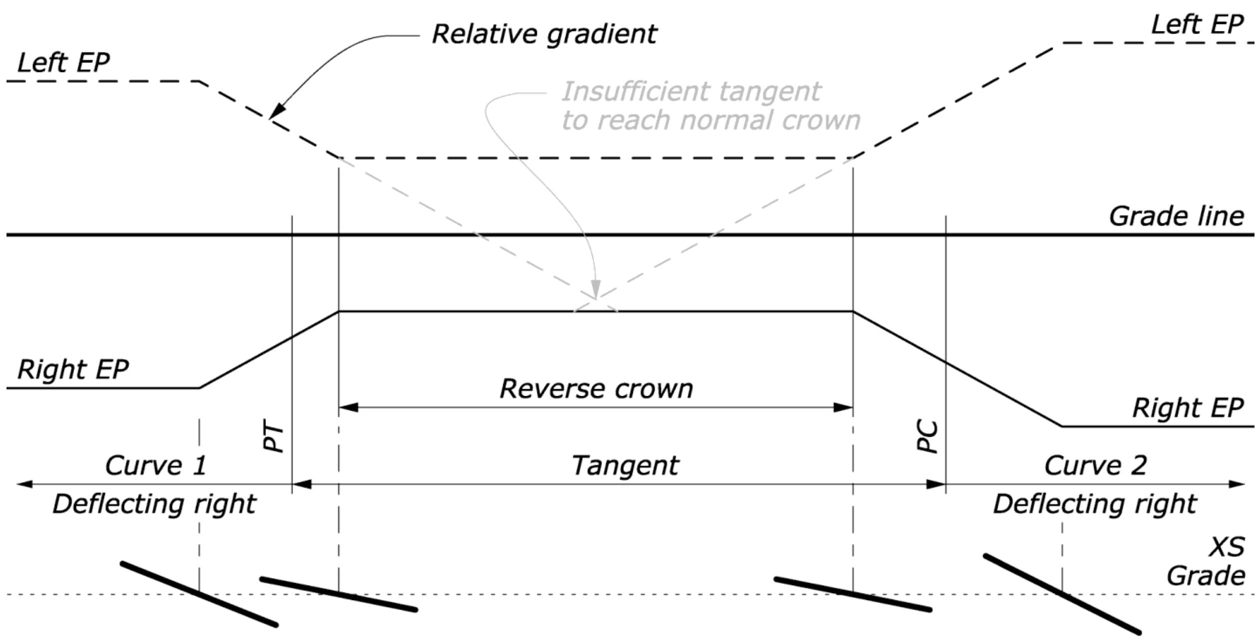
For short intervening tangent length treated as a compound curve, refer to Section 9.3.5.2.3. Avoid treatment as a compound curve if the intervening tangent length is greater than 200 ft [60 m], or more than 3 seconds of travel time at the design speed whichever is greater.

For intermediate tangent lengths, conflicts occur when the initial design of broken back curves have slightly overlapping superelevation transitions that cause the transition to be treated as a compound curve, instead of a preferred transition using a minimum super rate (reverse crown) template treatment. For a minimum super rate transition, there is no minimum length of reverse crown section (can be a singular location), although a desired length is 50 ft [20 m], or 1 second of travel time at the design speed whichever is greater. Recommended guidance to resolve such conflicts includes the following:

- If the initially designed lengths of reverse crown transitions overlap more than 50 ft [20 m], the situation should be treated as a compound curve, or
- If the initially designed lengths of reverse crown transitions overlap less than 50 ft [20 m], the situation may be treated either 1) as a compound curve, or 2) a minimal, or the desired, length of reverse crown may be provided by adjusting the location of the super transitions (full super to minimum super) relative to the ends of each curve (PT and PC). In this latter case the portion of the superelevation transition lengths that are located on each curve may be increased, providing that the portion of the theoretical superelevation runoff lengths located on each curve does not exceed 50 percent.

Exhibit 9.3-G describes an example of a transition between curves in a broken-back situation with minimum super rate (reverse crown) treatment.

Exhibit 9.3-G SUPERELEVATION TRANSITION ON SHORT TANGENTS



For longer intervening tangent lengths, conflicts occur when broken back curves initially have superelevation transitions that are in close proximity, such that the length of the normal crown section is less than the desired minimum of 200 ft [60 m], or 3 seconds of travel time at the design speed whichever is greater. Recommended guidance to resolve such conflicts includes the following:

- If the initially designed length of normal crown is less than 75 percent of the minimum, the treatment should either be a transition using the minimum superelevation rate (reverse crown) described above as treatment 2, or transition as a compound curve; or
- If the initially designed length of normal crown is more than 75 percent of the minimum of 200 ft [60 m] or 3 seconds of travel time at the design speed whichever is greater, the necessary length of normal crown section should be provided by adjusting the location of

the superelevation runoff relative to the ends of each curve (PT and PC), or by reducing the superelevation runoff length, or both, such that at least the minimum length of runoff as determined by *Green Book* Equation 3-23 is provided. In this situation the portion of the superelevation runoff lengths that are located on each curve may be increased, providing this portion does not exceed 50 percent.

9.3.5.2.5 Short Curve Transitions

Avoid designing short curve lengths, such as described in Section 9.3.5.1.8 if practical. A superelevation transition conflict can occur if the length of curve is too short to accommodate the combined standard proportions of the superelevation runoff lengths located on the curve, creating an overlap. Recommended guidance for resolving such conflicts includes the following:

- Preferably, increase the curve length by redesigning it with a sufficiently larger radius, with corresponding lower superelevation rate and resultant runoff length, to resolve the conflict; or
- Alternatively, reduce the percentage of superelevation runoff length located on the curve, but not less than 10 percent (preferably not less than 20 percent). If the above treatments are impractical, the design superelevation rate (*e*) of the curve may be truncated to a sufficiently lower value, with corresponding shorter runoff lengths that properly fit within the curve.

9.3.5.2.6 Vehicle Tracking

Often the driver's steered path is inconsistent with the alignment geometry such that the actual vehicle path does not follow a true circle, and drivers 'overshoot' the curve (track a path sharper than radius), and the tracked path is a spiral. Therefore, curve transitions should be designed to minimize and mitigate erratic vehicle tracking entering, during and exiting the curve. FLH standard practice is to:

- Provide traveled way widening in curves, and
- Use consistent methodology for the superelevation transition design from curve to curve, so that the driver can expect similar transition effects on their driving task.

Refer to Section 9.3.9.1 for additional guidance on vehicle tracking and traveled way widening on curves.

9.3.5.2.7 Spiral Transitions

Spiral transitions should be used whenever practical for smoother transitions and to enhance safety, particularly if using near-minimum standards for roadway widths or design speeds. For projects on a State DOT or local agency system, verify that using spiral transitions and the transition design criteria is consistent with the State DOT or local agency design policy.

When spiral transitions are used, FLH standard practice includes the following:

- The minimum length of spiral curve transitions is the length required for superelevation runoff, based on maximum relative gradient, and typical minimum superelevation runoff lengths are provided in *Green Book* Table 3-17;
- The superelevation runoff is applied uniformly over the full length of the spiral; and
- Design spiral transition curves to meet the additional criteria described in this section.

Ensure that the appropriate spiral length and transition treatment is used, and that the method for selecting spiral length is applied consistently throughout the project.

A discussion of transition spirals is provided in *Green Book* Section 3.3.8 subsection entitled "Spiral Curve Transitions".

Exhibit 9.3-H MAXIMUM RADIUS FOR BENEFIT OF A SPIRAL CURVE TRANSITION

US Customary		Metric	
Design speed (mph)	**Maximum radius (ft)**	**Design speed (km/h)**	**Maximum radius (m)**
15	211	20	45
20	375	30	100
25	585	40	177
30	842	50	276
35	1150	60	397
40	1500	70	541
45	1900	80	706
50	2340	90	893
55	2830	100	1110
60	3370	110	1340
65	3960	120	1590
70	4590	130	1870
75	5270		
80	5990		

Note: Spirals may be used on flatter curves if beneficial for aesthetic purposes. This table is not intended to define radii that either necessitate or prohibit the use of a spiral.

Green Book Table 3-20 provides recommendations on the maximum radius for spiral curve transition use, corresponding to the radius at which the safety and operational benefits of spiral curve transitions may become negligible. Based on consideration for aesthetics, anticipated operating speeds, and the unique conditions of FLH projects, the recommended maximum radius for use of a spiral transition curves for FLH projects are greater than the values provided in the *Green Book*. The maximum recommended radius shown in Exhibit 9.3-H are based on a lateral acceleration rate of 0.07g; expressed as 2.3 ft/s^2 [0.7 m/s^2] in the following equations:

$R = 2.1511V^2/A$ (US Customary)

$R = 0.07716V^2/A$ (Metric)

where: R is the maximum radius, ft [m]

V is the design speed, mph [km/h]

A is the lateral acceleration rate, ft/s^2 [m/s^2]

Green Book Table 3-21 provides recommendations on the desirable length of spiral transition curves, corresponding to approximately 2.0 seconds of travel time at the design speed of the roadway. Based on consideration for anticipated operating speeds, aesthetics, and the unique conditions of FLH projects, the desired lengths of spiral transition curves for FLH projects are increased slightly from the values provided in the *Green Book*. The values shown in Exhibit 9.3-I correspond to 2.3 seconds of travel time. Spiral curve lengths longer than those shown may be needed. To determine the minimum spiral length use the longest of:

- The minimum length for superelevation runoff (L_r) determined by the *Green Book* using either Equation 3-23 or Table 3-17; or
- The minimum spiral length (L_s, min) determined by *Green Book* Equations 3-26 and 3-27; or
- The desired spiral length shown in Exhibit 9.3-I.

If necessary for especially tight alignment locations, the desirable spiral length shown in *Green Book* Table 3-21 may be used, if it is greater than the minimum spiral length and the minimum superelevation runoff length described above.

Green Book Equation 3-28 provides recommendations for the maximum length of spiral transitions, based on the observed steering behavior of drivers. For FLH projects it is also desirable to limit the spiral length to the distance traveled on the spiral in 4 seconds at the design speed. The maximum spiral lengths shown in Exhibit 9.3-I are based on the greater of this 4-second rule, or the superelevation runoff length (L_r) for the limiting superelevation rates (see *Green Book* Table 3-19). If the maximum spiral length determined by *Green Book* Equation 3-28 is less than these maximum lengths, limit the spiral length to the shorter length. If the minimum length of superelevation runoff determined by *Green Book* Equation 3-23 is greater than the maximum length of spiral transition determined by *Green Book* Equation 3-28, do not use a spiral transition for the curve.

Determine the appropriate superelevation rate (e_d) and length of spiral transition curve (L_s) based on the given design criteria (design speed, maximum and minimum superelevation rates, lane width, and curve radius). The calculated L_s is often associated with the minimum length of spiral transition applicable for the given criteria and superelevation rate. Where practical, use the longer desired length of spiral curve transition shown in Exhibit 9.3-I. Greater spiral lengths up to the maximum length may be used in certain situations, such as minimizing or closing short intervening tangents between reverse spiral transition curves where the superelevation transitions are merged.

Green Book Equation 3-29 and Table 3-23 provide recommendations for tangent runout length (L_t) for spiral curve transition design. For FLH projects, the length of tangent runout for a spiral curve transition should be based on the continuation of the same superelevation transition rate (relative gradient) that is applicable to the superelevation runoff and which is applied on the spiral curve transition.

Exhibit 9.3-I DESIRED AND MAXIMUM LENGTH OF SPIRAL CURVE TRANSITION

US Customary			Metric		
Design speed (mph)	**Desired length (ft)**	**Maximum length (ft)**	**Design speed (km/h)**	**Desired length (m)**	**Maximum length (m)**
15	50	125	20	13	36
20	65	130	30	19	38
25	85	170	40	26	51
30	100	200	50	32	61
35	120	215	60	38	67
40	135	235	70	45	78
45	150	265	80	51	89
50	170	295	90	57	100
55	185	325	100	64	111
60	200	350	110	70	122
65	220	380	120	77	133
70	235	410	130	83	144
75	255	440			
80	270	470			

Note: Minimum spiral length must equal or exceed the superelevation runoff length. Maximum spiral length should not exceed the length determined by Green Book Equation 3-28.

9.3.5.2.8 Location of Profile Grade and Superelevation Pivot Point

Typically, the profile grade and superelevation pivot point on the highway cross section is at the finished grade centerline for all two-lane highways. Alternatively, the superelevation pivot point may be located at the finished grade roadway shoulder on the low side of the superelevated section, for two-lane highways where conditions are appropriate (e.g., for drainage purposes in flat low-lying terrain or swampy conditions). In this case, the profile grade elevation at centerline will be adjusted.

For two-lane or multilane highways with flush, paved medians 12 ft [3.6 m] width or less, the center of the median should be used as the axis of rotation, with the entire roadway section rotated about the axis. For multilane highways with medians wider than 12 ft [3.6 m] the median may be held horizontal and the superelevation pivot points for the two roadway directions may be located at the finished grade roadway shoulders adjacent the median, which are on the low side of the outer lanes and on the high side of the inner lanes. In this case the full superelevation stations of superelevation runoffs for both roadways should be designed at the same (concentric) location. The type of terrain will influence the preferred median treatment. For medians greater than 30 ft [9 m] it may be preferable to develop the superelevation for each roadway independently. Also refer to Section 9.3.10.

9.3.5.2.9 Combination of Superelevation Transition and Grades

In areas of especially steep or flat grades, evaluate the gradients along the edge of traveled way and the shoulder profiles, and correct or minimize any irregularities resulting from combinations of the superelevation transitions and the vertical alignment.

Consider that superelevation transitions will increase the effective grade along the outside edge of the traveled way. This increase is significant, particularly for trucks and recreational vehicles. To minimize this effect on long continuous runs of near maximum grades, the designer should flatten the grade throughout the horizontal curve to compensate for the effect.

Consideration of the effect of superelevation transition on the maximum grade at the edge of roadway is especially important when the design contains climbing lanes, auxiliary lanes, or turnouts adjacent the roadway that are superelevated.

In areas of minimum grades, evaluate the edge of traveled way and shoulder profiles to reveal any level, or nearly level (less than 0.2 percent), areas on the roadway surface resulting from superelevation transitions. Level areas are undesirable from a pavement drainage standpoint and should be avoided or minimized. Coordinate the design of vertical and horizontal curves such that the flat profile of a vertical curve will not be located near the flat cross slope of the superelevation transition.

Consider the effect of superelevation transition on the ditch grades and in curb and gutter sections in areas of minimum grades, to provide at least 0.5 percent gradient.

Refer to Exhibit 9.3-E for a method of adjusting the location of the flat template section between reversing curves with a short tangent.

9.3.5.3 Risk Assessment and Mitigation

Consider that horizontal curves tend to be high crash locations. The average crash rate for horizontal curves is about 3 times the average rate for tangents, and the average run-off-the-road crash rate for horizontal curves is about 4 times that of tangents. Consider the AASHTO *Green Book* assumptions, together with reliable information on actual speeds, site crash history, roadside conditions in the vicinity of the curve, and available pavement friction in assessing risk relating to horizontal curvature. Refer to the AASHTO *Guide for Achieving Flexibility in Highway*

Design, Sections 3.2.2, 3.2.3 and 3.2.4 for guidance in applying flexibility in the AASHTO guidelines, assessing risk and mitigating tight curvature.

Risk is primarily related to the traffic volume exposed to the situation. Risk varies with the length of the horizontal curve and the central angle of the alignment deflection, with curve angles greater than 30 degrees representing substantially higher risk. Risk increases as operating speeds exceed the design speed. For roads with more than 10 percent commercial truck traffic, the safety risk increases substantially if the operating speed exceeds the design speed by 6 mph [10 km/h] or more. Other design elements (e.g., sight distance, superelevation, pavement friction, signing, and delineation) can affect curve safety.

The project plans should include mitigation (e.g., curve signs, turn signs, advisory speed plates, positive guidance, appropriate roadside design features) when a curve design is an exception to the standard for the posted or regulatory speed limit. The *MUTCD* specifies installation of advisory speed plates following a determination of the safe speed by an engineering study. Also refer to the *Horizontal Curve Signing Handbook*, TTI, 2007.

Also refer to NCHRP Report 559, *Communicating Changes in Horizontal Alignment*, 2006 for additional guidance on mitigating inconsistent horizontal curvature. Also see FHWA Report 07-002, *Low-Cost Treatments for Horizontal Curve Safety*, 2006.

9.3.6 VERTICAL ALIGNMENT

Refer to *Green Book* Section 3.4 for guidance applicable to the design of vertical alignments. As practical, minimize vertical grades within the terrain context. Refer to Section 9.3.1.3 for guidance on terrain classifications. In addition, consider the following design controls:

- Climate (snow, ice, rainfall)
- Topography and terrain,
- Functional classification,
- Design speed,
- Sight distance needs,
- Traffic volume
- Compatibility with existing slopes, approach roads and driveways adjacent the roadway,
- Length of grade,
- Horizontal alignment,
- Construction cost,
- Pedestrian and bicycle use,
- Drainage considerations,
- Surfacing type,
- Vertical clearances (if applicable),
- Vehicular characteristics, and
- Aesthetics.

9.3.6.1 Vertical Curves

Refer to *Green Book* Table 3-34 for minimum design controls (K values) for crest vertical curves, and Table 3-36 for design controls (K values) for sag vertical curves, based on minimum stopping sight distances. If the design vertical curvature does not meet or exceed the applicable standards for K value, treat the deviation as a formal design exception. When faced with a choice of design exception, use a short sag curve rather than a short crest curve.

FLH standard practice includes the following:

- For design speeds less than 40 mph [60 km/h], the minimum vertical curve length should be 300 ft [100 m], except for grade differences less than 3 percent the minimum vertical curve length may be 200 ft [60 m],
- For design speeds of 40 mph [60 km/h] or more, the minimum vertical curve length should be 400 ft [120 m], except for grade differences less than 3 percent the minimum vertical curve length may be 300 ft [90 m], and
- The above minimum vertical curve lengths are not applicable for approach roads or other minor roads.

Sag vertical curves that are visible on long horizontal tangents should be two or three times the length required for stopping sight distance to avoid an abrupt appearance.

For sag vertical curves with a low point in curbed sections, consider the requirements for pavement drainage. If possible, provide a minimum gradient of 0.3 percent within 50 ft [15 m] of the low point.

Broken-back vertical curves consist of two vertical curves in the same direction separated by a short tangent grade (i.e., less than 200 ft [60 m]). Avoid using broken-back vertical curves in sags where the view of both vertical curves and the intervening tangent is evident.

For design of minimal vertical curves for driveways or low water crossings, limit the minimum K value to accommodate the design vehicle clearances (undercarriage or tow hitch). In such locations provide a minimum vertical curve length of 30 ft [9 m] and minimum K value of 1.5 [0.5].

9.3.6.2 Maximum Grade

Refer to the subsection on “Control Grades for Design” in *Green Book* Section 3.4.2 for general guidance on maximum grades. Consider the functional classification, the type of terrain, design speed, effect on operating speeds of the mix of vehicle types, along with the information provided in the *Green Book* to determine the maximum allowable grades. For Park roads refer to the *Park Road Standards* Table 3 to determine maximum design grades. If the applicable maximum grade must be exceeded, treat the deviation as a formal design exception.

Also consider weather and climatic conditions, and surfacing type, when determining a maximum practical gradient for design.

FLH standard practice for areas with winter snow-packed conditions, or for aggregate surface roadways, is to not exceed a maximum sustained grade of 9 percent (7 percent maximum grade preferable).

Evaluate steep (over 5 percent) sustained grades of 0.5 mile [0.8 km] or more, which may affect traffic operation in both uphill and downhill directions. If the critical length of grade is exceeded, determine the speed profile for a loaded truck (see Section 9.3.6.4).

Recommended guidance includes the following:

- For sustained grades over 5 percent and over 1 mile [1.6 km] with design traffic volume ADT greater than 2,000, determine the feasibility and, if applicable, the safety and operational effects of providing a slow moving vehicle lane or turnout;
- On sustained downgrades over 7 percent and over 1 mile [1.6 km], for ADT greater than 2,000 and volume of trucks over 10 percent; determine the feasibility of providing a truck escape ramp; and
- On sustained, steep grades also consider using wider shoulders, clear zones and increased superelevation rates at the bottom of the grade.

Refer to the IHSDM and its references, or the HCM, or both, for guidance on determining the safety and operational effects of design grades.

9.3.6.3 Minimum Grade

Refer to the subsection on “Control Grades for Design” in *Green Book* Section 3.4.2 for general guidance on minimum grades. FLH standard practice includes the following:

- A level longitudinal grade (zero percent) is acceptable in tangent alignment along through-fill sections where the roadway has proper crown to drain the surface laterally, and is without curbing;
- A level longitudinal grade is acceptable in tangent alignment on uncurbed pavements in cut sections where the pavement is adequately crowned, and special ditch gradients are adequate to convey the surface drainage;
- Minimum grades (0.5 percent minimum, 1 percent desired) are applicable in all other cases for providing drainage of roadway ditches in cut sections, drainage of curb sections and to ensure pavement drainage on superelevation transitions;
    - ◊ The 1 percent desired minimum grade particularly applies where flat grades on crest and sag vertical curves have substantial lengths that are essentially level;
    - ◊ The 1 percent desired minimum grade also applies where superelevation transitions introduce sags in the ditch or gutter line;
    - ◊ Evaluate ditch or gutter profiles to identify and correct any drainage problems; special ditch grade profiles may be used to correct sags or minimum gradients in the ditch line; and

- Provide grades exceeding the 1 percent desired minimum gradient where superelevation transitions create a pavement edge profile grade less than 0.2 percent (0.5 percent for curbed streets) through the transition section.

In areas where heavy rainfall occurs, or winter snowpack and freezing conditions routinely exist for portions of the year, particularly avoid the combination of minimum grades, or high or low points in vertical curves, and superelevation transitions that result in locations with a level surface on the pavement.

Refer to the subsection on “Minimum Transition Grades” in *Green Book* Section 3.3.8 and Equation 3-30 for additional guidance.

Where curbing is used in conjunction with minimum grades, ensure the design of inlets and their spacing will keep the spread of water on the traveled way within tolerable limits. Refer to Section 9.5.5.4 for pavement drainage and FHWA, HEC-12, Chapter 2 for additional guidance on recommended roadway geometry to provide for pavement drainage.

See Section 9.5.5.1 for guidance on design of roadway drainage ditches.

9.3.6.4 Critical Lengths of Grade

Where applicable, evaluate the length of a sustained grade in relation to desirable vehicle operation and safety. The critical length of grade is the maximum length of a sustained upgrade on which a loaded truck can operate without a 10 mph [16 km/h] reduction in speed. Consider the guidance and recommendations for different conditions contained in “Critical Lengths of Grade for Design” in *Green Book* Section 3.4.2.

9.3.6.5 Intersection Considerations

At intersections, the grade should not exceed 6 percent (5 percent maximum is preferred). As practical, avoid designing crest vertical curves in the vicinity of intersections.

9.3.6.6 Hidden Dips

Avoid designing intervening sags in a vertical alignment that is otherwise a uniform grade, in combination with tangent horizontal alignment or flat curvature, which create hidden dips. Also avoid designing a rolling vertical alignment in combination with long horizontal tangents, as such roller coaster profiles are visually distressing and may create hidden dips that are misleading for passing on two-lane roads.

9.3.6.7 Switchbacks

Switchbacks may be necessary in mountainous areas with steep grades. Where practical, reduce the gradient through sharp switchback curves to facilitate braking and vehicle control in the vicinity of the switchback. For switchbacks with a curve speed of 20 mph [30 km/h] a maximum gradient of 4 percent is recommended, and for switchbacks with curve speed of 25 mph [40 km/h] a maximum gradient of 5 percent is recommended.

9.3.6.8 Drainage Considerations

Where the highway crosses a waterway, design the profile consistent with the design flood frequency and elevation. The following FLH standard practices apply:

- For drainage structure inlets determine the design headwater elevation, and design the roadway elevation to exceed the headwater elevation, and to provide sufficient clearance and cover for construction of culverts and other components of the drainage system.
- In swampy terrain and areas subject to overflow and irrigation, design the low point of the subgrade to be at least 1.7 ft [0.5 m] above the ordinary high-water elevation.
- In areas of grades less than 2 percent, ensure drainage at the low point of the subgrade and ditch grades in the area of horizontal curves, where superelevation may lower the edge of the subgrade shoulder relative to tangents.

For roads located along main streams and rivers, refer to Section 7.4 for the appropriate hydraulic controls.

9.3.6.9 Vertical Clearance

FLH standard practice is to provide sufficient vertical clearance for the largest design vehicle, for the interim and ultimate potential roadway and pavement configurations, and with consideration for the accommodation or management of occasional oversize vehicles. Also refer to Section 10.4.1.1 for vertical clearances for structures.

The following standards apply:

- For local and collector roads, provide a vertical clearance of at least 14 ft [4.3 m] over the entire roadway width, with an additional allowance for future resurfacing.
- For rural and urban arterials, provide 16 ft [4.9 m] clearance over the entire roadway width for any new or reconstructed structures; and existing structures that provide clearance of 14 ft [4.3 m] may be retained if allowed by local statute.
- For arterials in highly urbanized areas, a minimum clearance of 14 ft [4.3 m] may be provided if there is an alternate route with 16 ft [4.9 m] clearance. Provide additional clearance for future resurfacing.

Structures should provide an additional clearance of 3 in [76 mm] for future resurfacing of the underpassing road.

Also consider needs for falsework and construction vehicles in determining vertical clearances.

Structures over railroads should typically provide a minimum vertical clearance of 23 ft [7.1 m] over both rails. Refer to individual State requirements for vertical clearance over railroads, and coordinate with the railroad for any special requirements at the structure location such as the potential for future electrification of the line.

9.3.6.10 Risk Assessment and Mitigation

The vertical alignment directly affects sight distance. Any evaluation of the vertical alignment risks should consider the resultant sight distance that is available. Risk is primarily related to the traffic volume exposed to the situation. Combinations of other higher risk road conditions (e.g., intersections) with vertical curvature or steeper grades will also increase the relative risk. Risk related to vertical curves generally increases where grade differentials are greater than 6 percent; and risks are greatest at or near the crest of the vertical curve. Crest vertical curves with less than 300 ft [90 m] stopping sight distance are particularly related to greater risk.

Where steeper grades are used, evaluate the operational effects on heavy vehicles. Mitigation of steep downgrades can include increased shoulder widths and clear zones, increased superelevation rates, increased pavement friction and provision of truck escape ramps for extended sustained downgrades. Provide flatter horizontal curves at the bottom of steep downgrades, allowing for potentially higher operating speeds.

Where very flat grades are used consider using special drainage features, such as special ditch grades, and provide special attention to the design of pavement cross slopes and reversals of superelevation. Avoid or minimize flat spots on the pavement surface, particularly in regions that experience intense rainfall, periodic snowpack or ice.

9.3.7 SIGHT DISTANCE

Maximize the continuous length of roadway ahead that is visible to the driver, and provide sufficient preview of the roadway to safely accomplish various driving maneuvers. Coordinate the geometric elements such that adequate sight distance exists for safe and efficient operation. Determine the various sight distance requirements for all allowable maneuvers – emergency stopping, passing, making a left-turn at an intersection, etc. Although design requirements are expressed as a design distance, consider the component time requirements for the driver to recognize the situation, understand its implications, decide on a reaction and initiate the maneuver. Consider the effects of grade and speed on sight distance requirements, and on the maneuver itself.

Green Book Section 3.2 provides criteria and guidance on stopping sight distance, decision sight distance, passing sight distance, and sight distance for multilane highways. *Green Book* Chapters 5, 6, 7, and 9 each has specific subsections on sight distance for local roads, collectors, arterials, and intersections, respectively. Also, the ITE *Traffic Engineering Handbook* (1999), Chapter 11 Geometric Design of Highways, has a section on sight distance, with subsections on stopping sight distance, passing sight distance, decision sight distance, and intersection sight distance.

9.3.7.1 Determination of Sight Distance Requirements

FLH standard practice is to follow the *Green Book* recommendations for determination of sight distance requirements, including consideration of:

- Perception-Reaction Time (PRT)
- Maneuver Time (MT), and
- Operating speed.

Refer to *Green Book* Section 3.2. Additional guidance for determination of these components is provided in the following sections.

9.3.7.1.1 Perception-Reaction Time

Refer to *Green Book* Section 2.2.6 for guidance on determining perception-reaction time (PRT). Consider that actual PRT can vary widely depending upon many factors specific to the site.

Refer to the *Manual on Uniform Traffic Control Devices* (MUTCD) 2003, Section 2C.05, Placement of Warning Signs. Also refer to the ITE Traffic Engineering Handbook (1999), Chapter 2 Road Users, sections on perception-reaction time and sight distance, and the ITE Traffic Control Devices Handbook (2001), Chapter 2 Human Factors, sections on driver perception reaction time.

Also refer to the FHWA *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians*, FHWA-RD-01-051 (2001), Rationale and Supporting Evidence section for perception-reaction time and sight distance requirements for older drivers.

9.3.7.1.2 Maneuver Time

Maneuver time (MT) is the interval from the initiation of the vehicle control response (i.e., end of the PRT) to the completion of the driving maneuvers (e.g., braking, turning, passing).

For braking MT refer to the “Braking Distance” discussion in *Green Book* Section 3.2.2 and Equation 3-1. For turning MT refer to *Green Book* Section 9.5.3 for maneuver time design values for the various control cases. For passing MT refer to the “Criteria for Design” inside *Green Book* Section 3.2.4.

Consider that the actual MT, and distance needed for the safe and comfortable completion of the maneuver, will vary with conditions of the site including tire-pavement friction, grade, vehicle performance capabilities, and individual driver characteristics.

The ITE *Traffic Control Devices Handbook* (2001), Chapter 2 Human Factors, also has guidance on maneuver time.

9.3.7.2 Stopping Sight Distance

Provide the minimum stopping sight distance (SSD) at all points along the roadway. Provide more generous stopping distances where practical.

Minimum stopping distance is the distance required to bring a vehicle traveling at the design speed to a stop before reaching a stationary object in its path. Consider the actual distance will vary, depending on the initial speed of the vehicle, the perception and reaction time of the driver, the gradient, and the coefficient of friction between tires and roadway for the prevailing conditions. The coefficient of friction is much lower for wet pavements; therefore, wet rather than dry pavement conditions apply for establishing minimum values.

Ensure that the minimum SSD control ("K" value) is provided at all vertical curves, and that the minimum SSD control (horizontal sightline offset) is provided at all horizontal curves.

Design controls for SSD are located in *Green Book* Section 3.2.2, Section 3.3.12, and both the "Crest Vertical Curves" and "Sag Vertical Curves" discussions inside Section 3.4.6.

For additional information on SSD, also refer to *Determination of Stopping Sight Distances*, NCHRP Report 400, 1997.

9.3.7.3 Decision Sight Distance

Decision sight distance (DSD) is the length of road a driver needs to receive and interpret information, select an appropriate speed and path and begin and complete an action in a safe maneuver. This distance is greater than the distance needed to simply bring a vehicle to a stop, and provides for a reasonable continuity of traffic flow.

If possible, provide decision sight distance in advance of any feature requiring increased driver awareness and action. This includes intersections, lane changes, congested areas, pedestrian crossings, turnouts, pullouts or other features. When decision sight distance is unavailable and relocation of the feature is not possible, provide suitable traffic control devices.

See design controls for DSD in *Green Book* Section 3.2.3. Refer to *Green Book* Table 3-3 for recommended DSD values.

9.3.7.4 Passing Sight Distance

Passing sight distance (PSD) is applicable to two-lane, two-way roads. PSD is the length of the highway ahead necessary for one vehicle to pass another before meeting an opposing vehicle that might appear after the pass begins.

Provide as many passing opportunities as possible in each section of road, and if practical ensure there are no long sections where passing is not possible. Evaluate the percentage and distribution of passing and no-passing zone markings, and their implication for traffic operations, in the geometric design of two-lane highways. Where operations indicate lack of PSD is a problem, consider design of passing lanes, truck climbing lanes, or intermittent slow-moving vehicle turnouts as described in Section 9.3.9.

Also consider PSD at the end of truck-climbing and passing lanes where traffic must merge. If practical, increase the sight distance in areas adjacent to passing zones where vehicles completing passing maneuvers may operate above the design speed.

Minimum passing distances for all classes of two-lane roads are given in *Green Book* Table 3-4. Also refer to the guidance in *Green Book* Section 3.2.4.

Current practice uses different PSD models in highway design and in marking of passing and no-passing zones. Geometric design for minimum PSD requirements should not be confused with values provided in the *MUTCD* for determining no-passing zone pavement striping. The *MUTCD* recommends much shorter distances for marking no-passing and passing zones than the *Green Book* recommends for developing a geometric design to provide PSD.

For developing a geometric design to provide PSD, consider the design vehicle characteristics, road grade and vehicle speeds at the specific location. The design for minimum PSD may be less than the minimum distances provided in the *Green Book* if consideration is given to the possibility that the passing maneuver can be aborted. Shoulder characteristics should also be considered in the geometric design for PSD. Also refer to NCHRP Report 605, *Passing Sight Distance Criteria* for additional guidance on geometric design to provide PSD.

9.3.7.5 Intersection Sight Distance

Intersection sight distance (ISD) is the minimum sight distance needed by drivers to safely negotiate intersections, including intersections with or without stop controls or traffic signals.

Provide sufficient sight distance to allow drivers to perceive the presence of potentially conflicting vehicles. If possible, provide decision sight distance (DSD) for the approach to intersections, if it is greater than the ISD.

FLH standard practice is to provide ISD based on *Green Book* Section 9.5. Also refer to the *Highway Capacity Manual*, which provides guidance on gap acceptance for vehicles departing from minor approaches.

For intersection sight distance in design of a left-turn from a stop based on gap acceptance refer to *Green Book* Table 9-5 and Equation 9-1. Determine the sight distances required for vehicles to turn left from a stop onto a two-lane highway and attain an average running speed without being overtaken by a vehicle going the same direction. Where practical, avoid using sight distances less than that required for the design vehicle, which will require the through traffic to reduce speed. For approach to at-grade intersection provide sufficient sight distance for an unobstructed view of the entire intersection and sufficient length of the intersecting roadway to discern the movements of vehicles. For intersections with stop signs on the minor road provide sight distance of the major highway to safely cross before a vehicle on the major highway reaches the intersection. Under some conditions, if it is impractical to provide adequate site distance for cross road traffic to safely enter the main road, it may be necessary to install traffic signals. (See Part IV of the *MUTCD*.)

Refer to *Green Book* Table 9-6, for minimum sight distance along the major road for level conditions, for left turns from a stop. Refer to *Green Book* Table 9-4, for adjustment of sight distance to reflect grades of the minor road approach.

Provide sight triangles along the intersection approach legs that are clear of obstructions that can block driver's view of oncoming traffic. The dimensions of the triangle are based on the design speed of the intersecting roadways and the type of traffic control used at the intersection, grades on the roadways, and the roadway width.

Within the sight triangle, remove, adjust or lower cut slopes, hedges, trees, signs, utility poles or anything large enough to constitute a sight obstruction (see *Green Book* Figure 9-15). Eliminate parking and offset signs to prevent sight distance obstructions.

Determine ISD for all applicable intersection maneuvers, including situations described in the *Green Book* for through, left and right-turning maneuvers at intersections with no control, four-way stop control, two-way stop control, yield control and signal control from the minor road; and for a left-turning maneuver from the major road.

Provide additional intersection sight distance wherever significant visual distractions, messages or driver workload exists, for example where there are:

- High traffic volumes on the major road;
- Complex signs (e.g. multiple destinations, route shield assemblies);
- Complex pavement markings (e.g. multiple turn lanes);
- Complex or unusual intersection geometry;
- Visual distractions in urban areas due to commercial signs and lighting; and
- A high percentage of unfamiliar or older drivers.

Also provide additional intersection sight distance wherever drivers are less likely to be expecting to respond to an intersection, such as for:

- A stop condition after having the right-of-way on previous road sections;
- An isolated stop or signal-controlled intersection; and
- Intersections with high traffic volume, but signals are not yet warranted. For these situations, ISD is a minimum and it is preferable to provide DSD.

For the following conditions, the sight distance for cross traffic to enter the roadway may need to be lengthened:

- Turning right through the minor angle of skew intersection (i.e., where drivers must turn their heads through a greater angle to assess the presence of oncoming vehicles);
- Crossing or turning at an intersection on a horizontal curve, especially where the main road curves behind the driver gap, may be more difficult to assess; and
- Crossing at an offset or skewed intersection, and

- Trucks turning.

Consider the need for additional sight distance where:

- The major road has complex signing, lane drops or other driver-attention demands prior to the intersection,
- Traffic conditions or site information indicates problems accommodating entering traffic, and
- At left-turn lanes where the decision to initiate the turn may occur significantly in advance of intersection.

At intersections, consider the driver's view of the intersection from all approaches. Of major concern are intersections where a driver may fail to recognize a potential conflict location. An example may be where an approach road intersects a divided roadway and the driver perceives the intersection across the median as the primary concern, and does not recognize the initial intersection. Evaluation of the driver's viewpoint with respect to the signing and pavement markings should be considered during the layout of the intersection.

9.3.7.6 Limiting Conditions and Restrictions

Provide adequate sight distance on horizontal curves by selecting the proper curve radius and arranging for the removal or relocation of obstacles. Refer to the "Stopping Sight Distance" discussion in *Green Book* Section 3.3.12 for guidance on evaluation of curve radius and horizontal sightline offset.

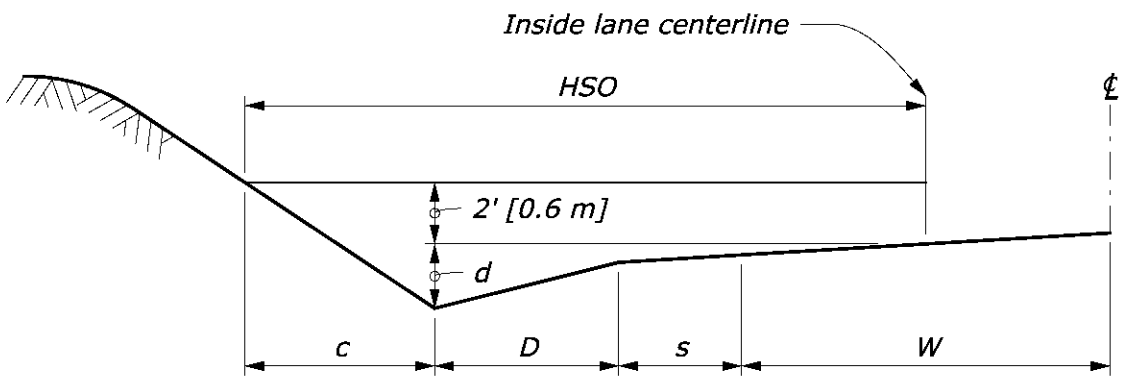
The sight distance available on horizontal curves is proportional to the radius of the curve, and depends on the location of obstacles to the line-of-sight across the inside of the curves. Verify the location of obstacles (e.g., cut slopes, tall grass on cut slopes, trees, shrubs, farm crops, buildings, bridge abutments and walls, bridge railing, traffic barrier) that may limit the sight distance across the inside of a curve. To facilitate safe operation, horizontal sight distance must equal or exceed the safe stopping distance for the selected design speed (listed in *Green Book* Table 3-1). To obtain the required sight distance, horizontal curves may be redesigned with larger radius or provide for the removal or relocation of obstacles.

See *Green Book* Figure 3-23 for a diagram illustrating horizontal sight line offset (HSO) to an obstruction. For geometric design to obtain sight distance determine the limiting HSO for the typical cut slopes and ditch configurations applicable for the project. See Exhibit 9.3-J for a diagram of a horizontal sight line offset (HSO) on a cut slope, and applicable design parameters.

Cut sections may restrict the horizontal sight distance, especially where crest vertical curves coincide with horizontal curves and there is a substantial change in grade. In this case consider using a longer vertical curve, flatter horizontal curve, wider and deeper ditch, flatter cut slope ratio, additional clear area beyond the ditch or shoulder, or a combination of these. Combinations of horizontal and vertical sight distance restrictions should be evaluated using a 3-dimensional design model and perspective views.

Consider sight distance restrictions created by the presence of other vehicles, such as at opposing left-turn lanes, or at right-turn lanes interfering with sightlines from the intersecting road.

Exhibit 9.3-J LATERAL CLEARANCE FOR STOPPING SIGHT DISTANCE



Horizontal Sightline Offset (HSO) = c + D + s + 0.5W

Where:

c = the drop (d) from the center of the inside lane to the bottom of the ditch plus 2 ft [0.6 m] multiplied by the cut slope ratio.

D = the total ditch width from bottom of ditch to edge of shoulder.

s = the shoulder width

W = width of the inside lane

Note: When vegetation is expected to grow on the cut slope, reduce the drop (d) by the estimated depth of the vegetation. When vegetation is not controlled on the cut slope, reduce c to zero.

9.3.7.7 Risk Assessment and Mitigation

In some situations the sight distance standards may be difficult to meet, or may be less than optimal. Trade-offs among competing requirements sometimes require compromising decisions. In some cases, time requirements may be less than those assumed in the criteria provided in the *Green Book*. In other situations, conditions may create a need to go beyond the minimum standards. Risk is primarily related to the traffic volume exposed to the situation. Combinations of multiple road conditions and additive demand for the driver's attention and decision-making will also increase the relative risk. When faced with a choice (e.g., determining which of several back-to-back vertical curves to adjust), designers should use shorter sag vertical curve lengths in favor of providing the longest crest vertical curve that is possible.

Stopping sight distance should always be provided because any road location can become a hazard. If stopping sight distance is below standard at a number of locations then priorities for correction may need to be set. Examples of conditions, which are high priority with respect to the need for stopping sight distance, are the following:

- Change in lane width;
- Reduction in lateral clearance;
- Beginning of hazardous fill slope;
- Crest vertical curve;
- Horizontal curve;
- Driveway;
- Narrow bridge;
- Roadside hazards (e.g., fixed objects at driveways);
- Unmarked pedestrian crossings;
- Unlit pedestrian crosswalks;
- High volume pedestrian crosswalks;
- Frequent presence of parked vehicles very near the through lane;
- Slow moving vehicles; and
- Frequent pedestrian or bicycle presence.

Examples of roadway geometric elements that are high priority to provide decision sight distance include:

- First intersection in a sequence;
- Isolated rural intersections; and
- A change in cross-section (i.e., two-lane to four-lane, four-lane to two-lane, passing lane, climbing lane, lane drop, deceleration lane, channelization).

Geometric or visual complexity combined with any of the above elements increases the needs for decision sight distance. Frequent truck or recreational vehicle traffic, that block the view of traffic control devices and road geometric elements may be mitigated by increased sight distance for the specific area.

Sight distance problems may be evaluated by developing a sight distance profile that shows the available sight distance (SSD, PSD) at each increment of the alignment location, to visualize graphically the overall severity and extent of the problem, and potential interaction with other geometric design elements or roadway features.

Recognize the complex realities of driver perception and behavior when evaluating sight distance problems. Evaluate the sight distances available to support the various maneuvers (i.e., SSD, PSD, ISD, DSD). The highway location may be divided into component sections based on specific driving demands (i.e. to perform a task or maneuver). Then analyze each section in terms of its availability of sight distance to support the specific task or maneuver. Compare the available sight distance with the required sight distance to safely perform the driving task.

Potential alternatives or mitigation for limited DSD include the separation of decision points to different locations for the driver, simplify the decisions to be made, reduce the operating speed to provide additional time for decision-making and to provide additional advance information.

Potential mitigation for limited ISD includes:

- Clear sight triangles of all obstructions,
- Provide additional traffic control devices or restrictions,
- Adjust stop line placement,
- Use offset median left-turn lanes,
- Adjust length or offset of turn lanes to minimize potential obstruction by turning vehicles,
- Adjust roadway alignment, and
- Adjust intersection configuration.

Also refer to the AASHTO publication *A Guide for Achieving Flexibility in Highway Design*, Section 3.5.1.4, Section 3.5.2.3, Section 3.5.3.3 and Section 3.5.4.3 for additional guidance on mitigating insufficient sight distance.

9.3.8 GEOMETRIC CROSS SECTION

The highway cross section is defined as the finished or the proposed finished section between construction limits as shown in Section 4.3.2.2.

Provide roadway section configurations consistent with the functional classification criteria. Design cross-section characteristics of the roadway section based on, or State developed and approved classifications, the NPS *Park Road Standards* or other applicable agency standards.

For urban cross section design guidance, also refer to *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities*, ITE, 2006.

9.3.8.1 Traveled Way (Lane) Width

Design the traveled way for the movement of through motorized and non-motorized vehicles, including through lanes, HOV lanes, and auxiliary lanes for through traffic. It does not include lanes for other purposes, such as turn lanes, acceleration lanes, deceleration lanes, or parking lanes, although the number and the width of those lanes influence the width of the traveled way. The *Green Book* and other agency standards show minimum recommended lane widths for each functional classification for various design speeds and traffic volume ranges. Refer to *Green Book* Table 5-5, Table 6-5 and Table 7-3, and the *Park Road Standards* Table 10.

When the percentage of trucks, tour buses or recreational vehicles is high in comparison to the ADT, consider increasing lane widths. Refer to *Green Book* Section 4.3 and the *Park Road Standards* Table 10 - footnote a/, as applicable for additional guidance.

A lane width should generally not exceed 12 ft [3.6 m], except where a wider outside lane up to 14 ft [4.2 m] is used for accommodating bicyclists, or where the center lane up to 16 ft [4.8 m] is reserved for left turns.

Provide traveled way widening on curves, as applicable.

9.3.8.2 Shoulder Width and Type

Design the shoulder width and type consistent with the functions that need to be provided, including accommodation of stopped vehicles, emergency use, support of the traveled way, and for use by pedestrians and bicyclists (where bicycle lanes and sidewalks or pathways are not provided). Higher functional classification, higher speeds and higher traffic volumes generally correlate with a need for wider shoulders.

The *Green Book* and other agency standards show minimum shoulder widths for each functional classification for various design speeds and traffic volume ranges. Refer to *Green Book* Table 5-5, Table 6-5 and Table 7-3 and the *Park Road Standards* Table 10.

In designing the shoulder width and type, consider needs for enhancing safety and enabling recovery from errant or evasive driving maneuvers, as well as the following operational functions:

- Contribution to capacity;
- Evasive maneuvers to escape potential crashes or reduce their severity;
- Space for stopping, emergencies, incidents, crash response, mail, trash pickup;
- Pedestrian and bicycle use;
- Law enforcement activities;
- Lateral clearance to roadside objects;
- Structural and lateral support of the pavement and base;
- Mail and other deliveries, garbage pickup
- Encroachment by oversize vehicles
- Routine maintenance activities;
- Flexibility for construction and maintenance of traffic;
- Needs for drainage off the roadway and in curbed sections; and
- Needs for snow removal.

When applicable, provide additional shoulder width beyond the minimum values for special circumstances (e.g., mailboxes, transit bus stops, heavy pedestrian, bicycle use). Refer to Table 3-2 of NCHRP *Report 254: Shoulder Geometrics and use Guidelines*, 1982 for recommended widths for various shoulder functions and highway functional classifications.

For divided arterial highways with one or two lanes in each direction, a 4 ft [1.2 m] paved left shoulder within the median is recommended. On divided arterials with three or more lanes in each direction, a full-width shoulder within the median is recommended.

Shoulders with a minimum of 4 ft [1.2 m] stabilized or paved surface should be provided along both sides of rural highways routinely used by pedestrians. For design of shoulders to accommodate use by bicyclists refer to the AASHTO *Guide for Development of Bicycle Facilities*.

In rural areas, paved shoulders should be included in all new construction and reconstruction projects on roadways used by more than 1,000 vehicles per day; see Sections 9.3.16 and 9.3.17. In urban areas, provide bicycle lanes or separate bicycle facilities. In lower-speed urban areas with posted speeds of 40 mph [60 km/h] or less, shoulders may be limited by adjacent development to only the width necessary to accommodate bicycle use, and may be further reduced or eliminated if separate bicycle and pedestrian facilities are provided, and curbs are used. For urban transitional roadways with posted speed of 45 mph [70 km/h], separate bicycle and pedestrian facilities should be provided, and shoulders also provided in undeveloped areas. For high-speed urban roadways with posted speeds of 50 mph [80 km/h] or more, separate bicycle and pedestrian facilities should be provided, and the standard shoulder width also provided in all areas.

In determining the shoulder type consider the needs for pedestrian and bicycle use, safety, structural stability, cross-slope for drainage, operational functions, traffic barrier installation, and construction and maintenance costs. Consider the following types and their performance in the design:

1. **Earth.** Earth shoulders are unstabilized soil generally without turf cover, and may be applicable for very low-volume local roads, particularly where rainfall is low. The soil should be well-graded and compactable material suitable for topping. Depending on use, they may occasionally require re-grading and re-compaction to maintain their usable width and to repair pavement edge drop-offs and rutting.
2. **Granular.** Granular shoulders are an aggregate base or surface course gradation which may also be mixed with topsoil to sustain a turf cover. Granular or turf shoulders may be applicable for low or medium-volume, low-speed roads and where the shoulder is designed only for emergency use. Turf shoulders may also be applicable for higher volume or high-speed roads where the turf is well maintained and is particularly desired for aesthetics. Granular or turf shoulders should not be subject to high amounts of surface runoff, vehicular use or off-tracking. With use, they typically require periodic re-grading and re-compaction to maintain their usable width and to repair pavement edge drop-offs and rutting.
3. **Recycled Asphalt Pavement (RAP).** RAP shoulders are pulverized asphalt pavement material which may be mixed with additional emulsion or a recycling agent. The same considerations should apply as for granular shoulders, except the RAP may be more stable and applicable for shoulders with slightly higher use.
4. **Surface Treatment.** Treated shoulders may be bituminous penetration treatment or other binder placed over aggregate material to reduce water infiltration and keep the aggregate in place. The shoulders should receive periodic crack sealing, or additional treatments, or both. Surface treatments may be applicable for shoulders subject to only infrequent operational use and light vehicular traffic, or pedestrian or bicycle use.
5. **Paved.** Paved shoulders consist of the same pavement material as the traveled way, and are generally preferred for all operational functions including pedestrian or bicycle use, and particularly safety performance. The opportunity to install rumble strips on paved shoulders further enhances their safety performance. A lesser structural section depth may be provided for paved shoulders; however, the constructability and long-term performance should be considered together with the lower material cost.
6. **Combination.** A combination of shoulder types and respective widths may be used, as appropriate to balance cost, stability, operational performance, or aesthetics. A minimum partially paved width of 2 ft [0.6 m] is recommended in all cases, and additional

width desired for pedestrian or bicycle use. Instead of a combination of types, a fully paved shoulder is particularly recommended for high-volume roads, arterials, or where the shoulder receives frequent use, or is regularly used by pedestrians or bicyclists. Any combination with an unstabilized shoulder type may result in eventual reduction of the useable shoulder width.

9.3.8.3 Horizontal Clearance to Structures

Provide the required minimum horizontal clearance to retaining walls (including cut and fill situations), and bridge structures in coordination with the Structural Design Unit.

A minimum offset of 18 in [500 mm] must be provided beyond the face of curbs, with 2 ft [0.6 m] preferred, and with wider offsets provided where practical. This offset distance is not considered the clear zone, although it must be clear of obstructions, but is needed for operational and capacity reasons. See Section 9.3.12.3 for lateral clearance and offset distance to features adjacent the roadway. Also see Section 8.5.3.3.4.

For roadside safety, the recommended clear zone and shy distances, or barriers, should be provided as appropriate in accordance with the guidance provided in the AASHTO *Roadside Design Guide*. When applicable, determine the requirements for clearance to railroad features or major utilities.

For bridge structures, refer to applicable sections of the *Green Book* for minimum horizontal clearance from the travel lanes to bridge railings, for the road functional classification and traffic volume. For local roads see Tables 5-6 and 5-7, and for collector roads see Tables 6-6 and 6-7, for minimum clear roadway widths for bridges; however, the full approach roadway width, plus 2 ft [0.6 m] lateral clearance on each side, is generally desired. For arterials the full approach roadway width, including lateral clearance, should normally be provided for new bridges; however, bridges having an overall length over 200 ft [60 m] may have a lesser width. For arterials, an existing bridge to remain in place should have a width at least equal to the traveled way plus 2 ft [0.6 m] clearance on each side. For a two-lane tunnel, the total clearance between the walls should be a minimum of 30 ft [9 m].

9.3.8.4 Cross Slope

9.3.8.4.1 Travel Lane

FLH standard practice is for the cross slope on tangents on paved highways to be from 1½ to 2 percent. Typically, normal crown cross slopes of 2 percent are used on paved surface roads.

Normally, the normal crown cross slopes on gravel surfaced roads should be 3 percent to facilitate roadway surface drainage.

9.3.8.4.2 Shoulder

For paved shoulders less than 5 ft [1.5 m] width, the shoulder cross slope should be the same as the adjacent traffic lane. Paved shoulders 5 ft [1.5 m] or wider may be sloped to drain away from the traveled way, and should be sloped to drain away from the traveled way in areas of routine snowplowing and on divided highways with a depressed median. In these cases, consider shoulder cross slopes of 2 to 6 percent. With curb sections or when the shoulder surface is an asphalt surface treatment, aggregate or turf, increasing the shoulder slope helps to facilitate drainage. In these cases, consider cross slopes of 4 to 6 percent for gravel or asphalt treated shoulders, and 6 to 8 percent for turf shoulders.

9.3.8.4.3 Differences in Cross Slope

Rollover is the difference in cross slope between two adjacent travel lanes or a travel lane and its adjacent shoulder. On normal crown sections the rollover between adjacent travel lanes should not exceed 4 percent, and between the travel lane and turf shoulder should not exceed 6 percent. On superelevated curves, the rollover in cross slope between the travel lane and shoulder must not exceed 8 percent. See *Green Book* Section 4.2.2 and Section 4.4.3 for additional guidance.

Typically, locate any breaks in cross slope at the edges of travel lanes or shoulders. Alternatively, for 10 ft [3.0 m] travel lanes the slope break for shoulders may be located 2 ft [0.6 m] outside the travel lane, and for 11 ft [3.3 m] travel lanes the slope break for shoulders may be located 1 ft [0.3 m] outside the travel lane.

The cross slope on the tops of base courses and the subgrade should be the same as on the finished pavement. For unpaved shoulders or shoulders wider than 7 ft [2.1 m], it is desirable to have a reverse slope on the subgrade (on the high side of curves and outside the edge of the pavement) to drain the shoulder surface away from the travel lane and drain moisture away from the base.

9.3.8.5 Pavements and Geometric Design Considerations

The pavement structure refers to the material and depth of base and pavement placed on the finished subgrade. Refer to Chapter 11 for guidance on developing the pavement structure design including the materials and minimum thickness. Consider the following for the geometric design of the roadway and pavement structure:

- Provide a smooth-riding, skid-resistant roadway surface,
- Minimize the necessary subgrade width and the overall depth of material necessary for the design service life of the pavement,
- Design the top portion of the subgrade to utilize the highest strength material available from the earthwork grading, and
- Design the roadway and overall geometric cross section to fully optimize, support and integrate the pavement structure design.

9.3.8.6 Risk Assessment and Mitigation

The traffic volume that is exposed to the condition primarily influences the safety and operational risks regarding the roadway cross section. Where roadway width is less than recommended, provide the safest roadside design possible, and provide enhanced delineation and warning devices. For narrow roadway widths, consider using centerline rumble strips and additional widening in curves beyond the normal guidelines.

Variations in the available shoulder width reduce the driver's expectations that the full shoulder width will be available when needed, and may affect driver behavior if evasive maneuvers are required. Consider adding more frequent pullouts where there are combinations of narrow shoulder width and severe terrain.

Also refer to the AASHTO publication *A Guide for Achieving Flexibility in Highway Design*, Section 3.6.1.3 for guidance on mitigating narrow travel lanes, and refer to Section 3.6.2.2 and Table 3-2 for additional guidance on mitigating narrow shoulder widths.

9.3.9 ROADWAY WIDENING

Consider the need for additional widening on curves, and the need for auxiliary lanes, turnouts, etc. These additional widening considerations and requirements are described in the following sections.

9.3.9.1 Traveled Way Widening on Curves

It is FLH standard practice to increase traveled way widths on curves, as recommended by *Green Book* Section 3.3.10. Traveled way widening values are shown in *Green Book* Tables 3-26 and 3-27.

When necessary, provide traveled way widening exceeding the minimum values. When applicable, provide additional traveled way widening on curves where lane widths are less than 10 ft [3.0 m], or if necessary to accommodate vehicle tracking and safe operations due to:

- Greater difficulty for drivers to control the vehicle in curves,
- "Overshoot" path behavior at tangent to curve transitions,
- Variations in speeds within the curve resulting in changing lateral accelerations,
- Variations in e, f, and R within the curve with resultant changing lateral accelerations,
- Difficulty in discerning the vehicle lane position, both own vehicle and opposing traffic,
- Difficulty in judging the clearance from objects along the roadway,
- Off-tracking (offset) of rear wheel to front wheel paths and towed vehicles, and
- Reduced lateral clearance due to vehicle overhangs in front and rear.

For simple (non-spiraled) curves, apply the total travel way widening on the inside of curves and transition it throughout the length of the superelevation runoff. The pavement joint and final centerline striping should be adjusted from the geometric centerline to split the roadway width and provide equal widening to both lanes.

For curves with spiral transitions, split the widening equally to both lanes and transition it on the spiral lengths.

Provide lane edge line striping consistent with the designed traveled way widening. Design the edge striping for the traveled way widening to apply the widening only to the travel lanes, and to maintain the same shoulder width in the curve as for the tangent section.

9.3.9.2 Auxiliary Lanes

Refer to the following sections for guidance on specific types of auxiliary lanes.

When evaluating the operational performance of alternatives to two-lane cross sections, including passing lanes, climbing lanes and short four-lane sections, or determining the need for passing lanes, consider the *IHSDM* Traffic Analysis Module, which uses the TWOPAS traffic simulation module to estimate traffic quality of service measures for an existing or proposed design under current or projected future traffic flows.

Coordinate signing and marking requirements of the *MUTCD* for the addition, continuation, or drop of travel lanes with the design for location of such signing along the roadway, and with the geometric design of the roadway and intersections. Refer to the *MUTCD*, Table 2C-4, Section 3B.09 and Figure 3B-12 for guidance on the minimum lengths and layout of lane reductions, speed changes, and similar auxiliary lane transitions.

9.3.9.3 Parking Lanes

Refer to *Green Book* Section 4.20, Section 5.3.2, Section 6.3.2 and Section 7.3.3 for criteria on design of parking lanes.

Exercise care in introducing any new on-street parking, as it affects operating speeds, capacity, and potential safety risk. On-street parking is not recommended where operating speeds are greater than 40 mph [60 km/h]. Parking lanes may be provided on lower-speed urban highways with 40 mph [60 km/h] or less posted or regulatory speed. The design of transitional (45 mph [70 km/h] and high-speed urban (50 mph [80 km/h] or more) arterial or expressway facilities should only accommodate emergency stopping. Do not add on-street parking to facilities with design or posted speeds of 50 mph [80 km/h] or more. Within lower-speed urban areas existing developed and developing land uses may require on-street parking lanes. Parking lanes may also be provided on rural highways passing through developed communities with urban cross-section elements. When adding on-street parking to low-speed facilities, consider:

- The effect on the highway's operating speed, safety and capacity,
- Sight distance requirements,
- Turning paths,
- Bicycle use,
- Needs for crosswalks, mid-block crossings and curb bulb-outs,
- Bus and transit use,
- Needs for access by emergency vehicles to adjacent buildings, and
- Snow removal and storage, if applicable.

When land use development requires parking lanes, consider only parallel parking. Do not use angle parking without a careful analysis of operational characteristics of the facility. Do not use angle parking in areas of operating speed greater than 25 mph [40 km/h]. Where angle parking is permitted and required to support adjacent land uses, back-in angle parking is the preferred treatment over head-in angle parking for visibility of motor vehicle and bicycle traffic, and safety of loading passengers and cargo.

The width of parallel parking lanes can vary from 7 ft to 12 ft [2.1 m to 3.6 m] depending on the roadway function and type of use. The desirable minimum width of a parking lane is 8 ft [2.4 m], particularly for areas with frequent parking turnover or loading activity. A minimum parking lane width of 10 ft [3.0 m] is desirable in areas where there is a need for lateral clearance from the traveled way, or there is substantial truck or recreational vehicle parking use, or for bus stops. Wider parking lanes up to 12 ft [3.6 m] are desired to provide better lateral clearance to the shoulder or traveled way, especially for higher function roadways, or to accommodate use of the parking lane as a through-travel lane during peak periods.

For design of bicycle routes, the combined width for bicycle travel and parallel parking should be a minimum of 14 ft [4.2 m]; 16 ft [4.8 m] being desirable. Refer to Section 9.3.17 for bicycle considerations and facilities.

Parallel parking stalls may be 22 ft to 26 ft [6.7 m to 7.8 m] long; 25 ft [7.6 m] being typical.

For angle parking provide a minimum width parallel to the roadway for parking of 17 ft [5.2 m] and preferably 20 ft [6 m]. Diagonal parking stalls may be 8 ft to 10 ft [2.5 m to 3 m] wide; 9 ft [2.7 m] being typical. Wheel stops may be provided to limit encroachment of parked vehicles; however, consider potential interference of wheel stops with snow removal operations if applicable.

The cross slope of parking lanes may be from 2 percent minimum to 4 percent maximum.

Avoid design of parking lanes within an 8 ft [2.4 m] offset from adjacent traffic barriers.

Consider parking requirements to accommodate persons with disabilities. Refer to the *Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities (ADAAG)* for the applicable standards. The *Green Book* contains information on sidewalk curb ramps in Section 4.17.3. Refer to Section 9.3.16.3 for accessibility requirements applicable to the design of parking areas and passenger loading zones. In general, accessible on-street parking should be located near facilities such as markets, post offices, drug stores, and medical facilities. Also consider designating passenger loading zones for accessible on-street parking. Where designing on-street accessible parking spaces consider the following:

- Design the cross-slope to not exceed 2.0 percent,
- If curbed, provide a curb ramp or locate accessible spaces adjacent to crosswalk,
- Provide an additional 5 ft [1.5 m] stall length to accommodate an access aisle,
- Avoid placing appurtenances adjacent to the accessible parking stall, and
- Avoid placing drainage inlets within the accessible parking stall.

9.3.9.4 Speed Change and Turning Lanes

When applicable, provide acceleration and deceleration lanes, including tapered areas, for vehicles entering or leaving the through traffic lanes. There are no definite warrants for providing speed change lanes; however many considerations are involved in the determination. The *Green Book* provides guidance on using these lanes in Section 9.7 and Section 10.9.6.

Consider providing speed change lanes for intersections on principal arterials. Also consider speed change lanes when recommended as the result of a safety and crash study. Speed change lanes should also be considered when:

- Operating speeds are 50 mph [80 km/h] or greater, and
- Daily peak hourly traffic volume of the through lane in the direction of travel exceeds 120 vph, and
- Turning vehicles frequently cause conflict with the through traffic, and
- The combined volumes of through traffic and vehicles entering or leaving the traffic lanes typically cause through vehicles to slow more than 10 mph [15 km/h].

Refer to Section 9.3.14.5 for specific considerations and design of left-turn acceleration and deceleration lanes, and Section 9.3.14.6 for right-turn lanes, at intersections.

9.3.9.5 Climbing Lanes

Evaluate the need for climbing lanes in areas with truck traffic and steep grades, or other areas subject to slow-moving traffic. Climbing lanes should be provided to assure a uniform level of service rather than as a necessity to avoid extreme congestion and disruption of traffic flow. Climbing lanes should be considered when the critical length-of-grade is exceeded (i.e., the length of grade causes a reduction of 10 mph [15 km/h] or more in the speed of a heavy truck) and the flow of traffic is significantly affected (DHV flow for LOS D is not attained). Refer to the *Highway Capacity Manual* or the *IHSDM* for methodology to analyze the traffic operations and effect of climbing lanes for specific locations.

Evaluate the effect of steep grades, both upward and downward, on capacity and safety for high traffic volumes and numerous trucks. In areas with especially long and steep grades, and high traffic volume, consider providing a truck lane (creeper lane) for slow-moving downhill traffic (e.g., trucks, vehicles with trailers, recreational vehicles), as appropriate. Design climbing lanes independently for each direction of travel.

Consider climbing lanes on two-lane highways under the following circumstances for the DHV:

- The upgrade traffic volume exceeds 200 vph,
- The upgrade truck volume exceeds 20 vph,
- LOS D is not attained on the grade,
- A reduction of two or more levels of service occurs when moving from the approach segment to the grade, or

- Trucks will experience a speed reduction of 10 mph [15 km/h] or greater.

For those unfamiliar with the level-of-service concept, it is difficult to visualize the operating conditions that characterize levels of service A through F. *Green Book* Table 2-4 presents a brief description of the operating characteristics for each level-of-service and type of highway.

Other factors to consider, on the upgrade, are the amount and location of left or right turns at intersections or driveways within the segment.

Refer to *Green Book* Section 3.4.3 for details on designing climbing lanes on two-lane highways. The *Highway Capacity Manual* also contains guidance and sample calculations.

For justification warrants and design criteria for climbing lanes on multilane highways, refer to Chapter 3 in the *Highway Capacity Manual* and *Green Book* Section 3.4.3.

If a climbing lane is provided, consider the following minimum criteria for design:

- The full width of the climbing lane should extend for the entire location where the truck speed is less than 10 mph [16 km/h] of the passenger car speed;
- The entering taper of the climbing lane should be at least 15:1 and preferably 25:1;
- The exiting or merging taper should be at least 30:1 and preferably 50:1 or more;
- Locate the ending merging taper of climbing lanes in areas where the available sight distance is maximized;
- The climbing lane width should equal or exceed that of the adjacent through lane, and preferably be at least 12 ft [3.6 m];
- Avoid locating the ending or merging taper within 500 ft [150 m] prior to an intersection or major side approach road;
- The merging taper should be located to avoid side approach roads or driveways on either side of the highway;
- Superelevate the climbing lane in the same manner as for a multi-lane highway;
- The shoulder width should be the same as the adjacent two-lane section and at least 4 ft [1.2 m];
- Provide the typical clear zone from the edge of the traveled way of the outer most lane (climbing lane); and
- Provide signing and markings in accordance with the *MUTCD*.

9.3.9.6 Passing Zones and Lanes

Consider the accommodation of passing maneuvers as an essential element of two-lane rural highway design. It is desirable to provide as many passing opportunities as possible, especially in areas where there are limited opportunities to pass or on highways that may have slow-moving traffic.

9.3.9.6.1 Passing Zones

FLH standard practice is to develop the roadway geometric design to provide passing sections based on the design controls for minimum passing sight distance found in the *Green Book* for the functional classification and design speed of the highway. Refer to *Green Book* Section 3.2.4 for guidance on the criteria for geometric design of passing sections (zones).

Consider the principles of design consistency in the geometric design of passing zones. The provision of short passing zones intermixed with long passing zones can violate a driver's expectations. Design of minimum passing zones may be necessary in mountainous or rolling terrain to permit passing of slow trucks and recreational vehicles when passing lanes or climbing lanes cannot be provided.

Signs, if used, and markings to designate passing and no-passing zones are designed in accordance with the *MUTCD* Sections 2B.29, 2B-30, 2C-35, and 3B-02.

9.3.9.6.2 Passing Lanes

Consider providing passing lanes in one or both directions of travel on a two-lane highway having inadequate passing opportunities, to:

- Improve passing opportunities,
- Enhance safety, and
- Improve traffic operations by breaking up traffic platoons and reducing delay.

Passing lanes differ from climbing lanes in that passing lanes are considered regardless of topography. Refer to Section 9.3.9.5 for guidance pertaining to climbing lanes.

Passing lanes can be used in either rolling or level terrain when passing restrictions exist because of limited sight distances or high volumes of oncoming traffic. Consider providing passing lanes particularly on highways with high traffic volumes (over 2,000 ADT) including slow-moving trucks and recreational vehicles, and that lack frequent sections with adequate passing sight distance, resulting in operational delays and potential safety conflicts. Consider passing lanes are less effective on sections that already provide good passing opportunities, at least during the off peak periods. Although potentially more costly, it may be desirable to locate passing lane sections in the rolling terrain at locations where passing sight distance is generally unavailable, rather than in level terrain sections. Passing should be allowed within passing lane sections for the opposing traffic if passing sight distance is available and access conditions are appropriate.

Refer to *Green Book* Section 3.4.4 and the *Highway Capacity Manual* for guidance on the design of passing lanes.

FLH standard practice for design of passing lanes includes the following:

- Design passing lanes to be at least 1,000 ft [300 m] long, excluding tapers,

- For two-way total DHV less than 600, the desirable length of a passing lane is 0.5 mile to 1 mile [0.8 km to 1.6 km], which does not include the taper length for the lane addition and lane drop,
- Design the lane addition taper at a ratio of 25:1,
- Design the lane drop taper in accordance with the *MUTCD*, Section 3B-8, or at a ratio of 50:1, whichever is longer,
- Superelevate the passing lane in the same manner as for a multi-lane highway; and
- Provide passing lane signing and markings in accordance with the MUTCD.

The lane addition and drop should be located in areas where sight distance is maximized, preferably where 1,000 ft [300 m] of sight distance is available, to allow a driver to anticipate the passing opportunity and also its end. The end of the merging taper should be visible from the lane reduction sign (W4-2R). Because of sight distance concerns, the merging taper should not be located just beyond the midpoint of a crest vertical curve.

The passing lane width should equal or exceed that of the adjacent through lane, and preferably be at least 12 ft [3.6 m]. The shoulder width should be the same as the adjacent two-lane section. The typical clear zone should be provided from the edge of the traveled way of the outer most lane (through lane).

Advance signing is beneficial to indicate to drivers that passing opportunities exist ahead (e.g., PASSING LANE 2 MILES AHEAD, PASSING LANE ½ MILE AHEAD).

The use of a passing lane is determined on a case-by-case basis. The justification for increasing the frequency of passing opportunities is usually based on an engineering study that includes judgment, operational experience and a capacity level-of-service analysis using procedures of the *Highway Capacity Manual*. Measuring traffic traveling in platoons (traffic with headway gaps of 5 seconds or less) can also be helpful in establishing need and identifying potential sites for passing lanes. Evaluating the need for passing improvements should consider traffic operations over an extended road length, usually at least 10 miles [16 km]. For additional information on passing lane warrants, see the FHWA publication *Low Cost Methods for Improving Traffic Operations on Two-Lane Roads*, Report No. FHWA-IP-87-2. It presents approximate adjustments that can be made to the capacity methodology in the *Highway Capacity Manual*. These adjustments can be used to estimate the level-of-service benefits from adding passing lanes to two-lane facilities.

When determining where to locate passing lanes, consider the following factors:

1. **Costs and Impacts.** Locate passing lanes to minimize costs and impacts. Difficult terrain will generally increase the costs and impacts for construction of passing lanes.
2. **Appearance.** The passing lane location, and its value, should appear logical and be obvious to the driver.
3. **Horizontal Alignment.** Where practical, avoid locating passing lanes on segments with lower-speed horizontal curves that restrict the speed for all vehicles.

4. **Vertical Alignment.** Where practical, construct passing lanes on a sustained upgrade. The upgrade will generally cause a greater speed differential between slow moving vehicles and passing vehicles. However, passing lanes in level terrain still should be considered where the demand for passing opportunities exceeds supply.
5. **Intersections.** Locations should be avoided that include major intersections or high-volume access points (over 500 ADT). Use special care when designing passing lanes through minor intersections and commercial entrances.
6. **Structures.** Avoid placing passing lanes where structures (e.g., large culverts, bridges) may restrict the overall width of the traveled way, passing lane and shoulder.
7. **Tapers.** Avoid locating the ending or merging taper within 500 ft [150 m] prior to an intersection or major side approach road. The merging taper should be located to avoid side approach roads or driveways on either side of the highway.

Separate left-turn lanes may be provided in a passing lane section when left turn volumes are significant. Refer to Section 9.3.14.5

When passing lanes are provided to improve the overall traffic operations over a length of roadway, they should be constructed systematically at regular intervals. Typical spacing for passing lanes may range from 3 to 8 miles [5 to 13 km] in the same traffic direction. Actual spacing of passing lanes will depend on the traffic volumes, right-of-way availability and existing passing opportunities. When spacing passing lanes in both directions, it is desirable to locate the first passing lane for the advancing traffic direction prior to a passing lane for the opposing traffic.

The design of three-lane roads with alternating passing lanes, in 0.5 mile to 1 mile [0.8 km to 1.6 km] increments, continuously over an extended section of road is known as “2+1” road design. This concept has been used to convert wide two-lane roadways, or narrow four-lane roadways, to a three-lane roadway with designated, alternating passing lanes in each direction to improve safety and operations. These roadways may be considered an intermediate solution to the ultimate future expansion to a four-lane highway constructed to full standards.

9.3.9.7 Bicycle Lanes

Bicycle lanes are portions of a highway or street that have been identified for bicycle travel by signs, pavement markings, or both. Consider bicycle lanes particularly for urban street designs. See Section 9.3.17 for guidance and details.

9.3.9.8 Slow Moving Vehicle Turnouts

Refer to the section on “Turnouts” in *Green Book* Section 3.4.4 for guidance on the design of slow moving vehicle turnouts.

When applicable, design slow moving vehicle turnouts to provide sufficient room for a slow moving vehicle to pull safely off the roadway, then re-enter the through lane after faster moving vehicles pass.

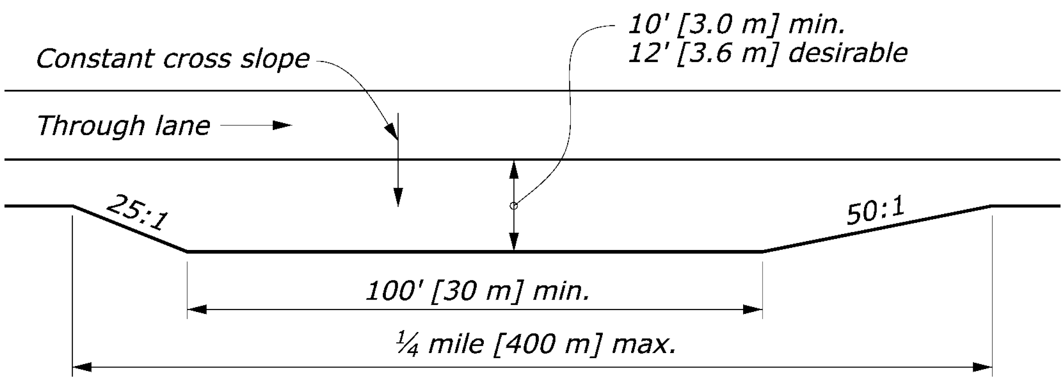
Consider the need for a turnout on paved roadways for the following situations:

- With limited passing opportunities,
- When slow-moving vehicles are prevalent but do not warrant climbing lanes, and
- Where the cost of an auxiliary lane is prohibitive.

Exhibit 9.3-K provides guidance for minimum dimensions of turnouts. Refer to *Green Book* Table 3-32 for recommended lengths of turnouts including taper. Greater turnout widths should be considered on curves and along steep fill slopes. Turnouts wider than 16 ft [4.8 m] are not recommended. The riding surface of a turnout should be similar to the adjacent travel way. Sign and mark all slow moving vehicle turnouts to identify their presence and purpose.

Turnouts should be located so that approaching drivers have a clear view of the entire turnout in order to determine whether the turnout is available for use. The available sight distance should be at least 1,000 ft [300 m] on the approach to the turnout. Provide adequate sight distance so the vehicle can re-enter the traffic stream safely. Slow-moving vehicle turnouts should not be located in areas where available sight distance is less than the length shown in the *Green Book* for decision sight distance for avoidance maneuvers C, D or E for the type of road.

Exhibit 9.3-K SLOW-MOVING VEHICLE TURNOUT



9.3.9.9 Parking Pullouts

Parking pullouts are advantageous for vehicle checks, orientation, brief driving breaks, vistas, recreation and other purposes. For operating speeds of 45 mph [70 km/h] or less, parking pullouts should be a minimum of 14 ft [4.2 m] wide and 50 ft [15 m] long, excluding tapers, for parallel parking beyond the normal roadway shoulder. For perpendicular or angle parking, pullouts should be a minimum of 40 ft [12 m] wide and 80 ft [24 m] long, excluding tapers, beyond the normal roadway shoulder. Tapers for parking pullouts should be at least 50 ft [15 m] in length. For operating speeds over 45 mph [70 km/h], the pullout and taper dimensions should be increased proportionately to the higher speed. Parking pullouts should not be located in areas where available sight distance is less than the length shown in the *Green Book* for decision sight distance for avoidance maneuvers C, D or E for the type of road.

9.3.9.10 Shoulder Widening for Barriers

Refer to the AASHTO *Roadway Design Guide* for recommended offset distance from the roadway to barriers such as guardrail, terminals, bridge railing, etc. Design sufficient shoulder widening to accommodate the barrier and the offset.

9.3.10 MEDIANS

Refer to *Green Book* Section 4.11 for guidance on the general design of medians. Specific guidance on the design of medians for collector roads, arterials and freeways is provided in the applicable sections of the *Green Book*.

9.3.10.1 Benefits and Disadvantages of Medians

The primary benefit of medians is to improve safety. Medians improve safety by separating opposing traffic thus reducing head-on and sideswipe crashes, and by providing a recovery area for errant vehicles, and by providing a refuge area for crossing and left-turning vehicles from intersecting roads. Medians also improve pedestrian and bicyclist safety by breaking up crossing distances and providing a refuge area for pedestrians and bicyclists crossing the roadway. Other benefits of medians include:

- Providing storage space for left-turning vehicles;
- Improving mainline traffic operations by controlling left turns from the mainline as well as from minor driveways, and channelizing traffic movements;
- Providing space for drainage and drainage facilities, bridge piers, and other structures;
- Providing a refuge area for disabled vehicles, and providing a snow storage area;
- Traffic calming; and
- Providing opportunities for landscaping and aesthetic treatments, which help buffer visual impacts and noise, and generally provide for increased driver comfort and ease of operation.

There are also disadvantages to medians. Raised medians may complicate snow plowing, storage and removal operations. In addition, plantings and other landscaping elements may obscure sight distance in horizontal curves and at intersections, and may constitute roadside obstacles. Such elements should be consistent with the AASHTO *Roadside Design Guide*.

For additional guidance on median width refer to NCHRP Report 375, *Median Intersection Design*.

9.3.10.2 Urban Medians

Medians for urban roadways are typically either raised or flush. Flush medians are typically 4 ft to 16 ft [1.2 m to 4.8 m] and should be well delineated by either painting or paving with a contrasting surfacing type, color or texture.

The raised area of urban medians should be curbed. Refer to Section 9.3.11. Raised medians in urban areas should be as wide as practical, with 30 ft [9 m] normally being the maximum width. Raised medians should be a minimum of 6 ft [1.8 m] width, which allows for a minimal 4 ft [1.2 m] width raised area with 1 ft [0.3 m] offset between the outside edge of the raised area and the travel lane. To accommodate left-turn lanes with a raised median and offsets for curb the raised median width in low-speed urban areas is 16 ft [4.8 m] minimum, and preferably 20 ft to 24 ft [6.0 m to 7.2 m]. For transitional speed urban roadways with 45 mph [70 km/h] posted speed, the recommended median width is 30 ft [9 m]. Raised, curbed medians are not recommended for high speed roadways, particularly for design speeds of 55 mph [90 km/h] or more. Instead, flush medians with traffic barriers are recommended, or widening the median to obtain sufficient separation width.

Provide a parabolic (desired) or semi-circular bullet nose at the end of all raised medians. Refer to *Green Book* Section 9.8 (including exhibits and tables) for design of median openings.

Consider a two-way continuous left-turn lane (TWLTL) if necessary to provide access in areas with frequent driveway spacing in highly developed or commercialized areas. A TWLTL should not be used on highways with more than two through lanes in each direction or average operating speed over 45 mph [70 km/h]. A center lane width of between 12 ft to 16 ft [3.6 m to 4.8 m] is suitable for a TWLTL; however 14 ft [4.2 m] minimum width is desired. Careful evaluation of individual sites is required for design of a TWLTL, as it may be inappropriate at many locations. A TWLTL may increase rather than control access opportunities. An alternative median treatment with dedicated left turn lanes where needed is preferable than a TWLTL for safety and access management.

Also refer to AASHTO *A Guide for Achieving Flexibility in Highway Design*, Section 3.6.4.2, for guidance on design of medians on urban highways.

9.3.10.3 Rural Medians

Medians for rural highways are typically either depressed or flush. In areas where there are no driveways or approach roads to cause left turn movements, a flush paved median width of 4 ft [1.2 m] or greater may be used. However, if there are regular turn movements a flush median width of 10 ft [3.0 m] or greater should be provided.

An appropriate median should be provided in the design for all new or reconstructed rural multi-lane arterials, including expansion of two-lane arterials to multi-lane facilities.

Depressed medians are generally used on rural divided highways for more efficient drainage and snow removal. Median side slopes should follow the recommendations of the AASHTO *Roadside Design Guide*. Careful consideration of longitudinal and transverse slopes, ditches and drainage features is necessary. Drainage inlets in the median should be designed either with the top of the inlet flush with the ground or with culvert ends provided with traversable safety grates.

Also refer to AASHTO *A Guide for Achieving Flexibility in Highway Design*, Section 3.6.4.1, for guidance on design of medians on rural highways.

9.3.10.4 Variable Medians and Independent Alignments

For median widths greater than 40 ft [12 m], variable medians and independent roadway alignments should be considered. Independent horizontal alignments and grades enable a closer fit of the roadway to the topography and typically reduce the overall clearing footprint and earthwork. With wider medians, especially with variable independent alignments, a desirable ease and freedom of operation is obtained, the noise and air pressure of opposing vehicle traffic is not noticeable, and the glare of headlights at night is greatly reduced. Additional opportunities for preservation of existing vegetation and landforms within the median are available, which enhances scenic beauty, environmental enhancements and wildlife crossings.

9.3.11 CURBS

The design of curbs and their offset should consider whether the highway cross-section is classified as rural or urban, and if urban whether categorized as lower-speed (40 mph [60 km/h] or less posted or regulatory speed) or transitional (45 mph [70 km/h]), or high-speed (50 mph [80 km/h] or more). The location of the highway within the corporate limits of a city does not determine if it should have an urban cross-section.

Curbs may be used for the following applications:

- On low-speed roadways for control of pavement drainage and to delineate and confine the edge of the roadway, for pavement edge support, right-of-way reduction, and aesthetics and for maintenance operations;
- In association with gutters or paved ditches for controlling drainage from a highway, especially in embankment areas with erodible soils or steep and high slopes or that drain into streams, lakes, wetlands and other bodies of water;
- With a paved foreslope ditch on the cut (uphill) side of a roadway for drainage control, instead of a graded roadside ditch, where rugged terrain, environmental impacts or other factors limit the space available for a conventional roadside ditch, and
- On low-speed roadways for channelization, access control, aesthetics, separation between pedestrians and vehicles, and to enhance delineation of the roadway.

Caution should be exercised when using curbs on high-speed rural highways. Where curbs are required for control of pavement drainage along high-speed rural highways, they should always be located at or beyond the outside edge of the shoulder, and should be the sloping faced type. The curb should be offset a minimum of 1 ft [300 mm] and preferably 2 ft [600 mm] outside the normal shoulder line, or as described in Section 9.3.11.3.

Curbs placed in front of traffic barriers can result in unpredictable impact trajectories, and should be avoided if practical. Curbs should not be used with concrete median barriers. The use of curbs with guardrail should be avoided, if not required for controlling drainage. Also refer to Section 8.5.3.3.3.

If a curb is required in conjunction with guardrail, the following applies:

- Do not use curb within 50 ft [15 m] of terminal sections,
- The height-of-curb should be 4 in [100 mm] or less, and it should be the sloping-faced type with batter 1V:3H or flatter, located flush with or behind the face of the guardrail; except, for speeds 50 mph [80 km/h] or less a 6 in [150 mm] or less sloping-faced curb may be used with strong-post (Type G) guardrails if the curb is located flush with or behind the face of the guardrail, and
- Curbs should not be located between the roadway and the face of the rail, except under the following conditions:
    - ◊ For low speeds 45 mph [70 km/h] or less, guardrails may be used behind sloping-faced curbs 6 in [150 mm] or less height if the face of the guardrail is located at least 8 ft [2.5 m] behind the curb.
    - ◊ For higher speeds up to 50 mph [80 km/h], guardrails may be used behind sloping-faced curbs 4 in [100 mm] or less height if the face of the guardrail is located at least 13 ft [4 m] behind the curb.

The above guidance results from crash testing; for additional guidance see NCHRP Report 537: *Recommended Guidelines for Curb and Curb–Barrier Installations*.

Coordinate with the Geotechnical Unit where the need for curb is to protect erodible soils. Coordinate with the Hydraulics Unit where curbing is used in conjunction with a closed storm drainage system.

When designing curbs, provide drainage inlets or waterways to collect and convey the concentrated water flow at low points, curb ends, intersections and prior to reversals in superelevation. Refer to Section 7.3.3 for pavement drainage design guidelines.

Curb with gutter pan may be used to prevent infiltration of water along the face of curb joint and to enhance the visibility of the curb and thus improve delineation. Gutter pans are typically 1.3 ft [0.4 m] wide but may be 1 ft to 4 ft [0.3 m to 1.2 m] in width, with cross slope of 1V:12H to 1V:20H to enhance the hydraulic capacity. Gutter pan cross slopes generally must be modified at curb ramps to meet accessibility requirements. When used on the high side of superelevation the gutter pan may be sloped away from the roadway to contain some of the gutter flow against the curb. Where the gutter pan is only used to enhance delineation and not to enhance the drainage function it should be on the same cross slope as the roadway.

Where curbs or gutters are used, particularly in areas of flat grades, sag vertical curves, and in through-cuts, consider the potential need for an edge drain or underdrain system where the base and subbase do not drain to daylight.

Curb designs are classified as either vertical or sloping, as described in the following sections.

9.3.11.1 Vertical Curbs

Vertical curbs should only be used on lower-speed roadways with posted speeds of 40 mph [60 km/h] or less. Vertical curbs are undesired on transitional roadways with 45 mph [70 km/h] posted speed, and instead sloping curbs are recommended if a curb is necessary. Avoid using vertical curbs with posted or operating speeds greater than 45 mph [70 km/h]. Vertical curbs are typically nearly vertical (approximate batter of 4V:1H) and are typically 6 in [150 mm] in height. Vertical curbs taller than 6 in [150 mm] should be avoided. Curbs or dikes for embankment drainage control are typically 4 in [100 mm] in height and are typically battered from 2V:1H to 1V:1H, and are typically placed at or preferably beyond the normal edge-of-shoulder. Vertical curbs within 7 ft [2.1 m] of the travel lane should be avoided in rural areas that are routinely snowplowed in winter.

9.3.11.2 Sloping Curbs

Sloping curbs are more easily traversed than vertical curbs. Sloping curbs have an approximate batter of 1V:4H or 1V:3H and are typically 3 in to 4 in [75 mm to 100 mm] in height. Sloping curbs with a gutter pan function to control drainage and delineate the edge of the roadway, foreslope or paved ditch while generally conforming to the cut slope behind it. Avoid using sloping curbs in conjunction with an attached sidewalk, particularly along a parking lane. If curbs are used on urban transitional roadways with 45 mph [70 km/h] posted speed, the sloping faced type is recommended. Although in general neither vertical nor sloping curbs are desired on high-speed roadways 50 mph [80 km/h] or more, if curb is necessary then use the sloping faced type.

9.3.11.3 Curb Offsets

This section provides guidance on minimum curb offsets from the roadway, for design speeds of 45 mph [70 km/h] or less.

FLH standard practice includes the following:

- Curbs should be offset 2 ft [0.6 m] from the normal edge of shoulder, or 1 ft [0.3 m] if a sloping curve is used,
- For roadways where shoulders are not provided, apply the minimum offset distance from the traveled way for vertical curbs as shown in Exhibit 9.3-L, and
- For roadways where shoulders are not provided, the left offset distance from the traveled way for sloping curbs may be 1 ft [0.3 m] less than shown in Exhibit 9.3-L.

Exhibit 9.3-L shows the minimum offset distances for vertical curbs. For sloping curbing installations, the minimum left offset distance may be 1 ft [0.3 m] less.

Where bicyclists are accommodated, provide at least 5 ft [1.5 m] and desirably 6 ft [1.8 m] offset from the traveled way to the face of the curb. Provide bicycle-safe inlet grates, or preferably recessed drainage inlets or curb inlets. For further information, see the AASHTO *Guide for the Development of Bicycle Facilities*.

Exhibit 9.3-L OFFSET DISTANCES FOR VERTICAL CURBS

Lane Width		Left				Right (Min.)	
		Rural		Urban		Rural and Urban	
(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
12	3.6	1	0.3	1	0.3	2	0.6
11	3.3	2	0.6	1	0.3	3	1
10	3.0	3	1.0	2	0.6	3	1

9.3.11.4 Accessibility Issues with Curbing

Refer to Section 9.3.16.3 guidance on design of curbs and ramps for accessibility and accommodation for the disabled.

9.3.12 ROADSIDE DESIGN CONSIDERATIONS

The roadside is the area between the shoulder and the construction limits. See Exhibit 4.3-A. The roadside design should blend the roadway with the surrounding natural or man-made community.

As practical, design the roadside to provide:

- A safe area for errant vehicles to recover,
- Separation of motorized and non-motorized travel,
- Areas for landscaping and for the control, storage, and filtration of drainage runoff, and
- A cohesive transition between the roadway facility and the environmental context beyond the highway corridor.

The design of clearing, earthwork, drainage, approach roads, pedestrian facilities and similar elements that extend outward from the roadside and interact with the surrounding context must especially strive to match and blend with their natural, or manmade, counterpart elements outside of the immediate roadway corridor. During the final design, emphasis should be placed on minimizing the overall footprint of the immediate roadway corridor, which may tend to result in a minimized and abrupt termination of the roadside design at the slope catch. However, a similarly high level of emphasis should be placed on creating a smooth and un-noticeable transition between the roadside design and the natural landscape, or the man-made community, beyond the immediate roadway corridor. This may result in extending the construction limits beyond what is minimally needed for the roadside design, and may create additional short-term impacts; however, the goal of this work is always to provide a more sustainable design with less overall impact in the long term. This design goal is achieved through attention to the details of quality roadside design; and by placing emphasis on restoring vegetation, improving vehicular and pedestrian access points, providing enhancements of the roadside, and otherwise blending the roadside at its interface with the adjacent landscape. See Section 9.5.4 for guidance on landscaping and restoration of vegetation.

Green Book Section 4.8 provides general guidance on roadside design. Refer to the AASHTO *Roadside Design Guide*, and *A Guide for Transportation Landscape and Environmental Design*, AASHTO 1991, for specific guidance on the roadside design. Also refer to the AASHTO *Guide for Achieving Flexibility in Highway Design* Section 3.6.3 for guidance on design considerations and associated flexibility regarding treatment of the roadside.

9.3.12.1 Forgiving Roadside Concepts

Wherever practical, design the roadside to provide a margin of safety for driver error, and to forgive driver errors when they occur. Ideally, the roadside should feature recoverable side slopes free of fixed objects. Where practical, avoid or minimize the design of embankment slopes steeper than 1V:3H. Slopes steeper than 1V:3H are non-traversable, and an errant vehicle is likely to overturn on them. Barrier protection should be considered when these slopes are located within the clear zone. While a 1V:3H slope is technically traversable by a passenger vehicle, it is of marginal safety value compared to recoverable slopes. Errant drivers trying to recover control of their vehicles often cannot successfully steer or brake on a 1V:3H slope. Slopes of 1V:3H become potentially dangerous when other features (e.g., drainage features, devices, trees, ditches) are located on or adjacent to the slope. Provide a recoverable slope (i.e., 1V:4H or flatter) adjacent the roadway where practical. Locate roadside hardware outside the recoverable clear zone or use breakaway devices. Relocate, redesign, or shield fixed objects, and provide effective delineation of the roadside, especially of any hazards that cannot be removed. Where practical, implement the concepts of the forgiving roadside beyond the clear zone. Give special attention to provide a forgiving roadside where a design exception or a variance from FLH standard practices is required for other geometric features such as alignment, sight distance or roadway width. Refer to Section 8.1.4 for additional guidance. Also refer to the AASHTO *Roadside Design Guide*, Chapter 1.2.

9.3.12.2 Clear Zone

As possible, provide an unobstructed, recoverable clear zone distance beyond the edge of the traveled way, as recommended by the AASHTO *Roadside Design Guide* (RDG) for the applicable functional classification in urban or rural areas, traffic volume, speed, curvature, embankment and back slopes. Determine a recommended range of clear zone distance using Table 3.1 or Figure 3.1 of the RDG.

Determine minimum clear zone distances commensurate with traffic volumes and speeds; however, the prescribed range of clear zone values represent only a general approximation of the needed clear zone distance. The effect of longitudinal grade, horizontal curves, drainage channels, and transverse slopes may influence the recommended clear zone distances. Use engineering judgment to determine how much clear zone distance to provide throughout the highway corridor. Document the applicable clear zone as a supplemental standard, and document any exceptions. The minimum clear zone distance values should be increased for horizontal curvature; and for areas where there is a crash history, or a relatively high potential for future crashes, or both, as appropriate and practical. The minimum clear zone distance should be increased at the outside of horizontal curves using RDG Table 3.2.

In cut areas the clear zone should be extended to the back of the ditch, which may be a greater distance than is recommended elsewhere. Where minimum sight distance lines extend beyond the clear zone in rural areas, or in undeveloped urban areas, the design should be adjusted to maintain the necessary sight lines.

For high-speed urban roadways with 50 mph [80 km/h] or more posted speeds, the recommended clear zone distances apply. For low-speed urban roadways, the recommended clear zone distance should be provided wherever possible, such as in undeveloped areas. For low-speed urban roadways where adjacent development constrains the clear zone, and curbs are used, provide the maximum practical clear zone and the following guidance also applies:

- For lower-speed urban roadways with 40 mph [60 km/h] or less posted speeds and parking lanes, the clear zone should extend at least to the minimum offset distance beyond the face of curb as described in Section 9.3.12.3;
- For lower-speed urban roadways without parking lanes, the clear zone should extend at least 4 ft [1.2 m] beyond the edge of traveled way or turning lanes, or at least to the minimum offset distance beyond the face of curb, whichever is greater;
- For urban transitional roadways with 45 mph [70 km/h] posted speed, in undeveloped areas, the recommended clear zone distance should be provided wherever possible; and
- For urban transitional roadways in developed areas, the clear zone should extend at least 7 ft [2.1 m] beyond the edge of traveled way or auxiliary lanes, or at least to the minimum offset distance beyond the face of curb and preferably 4 ft [1.2 m] beyond the face of curb, whichever is greater.

Refer to the Section 9.3.11 for design of curbs and offsets. Refer to Section 8.5.2 for additional clear zone guidance.

9.3.12.3 Lateral Clearance and Offset Distance

Provide a minimum of 2 ft [0.6 m] lateral clearance from the edge of shoulder to any features over 6 in [150 mm] height, such as guardrail, bridge rail, barriers, walls, signs, utilities, parking, etc. Any lesser lateral clearance reduces the effective usable shoulder width by that amount.

For low-speed urban roads where curbs are used, provide a minimum offset distance of 18 in [500 mm] beyond the face of the curb for clearance to obstructions, and preferably 2 ft [0.6 m], with wider offsets provided where practical. For intersections provide a minimum lateral clearance and offset distance beyond the face of curb of 3 ft [1 m] and preferably 4 ft [1.2 m], at the corner turning radii. For high-speed urban roadways where curbs are used, provide a minimum offset distance of 4 ft [1.2 m] beyond the face of curb, with wider offsets provided where practical.

See Section 9.3.8.3 for horizontal clearance to structures. Also see Section 8.5.3.3.4 regarding shy distance to traffic barriers. Refer to *Green Book* Section 4.6.2 for additional guidance.

9.3.12.4 Considerations for Existing Features

In determination and application of clear zone concepts, consider the presence and value of existing unique mature vegetation, natural and historic features, consistency of driver expectations and safety risk assessment.

9.3.12.5 Access Management

Apply access management techniques according to the function of the roadway and the context of the area through which it passes. Access management includes a wide range of regulatory and design techniques to ensure that both access to adjacent land and regional mobility are provided by highway facilities. Varying degrees of access control are appropriate depending on the conditions. The roadside design should be consistent with established access management guidelines of the land management agency and the highway facility owner. Most State highway agencies have design standards for the provision of access onto State highways. For additional guidance refer to the TRB *Access Management Manual*.

9.3.12.6 Driveways

Driveways and non-public approach roads are not considered intersections; however the requirements and criteria for design of turning movements are similar.

As practical, locate driveways away from intersections and other driveways. Consider driveway spacing guidelines recommended by the TRB *Access Management Manual*. Locate driveways to provide:

- Favorable visibility, sight distance, and horizontal and vertical alignment conditions for users of the driveway and the highway;
- Safety and convenience for all highway users;
- Non-interference with nearby driveways, intersections, or auxiliary lanes;
- Control and conveyance of drainage from the highway and from the driveway;
- Conformance with applicable State or local standards, or access management plan.

Driveways are intended for low-speed vehicle operation, and should have corner radii reflecting low speeds. Single-lane driveways are appropriate for two-way traffic for single-family residential uses and for small groups (less than 10) of residential units, and for small commercial uses with employees only (no retail customers or regular visitors). For larger groups of residential units, or commercial uses with retail customers and regular visitors, a two-lane driveway is appropriate. Maximum grades for residential driveways are 10 to 15 percent depending on climate and terrain, and maximum 8 to 10 percent for commercial uses. Provide a flatter landing area at the connection to the mainline.

Provide clearance to the design vehicle chassis for the design of driveway profiles, particularly where there is curb, gutter or sidewalk. For a passenger car (P) design vehicle, the minimum clearance consists of vertical departure angles of 12 degrees from the front and rear wheels, and undercarriage clearance of 6 in [150 mm]. Limit the minimum K value of vertical curves to accommodate the design vehicle clearances (undercarriage or tow hitch). For driveway profiles provide a minimum vertical curve length of 30 ft [9 m] and minimum K value of 1.5 [0.5].

Sidewalks and bikeways must be considered in the geometric design of driveways. A minimum 4 ft [1.2 m] wide path of 1.5 to 2.0 percent maximum cross slope must be provided where a driveway crosses a sidewalk. Where possible provide continuity of the sidewalk paving material across the driveway, rather than continuity of the driveway paving material across the sidewalk. Where paving materials are the same, the sidewalk should be outlined with joints or saw cuts across the driveway. Provide minimal change to grade and cross slope of the sidewalk, even if this requires a break in the driveway grade.

9.3.13 FORESLOPES

FLH standard practice is to design the foreslope ratio (i.e. the slope ratio from the edge of the surfaced shoulder to the edge of the subgrade shoulder) in accordance with guidelines of the AASHTO *Roadside Design Guide* (RDG). Although the RDG describes the foreslope as the entire shape of the embankment from the edge of the roadway to an intersection with natural ground or a backslope, FLH terminology describes the foreslope as the initial slope from the edge of the surfaced roadway shoulder to the edge of subgrade shoulder on the embankment. When using the RDG consider the entire shape of the embankment for evaluation of the roadside geometry.

The slope ratio from the edge of the subgrade shoulder to the bottom of the ditch should normally be an extension of the foreslope ratio.

Consider the foreslope to backslope ratios when designing foreslopes that are within the designated clear zone, in accordance with the RDG.

9.3.13.1 Recoverable Foreslopes

Within the designated clear zone, FLH standard practice is to design slopes to be 1V:4H or flatter and free of fixed objects, to the maximum extent practical. Flatter slopes of 1V:6H or 1V:10H are desirable, as they are easier to maintain and safer to negotiate. Foreslopes steeper than 1V:4H are not considered recoverable and should be avoided within the clear zone.

When the existing roadway geometrics are retained and the foreslopes are steeper than 1V:4H, reshaping to provide a 1V:4H foreslope or flatter is recommended.

9.3.13.2 Traversable Foreslopes

Where practical beyond the clear zone, it is preferable to design slopes to be traversable (i.e., 1V:3H or flatter) and free of fixed objects. The design of traversable 1V:3H fill slopes should also provide for removal of fixed objects and a clear zone in the vicinity of the toe. Consider available right-of-way, environmental concerns, aesthetics, economic factors, safety performance and future safety needs in determining the width of a clear recovery area at the toe of traversable slopes.

Refer to the *Roadside Design Guide*, Chapter 3 for roadside safety design guidance.

9.3.13.3 Pavement Edge Transitions

It is FLH standard practice to design pavement outside edge transitions that are either:

1. Sloped between 30 to 35 degrees; or
2. Sloped at the same ratio as the adjoining recoverable foreslope of 1V:4H (14 degrees) or flatter, with a truncated edge less than 2 in [50 mm] high.

Avoid designing pavement outside edge transitions sloped steeper than 35 degrees or between 1V:4H (14 degrees) and 30 degrees. Design the adjoining graded slope or unpaved shoulder to match and "shoulder up" with the top surface of the pavement edge transition with less than a 1 in [25 mm], and preferably an indiscernible, drop-off following the completion of construction.

For transitions listed in item 1 above, the adjoining graded slope or unpaved shoulder should be designed either at the same cross slope as the roadway or within 6 to 8 percent rollover, for a minimum distance of 2 ft [0.6 m] from the edge of pavement, before beginning the ditch slope or embankment foreslope. See Section 9.3.8.4.2 for shoulder rollover. Provide recoverable foreslopes within the clear zone.

Refer to The Safety Edge from FHWA for more information.

9.3.13.4 Pavement Drainage Considerations

Design roadway foreslopes to provide surface drainage away from the pavement. Provide pavement drainage with consideration for safe traffic operations, control of drainage away from sidewalks, driveways, adjacent slopes and developed private property and public land uses. Paved foreslopes and paved ditches may be used where right-of-way or topography restrict the use of normal graded ditches. Isolation of drainage away from the subgrade and base layers of the pavement also should be provided. Refer to Section 7.3.4 for considerations, criteria, and guidance on procedures for design of roadway pavement drainage. Also refer to Chapter 11 for recommendations regarding drainage of the subgrade and structural pavement section.

9.3.13.5 Foreslope Considerations at Intersections

It is desirable to flatten crossroad or road approach foreslopes to 1V:10H. Provide at least a 1V:4H minimum slope. Move the crossroad or road approach drainage away from the mainline to maintain the integrity of the clear zone and minimize the length of culvert pipe required crossing the approach road.

9.3.14 DESIGN OF INTERSECTIONS

This section provides guidelines for design of at-grade intersections. Refer to *Green Book* Chapter 9 for additional guidance. For information on intersections with grade separation and interchanges, see Chapter 10 of the *Green Book*.

The intersection design should accomplish the following general objectives:

- Provide adequate sight distances,
- Minimize points of conflict,
- Limit conflict frequency,
- Minimize severity of conflicts,
- Simplify the conflict areas,
- Minimize delay, and
- Provide acceptable capacity for the design year.

Consider the type of traffic control in developing the intersection geometry. Consider the traffic characteristics, driver characteristics, driver expectations, physical features and economics in the design of channelization and traffic control measures.

The intersection includes the areas needed for all modes of travel: pedestrian, bicycle, motor vehicle, and transit. All users are affected by the intersection design. Therefore the intersection design includes not only the roadway area, but also may include bicycle and pedestrian facilities, bus stops and other multi-modal features and considerations. See Section 9.3.14.10.

Where a traffic engineering study is appropriate, it should include recommendations for channelization, turn lanes, acceleration and deceleration lanes, intersection configuration and traffic control devices. Coordinate with the safety and traffic engineer in the design of all such intersection features. Refer to Section 8.6 for information on traffic engineering studies.

Consider the primary factors that determine the minimum dimensions of intersection design are the speed at which vehicles approach and move through an intersection, and the type of the design vehicle. The intersection design criteria (e.g., minimum sight distance, curve radii and lengths of turning and storage lanes) directly relate to speed and design vehicle.

Refer to Section 9.3.7.5 for determination of minimum sight distance requirements for design of intersections.

9.3.14.1 Intersection Characteristics

The intersection characteristics include both the intersection itself, as well as the approach to the intersection. The functional area of the approach to an intersection or driveway consists of three basic elements:

- Perception reaction distance;
- Maneuver distance; the maneuver distance includes the length needed for both braking and lane changing when there is a left or right-turning lane. In the absence of turn lanes, the maneuver distance is the distance to brake to a comfortable stop; and
- Queue storage distance.

Evaluate the intersection characteristics for determination of appropriate treatment. Consider and address the following factors in the intersection design:

- Physical characteristics (e.g., roadway width, sight distance, curbs, sidewalks, medians, islands, drainage features, obstacles),
- Operational characteristics (e.g., lane use, lane delineation, speed, traffic controls, turn prohibitions, pedestrian controls, crosswalks, accessibility),
- Traffic characteristics (e.g., traffic volumes, vehicle composition, peaking characteristics, pedestrian and bicycle volumes),
- User characteristics (e.g., driver familiarity, age, experience), and
- Location characteristics (e.g., functional classification, rural or urban, roadside development, access control, proximity to traffic generators).

9.3.14.2 Intersection Types

The three-leg, four-leg, multi-leg, and modern roundabout configurations are the basic types of intersections. See *Green Book* Section 9.3.

For new construction or reconstruction of intersections having traffic controls on the mainline, particularly those having low speeds and traffic volumes, a roundabout configuration should be analyzed as an alternative to other proposed or existing intersection types; unless the intersection has no current or anticipated safety, capacity, or operational problems. Roundabout design and analysis of their operation should be done using specialized roundabout design software, such as SIDRA, RODEL or ARCADY. For detailed information on modern roundabouts see the FHWA publication *Roundabouts: An Informational Guide* (FHWA-RD-00-67) and NCHRP Report 572, *Roundabouts in the United States*. Also refer to *Green Book* Section 9.3.4 and the *Highway Capacity Manual*, Chapter 17, pages 45-48.

9.3.14.3 Intersection Design Vehicle

The design vehicle for any intersection depends on the roadways involved, the location of the intersection and the types and volume of vehicles using the intersection. Exhibit 9.3-M provides a guide to determine the design vehicle appropriate for various intersections.

Design an intersection so the design vehicle can make all turning movements without encroaching on adjacent lanes, opposing lanes, curbs or shoulders. Design the intersection with consideration that oversize vehicles, on necessary occasions, need to maneuver through the intersection with an encroachment, if allowed by the State’s vehicle code. Using a taper at the exit end of the right-turn corner will reduce the radius and the pavement area. For the recommended right-turn lane corner design described in Section 9.3.14.6.

For urban streets with parking lanes, or bike lanes, or both, consider the effective turning radius. Refer to *Green Book* Section 5.3.5 and Figure 5-3.

Exhibit 9.3-M INTERSECTION DESIGN VEHICLE

Intersection Type	Design Vehicle		Inside Radius	
	Desired	Minimum	Desired	Minimum
US Customary				
Junction of Major Truck Routes	WB-67	WB-62	130 ft	100 ft
Junction of State Routes	WB-62	WB-40	100 ft	65 ft
Ramp Terminals	WB-62	WB-40	100 ft	65 ft
Other Rural	WB-40	SU-30	75 ft	50 ft
Urban Industrial	WB-40	SU-30	75 ft	50 ft
Urban Commercial	SU-30	P	50 ft	30 ft
Residential	SU-30	P	50 ft	30 ft
Metric				
Junction of Major Truck Routes	WB-20	WB-19	40 m	30 m
Junction of State Routes	WB-19	WB-12	30 m	20 m
Ramp Terminals	WB-19	WB-12	30 m	20 m
Other Rural	WB-12	SU-9	23 m	15 m
Urban Industrial	WB-12	SU-9	23 m	15 m
Urban Commercial	SU-9	P	15 m	9 m
Residential	SU-9	P	15 m	9 m

Note:

P = Passenger car, including light delivery trucks
SU-30 [SU-9] = Single unit truck, overall wheelbase of 30 ft [9 m]
WB-40 [WB-12] = Semitrailer truck, overall wheelbase of 40 ft [12 m]
WB-62 [WB-19] = Semitrailer truck, overall wheelbase of 62 ft [19 m]
WB-67 [WB-20] = Semitrailer truck, overall wheelbase of 67 ft [20 m]

9.3.14.4 Intersection Alignment

Refer to guidance in *Green Book* Section 9.4 on intersection alignment. Specific considerations that should be addressed in the intersection design are discussed in the following sections.

9.3.14.4.1 Horizontal Alignment and Skew

Design Intersection angles between 75 degrees and 105 degrees, and desirably as near 90 degrees as practical, to facilitate traffic control, good visibility, and safe operation by drivers and pedestrians. When the desirable alignment is not attainable for an intersection, suitable curves introduced into the horizontal alignment of the less important road will reduce the angle of the intersection. The horizontal alignment approaching a stop sign may be designed to a lower speed, consistent with the deceleration, comfortable rate, shown in *Green Book* Figure 2-25. Any adjustment must provide the minimum stopping sight distance, and preferably decision sight distance, for the intersection approach at the normal design speed. *Green Book* Figure 9-14 shows some examples of intersection horizontal realignments.

For highways with a maximum superelevation rate greater than 6 percent, the horizontal curvature of the main road through intersections should be designed such that the superelevation rate is 6 percent or less. For highways in areas where snow and ice routinely accumulate in winter, and with a maximum superelevation rate greater than 4 percent, the horizontal curvature of the main road through intersections should be designed such that the superelevation rate is 4 percent or less.

9.3.14.4.2 Lane Shifts

Avoid lane shifts through intersections. When lane shifts are unavoidable, provide a smooth alignment consisting of horizontal curves and interconnecting tangent meeting the design speed of the approach. Because pavement markings are often not placed through the intersection, the shifting of traffic can be confusing to the driver. Pavement markings through the intersection may be needed to ensure the following vehicles have a clearly delineated path to follow.

9.3.14.4.3 Vertical Alignment

Provide intersection approach alignment grades as flat as possible. Provide a flatter area for the minor road approach grade where vehicles are stopped.

When the gradient of an intersecting approach roadway exceeds the cross slope of the through pavement, it is desirable to adjust the vertical alignment of the approach using suitable grades and vertical curves. The vertical alignment approaching a stop sign may be designed for a lower speed, consistent with a braking deceleration rate of 11.2 ft/s^2 [3.4 m/s^2]. Any adjustment must provide the minimum stopping sight distance, and preferably decision sight distance, for the intersection approach at the normal design speed.

In areas of ice or snow conditions, it is desirable that the grade and cross slope be less than 3 percent through the intersection, and the grade and cross slope should not exceed 5 percent. Provide a minimum grade of ½ percent (1 percent desired) for drainage at the intersection.

Where the cross slope of the main road is in the same direction as the gradient of the intersecting cross road, adjust the vertical alignment of the cross road to meet the pavement cross slope of the highway.

If possible, avoid or realign intersections where the cross slope of the superelevated main road is not in the same direction as the grade of the intersecting cross road. If this is unavoidable, adjust the vertical alignment of the cross road far enough from the intersection to provide a smooth junction and proper drainage. Provide a vertical alignment that enables the mainline and approach road traffic to view the entire layout of the intersection sufficiently in advance, and provides adequate decision sight distance for the approach to the intersection.

9.3.14.4.4 Intersection Lane Widths

Lane widths may need to be increased at intersections to enhance safety and operations. Refer to Exhibit 9.3-N for recommended minimum lane widths at intersections.

Exhibit 9.3-N MINIMUM RECOMMENDED INTERSECTION LANE WIDTHS

Roadway Functional Classification	Through Lanes		Turn Lanes		Bicycle Lane	
	(ft)	(m)	(ft)	(m)	(ft)	(m)
Arterial (Rural)	12	3.6	12	3.6	5	1.5
Arterial (Urban)	12	3.6	12	3.6	4	1.2
Collector (Rural)	12	3.6	11	3.3	5	1.5
Collector (Urban)	11	3.3	11	3.3	4	1.2
Local (Rural)	10	3.0	10	3.0	5	1.5
Local (Urban)	10	3.0	10	3.0	4	1.2

9.3.14.4.5 Intersection Cross Slopes

Refer to Section 9.3.14.3 for guidance to design the intersection approach vertical alignment, as applicable for situations described below.

When both the mainline and the approach roadways are at normal crown (or the approach roadway does not require superelevation) the intersection cross slopes should be treated as follows:

- If the approach is a stop condition, or is a signalized crossing with a design speed less than 45 mph [70 km/h] through the intersection, maintain the normal crown on the mainline roadway. Transition the approach edge of travel lanes to match the longitudinal gradient of the mainline roadway, not exceeding the maximum relative gradient for the design speed of the approach roadway.
- If the approach is a signalized crossing with a design speed of 50 mph [80 km/h] or greater through the intersection, transition the mainline cross slope to a plane section through the intersection. The mainline may be designed with a cross slope between zero and 2 percent to best accommodate the approach crossing grade. Maintain a minimum mainline longitudinal gradient of 0.5 percent and preferably 1 percent. Transition the edge of travel lanes on all approaches to match the intersection plane, not

exceeding the maximum relative gradient for the design speeds of the mainline and approach roadways, respectively.

When the mainline roadway is superelevated and the approach is either normal crown or does not require superelevation, maintain the design superelevation rate of the mainline. Transition the edge of travel lanes of the approach to match the longitudinal grade of the mainline roadway and not exceed the maximum relative gradient for the design speed of the approach roadway.

When both the mainline and approach roadways require superelevation, adjust the horizontal and vertical alignments of either the mainline or the approach, or both, such that the cross slope of the approach can match the longitudinal grade of the mainline roadway, and can also meet allowable superelevation or side friction design criteria. In extreme cases, a broken back curve may be needed.

9.3.14.4.6 Turning Roadways at Intersections

Turning roadways include separated turn lanes, connections for channelized intersections, and ramps. As applicable, determine the appropriate design speed, radii, width, superelevation, and stopping sight distance for turning roadways based on the design vehicle, and consideration for accommodating a larger oversize vehicle with encroachment. Refer to the following sections of the *Green Book*:

- Section 3.3.7 for guidance on selection of design speed for the turning roadway and use of compound curves,
- Section 3.3.11 for the design widths of turning roadways,
- Section 9.6.6 for superelevation guidelines, and
- Section 9.6.7 for stopping sight distance.

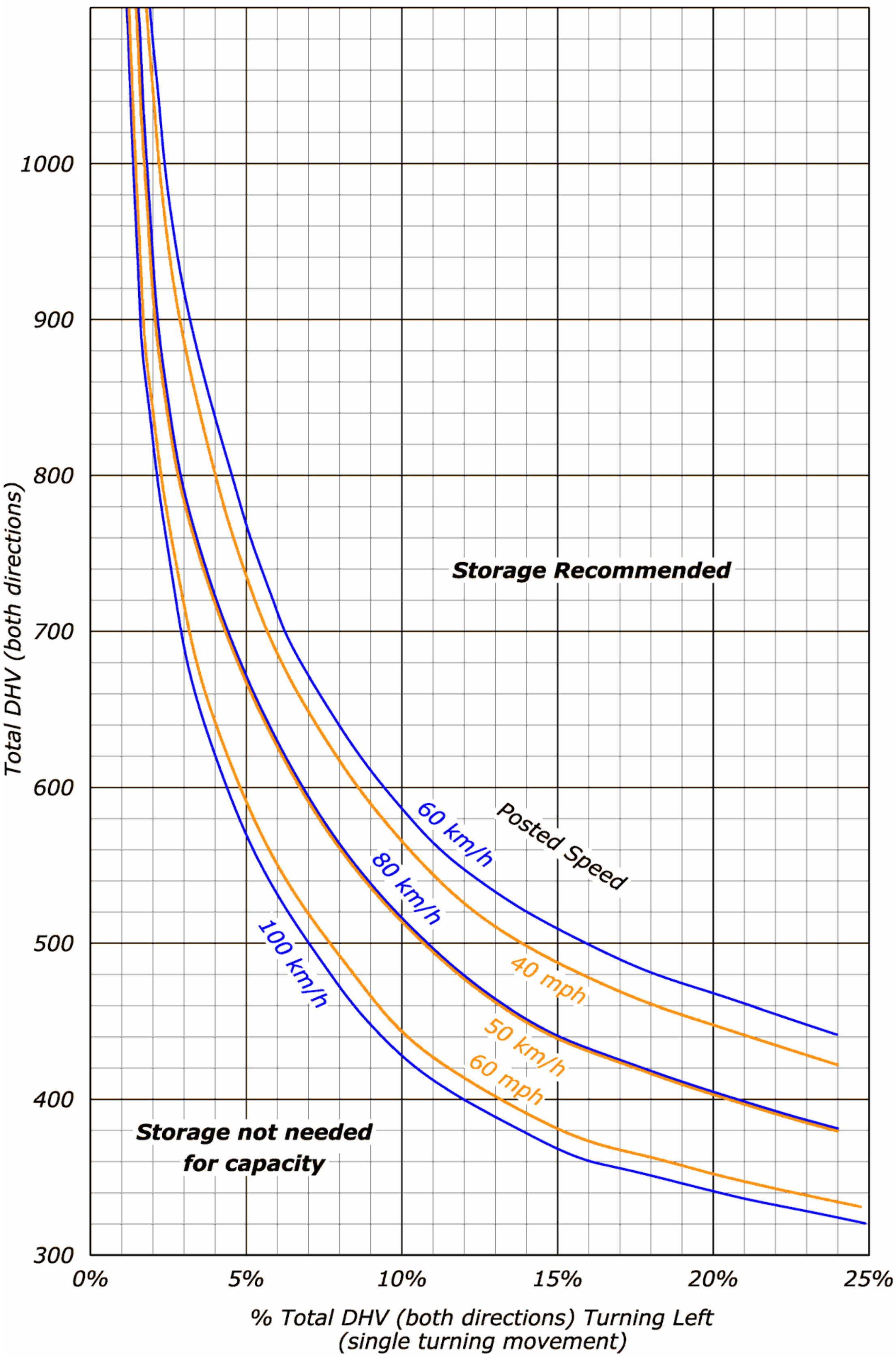
Determine the operational classification as one of 3 cases (I, II, or III), and determine the design traffic condition as one of 3 conditions (A, B, or C), as described in the *Green Book* to allow for passing a stalled vehicle on the turning roadway. The recommended design pavement widths of turning roadways for typical conditions of mixed traffic and various radii are provided in *Green Book* Table 3-29. Determine the width of the shoulders or equivalent lateral clearance outside the traveled way using *Green Book* Table 3-30.

9.3.14.5 Left-Turn Lanes

Left-turn lanes should be used for the major road approaches of 3-leg or 4-leg intersections where significant turning volumes exist or to reduce crashes related to left-turning vehicles.

Determine the volumes of left-turning and opposing vehicles for the major approaches, which are critical factors in the evaluation of intersection capacity, delays, queuing and traffic signal timing. Design left-turn channelization with enough operational flexibility to function under peak loads and adverse conditions. Also see Section 9.3.9.4.

Exhibit 9.3-O LEFT-TURN STORAGE GUIDELINES FOR UNSIGNALIZED TWO-LANE HIGHWAY INTERSECTIONS



At unsignalized intersections on two-lane highways, use Exhibit 9.3-O for guidance on the need for left-turn lanes. Criteria for left-turn lanes are also provided in *Green Book* Table 9-23, Section 9.3, Section 9.7, and the "Speed-Change Lanes" portion of Section 10.9.6. Also refer to NCHRP Report 279, *Intersection Channelization Design Guide* (1985), and the left-turn lane guidance in the *Highway Capacity Manual*.

Consider the need for additional decision sight distance approaching the intersection, in advance of left turn maneuvers, and where possible avoid beginning design of left turn lanes on crest vertical curves or horizontal curves where sight distance is limited. Also consider that left-turning vehicles may not slow to a stop (*Green Book* Case F), and may decide to begin turning in advance of the intersection coupled with the need for additional decision sight distance to judge the presence or gap of opposing traffic from a location significantly in advance of the intersection.

Consider a left-turn acceleration lane when operating speeds are 50 mph [80 km/h] or greater and daily peak hourly traffic volume, i.e. vehicles per hour (vph) of the through lane in the direction of travel exceeds 120, turning vehicles from the approach frequently cause conflict with the through traffic, or when the turning volume from the approach exceeds 100 vph.

At unsignalized intersections, the storage length must accommodate the number of turning vehicles expected to arrive in an average 2-minute period within the peak hour. The minimum storage length should be 100 ft [30 m], or longer if necessary to store at least one car and one truck representing the design vehicle if there are over 10 percent trucks. Provide a 6 ft [1.8 m] space between queued vehicles. At signalized intersections, the left-turn storage length is dependent on capacity and level-of-service criteria found in the *Highway Capacity Manual*. For signalized intersections a capacity analysis should be performed to determine the storage requirements. Specialized software such as Vissim or Synchro or Sim Traffic should be used for such capacity analyses. Exhibit 9.3-P provides additional left-turn storage for trucks to accommodate a left-turn lane. For left turn volumes over 300 vph consider double left-turn lanes. See *Green Book* Section 9.7 for additional design guides and for left-turn treatments on multilane facilities.

FLH standard practice is to determine the minimum length of acceleration and deceleration lanes based on the AASHTO *Green Book* guidelines for acceleration and deceleration lanes and transition tapers, including grade adjustment factor, plus queuing. Refer to the "Deceleration Length" discussion in *Green Book* Section 9.7.2; and Tables 10-3 to 10-5. The deceleration or acceleration is typically for a stop condition from or to the highway design speed.

FLH standard practice is to design the taper length based on the AASHTO *Green Book* guidelines, and the following:

- In urban areas, a 10 mph [16 km/h] deceleration is permissible in the through lane before entering the taper, and
- In rural areas, all deceleration should be accommodated within the taper and deceleration lane.

Exhibit 9.3-P ADDITIONAL LEFT-TURN STORAGE FOR TRUCKS AT UNSIGNALIZED TWO-LANE HIGHWAY INTERSECTIONS

Standard Storage Length	Trucks in Left-Turn Movement				
	10%	20%	30%	40%	50%
	Additional storage length to be added to standard values of left-turn lengths.				
US Customary					
100 ft	25 ft	25 ft	50 ft	50 ft	50 ft
150 ft	25 ft	50 ft	50 ft	75 ft	75 ft
200 ft	25 ft	50 ft	75 ft	100 ft	100 ft
Metric					
30 m	7.5 m	7.5 m	15 m	15 m	15 m
45 m	7.5 m	15 m	15 m	22.5 m	22.5 m
60 m	7.5 m	15 m	22.5 m	30 m	30 m

Refer to *Green Book* Figure 9-49 for recommended taper design for auxiliary lanes; however, the following also applies:

- Do not use the straight line taper and instead use either a partial tangent taper or reverse curve taper design,
- A 15:1 approach taper rate should be used in rural areas with design speeds above 30 mph [50 km/h],
- A 100 ft [30 m] minimum approach taper length is applicable for urban areas, and
- Provide a 25:1 departure taper at the end of acceleration lanes.

9.3.14.6 Right-turn Lanes

Right-turn lanes should be considered for the major approaches of intersections where significant turning movements exist, or to reduce crashes involving right turns. Also see Section 9.3.9.4. Consider the following factors for right-turn lane design, and right-turn lane applicability to a particular location:

- Speeds,
- Traffic and pedestrian volumes,
- Design vehicle,
- Percentage of trucks,
- Type of highway,
- Volumes and capacity, and

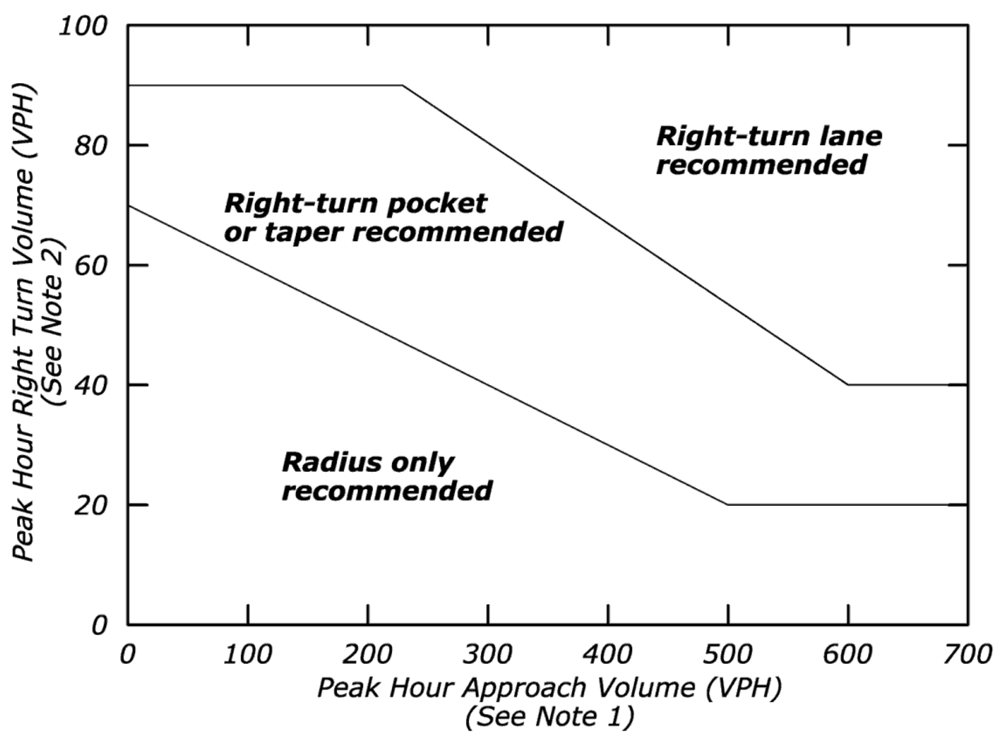
- Arrangement and frequency of intersections.

Right-turn movements at intersections influence intersection capacity, although not usually to the same extent as left-turning movements. Conflicts between the opposing traffic and the right-turning vehicle are usually not a factor. Pedestrian movements, especially those in the crosswalk of the leg into which the turn is being made, affect right-turning vehicles.

Consider right-turn lanes at unsignalized intersections when:

- Approach and right-turn traffic volumes are high (see Exhibit 9.3-Q),
- Presence of pedestrians requires right-turning vehicles to stop in the through lanes,
- Restrictive geometrics require right-turning vehicles to slow considerably below the speed of the through traffic,
- The decision sight distance is below minimum at the approach to the intersection, and
- Crashes involving right-turning vehicles are high.

Exhibit 9.3-Q RIGHT-TURN LANE GUIDELINES



Notes:

1. For two-lane highways use the total peak hour approach volume. For multi-lane, high Speed (posted at 45 mph [70 km/h] or above) highways use the total peak hour approach volume per lane.
2. Reduce peak hour right-turn volume by 20 VPH when all three of the following conditions are met:
   - Posted speed ≤ 45 mph [70 km/h],
   - Right-turn volume > 40 VPH, and
   - *Total* approach volume < 300 VPH.

Consider a right-turn acceleration lane at unsignalized intersections when operating speeds are 50 mph [80 km/h] or greater, and daily peak hourly traffic of the through lane in the direction of travel exceeds 120 vph, right-turning vehicles from the approach frequently cause conflict with the through traffic, or the right-turning volume from the approach exceeds 50 vph.

At signalized intersections, perform a capacity analysis using the *Highway Capacity Manual* or specialized traffic software to determine if right-turn lanes are necessary to maintain the desired level-of-service.

For the design of right-turn lanes refer to *Green Book* Section 9.6.4 and Figure 9-42. Also refer to the right-turn guidance in NCHRP Synthesis 299, *Recent Geometric Design Research for Improved Safety and Operations*.

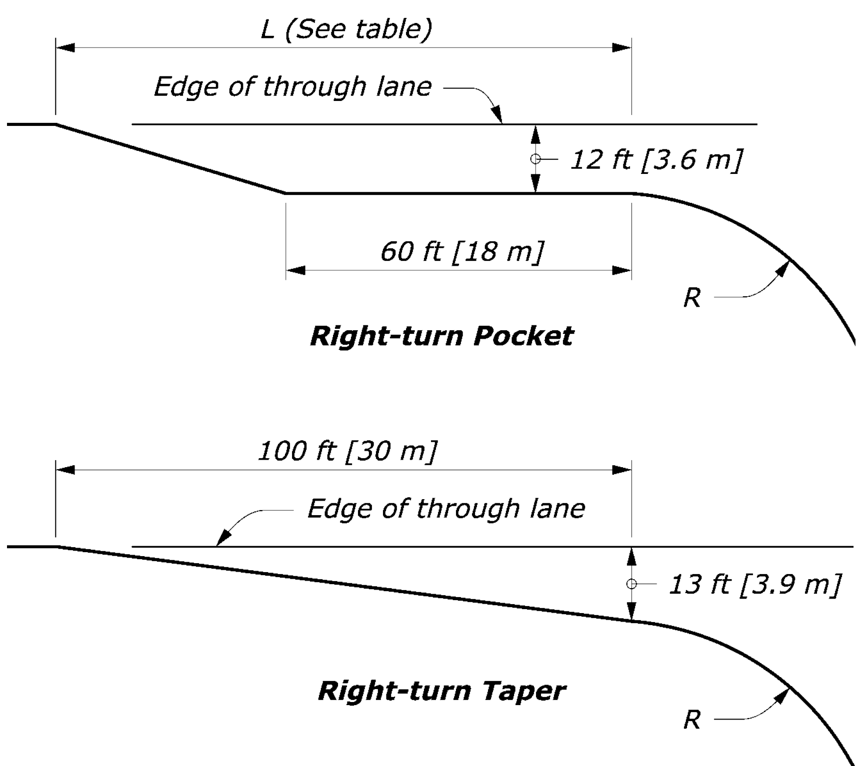
Design right-turn lanes to provide space for the deceleration, storage of turning vehicles and turning maneuvers to occur outside of the normal flow of highway traffic. Design of right-turn lanes includes the taper and deceleration area.

Right-turn corner designs should allow the design vehicle to turn without encroaching on adjacent lanes, curbs, shoulder edges or opposing traffic lanes. Also consider the largest size vehicle that may periodically use the roadway, with allowable encroachments.

Exhibit 9.3-R shows typical design details for a right-turn pocket and a right-turn taper. At signalized intersections, some encroachment on adjacent lanes of the approach leg is usually acceptable to obtain an adequate radius for oversize vehicles.

Exhibit 9.3-R RIGHT-TURN POCKET OR TAPER

Posted speed limit	*L*
Below 35 mph	***100 ft***
Below 60 km/h	***30 m***
35 mph or above	***175 ft***
60 km/h or above	***50 m***



Note: See Exhibit 9.3-M for right-turn "R" values.

See the subsections on “Minimum Edge-of-Traveled-Way Designs” and “Design for Specific Conditions (Right-Angle Turns)” in *Green Book* Section 9.6.1 for guidance on use of compound curves and other guidelines for corner radius returns.

Consider that the corner radius also affects the pedestrian crossing time and provision of islands. FLH standard practice for design of corner radius includes the following:

- For passenger cars provide a corner radius of from 15 ft [4.5 m] minimum to 25 ft [7.5 m] desired,
- For SU-30 [SU-9] truck or motor home provide a corner radius of from 25 ft [7.5 m] minimum to 40 ft [12 m] desired, and
- For WB-40 [WB-12] truck or bus provide a corner radius of from 40 ft [12 m] minimum to 50 ft [15 m] desired, if minor encroachment is allowable. If no encroachment is allowable outside a single approach and departure lane, a corner radius of 80 ft [24 m] may be needed for a WB-40 [WB-12] truck design vehicle. In this situation, a 3-radius corner or a turning lane with a corner island may be preferable.

Refer to Section 9.3.14.9 for design of corner islands.

FLH standard practice is to base the minimum length of right-turn acceleration and deceleration lanes based on AASHTO *Green Book* guidelines for acceleration and deceleration lanes and the transition tapers, including grade adjustment factor, plus any storage length for queuing if applicable (e.g., for pedestrian movements at signalized intersections). The following also applies:

- In urban areas, a 10 mph [16 km/h] deceleration rate is permissible in the through lane before entering the taper.
- In rural areas, all deceleration rates should be accommodated within the taper and deceleration lane.

Refer to the “Deceleration Length” discussion in *Green Book* Section 9.7.2; and Tables 10-3, 10-4 and 10-5. The deceleration or acceleration is typically for a stop condition from or to the highway design speed.

FLH standard practice is to design the taper length based on AASHTO *Green Book* guidelines. Refer to *Green Book* Figure 9-49 for recommended taper design for auxiliary lanes; however, the following also applies:

- Do not use the straight line taper and instead use either a partial tangent taper or reverse curve taper design,
- A 15:1 approach taper rate should be used in rural areas with design speeds above 30 mph [50 km/h],
- A 100 ft [30 m] minimum approach taper length is applicable for urban areas, and
- Provide a 25:1 minimum departure taper at the end of acceleration lanes.

Storage for turning traffic is advantageous and provides improved intersection capacity and safety performance. Storage length calculations should consider the queue from the adjacent through-movement might affect entry to the right-turn lane. If right-turn lanes are necessary at a signalized intersection, the storage requirements should be determined by a capacity analysis. Specialized software such as Vissim or Synchro or Sim Traffic should be used to perform such signalized intersection capacity analyses.

9.3.14.7 Bypass Lanes

Bypass lanes may be used on rural two-lane highways to accommodate occasional left-turning vehicles at unsignalized Tee intersections, if needed to address speed differential or improve safety. Where frequent queuing of left-turning vehicles may be expected, a dedicated left-turn lane may be necessary instead of a bypass lane, to address capacity. Use of a bypass lane may be justified, in lieu of a left-turn lane, to reduce crashes or improve traffic operations. Consider a bypass lane where:

- The sight distance in advance of the intersection is less than the decision sight distance for avoidance maneuver B shown in *Green Book* Table 3-3,
- Opposing traffic volume often cause a delay for the left-turn movement, or
- A crash history is identified at the location that may be alleviated by separating left-turning traffic from through traffic.

A bypass lane should only be designed if a left-turn deceleration and storage lane is not practical. A bypass lane should not be a substitute for a conventional left-turn lane as part of a reconstruction or major redesign project where right-of-way is available and construction is feasible. Provide the same shoulder as the rest of the roadway for the bypass lane.

The length recommended for bypass lanes varies with the posted speed of the highway. Refer to Exhibit 9.3-S for recommended lengths of bypass lanes.

Exhibit 9.3-S RECOMMENDED MINIMUM LENGTHS FOR BYPASS LANES

(US Customary)					
Posted Speed (mph)	Approach Taper (ft)	Approach Lane (ft)	Departure Lane (ft)	Departure Taper (ft)	Total Bypass Length (ft)
30	180	180	180	180	720
35	245	210	190	245	900
40	320	240	200	320	1080
45	540	270	210	540	1570
50	600	300	220	600	1740
55	660	330	230	660	1910
60	720	360	240	720	2080

(Metric)					
Posted Speed (km/h)	Approach Taper (m)	Approach Lane (m)	Departure Lane (m)	Departure Taper (m)	Total Bypass Length (m)
50	58	55	55	58	226
60	84	70	60	84	298
70	157	82	64	157	460
80	179	90	67	179	515
90	201	101	70	201	573
100	224	110	73	224	631

Note: Taper lengths are based on the MUTCD taper design for lane reduction, Section 3B.09 for 12 ft [3.6 m] lane. For narrower lane widths, reduce taper length proportionately.

9.3.14.8 Channelization

When applicable, provide channelization to separate traffic into definite paths of travel using combinations of pavement markings, markers, rumble strips, contrasting pavement, or raised islands, to facilitate the safe and orderly movement of vehicles, bicycles and pedestrians.

It is FLH standard practice to use curbing for channelization only on urban and suburban highways with a design speed of 45 mph [70 km/h] or less. On these types of highways, drivers expect to encounter confined facilities and raised channelization is applicable.

Preferably, use pavement markings consisting of painted stripes reflectorized with glass beads to delineate travel paths. Raised Pavement Markers (RPM), reflectorized and non-reflectorized, may supplement pavement striping when increased visibility is desirable. RPM may replace painted stripes when climatic or traffic conditions warrant as described in Section 8.7.1.3.

The use of curbing or raised islands for channelizing traffic should be kept to a practical minimum, as they can present problems, especially for winter maintenance. Curbing for channelization is undesirable at any location where painted pavement markings with or without reflective lane markers attain the same objective.

Curbing is permissible for channelization under the following conditions:

- Low design speed,
- Prevention of mid-block left-turns,
- Raised divisional and directional islands,
- Raised islands with luminaries, signals or other traffic control devices,
- Pedestrian refuge islands, and
- Landscaped areas within the roadway.

The two general classifications of curbing for channelization are sloping curbs and vertical curbs of the types shown in *Green Book* Figure 4-5. Use sloping curbing for channelization when vehicles may occasionally mount the curb (e.g., inscribed radius of roundabouts). Use vertical curb for raised islands with traffic control devices or luminaries and for pedestrian refuge.

9.3.14.9 Islands

An island is a defined area between traffic lanes for channelization. The use of raised islands should be limited to those urban and suburban highways with a design speed of 45 mph [70 km/h] or less. Provide the minimum curb offsets to raised islands as described in Section 9.3.11.3 and *Green Book* Figures 9-38 and 9-39. Provide the required lateral clearance and offset distance within raised islands, and where possible, provide the recommended clear zone. See Sections 9.3.12.2 and 9.3.12.3.

Consider islands when needed to perform the following functions:

- Control and direct traffic movement,
- Separate opposing or same direction traffic streams,
- Provide refuge for pedestrians, and
- Provide for proper placement of traffic control devices.

Traffic separation islands are normally elongated and should be at least 4 ft [1.2 m] wide and 20 ft to 25 ft [6 m to 8 m] long. For pedestrian refuge islands with crosswalks provide a minimum width of 6 ft [1.8 m], and preferably 8 ft [2.4 m], to accommodate pedestrians (including ADA requirements such as detectable warnings and landing) and bicyclists. When practical, the beginning of raised median islands should be offset 4 ft to 8 ft [1.2 m to 2.4 m] from the travel lane and transitioned to a normal curb offset, typically 2 ft [0.6 m] desired. See *Green Book* Figure 9-41.

Corner islands may be used to reduce conflicts and to delineate turning path where large (50 ft [15 m] or more) radii or oblique intersections lead to large areas of pavement. Corner islands are typically triangular with one side curved concentric with the corner radius and the noses rounded and offset from the travel lanes. In rural areas, they should contain an area of at least 75 square feet [7 m^2] with 100 square feet [9 m^2] as a desirable minimum. In urban areas where speeds are low, raised islands should be a minimum size of 50 square feet [5 m^2], with 100 square feet [9 m^2] as a desirable minimum. Raised islands with traffic control devices or luminaries, and islands crossed by pedestrians, require 200 square feet [18 m^2] as a minimum area.

Design triangular shaped islands as shown in *Green Book* Figures 9-38 and 9-39 for urban or rural locations, respectively. For painted islands in rural areas, the offset distances from the through lane are not required if the lane width is 12 ft [3.6 m]. Where a curbed corner island is proposed on a roadway with shoulders, the face of curb on the corner island should be offset by an amount equal to the shoulder width. If the corner island is preceded by a right-turn deceleration lane, the shoulder offset should be at least 8 ft [2.4 m].

Corner islands should accommodate turning roadway widths of 14 ft [4.3 m] minimum and allow turning vehicles to keep their wheel tracks within the traveled way by approximately 2 ft [0.6 m] on both sides. If large trucks are used as design vehicles this may result in wide lanes that could encourage the driver to use the facility as if it had two lanes. Paint or other flush markings can delineate the desired path and discourage this behavior. Refer to *Green Book* Section 9.6.5, Figure 9-43 and Table 9-18.

The offset from the edge of through travel lanes must be no less than the shoulder, and should be offset from the normal roadway edge, especially if no gutter pan is used. Refer to Exhibit 9.3-L for the minimum offset distances recommended for vertical curbs. For sloping curbing installations, the left offset distance is optional. Avoid roadway offset distances wider than 5 ft [1.5 m] as this gives the appearance of an added lane. Retro-reflective (preferably), or reflective, raised pavement markers may supplement island pavement markings.

Raised islands at crosswalk locations require barrier-free access for the disabled, including curb ramps, detectable warnings, and maneuver or refuge platforms. Pedestrian refuge platforms in islands or raised medians should be elevated a minimum of 2 in [50 mm] above the pavement surface. See Section 9.3.16.3.

Design approach ends of islands to provide adequate visibility and advance warning of their presence. A sloping curb should typically be used on the approach nose to minimize damage to errant vehicles or to snowplows. Also see *Green Book* Figure 9-40 for nose ramping. Islands should not cause a sudden change in vehicle direction or speed. Transverse lane shifts should begin far enough in advance of the intersection to allow gradual transitions. Avoid introducing islands on a horizontal or vertical curve. When islands on curves are unavoidable provide adequate sight distance, and illumination, or extension of the island, or both. Consider using a flexible raised delineator, or a rumble strip, or both.

Avoid using islands to channelize mid-block access “right-in, right-out” turning movements, unless a physically closed, depressed or raised median is used for the main roadway.

See *Green Book* Section 9.6.3 for additional design criteria for islands and Part III of the *MUTCD* for markings for the islands.

9.3.14.10 Pedestrian, Bicyclist and Transit Considerations at Intersections

Pedestrian crossing distances should be minimized at intersections. Crossing locations should correspond to the placement of sidewalks along approaching streets, and likely crossing locations. Balance intersection widening for vehicle turning lanes and clearances at the curb returns against the need to keep the pedestrian crossing distances to a minimum. In urban areas with parking lanes and curbs, consider ending the parking lane ahead of the intersection and adjusting the curb returns to be just offset to the travel lane or bike lane. These intersection curb “bulb-outs” have the effect of narrowing the overall roadway, slowing traffic and reducing the distance of the pedestrian crossing. Pedestrian facilities must meet the requirements of the disabled. Pedestrian facilities include curb ramps and sidewalks, adequate longitudinal slopes and cross slopes, and detectable warnings. New signal installations at intersections with pedestrian facilities must include accessible pedestrian signals, with well-placed locations of pushbutton activation controls. For design of intersections use a maximum walk speed of 3.0 ft [0.9 m] per second over the entire length of crosswalk plus the length of one pedestrian curb cut ramp. See Section 9.3.16.3 for additional information.

Consider how bicyclists will negotiate intersections. Approach roadways may include provision for bicyclists, including: separate off-highway multi-use paths, designated (striped with special markings) bicycle lanes or undesignated (striped without special markings) bicycle lanes. These will need to be accommodated through the intersection. Bicyclists may position themselves for their intended destination regardless of the presence of bike lanes or shoulders. If bicycle lanes are not provided, the bicyclist may use either the shoulder or the traffic lane. If bicycle lanes are present, provide that bicyclists can merge to the proper location for any travel direction. Consider the needs of the bicyclist as well as the interaction of bicycle traffic with the motorized vehicle users.

Transit stops are typically located at intersections, particularly where transit routes cross. The design vehicle for most types of transit service is the AASHTO City-Bus, which is 40 ft [12 m] length. Transit stops may be located at intersections either as a near-side stop on the approach to the intersection, or as a far-side stop on the departure leg. For a near-side intersection bus stop provide a minimum length of 70 ft [21 m] and preferably 100 ft [30 m] space. For far-side intersection bus stop, provide a minimum length of 50 ft [15 m] and preferably 70 ft [21 m] space. Consider providing bus turnouts based on the volume and turning movements of both the bus and through traffic, the distance between bus stops, and right-of-way limitations.

9.3.14.11 Signalization

Refer to Section 8.7.2 for information on warrants and design for signalization. For highway design purposes, consider the following options to the installation of signalization at intersections:

- Improve the sight distance of the mainline, or approaches, or both;
- Revise the geometry at the intersection to channelize vehicular movements and reduce the time required for a vehicle to complete a movement;
- Add lanes on the minor approach to reduce the number of vehicles queued for each movement;
- Relocation of the stop line(s) to reduce crossing maneuver time;
- Install advance warning signs of the intersection on the mainline;
- Install advisory or regulatory speed limit signing to encourage lower speeds on the approaches;
- Install a flashing warning beacon;
- Install roadway lighting for nighttime operations;
- Restrict one or more turning movements if alternate routes are available, or possibly on a time-of-day basis;
- Install multi-way STOP sign control if the warrant is satisfied; and
- Construct a modern roundabout.

9.3.15 RAILROAD-HIGHWAY GRADE CROSSINGS

Refer to the *FHWA Railroad-Highway Grade Crossing Handbook*, FHWA-SA-07-010. Also, refer to *Green Book* Section 9.12 for guidance on the design of railroad crossings. Refer to Section 12.4 for agreements and right-of-way considerations and requirements in design of railroad crossings. Refer to Section 8.7.4 for traffic control and protection at railroad-highway grade crossings. Coordinate with the Division Traffic Safety specialist and the railroad company for design of all railroad-highway grade crossings. Even if no improvements are made to the railroad crossing, coordination is needed early with the railroad company in regard to temporary traffic control that may affect the railroad. Include the special considerations and coordination in the Temporary Traffic Control Plan and in the Special Contract Requirements.

Sight distance is of primary consideration at grade crossings. If possible, avoid designing a grade crossing on a horizontal curve of either the highway or the track. The condition at a railroad grade crossing is comparable to that of intersecting highways where a corner sight triangle must be kept clear of obstructions. Where feasible remove obstructions that reduce the desired sight distance. The corner sight distance should allow a driver approaching the grade crossing to see an approaching train at such a distance to either allow the vehicle to cross prior to the train's arrival, or to comfortably stop in advance of the crossing. For either case, establish both the vehicle and train speeds to determine the necessary corner sight distance. Stopped vehicles require additional sight distance to safely proceed across a crossing. This is measured along the track and is determined by establishing both the train's approach speed and the time required for the motor vehicle to accelerate and clear the crossing as shown in *Green Book* Table 9-32. The ITE *Traffic Control Devices Handbook* (2001), Chapter 11 "Highway-Rail Grade Crossings" also contains discussion of sight distance requirements for at-grade crossings.

When any of the sight distances are insufficient at a crossing, either:

- Increase available sight distances (corner, stopping, or clearing) by clearing obstructions or modification of the horizontal alignment of the crossing;
- Establish a posted approach speed for the highway that provides sufficient time for the sight distance; or
- Provide applicable crossing protection such as automatic flashing light signals, either with or without gates.

Consider the need for providing an additional stopping lane for vehicles that are required to stop at the crossing, particularly if the crossing is a high-speed, multi-lane highway. If provided, the stopping lane geometry should meet the following minimum guidance:

- The approach taper to the stopping lane should be at least 165 ft [50 m] long and the width may vary from zero to 12 ft [3.6 m];
- The length of the full width stopping lane should be at least 100 ft [30 m] in advance of the centerline of the first set of tracks to 85 ft [25 m] beyond the last set of tracks;
- The acceleration taper should be at least 200 ft [60 m] long and the width may vary from 12 ft [3.6 m] (full width) to zero; and

- The shoulder along the stopping lane should be a minimum width of 3 ft [0.9 m].

The decision to add stopping lanes is made on a project-by-project basis after review of the site and after determining legal requirements under the applicable State regulatory authority.

Establish the grade and cross slope of the roadway to match the grade along and across the track rails, corresponding to the alignment, gradient and superelevation of the railroad. Provide an approach section with vertical alignment having a maximum deviation of 3 in [75 mm] at a distance of 30 ft [9 m] from the rails as shown in *Green Book* Figure 9-75. For vertical alignments with minimum K values greater than 15 [5], a lesser deviation may be necessary.

Provide a smooth, high-friction surface as an important part of the railroad-highway grade crossing that contributes to the safety of crossing vehicles. Typical types of crossing surfaces for railroad/highway grade crossings include:

- Asphalt concrete,
- Concrete,
- Steel,
- Timber,
- Rubber (elastomeric) panels,
- Linear high density polyethylene modules, and
- Epoxy-rubber mix cast-in-place.

Provide adequate drainage to channel runoff and subsurface water away from the crossing, including adjusting the vertical grades of the roadway, special ditch grades, underdrains, controlling pavement drainage, curb and gutter, inlets or a storm drain system.

For crossings with gates, consider providing at least 100 ft [30 m] of vertical face curb in each direction, extending to 12 ft [3.6 m] from the track centerline, to discourage traffic from passing around the gates.

Consider that the railroad crossing protection devices may be a fixed object hazard that warrants the use of a traffic barrier or a crash cushion. Design all traffic barriers or crash cushions to be installed outside the minimum railroad clearance as shown in the *MUTCD*.

Consider providing illumination of railroad crossings to improve visibility and supplement other traffic control devices for nighttime railroad operations. Consider lighting where train speeds are low, where crossings become blocked for long periods, or where crash history shows that motorists experience difficulty in seeing the crossing, trains or control devices at night.

As early in the preliminary design process as possible, provide highway design plans, profiles, cross-sections and structure clearance, if applicable, to the owner agency and request their review and comments. A request to begin preparation of the formal agreement can accompany this submittal. Check with the railroad company if any future tracks are proposed, to ensure that the project clears both existing and planned tracks.

Plan and profile on both the railroad and highway should show for a minimum of 500 ft [150 m] on both sides of the crossing. Extend the roadway profile as necessary to show all important vertical alignment data. Also, show other important features that may affect the design of traffic operation of the crossings. These features include proximity of crossroads or city street intersections, nearby driveways or entrances, highway structures, vehicular ADT (including percentage of trucks and number of school buses) and train ADT.

The railroad stationing and curve data, including beginning and ending of the curves through areas affected by encroachment or crossing, must be shown on the highway plans. Show on the plans all railroad and highway right-of-way lines and widths, including easements. Compute the ties at right angles from the highway centerline and show all intersecting corners of the right-of-way. Show the ties at the beginning and the end of each encroachment and at the points of maximum encroachment. Show all railroad drainage structures and other topographic data pertaining to railroad buildings, head blocks and other points of control.

If the railroad track is superelevated, the highway profile must conform closely to the grade across the top of the rails.

For a new crossing of the railroad tracks, prepare a special profile on either side of the crossing along the track centerline for several hundred feet [meters]. An adjustment in the railroad line (e.g., raising or lowering tracks to accommodate highway construction) is occasionally necessary. In this case, a special profile along the railroad alignment will show the full extent of the raising or lowering of tracks. Carry the profile a sufficient distance outside of the adjusted area to give a complete picture of the proposed adjustment.

On the highway design plans, show the basic roadway dimensions of shoulders, medians, traffic lanes, stopping lanes and acceleration lanes, including pavement markings requirements. Show the angle of crossing, number of tracks, location of signals and other railway facilities (e.g., signal power lines, signal control boxes, switch control boxes). The name of the railroad and whether the track is a mainline or branch line should be noted.

Include typical sections in the highway design railroad crossing plans to show roadway and lanes widths, stopping lanes if provided, shoulders, crossing surfacing, and other roadway details.

Provide profiles for any proposed special drainage or waterway channels affecting the railroad property.

The final PS&E package review should ensure that the contract contains all conditions listed in the approved railroad agreement.

9.3.16 PEDESTRIAN CONSIDERATIONS AND FACILITIES

The FHWA guidance entitled *Accommodating Bicycle and Pedestrian Travel* includes a DOT policy statement that walking facilities will be incorporated into all projects, unless exceptional circumstances exist. In rural areas, paved shoulders should be included in all new construction and reconstruction projects on roadways used by more than 1,000

vehicles per day. In urban areas, provide sidewalks or separated paved pathways in new construction and reconstruction projects unless:

- Pedestrians are prohibited by law from using the roadway,
- The cost exceeds 20 percent of the project, or
- There is well demonstrated absence of potential need.

Pedestrians include persons of all ages and abilities, and their actions are less predictable than motorists. Designers must be sensitive to this situation and keep their needs in mind in the design of pedestrian facilities. Pedestrian needs can conflict with the requirements for vehicular travel, particularly when crossing, but pedestrian facilities may provide safe and efficient solutions. Pedestrian facilities consist of adequate shoulders, sidewalks, crosswalks, pedestrian refuge areas, hiking or walking trails, shared use paths, and pedestrian grade separation structures. Sidewalks are generally located immediately adjacent to the highway or parking area. Walking and hiking trails are independently aligned and usually serve recreational activities (e.g., paths from parking areas to scenic overlooks). Refer to *Green Book* Section 2.6 and Section 4.17 for pedestrian considerations, as well as the *Guide for the Planning, Design and Operation of Pedestrian Facilities* (AASHTO, 2004). Pedestrian separation structures are not discussed here. *Green Book* Section 4.17.2 addresses pedestrian structures. Also see *How to Develop a Pedestrian Safety Action Plan*, FHWA-SA-05-12, and the Pedestrian and Bicycle Information Center.

9.3.16.1 Sidewalks

As applicable, provide paved sidewalks along the edges of roadways suitable for pedestrian use in areas where pedestrian activity is present, expected or desired. Consider sidewalks to increase the safety of pedestrians along the roadway, improve access, and reduce conflicts. Refer to *Green Book* Section 4.17.1 and the references described in Section 9.3.16 for additional guidance on the design of sidewalks.

All sidewalk designs must accommodate persons with disabilities, unless it is not technically feasible; see Section 9.3.16.3.

It is FLH standard practice to provide continuous sidewalks along both sides of urban area highways, particularly where there is a need for pedestrian access to schools, parks, commercial areas, transit stops and where there is frequent pedestrian activity. In suburban residential areas, provide a continuous sidewalk on at least one side of the highway and locate it close to the right-of-way line, if possible.

Sidewalks must have a minimum width of 4 ft [1.2 m]; however 5 ft [1.5 m] minimum width is preferred. Sidewalks in residential areas should have 5 ft [1.5 m] minimum width.

In lightly populated suburban areas and in rural areas, consider sidewalks at points of community development (e.g., schools, businesses, industrial plants, transit stops).

In urban and in major residential areas, sidewalks should be raised above the roadway. Sidewalks that are adjacent to the back of curb should be 6 ft [1.8 m] minimum width. To provide a planting strip between the sidewalk and curb allow a minimum of 2 ft [0.6 m], and additional width that may be needed to provide horizontal clearance to obstructions. For design of sidewalks adjacent curb parking, widen the sidewalk 2 ft [0.6 m] more than the minimum width elsewhere, to accommodate open doors of parked vehicles.

Sidewalks in areas of high pedestrian traffic (e.g., schools, businesses, industrial areas) should be wider than the minimum. In areas of very high pedestrian traffic (e.g. transit stops, entrances to schools or businesses) sidewalks should be paved to the curb in most cases.

Sidewalks on bridges should be 6 ft [1.8 m] minimum width, and 12 ft [3.6 m] if it is designed for shared use with bicycles.

Design of raised sidewalks should slope to drain toward the roadway at 1.5 to 2.0 percent. A slope of 1.5 percent is recommended for design, for accessibility and to allow a construction tolerance and lessen the potential for violating the ADAAG requirement of maximum cross slope of 2.0 percent.

In many cases where pedestrians may use the roadway shoulder for walkways, there are no special markings or signs for pedestrian use. In rural, low-speed areas of pedestrian use, an additional 4 ft [1.2 m] of paved shoulder width may satisfy the purposes of a sidewalk. A wider shoulder is desirable when there is significant truck traffic or higher traffic speeds. An 8 in [200 mm] solid white stripe should mark the edge of the traveled way at these locations.

Pedestrian crosswalks are regularly marked in urban areas. In residential and rural areas, marked crosswalks are normally not necessary except in locations of regular pedestrian use such as pedestrian routes to schools. In the vicinity of schools, convalescent centers, local parks or community centers, marked crosswalks should be considered. For multi-lane highways consider geometric features that improve the pedestrian environment, such as crossing islands or curb extensions. Align crosswalks with connecting curb ramps and sidewalks. For additional details on pedestrian crosswalks see the *MUTCD* and the ITE *Traffic Control Handbook*. Also refer to NCHRP Report 562, *Improving Pedestrian Safety at Unsignalized Crossings*.

9.3.16.2 Walking and Hiking Trails

These pedestrian facilities usually provide connections with existing trails, lead to roadside points of interest, allow access to streams or permit leisurely walks. They often have a natural surface, except in high-use locations. These locations may require paving to protect existing environmental conditions.

The design standards for shared use paths and trails are specific to the function of the path or trail:

- Shared use paths and pedestrian trails that function as sidewalks shall meet the same requirements as sidewalks. Where shared use paths and pedestrian trails cross highways or streets, the crossing also shall meet the same requirements as street crossings, including the provision of detectable warnings.

- Shared use paths and pedestrian trails that function as trails should meet the accessibility guidelines proposed in the Access Board's Regulatory Negotiation Committee on Accessibility for *Outdoor Developed Areas Final Report*. This report also has guidelines for Outdoor Recreation Access Routes (routes connecting accessible elements within a picnic area, camping area, or a designated trailhead).
- Recreational trails primarily designed and constructed for use by equestrians, mountain bicyclists, snowmobile users, or off-highway vehicle users, are exempt from accessibility requirements even though they have occasional pedestrian use.

Typically, trailside and trailhead structural facilities (parking areas, restrooms) must meet the ADAAG standards.

Prior to designing walking/hiking trails, verify with partner agency and owner that non-ADA compliant trails are acceptable. The following guides for walking and hiking trails apply when persons with disabilities do not require accommodations:

- The clear area around walking and hiking trails should encompass 8 ft [2.4 m] laterally and 10 ft [3.0 m] vertically. Any trees or brush removed from this area must be flush cut at ground level and intruding branches trimmed flush with the tree trunk.
- Walking trails should be a minimum of 4 ft [1.2 m] wide and have a maximum grade of 10 percent. The trail should have independent horizontal and vertical alignment. Always locate a trail outside the clear recovery zone or behind guardrail when it parallels the main roadway. If behind guardrail locate the trail beyond the guardrail deflection zone.
- Hiking trails should have a minimum surface width of 2 ft [0.6 m] and a maximum sustained grade of 10 percent. The grade may be up to 20 percent for short distances. A hiking trail constructed in a riprap slope, talus slide or other rock slope should have all voids filled at least 2 ft [600 mm] below the rock surface. Provide a 3 in [75 mm] cover of soil or small rock for a final surface.

For guidance on design of shared-use trails, refer to the *Evaluation of Safety, Design, and Operation of Shared-Use Paths,* FHWA-HRT-05-139, 2006.

9.3.16.3 Accommodation of the Disabled

Pedestrian access is required by the *Rehabilitation Act* - Section 504, 1973 and the *Americans with Disabilities Act* (ADA) – Title II, 1990. Where pedestrian access is provided it must also accommodate those with disabilities. This includes providing continuous unobstructed sidewalks, and curb cuts with detectable warnings at highway and street crossings. There are no exceptions to this policy, unless a solution is determined to be not technically feasible. Unit cost is typically not considered the primary factor in such feasibility determinations. For information on ADA refer to the U.S. Department of Justice *ADA Home Page*.

The *Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities (ADAAG)* contains most of the applicable standards. The *Revised Draft Guidelines for Accessible Public Rights-of-Way* (PROWAC) are recommended for use as current best practice for highway design; however these have not yet been officially adopted by the FHWA. When the guidelines for public rights-of-way are completed and adopted by the US DOT and DOJ as standards under the ADA and Section 504, they will supersede the currently used standards and criteria.

The *Green Book* contains information on sidewalk curb ramps in Section 4.17.3. Refer to the AASHTO *Guide for the Planning, Design and Operation of Pedestrian Facilities*, 2004, and the FHWA *Designing Sidewalks and Trails for Access, Part II: Best Practices Design Guide*, 2001. Also see the Access Board alterations guide *Special Report: Accessible Public Rights-of-Way Planning and Design for Alterations*.

All sidewalk curb transitions and ramps require installation of a tactile and visual device known as a detectable warning surface (truncated domes) to warn disabled persons that they are leaving the sidewalk and about to enter the roadway. Refer to the Access Board PROWAC Section R304 for guidance on design of detectable warning surfaces. FHWA guidance is also provided by the FHWA Memorandum, *ADAAG Detectable Warnings*, May 6, 2002, the FHWA Memorandum, *ADAAG and Detectable Warnings*, July 20, 2004; and the US DOT Final Rule, November 29, 2006, *Transportation for Individuals With Disabilities; Adoption of New Accessibility Standards*.

As with new construction, incorporate accessibility improvements to existing pedestrian facilities for any alterations that may affect access, circulation, or use by persons with disabilities; or changes that could affect the structure, grade, function, or use of the roadway. This includes reconstruction, rehabilitation, structural resurfacing (e.g. mill and overlay), widening, signal installation, pedestrian signal installation, and projects of similar scale and effect.

Design facilities to maintain existing pedestrian access during construction, including accommodation of those with disabilities. This includes provision for removal of snow, debris and surface disruptions, and maintenance of a safe, accessible and detectable pedestrian access route in work zones.

9.3.17 BICYCLE CONSIDERATIONS AND FACILITIES

The FHWA guidance entitled *Accommodating Bicycle and Pedestrian Travel* includes a DOT policy statement that bicycle facilities will be incorporated into all projects, unless exceptional circumstances exist. In rural areas, paved shoulders should be included in all new construction and reconstruction projects on roadways used by more than 1,000 vehicles per day. In urban areas, provide bicycle lanes or separated paved paths in new construction and reconstruction projects unless:

- Bicyclists are prohibited by law from using the roadway,
- The cost exceeds 20 percent of the project, or
- There is well demonstrated absence of potential need.

In rural areas, for design of a shared-use facility that both bicycle and motor vehicle travel are designed to share the roadway, a combined lane and shoulder width of at least 14 ft [4.2 m] should be provided, which is the minimum necessary for a motor vehicle and bicycle to operate side by side. In rural areas with motor vehicle design ADT greater than 1,000 and bicycle ADT greater than 25, a paved shoulder width of 5 ft [1.5 m] is recommended to accommodate bicycle use.

Where applicable, design bicycle lanes specifically for bicycle use, to provide a dedicated space for bicycle travel along the roadway, and a consistent separation between bicyclists and passing motorists, and pedestrians. Design striping and signing to designate bicycle lanes in accordance with the *MUTCD*.

Bicycle lanes that are not physically separated from the highway should be located between the travel lane and the roadway shoulder. A minimum width of 4 ft [1.2 m] is required for a bike lane; however 5 ft [1.5 m] bicycle lanes are preferred for most conditions, especially when the lane is adjacent to a curb, curbside parking, or guardrail. Exclude the width of gutter from the bicycle lane design width. Where parking is permitted, the combined width for bicycle travel and parking should be a minimum of 14 ft [4.2 m], and 16 ft [4.8 m] desired. Where motor vehicle operating speeds exceed 45 mph [70 km/h], or the volume of trucks and buses is 30 or more per hour, the minimum bicycle lane width is 5 ft [1.5 m], and 6 ft [1.8 m] bicycle lane width is desirable. Bicycle lanes wider than 6 ft [1.8 m] are generally not used since they may encourage inappropriate use by motor vehicles. Designate bicycle lanes with a 6 in [150 mm] solid white line on the right edge of the motor vehicle travel lane, bicycle lane pavement markings, and signs at periodic intervals. The solid lane marking should change to a broken white line before any intersections on the right side, providing sufficient distance for motorists to merge to the right side of the roadway before making a right-turn. A 4 in [100 mm] solid white line, or parking space markings, on the right edge of the bicycle lane should be used when adjacent to parking areas or parking lanes.

Provide bicycle-safe drainage grates for all inlets adjacent to bicycle facilities. Design all grates and utility covers to be set flush with the pavement surface. Design the pavement cross slope to not exceed 10 percent, and avoid design of an abrupt pavement edge at the inlet. Where shoulder width, or a bike lane, adjacent to a curb is less than 5 ft [1.5 m], recessed drainage inlets or curb inlets should be used.

Where the corridor is constrained and a separate bicycle lane or path is beneficial, it may be practical to provide the facility in only one direction of travel.

When applicable, consider including a separate two-way bikeway or shared-use path in the overall design of the highway project when the level of bicycle use is high and safety, operational or other benefits to the mix of facility users are sufficient to justify a designated bicycle facility, either on a separate independent alignment or parallel to the roadway. See 23 CFR 652. Provision of shared-use paths is particularly suited to high-speed, high-volume highways where the traffic characteristics or the roadway geometry is incompatible with typical bicycle and pedestrian use. However, exercise care in the design of shared-use paths to minimize the conflicts between bicyclists and pedestrians. Two-way bikeways and shared-use paths should always be physically separated from the roadway by a significant terrain feature and at least 5 ft [1.5 m] width, or by a crashworthy barrier system. The paved width of a two-way bike path should be a minimum of 8 ft [2.4 m]. Where pedestrians will routinely share the path with bicyclists it should be a minimum width of 10 ft [3.0 m], and 12 ft [3.6 m] desired. The presence of a bikeway or shared-use path near a highway does not eliminate the need to consider the presence of bicyclists in the design of the highway, unless bicycle use is specifically prohibited on the facility.

The AASHTO *Guide for Development of Bicycle Facilities* provides criteria for the design of bikeways. For guidance on design of shared-use trails, refer to the *Evaluation of Safety, Design, and Operation of Shared-Use Paths,* FHWA-HRT-05-139, 2006. Also see ***Bikesafe: Bicycle Countermeasure Selection System***, FHWA-SA-05-006, and the Pedestrian and Bicycle Information Center.

9.3.18 TRANSIT CONSIDERATIONS AND FACILITIES

The design of public transit facilities requires specialized planning and operational expertise. Refer to *Green Book* Section 2.1 for bus characteristics and turning paths; Section 4.19 and Section 7.3.18 for design of bus stops, turnouts, and lanes; and Section 84.8 for accommodation of transit. Also refer to the *Interim Geometric Design Guide for Transit Facilities on Highways and Streets*, AASHTO, 2002 for applicable design guidance. Also refer to the *Guide for High-Occupancy Vehicle (HOV) Facilities*, AASHTO, 2004 and the *Guide for Park-and-Ride Facilities*, AASHTO, 2004.

9.3.19 PARKING LOT LAYOUT CONSIDERATIONS

Parking lot stalls should be a minimum of 9 ft [2.7 m] wide and 18.5 ft [5.6 m] length; however, preferably 10 ft [3.0 m] wide and 20 ft [6.0 m] length, if practical. For short-duration high-turnover parking, or where loading of vehicles is common, a 10 ft [3.0 m] stall width should be provided. Parallel parking stalls should be a minimum of 22 ft [6.7 m] and preferably 25 ft [7.6 m] length, if practical. Parking access aisles should be a minimum of 13 ft [4.0 m] width for one-way traffic flow and 20 ft [6.0 m] width for two-way traffic flow; however, preferably 14 ft [4.3 m] width for one-way traffic flow and 24 ft to 26 ft [7.3 m to 7.9 m] width for two-way traffic flow, if practical.

For angle parking, design parking stalls as rectangles with the above dimensions, with no encroachments or overhang into the parking access aisles. For end stalls, provide a return area sufficient for maneuvering and backing.

Bus parking stalls should be a minimum of 10 ft [3.0 m] wide and 50 ft [15 m] deep; however, for parallel bus parking provide a minimum of 100 ft [30 m] length for the first bus stall and 50 ft [15 m] length for a second bus stall. For multiple bus stalls, provide angled (11.3 degrees) bus parking with 12 ft [3.6 m] wide and 60 ft [20 m] long stalls, with a 8 ft to 10 ft [2.4 m to 3.0 m] clearance offset from the access aisle for maneuvering and backing. Where longer, articulated buses are used: add 20 ft [6 m] for all the above length dimensions.

The inside turning radius in parking lots should be a minimum of 20 ft [6 m] for passenger cars and 30 ft [9 m] for busses; however, desirably 30 ft [9 m] for passenger cars and 40 ft [12 m] for busses, where practical.

Provide and locate pedestrian walkways in parking lots to avoid conflict with vehicles, to the maximum extent practical.

See Section 9.3.16.3 for applicable requirements, dimensions, and number of required accessible spaces and access aisles.

Refer to Section 9.3.9.3 for design of parking lanes.

For additional guidance on parking lot design refer to the *Guide for Park-and-Ride Facilities*, AASHTO, 2004.

9.4 RESURFACING, RESTORATION AND REHABILITATION (RRR) DESIGN

See Section 4.4.2 for the RRR projects design approach. Also see *FHWA Technical Advisory T 5040.28* and TRB Special Report 214, *Designing Safer Roads* for additional guidance. Also refer to the Technical Practices described in Chapter 5 of FHWA-SA-07-001, *Good Practices: Incorporating Safety into Resurfacing and Restoration Projects*.

Before beginning design on RRR projects perform a site inspection (see Section 4.3.3).

9.4.1 APPLICATION OF DESIGN STANDARDS

The design policy applicable for RRR projects is the same as for new construction and reconstruction, unless a separate FHWA approved State or local RRR design policy is applicable to the project (see Section 4.4.1). Identify all substandard features and document each exception to the standards as outlined in Section 9.1.3.

9.4.2 IMPROVEMENT OF SAFETY PERFORMANCE

Use a safety conscious design process for RRR improvements. See T 5040.28. Also see pp. 190-193 of TRB Special Report 214, *Designing Safer Roads*. Evaluate the safety performance of RRR projects based on analysis of the facility's crash history. Collect and analyze crash numbers, types and rates for the project to identify safety problem areas (Section 4.3.2.4). Also refer to FHWA-SA-07-001. For RRR projects on local roads, also refer to *Low Cost Local Road Safety Solutions*, ATSSA, 2006.

All safety elements of an RRR project require specific consideration. During site inspections and field reviews identify and evaluate potentially hazardous conditions, and include practical, low-cost safety enhancements in all RRR projects. These may include the following:

- Roadside obstacle removal,
- Traffic barriers and terminal sections,
- Bridge rails and transitions,
- Traffic control devices,
- Shoulder improvements,
- Minor widening,
- Minor horizontal or vertical alignment adjustments,
- Minor intersection improvements,
- Sight distance improvements,
- Longitudinal rumble strips,
- Skid-resistant surface texture,
- Railroad-crossing improvements, and
- Illumination.

Many of these items will enhance the traffic operation as well as safety performance. Refer to Section 9.4.5 for guidance on traffic operation improvements, and signing and marking requirements for RRR projects.

When applicable, consider the predicted safety performance of the facility over the project's anticipated design service life when making decisions regarding the above safety enhancement items, based on evaluation of:

- Past safety performance,
- Future traffic conditions,
- Existing roadway geometry, and
- Roadside conditions.

Consider using the crash prediction module of the IHSDM in such evaluations.

9.4.3 EVALUATION OF EXISTING GEOMETRIC DESIGN

Evaluate existing geometric design elements (Section 4.3.2.2) that are not performing in a satisfactory manner. As applicable, evaluate geometric deficiencies in the following areas:

- Horizontal and vertical alignment,
- Cross-sectional elements,
- Sight distance,
- Pedestrian facilities including ADA compliance, and
- Bicycle facilities.

It is FLH standard practice to restore the normal crown cross slope on tangent sections to at least 1.5 percent and preferably 2.0 percent.

Select a maximum superelevation rate, e_{max}, (Section 9.3.1.11) that is practical to apply for the project, and determine applicable superelevation rates for horizontal curves.

It is FLH standard practice to provide the standard superelevation (Section 9.3.5.1.3) and transitions (Section 9.3.5.2), to the maximum extent practical. The maximum practical depth for correction of superelevation deficiencies is equivalent to, or less than, the nominal pavement thickness. If the existing conditions or the ability to provide the standard superelevation rate of curves cannot be verified during the design process, provide construction contract provisions specifying that the superelevation rate will be verified and corrected during construction operations, to the maximum extent practical. When standard superelevation rates are impractical, the highest practical rate applies, subject to approval through the design exception process. Even if it is not possible to construct the standard superelevation rate for a particular curve, it is essential to design a consistent superelevation rate uniformly throughout the entire curve, with proper transitions. Where exceptions are necessary, engineering studies should be performed to identify locations for advisory speed and warning sign installations and other mitigation techniques.

The superelevation deficiencies of an asphalt surface may be improved by providing a leveling course. This additional course depth may increase the pavement structure capabilities and should be considered in the pavement structural design when leveling is relatively uniform over the length of the project. If adequate field measurements for calculating leveling course quantities are not practical, increase asphalt concrete pavement quantities approximately 20 to 25 percent for use as leveling material. When considering an additional leveling course, ensure that sufficient roadbed bench width exists to support the additional foreslope width, without creating a pavement edge drop-off or reduction in the standard ditch capacity.

Provide the standard superelevation and transitions particularly where the inferred design speed of a horizontal curve is less than the average running speed. In addition to improving superelevation, consider flattening horizontal curves when crash data indicates that geometrics are a contributing factor.

When horizontal curvature is the probable cause of crashes, consider corrective action. This can range from positive guidance (e.g., placement of additional warning signs and markings) to reconstruction. If existing substandard horizontal and vertical alignments do not warrant reconstruction, evaluate improvements to signing and marking, longitudinal rumble strips, or other cost beneficial safety enhancements. Consider alignment improvements when crash experience is high and previously installed warning signs, markings or other devices have been ineffective.

When the operating speed for a horizontal or vertical curve is less than 15 mph [20 km/h] below the operating speed of the adjacent sections, and has a low crash history, improvement of signs and marking may be applicable in lieu of reconstruction. When the difference in operating speed is 15 mph [20 km/h] or more, or the operating speed of the horizontal or vertical curve is less than 20 mph [30 km/h], or if the location has higher crash history, corrective action is essential. In this case consider cost-effective geometric improvements to the curve site, including curve flattening, lane or shoulder widening, additional roadside recovery area, additional superelevation, enhanced sight distance, slope flattening, removal of obstructions, selective clearing, or other physical modifications, even if such modifications exceed the normal roadbed bench width. Where the ADT is greater than 750, and the difference in the average running speed and the inferred design speed of the horizontal curve is more than 15 mph [20 km/h], also evaluate spot reconstruction of the horizontal curve. If improvement to correct the difference in operating speed is not possible, provide the appropriate signs and markings and other provisions to best facilitate proper speed transition.

Evaluate the need for restoration or improvement of sight distance on the inside of horizontal curves and at intersections. Include practical, low-cost corrective measures such as relocating signs and sight obstructions, selective clearing, minor widening of ditches, flattening minor cut slopes, etc. on RRR projects as needed.

Generally, grades cannot be flattened significantly on RRR projects. However, steep grades combined with restricted horizontal or vertical curvature, or crash history, may warrant corrective action in the form of spot improvements of the geometry, roadway cross section, or roadside safety features. For crest vertical curves where the ADT is greater than 1,500 and the difference in the average running speed and the inferred design speed of the vertical curve is more than 20 mph [30 km/h], and the crest hides from view a major hazard such as an intersection, sharp horizontal curve, or narrow bridge; evaluate spot reconstruction of the vertical curve.

If alterations adjoin pedestrian facilities, they must meet current ADA standards and be reconstructed, if necessary for compliance (Section 9.3.16.3).

As applicable, adjust existing features that are affected by the resurfacing, such as pavement drainage spillways, inlets and grates, catch basins, manholes, and utility access covers.

9.4.4 IMPROVEMENT OF ROADSIDE CONDITIONS

See Section 8.1.4 for general approach to roadside safety applicable to RRR projects.

Design the final surface of unpaved shoulders and roadway foreslopes to match the finished edge of pavement, to prevent a pavement edge drop-off and to provide a stable surface, after construction.

Evaluate existing traffic barrier rail and end treatments, bridge rail and transitions, guardrail and terminal sections, for crash worthiness and compliance of hardware with current standards (NCHRP Report 350 evaluation criteria). Include upgrading all substandard barrier hardware elements, or document their retention as a formal exception. Alternatively, guardrails meeting NCHRP Report 230 evaluation criteria may be retained for RRR projects; however, include upgrading all terminal sections not meeting current standards. Refer to Section 8.5.4. As applicable, adjust guardrail height to meet current standards.

Evaluate the widths and consistency of the existing clear zone throughout the project. Establish a minimum clear zone for the project that is as wide as practical, considering the guidelines in the AASHTO *Roadside Design Guide*, and the width of the existing roadbed bench including the foreslope and ditch. During field reviews visually inspect the established clear zone for potential roadside hazards; see Section 8.4.2.1. Give particular attention to the clear zone at identified high roadside crash locations (fixed object crashes), and the outside of sharp horizontal curves, and at the bottom of downgrades on horizontal curves. Determine the severity of identified roadside hazards and analyze appropriate countermeasures (e.g., do nothing, remove, protect) to address or mitigate the hazardous conditions. On the basis of these analyses, determine the appropriate remedial action.

Consider the following roadside safety enhancements on all RRR projects:

- Extending cross pipes outside of the clear zone, if practical,
- Removing headwalls or non-traversable end sections within the clear zone and replacing with traversable end sections,
- Relocating, protecting or providing breakaway features for sign supports and luminaires located in the clear zone,
- Shielding exposed bridge piers and abutments within the clear zone,

- Modifying raised drop inlets that present a hazard within the clear zone, and
- Clearing vegetation within the clear zone for lines of sight to meet the standard sight distance requirements.

Consider widening to provide additional clear distance through short sections of rock cuts. In longer rock cuts, isolated protrusions should be cut back or protected where warranted.

Review crash data to define dangerous obstructions as applicable. Apply engineering judgment, cost effectiveness, analysis of operational and safety effects, and consideration of environmental and community impacts in improvement decisions.

In cases where the existing roadbed bench width will not accommodate recoverable foreslopes of 1V:4H or flatter, and ditch filling to provide width or widening of foreslopes is restricted; consider strengthening the existing pavement structure through a recycling-in-place process rather than overlaying the existing pavement. Depending on the type of traffic and existing roadbed width, reducing the overall pavement structure thickness to maintain a 1V:4H recoverable foreslope and prevent an undesirable edge drop-off may be a reasonable compromise.

Provide a minimum lateral clearance of 2 ft [0.6 m] from the edge of shoulder to any obstructions. Where curb is used, the minimum lateral clearance for obstructions should 2 ft [600 mm] behind the curb and a minimum lateral clearance of 18 in [500 mm] must be provided behind the curb, in all cases. Where there are sidewalks, it is desirable to locate the obstructions behind the sidewalk.

9.4.5 IMPROVEMENT OF TRAFFIC OPERATIONS

Sign and mark all RRR projects in accordance with the *MUTCD*.

It is FLH standard practice on RRR projects to correct existing non-conforming, substandard or deficient signing and markings, and to replace sign panels not meeting minimum retroreflectivity standards and sign posts that are not crashworthy.

It is FLH standard practice to use edge line pavement markings on all RRR projects.

Refer to Section 8.7 for guidance on the evaluation of existing traffic operations and low cost traffic operations improvements. As applicable, consider low-cost enhancements of traffic operations including:

- Enhanced guide signing,
- Raised pavement markers,
- Post delineation,
- Enhanced directional and recreational signing,
- Minor improvements of intersections, approach roads and driveways,
- Channelization,
- Illumination, and

- Access management features.

Refer to Section 9.3.4.2 for evaluation of design consistency including existing operating speed variations, variations in theoretical inferred design speed, variations in template width, superelevation, etc. When advisory speed plates are warranted, design curve signs, turn signs and advisory speed plates based on the theoretical design speed criteria of the existing geometry, in relation to the posted or regulatory speed limit. Normally, show the design of signing and pavement markings on the plans; however, supplemental studies may determine the need to forward additional engineering data to the field.

If engineering data is unavailable for design of curve signs, provide construction contract provisions to specify a field method of measuring speed for horizontal curvature using a slope meter, more commonly referred to as the ball bank indicator, after construction of cross slope corrections. See the subsection on "Side Friction Factor" in *Green Book* Section 3.3.2 for a discussion on the relationship of ball bank readings and curve speeds.

Where applicable, provide signing and markings for pedestrian crossings, bicycle facilities, school areas, and highway-rail crossings, as recommended by the MUTCD.

9.4.6 EVALUATION OF PAVEMENT AND DRAINAGE STRUCTURES

See Section 11.6 for guidance on evaluation of existing pavement performance and rehabilitation methods, and details on the design of asphalt and concrete pavements. Refer to Section 11.7 for guidance on pavement preservation.

See Section 6.3.3 for guidance on performing site and subsurface investigations to identify subgrade problems, subsurface drainage problems, etc.

Refer to Section 7.1.6.3 for guidance on evaluation and treatment of existing and rehabilitated drainage structures.

Refer to Section 10.3.6 for guidance on evaluation of bridges within RRR projects.

9.4.7 MITIGATION OF SUBSTANDARD DESIGN FEATURES

When reconstruction of substandard design features to current standards is not feasible, determining the appropriate design criteria to be applied for the roadway, including lane and shoulder widths, is sometimes difficult. In some cases, the project may be the only improvement on a route for many years. In other cases, the maintaining authority may have a policy that only resurfacing projects will be applicable to a route, to conserve available funding for other higher priority transportation facilities. In these instances, the compatibility with adjacent sections of the highway may be the primary consideration. When compatibility with adjoining roads is the controlling factor, a design exception may be appropriate to establish the specific design criteria for the RRR project such that a consistent and uniform approach is taken for the corridor design.

Extraordinary cost or adverse environmental impacts could also result in design exceptions for the incorporation of substandard design features. When the highway operating agency's approved transportation plan specifies less than the standard lane and shoulder widths for a route, this width also requires documentation as a design exception. Exceptions to geometric design controlling criteria other than widths are usually limited to site-specific locations. The designer must mitigate these design exceptions through the established design exception process, as described in Section 9.1.3.

Refer to applicable portions of Section 9.3 for guidance on mitigation of substandard design features. Guidance for assessing risks and identifying appropriate mitigation of geometric design features and safety considerations is also available in Chapter 3 of the AASHTO *Flexibility Guide*. For mitigation of substandard design features, also refer to FHWA-SA-07-011.

9.5 OTHER HIGHWAY DESIGN ELEMENTS

The following sections address highway design elements other than the geometric design.

9.5.1 EARTHWORK DESIGN

As applicable, consider the following when developing an earthwork design:

- Clearing and grubbing,
- Removal of structures and obstructions,
- Excavation and embankment,
- Earthwork computation,
- Borrow and waste,
- Rock blasting,
- Watering,
- Structural excavation and backfill,
- Conservation of materials,
- Subgrade treatments and stabilization,
- Linear grading, and
- Roadway obliteration.

Also refer to the *FP-XX*, Division 200.

9.5.1.1 Clearing and Grubbing

FLH standard practice is to design clearing widths to extend a minimum of 5 ft [1.5 m] beyond the outer limit of slope rounding for cuts and 5 ft [1.5 m] beyond the toe of fill.

For shallow cuts and fills, and daylight sections, extend the clearing width beyond the edge of the slope intercept as necessary to provide the designated clear zone. Refer to the *Roadside Design Guide* for information on determining clear zone widths and recommended slope ratios.

Evaluate the needs for additional intersection and decision sight distance near intersections, and evaluate sight distance restrictions on the insides of horizontal curves, which may require wider clearing than normal. See Exhibit 9.3-J and *Green Book* Figure 3-23 in determining lateral offset and widening needed to provide adequate sight distance. When wider clearing is necessary to provide horizontal sightline offset, determine the location of sight lines and designate the wider clearing dimensions on the plans.

In heavily forested areas, consider selective thinning methods for a more natural appearing edge of clearing and a natural transition effect of the forest edge. Consider scalloped clearing lines and vista clearing to promote and frame scenic views will enhance the roadway aesthetics. In selected areas, the design should retain vegetation close to the roadway clear zone. Design slopes and clearing to emphasize variations in the clearing width, slope ratios, and proximity of vegetation patterns on either side of the roadway.

When applicable, widen the clearing to create openings and irregularities in a long straight clearing line, to emulate natural conditions. Designate varying clearing treatments with the type, size and density of the trees and ground cover, and on the terrain.

Consider additional clearing and grubbing width for the following situations:

- Selective thinning of vegetation at the top of high cuts,
- Scalloping and opening vistas to improve visual interest,
- Accommodation of utilities, and
- Solar exposure to assist in melting snow in high elevations.

Clearing and grubbing widths may be reduced in sensitive environmental areas and limited right-of-way.

9.5.1.2 Removal of Structures and Obstructions

Identify and specify the removal and disposal of all buildings, fences, structures, old pavements, abandoned pipelines and other obstructions that interfere with construction or otherwise cannot remain in place.

9.5.1.3 Design of Excavation and Embankment

The design of excavation and embankment should vary with the characteristics of the material. The designer should refer to the Geotechnical Report for recommended slope ratios. Cut and fill slope treatments are addressed in Section 9.5.2.

During earthwork design analyze the earthwork distribution to consider haul lengths, haul direction (upgrade or down), and the capabilities of typical earthmoving equipment. In general, strive to minimize the length of individual cuts and fills for efficient earthmoving operations. Consider that long cuts and fills over 1,000 ft [300 m] may require use of dump trucks loaded by front-end loaders or hydraulic excavators, instead of direct movement by track or wheel type bulldozers. Determine the location of earthwork divisions and identify areas and quantities where the haul length is over 2,000 ft [600 m], and evaluate possible alignment, grade or slope adjustments to minimize the volume and length of long hauls, particularly where they are upgrade.

9.5.1.3.1 Roadway Excavation

Design the roadway excavation to include all material excavated from within the right-of-way or easement areas, except subexcavation (see Section 9.5.1.16.1) and structure excavation. Roadway excavation volume includes all type material encountered regardless of its nature or characteristics.

Although not included in the roadway excavation quantity, consider the disposition of subexcavation and structure excavation materials for culverts, bridges and retaining wall structures. Consider the disposition of all excavated materials that affect the earthwork design, whether directly part of the roadway or for associated work adjacent the roadway.

9.5.1.3.2 Embankment

Identify the needs for embankment construction and compaction of roadway or borrow excavation, including:

- Preparing embankment foundations;
- Benching for side-hill embankments;
- Constructing dikes, ramps, mounds and berms; and
- Backfilling subexcavated areas, holes, pits and other depressions.

Account for all embankment materials in the earthwork design, whether directly part of the roadway or for associated work adjacent the roadway.

Embankment is normally not measured or paid for separately as a bid item. However, when the volume of embankment is much greater than the roadway excavation, consider measurement and payment for embankment in lieu of measurement and payment for roadway excavation and borrow excavation.

9.5.1.4 Determination of Excavation and Embankment Volumes

9.5.1.4.1 General

In cases where there is a preponderance of curvature in one direction, or large cuts and fills are greatly offset from centerline, in sharp curvature, consider the effect of curvature on the earthwork volumes.

Account for miscellaneous excavations and embankments in addition to the roadway prism excavation and embankment, for determination of the total excavation and embankment quantities.

9.5.1.4.2 Shrink and Swell Factors

See Section 6.4.6.2 and coordinate with the Geotechnical unit for determination of specific project site material shrink/swell factors.

9.5.1.5 Balancing Earthwork

The earthwork is balanced when the volume of excavation (with the appropriate allowances made for shrink and swell) approximately equals the volume of embankment.

Consider the disposition of all materials that will be incorporated in the earthwork construction (e.g., subexcavation removed and topsoil conserved) in determination of the earthwork balance.

Consider the effect of materials that are imported from outside the roadway and used within the prism, or that are exported for use outside the roadway prism.

The Geotechnical Unit should evaluate the sites and provide recommendations on classification of borrow material or slopes and depth of embankment allowed in disposal sites. Appropriate environmental considerations apply to reclamation or rehabilitation plans for any borrow or waste disposal sites. Coordinate with the site landowner to ensure reclamation and rehabilitation plans are in conformance with the owner's requirements.

9.5.1.6 Haul

The designer should consider haul when developing the earthwork design of grading projects, and strive to minimize the overall haul volume and cost. When applicable, the cost for haul should be estimated, based on equipment needs and labor rates to move the material, for development of the pay item unit price analysis.

9.5.1.7 Mass Diagram

As applicable, a mass diagram should be used to evaluate and optimize the earthwork design to minimize the overall excavation, embankment and haul. When appropriate, provide a mass diagram in the plans to represent the earthwork design.

9.5.1.8 Borrow and Offsite Borrow Areas

As applicable, borrow areas may be designated and included as part of the overall design and PS&E preparation. Roadway guidance for grading, drainage, slope treatment, restoration of vegetation, etc., is also applicable to offsite borrow areas.

9.5.1.9 Waste and Offsite Waste Areas

As applicable, waste areas may be designated and included as part of the overall design and PS&E preparation. For purposes of drainage, slope treatment, restoration of vegetation, etc., the same guidance for the roadway is applicable to offsite waste areas. Provide site-specific details for grading, slope ratios, and any compaction requirements.

9.5.1.10 Rock Blasting

Coordinate closely with the Geotechnical Unit for the design of materials and slopes that are anticipated to require rock blasting.

9.5.1.11 Watering and Water Sources

Consider the need for watering and water sources to facilitate the compaction of embankment materials and for dust control during grading operations. Water may also be needed for irrigation during plant establishment periods for restoration of vegetation. The water quantity needed should be evaluated as part of the design process. When applicable, adequate water sources should be designated and included as part of the overall design and PS&E preparation.

9.5.1.12 Structural Excavation and Backfill

When applicable, determine the quantity of structure excavation for pipe culverts, box culverts or other drainage structures. In this case, prepare a cross section at the structure location, showing the roadway template and the structure grade line.

Consider the volume and costs of structural excavation and backfill in developing the unit price analysis for the drainage structure.

9.5.1.13 Conservation of Materials

Consider the conservation of materials for selected uses in the earthwork design to minimize the cost of importing materials and to improve the quality and durability of the overall roadway construction. When applicable, evaluate the materials within the proposed construction limits for use as topsoil, subgrade topping, riprap, crushed aggregate, select backfill, reinforced fill for mechanically stabilized embankment, and other special uses. Coordinate with the Geotechnical Unit to investigate, sample and test materials that are of value above their use in general roadway embankments. When applicable, designate in the design and PS&E that the proven materials be conserved and used for these purposes.

9.5.1.14 Roadway Obliteration

Roadway sections no longer needed for traffic and located outside the cuts or fills should be obliterated by restoring the ground to approximately the original contour to produce a natural appearance by forming naturally shaped slopes. In obliteration areas evaluate existing drainage pipes regarding need for removal, or to be plugged, or to remain in place. Natural drainages should be restored to their original condition. Evaluate salvaging existing base rock or other surfacing materials from obliteration areas for incorporation into the new construction.

9.5.1.15 Linear Grading

When applicable, consider linear grading in lieu of the design, control and measurement of roadway excavation quantities. Consider linear grading for light re-grading of existing roads where the close adherence to a designed alignment and grade is not essential, and a reasonable roadway finished product can be anticipated without precise surveys or normal geometric design engineering processes. Linear grading should not be used where the existing roadway geometry is unsatisfactory.

9.5.1.16 Subgrade Treatments and Stabilization

When applicable, consider subgrade treatments that may be necessary, or simply cost-effective to improve the subgrade. Coordinate closely with the Geotechnical Unit to determine the need for any subgrade treatments or stabilization. The Geotechnical Report should identify the location of and propose a solution for any subgrade problems. When applicable, incorporate appropriate corrective measures into the design including any Special Contract Requirements and special drawings into the PS&E package. Refer to Chapter 6 for additional guidance using earthwork geotextiles.

Consider the techniques described in the following sections.

9.5.1.16.1 Subexcavation

When applicable, consider subexcavation of material from below subgrade elevation in cut sections or from below the original groundline in embankment sections. Consider the need to remove topsoil, humus material, or loosely compacted materials. Consider that subexcavation may be needed to remove unsuitable material, or to remove otherwise suitable material that must be dried, screened, crushed or processed for appropriate use in the roadway. Subexcavated materials may be replaced with granular backfill or topping to improve the subgrade.

Coordinate with the Geotechnical Unit for the need and design of any subexcavation areas.

9.5.1.16.2 Subgrade Stabilization

When applicable, consider stabilizing poor quality subgrade materials in-situ with additives (e.g., lime, fly ash, cement). Consider that subgrade stabilization in-situ may be an economical alternative to removal of the poor quality materials, waste and backfill with imported materials; or to the design of a stronger pavement structural section for the poor quality subgrade materials. Coordinate closely with the pavements and geotechnical units when considering the development and design of in-situ subgrade stabilization measures.

9.5.1.16.3 Topping

Where applicable and cost-effective, consider topping with a quality granular soil material in the upper layer of the subgrade to increase subgrade strength and bearing capacity, and reduce the pavement structure or to increase its durability. When applicable, topping may be placed in the upper 6 in to 12 in [150 mm to 300 mm] of the subgrade, in excavation areas after excavating below the subgrade or subexcavation, and in embankment areas after finishing the normal embankment to a lower subgrade elevation. Topping material may be either conserved from the roadway excavation in areas where the material meets the quality requirements, or furnished from offsite borrow areas.

9.5.1.16.4 Earthwork Geotextile Stabilization

Where applicable, consider using earthwork geotextiles to increase support values of the subgrade or base materials, and to enhance the function of roadway materials when conventional local materials are of lesser quality, or if higher material performance is needed. Coordinate closely with the Geotechnical and Pavements Units when geotextile applications are considered. Refer to Chapter 6 for additional guidance on using earthwork geotextiles.

9.5.1.16.5 Subgrade Drainage and Underdrains

Where applicable, consider using subgrade drainage systems including drainage blankets, underdrains, sheet drains and pavement edge drains. Consider subgrade drainage systems when needed to facilitate the interception and removal of water from the subgrade to improve the strength and bearing capacity, and to improve long-term performance of the base and pavement. As applicable, consider subgrade drainage and underdrains where subsurface water is apparent and abundant. In addition to subgrade drainage systems, consider widening and deepening shallow ditches in cut areas. Also consider longitudinal subgrade drainage systems in cut areas where side slope stability is a concern. Coordinate closely with the Geotechnical Unit in the location, depth, materials and other aspects of the subgrade drainage design, as described in Chapter 6.

9.5.2 SLOPE TREATMENTS

Slope treatments are essential roadside design elements and affect safety, stability, and the restoration of vegetation, cost, aesthetics and environmental impacts. To the extent practical, flatten and shape slopes to fit the existing topography and to provide a pleasing, natural appearance consistent with effective revegetation, erosion control, and drainage. Specific considerations and requirements to be included in the design are discussed in the following sections.

9.5.2.1 Safety Considerations

Within the designated clear zone, it is FLH standard practice to design slopes to be recoverable (i.e., 1V:4H or flatter) and free of fixed objects, to the maximum extent practical. Where practical beyond the clear zone, preferably design slopes to be traversable (i.e., 1V:3H or flatter) and free of fixed objects. Refer to Section 8.1.4 for general guidance on roadside safety design and Section 9.3.13 for design of foreslopes.

9.5.2.2 Geotechnical Considerations

Geotechnical reports may not be available for the project when beginning a design. If this is the case, then design cut and fill slopes based on available survey or field review data. When a geotechnical report becomes available, the designer must review the slopes initially used and make any necessary adjustments in the earthwork design.

9.5.2.3 Grading Techniques

FLH standard practice is to use variable slope ratios for both cut and fill slopes. Avoid using constant slope ratios. When varying slopes, a rule-of-thumb is at minimum to vary one unit of the horizontal slope ratio over one cross-section interval of 50 ft [20 m] of linear roadway distance, e.g. a transition from a 1V:2H slope to a 1V:4H slope should be over a minimum distance of two cross-section intervals or 100 ft [40 m], for constructability.

Use slope rounding at the top of cuts.

Design slopes for stability, to balance material quantities, as well as to enhance the roadway corridor appearance.

Evaluate the proposed slope and grading design, both in-office and during on-site reviews, for opportunities to enhance natural features that are adjoining or will be affected during the grading operations, and adjust the grading design accordingly. Whenever possible, use an interdisciplinary design approach with expertise from specialists in landscape architecture, geotechnical, restoration of vegetation, construction, and other applicable disciplines to assist in the grading design and to optimize the use of the grading techniques that are described.

Whenever practical, warp and blend slopes to emulate the existing landforms. Slope blending is done in addition to variable slope and rounding techniques. The intent of slope molding is to create natural variations instead of an engineered uniformity of a finished slope.

Warp slopes around existing large boulders and preserve stable rock outcrops as practical.

In areas with natural draws, lay back or flatten the cut slope to match that of the draw. This additional flattening only generates a relatively small amount of additional material but greatly enhances the appearance of the cut slope. This material can be used to flatten fill slopes or mold them into more natural appearing landforms representative of the project vicinity.

To the maximum extent practicable accent ridges by designing steeper slopes adjacent to these locations, in conjunction with rounding slopes. Stable slopes are a primary objective for any slope treatment, so the steeper slope design should not exceed Geotechnical recommendations.

For large or extended cuts, merely laying back the slopes into draws and accenting existing ridges may not be sufficient to produce the natural appearance desired. Consider additional excavation of flatter slopes to exaggerate existing small draws, and exaggerate the creation of steeper slopes in slight ridges, to recreate the natural diversity of the landforms; however, these exaggerated grading techniques could result in a substantial increase in the roadway excavation or environmental impact if the flattening is overdone, or create surface slides if the steepened material is not stable at the steeper designed slopes.

9.5.2.3.1 Slopes of Cuts and Fills

Design slopes to be as flat as is reasonable. Cut and fill slope design is a compromise between aesthetics, safety, stability, and economics. Generally, low cuts and fills are economical to construct on relatively flat slopes and will enhance aesthetics, safety, and maintenance. Where practical, embankment slopes should be 1V:4H or flatter. Slopes 1V:3H are generally traversable by an errant vehicle that has run off the road but do not provide for vehicle recovery. Since a high percentage of errant vehicles will reach the toe of these slopes, the recoverable area should be extended beyond the toe of slope. Refer to the AASHTO *Roadside Design Guide* for methods of determining the preferred extent of the runout area. Slopes 1V:3H and flatter are also traversable by self-propelled mowers, and should be used at locations where the grass will be regularly cut. High cuts and fills normally have steeper slopes.

For higher speed roadways over 45 mph [70 km/h], a slope of 1V:6H or flatter is recommended whenever achievable, and 1V:10H embankment slopes are desirable for safety. Recoverable slopes are slopes 1V:4H or flatter. Motorists who encroach on recoverable slopes can generally stop their vehicles or slow them enough to return to the roadway safely.

Regardless of the slope steepness, it is desirable to round the top of intersecting slopes so an errant vehicle is more likely to remain in contact with the ground. Where runout distance exists, the toe of intersecting slopes should be rounded to prevent vehicles from nosing into the ground.

Right-of-way, excavation, borrow and environmental impacts typically influence the decision of slope width and steepness. In some cases, the cost and difficulty of effectively stabilizing, vegetating and maintaining steep slopes may exceed the initial cost and short term impact of additional grading and right of way to provide a flatter slope.

In level or gently rolling terrain with grassy vegetation, it may be desirable to use a constant distance to the slope catch point and a continuously varying slope may be appropriate to blend to the natural landscape.

In steep terrain, the slopes may be varied slightly from standard slopes in order to better fit the topography or eliminate high “sliver” cuts or fills. Transition slopes between common material and rock require special consideration. Blend the ends of cut slopes into the natural terrain by rounding, flattening, or otherwise shaping the ground line.

Exhibit 9.5-A lists commonly used slopes for cuts and fills in earth materials. Use this table as a guide for preliminary slope design of projects. Use the recommended slope ratios provided by the geotechnical engineer, or in the geotechnical report as soon as it is available, to then design the slopes on the project. The fill slope ratios listed as desired should be used as the recommended maximum slope ratio for roadways with design speeds of 50 mph [80 km/h] or higher. All fill slopes steeper than 1V:4H should be evaluated for safety. See the *Roadside Design Guide*, Chapter 3 for additional guidelines.

9.5.2.3.2 Transitioning Cut and Fill Slopes

If possible, transition fill slopes from the main portion of the fill into the cut section. Transitions between flat and steep slopes should be sufficiently long to provide a pleasing appearance. When varying slopes, a rule-of-thumb is at minimum to vary one unit of the horizontal slope ratio over one cross-section interval of 50 ft [20 m] of linear roadway distance, e.g. a transition from a 1V:2H slope to a 1V:4H slope should be over two cross-section intervals or a minimum distance of 100 ft [40 m], for constructability.

At culvert inlets in cut sections, transition the ditch width and depth and cut slope ratio to provide a smooth transition and to emulate natural draws.

Exhibit 9.5-A DESIRABLE AND MAXIMUM SLOPES

Cut and Fill Slope Ratios for Soil Materials								
Height		**Slope Type**	**Flat**		**Rolling**		**Mountainous**	
(ft)	**(m)**		**Des.**	**Max.**	**Des.**	**Max.**	**Des.**	**Max.**
0-3	0-1	Cut Fill	1V:6H 1V:6H	1V:4H 1V:4H	1V:6H 1V:6H	1V:4H 1V:4H	1V:6H 1V:6H	1V:3H 1V:4H
3-10	1-3	Cut Fill	1V:4H 1V:4H	1V:3H 1V:4H	1V:3H 1V:4H	1V:2H 1V:4H	1V:3H 1V:3H	1V:2H 1V:3H
10-15	3-4.5	Cut Fill	1V:3H 1V:4H	1V:2H 1V:3H	1V:3H 1V:4H	1V:2H 1V:3H	1V:3H 1V:3H	1V:2H 1V:2H
15-20	4.5-6	Cut Fill	1V:3H 1V:3H	1V:2H 1V:2H	1V:2.5H 1V:3H	1V:2H 1V:2H	1V:2H 1V:2H	1V:1.5H 1V:1.5H
> 20	> 6	Cut Fill	1V:3H 1V:3H	1V:2H 1V:2H	1V:2H 1V:3H	1V:1.75H 1V:1.75H	1V:2H 1V:2H	1V:1.5H 1V:1.5H

Note: Cut and fill slopes steeper than 1V:2H should be avoided in clay or silty soils subject to erosion. Fill slopes steeper than 1V:1.5H may be used in critically tight areas with geotechnical guidance when the fill material is composed of quality rock.

9.5.2.3.3 Slope Rounding

It is FLH standard practice to use slope rounding at the top of cuts on all grading projects.

The amount of cut slope rounding may depend on the environmental impact and on the desires of the agency having jurisdiction. A general recommendation is to extend the clearing limits and provide additional width for slope rounding beyond the slope catch point for a distance of approximately 1/3 the vertical height of the cut slope, or for a distance of 10 ft [3.0 m].

Where applicable, consider using fill slope rounding to transition the toe of fill slopes with the natural terrain, within the clearing limits. Fill slopes that are within the clear zone should be rounded beyond their intersection with the natural ground for a distance of at least 6 ft [1.8 m]. Fill slope intersections parallel to the roadway and within the clear zone (e.g. at culverts, driveways, intersections) should be rounded longitudinally for a total distance of 20 ft [6 m].

9.5.2.3.4 Slope Roughening and Terracing

Slope roughening is applicable to slopes in medium to highly cohesive soils or in soft rock, which can be excavated without ripping. When applicable, design slope roughening to provide flatter spots and small pockets on the slope to facilitate seed germination and plant establishment, and to help control erosion. All slopes steeper than 1V:4H and greater than 7 ft [2.1 m] of vertical height should be designed for slope roughening. As applicable, these types of slopes should also be designed for more intensive terracing or pocketing to provide larger planting areas, yet still achieve a random and natural appearance.

Only minor slope roughening is recommended for slopes 1V:1.5H or steeper overall. Slopes steeper than 1V:1.75H are generally inaccessible by tracked equipment except during the time that the slope is being constructed in lifts. Materials that would normally be stable on a 1V:1.5H slope may be designed for 1V:1.75H or 1V:2H with slope roughening techniques. Slopes steeper than 1V:2H should be designed to be randomly terraced or stair-stepped with short, intermittent, benches only wide enough to retain sediment that may erode from the steeper slope above.

Where practical, slopes steeper than 1V:4H up to 1V:2H, and greater than 10 ft [3.0 m] vertical height, should be designed with allowance for a series of compound, gradient terraces to emulate adjacent natural slopes and to reduce runoff velocity and minimize erosion. Gradient terraces should not be designed on slopes steeper than 1V:2H or in areas with sandy or un-cohesive soils. If used, the design for gradient terraces should be included on the plans and cross sections or typical details, as a general feature to be incorporated during the construction of the slopes to suit local conditions. The gradient terraces should be designated as intermittent for a random appearance, rather than designed as continuous benches. In special circumstances, compounded slopes may be designed in cuts or fills and controlled as part of the slope construction.

9.5.2.3.5 Embankment Slope Benching

Consider the need for embankment slope benching consisting of excavation of a series of benches into the existing terrain to interlock and found the new embankment into the existing natural ground. Embankment slope benching may also be necessary for the construction equipment to grade and compact narrow embankments that are less than 15 ft [5 m] horizontal width from the outside of the embankment to the existing ground.

Embankment benching should be designed for construction of embankments placed on existing ground that is sloping 1V:3H or steeper, and for narrow embankments. The bench height should be an increment of one or more layers of the embankment lift thickness as applicable for material type and conditions encountered.

As applicable, consider the compaction of material excavated for benching in the design of earthwork volumes, shrinkage factor and balancing of earthwork quantities.

9.5.2.3.6 Slope Daylighting

In shallow cuts, it is recommended to daylight the excavation slope to facilitate drainage, roadside safety, visibility and future maintenance activities, when practical. Daylight slopes are typically constructed at a 1V:20H or 1V:10H slope similar to an embankment slope, and may extend outward as much as approximately 20 ft [6 m] horizontally to intersect the natural ground that is sloping downward away from the roadway. Slopes should normally daylight from the normal ditch flow line elevation, or from a slightly deeper ditch in transitions from cut to fill.

In locations where the view of the road from other locations is a concern, slope daylighting may not be appropriate.

9.5.2.3.7 Slope Snow Drifting and Storage Considerations

In areas subject to frequent winter snow and wind, consider providing an aerodynamic cross section that allows the roadway to be naturally swept clear by the wind. Also consider adjusting slopes to provide snow storage upwind from the road. Where applicable, consider the following recommendations to improve snow storage and alleviate drift-prone areas:

- Flatten backslopes and foreslopes to at least 1V:6H ratio and preferably flatter,
- Widen ditches as much as practical,
- Raise the road profile to 2 ft [0.6 m] above the ambient snow cover,
- Provide a ditch section that is adequate for storing snow plowed off the road,
- Widen cuts to provide increased snow storage,
- Flatten slopes to eliminate the need for traffic barrier, and
- If traffic barrier is necessary, consider cable or box-beam rail in lieu of W-beam rail.

9.5.2.4 Slope Waterways and Catchment Basins

As applicable, adjust the design of cut and fill slopes and ditches at the location of slope waterways and catchment basins to emulate natural waterways. Design cut slope waterways to intercept natural drainages that are undercut by excavation slopes, and design embankment slope waterways to convey pavement or ditch drainage over or along embankment slopes. Design catchment basins to collect drainage from ditches or slope waterways at inlets to culverts. Refer to Section 7.3.2 for channel lining design and permanent erosion protection for slope waterways and catchment basins.

9.5.2.5 Rock Cut Slopes

9.5.2.5.1 General

Consider presplitting along a rock slope face or along a number of benched rock faces may be beneficial for slope stability; however, presplitting may not be appropriate in all locations. In these locations consider using other than presplit blasting techniques, using irregular drill hole patterns following the natural joints and strata along natural rock fractures.

Consider designing rock cuts to produce a staggered bench effect to emulate the natural terrain and accent natural fracture lines in the rock. When presplitting is necessary to create stable rock slopes, consider design of staggered benches, at varying elevations in the cut slope, to break up the appearance of uniform and closely spaced vertical drill holes.

When soil or highly weathered rock overlays the solid rock, consider designing overburden benches at the top of the solid rock. The overburden slope should range from 1V:1.3H to 1V:2H, depending on the type and depth of overburden and the steepness of the topography. When the rock surface is known, developing the design of compound slopes is recommended.

9.5.2.5.2 Rockfall Considerations

As applicable for design of rock excavation or rockfall mitigation, provide design details that describe techniques for slope scaling of existing rock cut slopes using machine scaling and hand scaling techniques, and scaling of excavated rock slopes after blasting. Coordinate closely with the geotechnical discipline to develop techniques for rock bolting, netting, etc., and how to present these in the PS&E.

Refer to Chapter 6 for guidance for designing rock cuts and fallout ditches. Rely on the recommendations in the Geotechnical Report. Typical sections for rock cuts should be shown on the plans.

Rock slopes higher than 30 ft [10 m] from shoulder grade may require wider fallout ditches and the geotechnical staff should be consulted. Cuts less than 20 ft [6 m] in height generally do not require a fallout ditch.

Special rock protection features may be applicable on higher volume highways experiencing falling rock. The Geotechnical Unit should recommend or approve these features before inclusion into a project.

9.5.2.6 Slides and Slope Stabilization

When the Geotechnical Report identifies potential areas for slides, the earthwork excavation quantities may require adjustment to cover potential slide removal. Provide for the removal and disposal of excess slide material, if necessary.

Coordinate closely with the Geotechnical Unit to develop techniques for rock buttresses, drainage layers and similar techniques for stabilizing cut and fill slopes and how to present these in the PS&E. Refer to Chapter 6 for additional guidance.

9.5.2.7 Slope Protection

Coordinate closely with the Hydraulics Unit to develop techniques for embankment slope protection for erosion, stream impingements, etc., and how to present these in the PS&E. Refer to Section 7.4.4 for additional guidance on such details.

9.5.3 EARTH RETAINING STRUCTURES

Information on retaining wall design may be found in Section 10.4.12 and Section 6.4.4.

9.5.3.1 Determination of Need

The determination that a retaining wall may be needed should be made early in the conceptual studies and preliminary design phase. Refer to Section 4.8.4.

9.5.3.2 Alternative Wall Systems

When it is determined that a retaining wall is needed, identify and determine the retaining wall system alternatives that are technically suitable to the site, and aesthetically acceptable to the highway facility owner and the land-owning agency.

Determine which alternative wall system(s) will be designed and included in the PS&E, and which wall systems will be designated as alternative contractor designs. Determine the alternatives permitted for design by the contractor that are technically suitable, cost-effective and aesthetically acceptable to the highway facility owner and the land-owning agency.

Avoid designating only one retaining wall system, if the system is proprietary. Contracts specifying a proprietary wall system must have at least one other reasonably competitive proprietary or non-proprietary wall system permitted as an alternative.

9.5.3.3 Selection of a Retaining Wall System

Unless alternative wall systems are applicable, determine the retaining wall system or type that will be designated. Coordinate this decision with the project manager, geotechnical, highway design, structural design, environmental specialists, highway facility owner and land-owning agency. Evaluation factors to consider in the selection include:

- Terrain,
- Soil conditions,
- Constructability,
- Demonstrated performance and durability,
- Estimated cost,
- Aesthetics,
- Environmental compatibility,
- Geotechnical considerations, and
- Maintenance.

Document the selection process. The designated wall system or type should be based upon an analysis of the specific constraints and conditions. The analysis must consider the suitability or compatibility of various wall systems to the site.

9.5.3.4 Retaining Wall Systems

When applicable, the roadway design should include the general layout of the retaining wall systems including the geometry, location, offset from the roadway, length, batter or slope, foundation embedment, excavation and backfill requirements, and the coordination with other roadway design elements. Incorporate the design considerations of the wall type into the general layout of the retaining wall system and coordinate the layout with the overall highway design. Refer to Chapter 6 and Chapter 10 for design guidelines applicable to the specific retaining wall systems.

Consider the following in the layout, overall design and construction of a retaining wall system:

- Highway geometry,
- Topography,
- Subsurface conditions and soil parameters,
- Loading conditions,
- Length and height of wall required,
- Material to be retained,
- Presence of ground water,
- Scour protection if adjacent to surface waters,
- Future planned improvements that may affect design of the wall, and
- Appearance and aesthetics of the completed structure.

Walls installed near the roadway can also serve as traffic barriers if they have an approved traffic barrier design incorporated into the wall details.

Whenever practical, design the retaining walls to allow usage of native soil conserved from the roadway or wall excavation for the backfill, if it meets the requirements for the particular wall system. Coordinate the estimated volume of wall excavation and backfill with the roadway earthwork design.

All retaining walls require a geotechnical investigation and report of the underlying foundation soils. Refer to Section 6.3 for guidance on the investigation of foundation soils and native soils that may be used for backfill.

Design retaining walls, as applicable, with an aesthetically pleasing appearance compatible with other structures in the area and with the surrounding terrain. Although economics generally dictate wall selection, an aesthetic wall facing treatment could be an overriding selection factor. Consistent architectural treatment and economy of scale will frequently result in the same wall type being used throughout any given project. Aesthetic requirements may include the wall's material, top profile, terminal transitions and the surface finish for texture, color and pattern. Short sections of walls should be avoided if possible.

9.5.3.5 Geometric Information for Design of Retaining Wall Systems

The following lists the minimum geometric information to be developed and included for the design of retaining wall systems:

- Beginning and ending wall stations;
- Horizontal alignment;
- Offset from the roadway to the face of the wall;
- Profile elevation of top of wall;
- Typical cross-sections of the wall geometry and required elements;
- Representative existing ground topography, or cross sections, or both, in relation to the wall geometry;
- Estimated foundation elevations;
- Estimated wall face area;
- Wall base width;
- Layout of appurtenances in the area (e.g., culverts, guardrail);

- Proposed construction limits;
- Right-of-way limits;
- Locations designated for removal of unsuitable foundation materials; and
- Construction sequence or staging for traffic control needs.

9.5.4 LANDSCAPING AND RESTORATION OF VEGETATION

As applicable, retain, restore, or include landscaping and vegetation to provide the following operational, environmental, and visual benefits:

- Prevent soil erosion,
- Enhance water quality,
- Provide runoff storage,
- Provide slope stabilization,
- Preserve and provide wildlife habitat,
- Preserve scenic views, and
- Serve as a buffer and glare screen.

Whenever practical, incorporate the following landscaping and vegetation treatments to restore, enhance and emphasize the natural beauty of the roadside. Consult with a professional landscape architect (e.g., the Federal land management agency landscape architect) or include a landscape architect in the project design team to identify opportunities and provide specific recommendations regarding enhancements or modifications of the slope design and grading, for design of landscaping treatments, and for restoration of vegetation.

For additional guidance refer to *A Guide for Highway Landscape and Environmental Design*, AASHTO, 1990.

9.5.4.1 Enhanced Clearing Techniques

When applicable, incorporate enhancements to the clearing techniques described in Section 9.5.1.1.

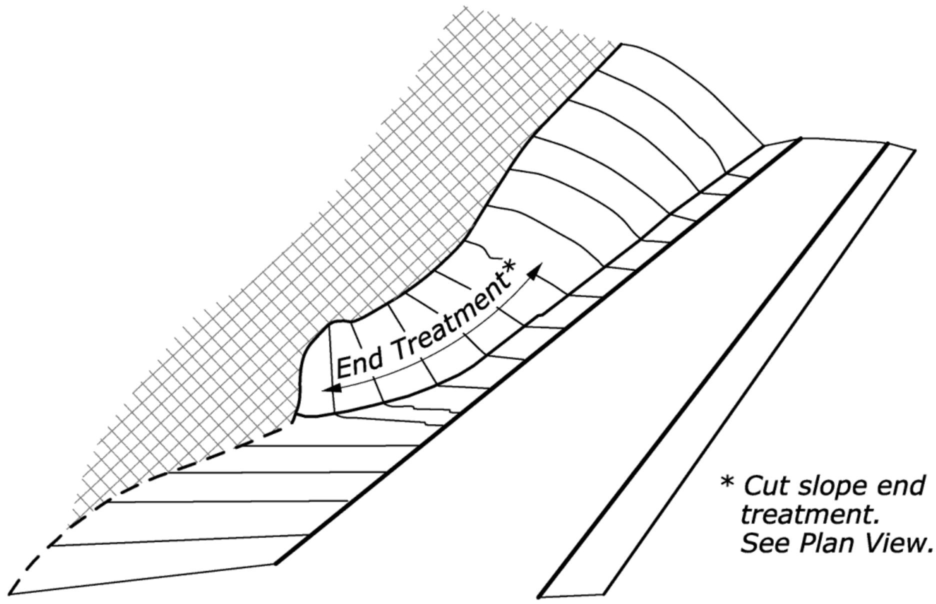
9.5.4.2 Enhanced Grading Techniques

When applicable, incorporate enhancements to the grading techniques described in Section 9.5.2 and as described in the following sections.

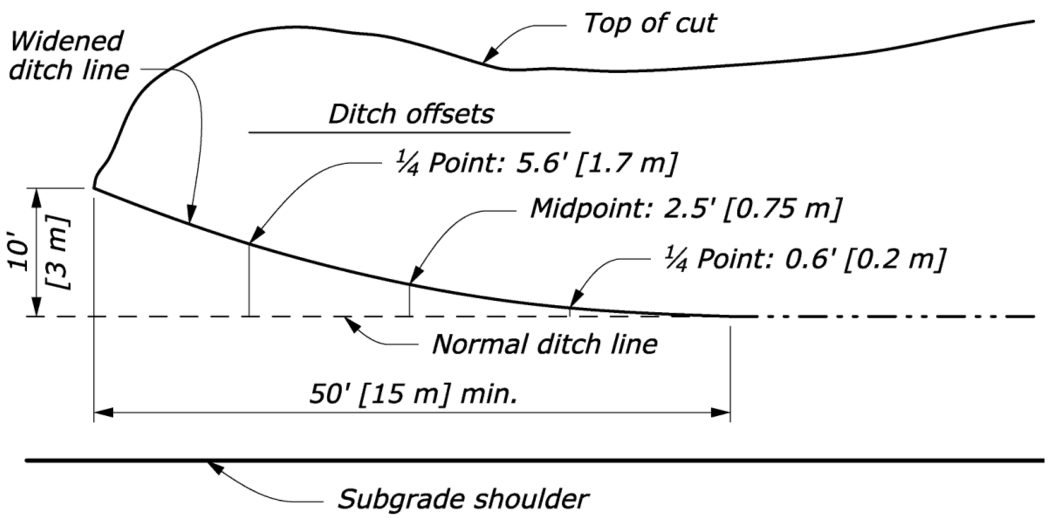
9.5.4.2.1 Cut Slope End Treatment

As applicable, transition cut slopes from the cut into the fill section with varying slope ratios. Flare the ends of cuts and blend the ends of fills into the cut slopes. Refer to Exhibit 9.5-B. Using a special ditch grade or widening the ditch can accomplish this objective.

Exhibit 9.5-B ENHANCED CUT SLOPE END TREATMENT



OVERHEAD PERSPECTIVE



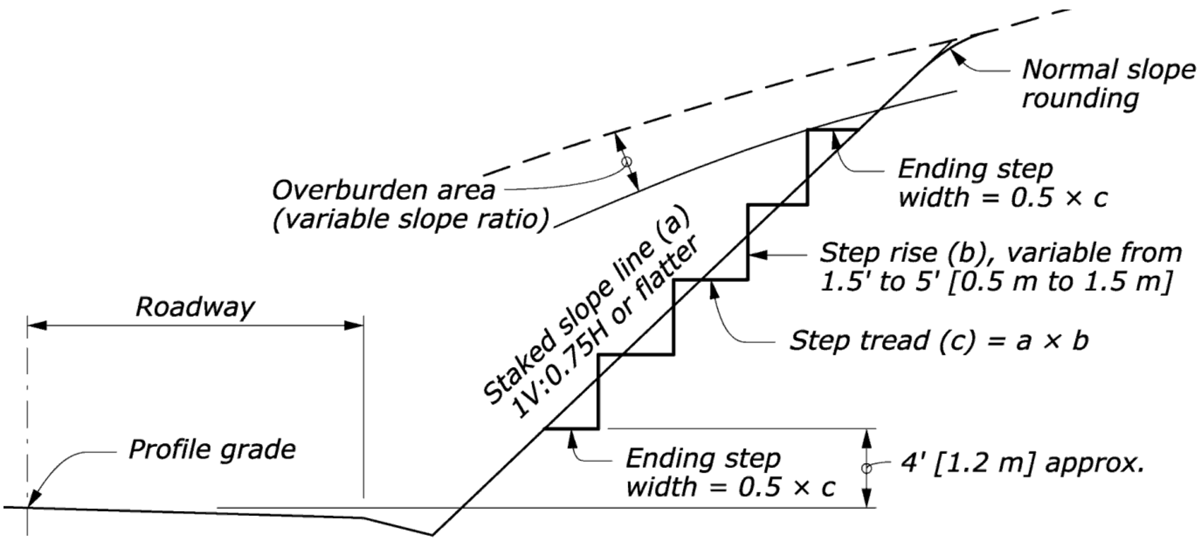
PLAN VIEW

9.5.4.2.2 Serrated Slopes

As applicable, consider design of serrated (stepped) slopes, which are a series of small steps, in soft rippable rock cuts having slope ratios between 1.3V:1H and 1V:2H. Exhibit 9.5-C shows a typical section of a serrated slope.

If used, include a drawing in the plans showing step tread and rise dimensions. Generally, the step rise varies from 1.7 ft [0.5 m] for easily ripped rock to 5.0 ft [1.5 m] for harder rippable rock. If the slope contains nonrippable rock outcrops, design the steps to blend into the rock. The step tread width is equal to the rise multiplied by the cut slope ratio.

Exhibit 9.5-C SERRATED SLOPES



At the ends of the cut slopes blend the steps smoothly into the natural ground.

Where the series of steps in the slope is a concern from a visual or aesthetic standpoint, serrated slopes may not be appropriate.

9.5.4.3 Enhanced Rock Work

Incorporate enhancements to the rock slope techniques described in Section 9.5.2.5. Where practical, design planting pockets or benches in the slopes for the introduction of plant material. It is desirable to spread topsoil on all rock benches to encourage grass growth and minimize the visual scar through restoration of vegetation. Consider planting seedlings of trees and shrubs.

9.5.4.4 Topsoil Placement

Where practical, design the project to conserve topsoil from within the project limits and replace it on the finished slopes, within the same growing season. The topsoil provides needed chemical and organic materials for the vegetation, and it contains an abundance of native seeds. Native forbs and grasses present in conserved and topsoil usually grow quickly, dense and blend with the existing undisturbed vegetation, which most effectively restores the indigenous vegetation onto the new slopes.

Coordinate closely with the Geotechnical Unit to determine the locations, depth, quality and other information about factors that may influence special contract requirements, such as for the potential need for special equipment or construction methods to salvage, stockpile and place the topsoil.

Where existing topsoil from the project is limited, consider designing the slopes for placement of furnished topsoil, or topsoil manufactured on the project site from a well-blended mixture of the limited existing topsoil combined with finely chipped clearing slash, conserved fine-grained soil excavation and furnished compost.

9.5.4.5 Restoration of Vegetation

Include treatments for restoration of roadside vegetation using appropriate planting to pro-actively improve the quality of the highway and its surrounding ecosystem. Refer to *Roadside Revegetation*, FHWA-WFL/TD-07-005.

Coordinate with botanists or specialists in restoration of vegetation to select species and application rates of grasses and other plant seed that is native to or compatible with the area. The Federal land management agency will typically have expertise and local knowledge of native and compatible vegetation species. The seed mixture should be diverse to establish growth in the differing soils, slopes, moistures, elevations, aspects and solar exposures present along the project, and different seed mixtures may be needed on a relatively long project. Use soil mulches and mulch blankets as appropriate to protect the disturbed soil and stabilize soil moisture until vegetation becomes established.

When appropriate, include planting containerized native plants, shrubs and trees, or seedlings, to restore the disturbed roadside slopes and blend them with the adjacent undisturbed landscape. If plant materials are limited, prioritize the location and density of plant groupings in those areas most visible to the user, and most beneficial to mitigate visual or environmental impacts.

As applicable, include design specifications for monitoring and control of noxious weeds prior to, during, and for a period subsequent to construction operations.

To assure successful growth, the design specifications should provide for a period of monitoring the viability of the restored vegetation and establishment of new vegetation.

9.5.4.6 Landscape Planting

Landscape and planting treatments should blend and transition with existing features, to simulate natural forms and landscapes.

In a rural environment, design treatments to emulate the existing landscape elements. Consider that a motorist traveling at higher speeds (i.e., at 50 mph [80 km/h]) is less able to recognize detailed landscape patterns. In areas of slower travel speeds (e.g., parking areas, overlooks, vistas), a more detailed landscape planting approach is appropriate to present landscape plantings to the highway user.

Vary the intensity of landscape treatment to be consistent with to the extent of landscape changes and visibility. The most visible and noticeable areas should receive the greatest attention. Recommended treatments for the highest priority locations are plantings, site-specific slope molding, rock cut sculpturing, etc., where less visible locations may receive typical grading techniques and more general vegetation restoration methods.

To blend the new construction with the existing landscape, emphasize landscaping efforts near the base of fill slopes and along the top of cut slopes. Locate larger diameter tree plantings near the top of cut slopes or near the toe of fills. Locate tree species that mature to 4 in

[100 mm] or larger trunk diameter beyond the clear zone and, when applicable, beyond the snow storage area in snow plowing areas.

On higher speed rural roadways, consider individual groupings of one or two native tree species may provide an effective treatment. Greater species diversity together with an appropriate mix of groundcover and shrubbery is recommended in urban situations.

9.5.4.7 Slope Enhancements

As applicable, consider design of embedding boulders, stumps and old logs on cut and fill slopes, outside of the clear zone, to represent natural conditions that exist beyond the clearing limits, using materials that are generally available on the project. Logs and stumps should be randomly located and established to approximate the natural scattering of such material on adjacent undisturbed slopes. Boulders may be embedded individually or in naturally appearing clusters. Boulders should be buried from 1/3 to 2/3 of the diameter into ground to appear as natural rock outcroppings.

9.5.4.8 Ornamental Landscapes

An ornamental landscape is one that is intended to showcase the various plant species and which is typically irrigated, mulched, routinely weeded, organized with shrub or flowerbeds and with delineated grass areas that are routinely mowed. Coordinate with a landscape architect or other landscaping specialists in this field for the design of such areas, as applicable.

9.5.5 DRAINAGE DESIGN

Refer to Section 7.3 for standards, references and guidance for designing roadway drainage facilities. Also refer to *Green Book* Section 4.8.2.

Existing culverts should be inspected and evaluated to determine their performance and remaining service life, both in hydraulic capacity and durability of materials.

Incorporate the design of drainage facilities, and provide design data and coordinate any needed information and reports with the Hydraulic, Structural Design, and the Geotechnical Units regarding drainage features. Design minor drainage structures and appurtenances (e.g., small culverts 48 in [1200 mm] and smaller, end sections, catch basins, inlets) as well as minor drainage channels and ditches using standard methodology as described in Section 7.3.

Large (over 4 ft [1.2 m] diameter) culverts and channels are normally sized by the hydraulic engineer or may be sized by the designer using methodology and oversight provided by the hydraulic engineer. For large culverts and channels, the hydraulic engineer may develop a conceptual or preliminary design with the final design and detailing performed by the roadway designer.

Coordinate the roadway design with the bridge and hydraulic design features and elements.

Coordinate the roadway design and adjust the alignment, grades and slopes to accommodate the natural flow lines of streams and channels, to provide adequate cover for culverts and other drainage considerations, as well as to accommodate drainage facility designs performed by others.

Early in the design process, consult with the hydraulic, structural design and geotechnical disciplines when special drainage design needs are anticipated. Also, discuss the need for various Federal, State and local water quality permits and approvals with the hydraulic discipline early in the design process.

Review and incorporate commitments from the environmental documents and correspondence with fish and wildlife agencies, and review all permit requirements to ensure that all drainage requirements and water quality considerations are incorporated in the roadway design and in the PS&E.

The hydraulic or the structural design discipline specialists provide the technical recommendations or the designs for the larger and more complicated drainage facilities. Coordinate the roadway design and supply adequate information so others can design these facilities. Obtain the existing vertical clearance dimensions of overpass structures to adjust the highway grade, and consider alternative drainage designs that may affect the alignment and grade of the highway.

For every new or existing drainage facility, determine the quantity of flow that the facility must pass. Various methods are described in Section 7.2 to accomplish this.

Consult with the Hydraulics Unit for guidance on the design of ditch relief cross-drains and downdrains that are proposed near retaining walls. Verify the ditch capacity and do not rely on a set interval for cross drains where structures are potentially at risk from water escaping the ditch and flowing across the roadway.

9.5.5.1 Safety Considerations

Design drainage features, including channels, inlets, grates, etc., to provide a safe environment for all users including drivers, pedestrians, bicyclists and other users. Refer to Section 8.1.4 for general roadside safety design guidelines as applicable to drainage features. Also see the AASHTO *Roadside Design Guide* for information on roadside safety in the design of drainage structures.

9.5.5.2 Roadway Ditches and Channels

Design roadway ditches and channels to:

- Intercept and drain surface runoff and small streams away from the roadway into culverts and cross drains, and
- Drain and lower the ground water level below the subgrade.

See Section 7.3.2 for applicable hydraulic standards and guidance.

9.5.5.2.1 Shape and Depth

Design ditch cross sections to accommodate drainage of the roadway and the drainage that flows directly into the roadway ditch from uphill areas. Design the depth of the ditch to meet hydraulic needs and groundwater control needs. Design roadway cut ditches to meet AASHTO, State or county minimum standards for depth and foreslope shape. The minimum depth should be 6 in [150 mm], and preferably 1 ft [300 mm] below the subgrade shoulder for drainage and maintenance purposes.

Ditches should preferably have a smooth and rounded cross section for safety (see the AASHTO *Roadside Design Guide*) and ease of maintenance. Wide ditch bottoms are used in rock fallout areas as well as in projects designed with side borrow.

When hydraulic needs dictate ditches of greater capacity, a flat bottom ditch should be used versus deepening the v-ditch. For additional groundwater control purposes, a deeper "V" shape ditch is preferred.

Drainage channels may require a design by the hydraulic engineer when the accumulated discharge is greater than the capacity of the normal roadway ditch. When applicable, furnish the alignment, grades, cross sections and pertinent information about the existing site conditions to hydraulic discipline for the channel design. As applicable, include provisions for fish habitat and aesthetics in the channel design. Fish habitat includes pools, riffles, boulders, logs and gravels in the streambed and brush and shade on the stream banks. For design of channel changes, obtain guidance and direction regarding specific habitat features to include. If used, include the design of drainage channels and channel changes in the roadway design, and provide typical sections and detailed drawings in the design plans. See Section 7.3.2 for guidance on hydraulic design of open channels.

9.5.5.2.2 Lining Materials

In soils subject to erosion, consider lining the ditches with rock or some other suitable material especially on grades steeper than the natural channels. Refer to *HEC 15, Design of Roadside Channels with Flexible Linings* for additional guidance. Consultant the hydraulics engineer when ditch erosion is a concern and the suitable ditch lining cannot be identified (See Section 7.3.2.5).

9.5.5.2.3 Ditch Grades and Transitions

Design ditch gradients at a minimum of 0.5 percent, with 1 percent being the desired minimum ditch grade where practical. Transition the depth and gradient of ditches at transitions from cuts to fills. Where applicable, design special ditch gradients to provide a gradual depth transition and a uniform gradient from the normal ditch flow line to the inlet of culverts, to convey drainage from cut slope waterways into culvert inlets, in areas of flat roadway or ditch grades and at other locations as needed.

Also consider the need for special gradients for ditches on long crest and sag vertical curves and in superelevation transition areas where ditch grades may be flat for substantial lengths. Evaluate the roadway ditch profile to identify any sags in the ditch line or in shallow fills, and identify and locations where culverts or special ditch grades should be provided to ensure drainage.

9.5.5.3 Culverts

Design culverts to carry the flow of ditches, natural drainages, streams and surface runoffs. Design culverts with consideration for minimum size requirements, minimum and maximum gradients, sediment and debris transport, materials and other factors as described in the following sections. See Section 7.3.2 for hydraulic standards and guidance.

When applicable, include provisions for fish habitat or special aesthetic considerations in the design. Fish habitat features may include baffles, energy dissipation structures within the culvert or at the inlet or outlet, inlet or outlet pools, riffles, boulders, logs and gravels within the culvert and the adjacent streambed, and restoration of vegetation, brush and trees for cover and shade on the adjacent slopes and stream banks.

9.5.5.3.1 Locations

Locate the culverts on the detail topographic map or plan sheets based on the location of natural drainages, streams, swales, low points in the terrain, ditch relief or other drainage considerations. Consider the location of cut and fill slopes, natural drainage flow lines and design cross sections to determine the length of culvert invert, inlet and outlet elevations and available depth for headwater.

Evaluate the ditch profile, transitions from cut to fill, low areas of fill slopes and other aspects of the cross sections and roadway plans and profiles. Streams crossing the alignment, draws and low spots in fills and ditch lines are the obvious sites for culverts. In long cut sections between the obvious culvert locations, space the cross drains such that water does not build up in the ditch line and infiltrates the subgrade or cause erosion problems. There is no set rule for minimum spacing between cross drains because of various soil types encountered and the wide differences in rainfall in different geographical areas. Consult with the hydraulic engineer on a project-by-project basis for recommended minimum and maximum culvert spacing.

9.5.5.3.2 Cover and Roadway Grade

After locating the culverts on plotted cross sections, verify that the roadway grade is sufficient to accommodate the design headwater and minimum cover requirements. Determine the culvert slope, maximum cover and prepare a drainage summary sheet for the plans. See Section 7.3.1 and Section 7.3.6 for more information on culverts.

9.5.5.3.3 Inlet Considerations

Design grated drop inlets, as applicable, to intercept all ditch flow or as a safety measure in roadway ditch lines. In this case, maintain the normal ditch depth at a culvert inlet and provide a traversable grate at the top of the catch basin or inlet.

Design inlets to intercept all runoff and ditch flow to prevent bypass flow from running across the roadway or onto an embankment slope, retaining wall, bridge deck or other structure.

9.5.5.3.4 Outlet Considerations

Locate culvert outlets to closely match natural drainage channels and to minimize erosion at the outlet. Design outlet channels, as applicable, for culvert outlets that are located in cut sections. Design outlet ditches at a gradient sufficient to ensure drainage and sediment conveyance and with configurations that facilitate future maintenance, safety, aesthetics, water quality and restoration of vegetation. When applicable, design outlet sediment detention structures and energy dissipation devices in consideration of the culvert outlet velocity and discharge volume. See Section 9.5.5.9. Include the volume of excavation for outlet ditches in the earthwork design.

9.5.5.4 Pavement Drainage

Design pavement drainage, as applicable, for curb and gutter sections, storm drains, embankment protection curbs, paved ditches, depressed medians and bridge ends. Evaluate pavement drainage using the hydrology and hydraulic standards, references, and guidance described in Section 7.3.3.

In curb and gutter or embankment curb sections, space the catch basins and inlets close enough together so water spread on the traveled way is within the allowable criteria. Spacing will depend on the gutter grade, cross slope and width of the road or gutter. Consult with the hydraulic engineer on spacing design requirements.

At the lower ends of bridges, design catch basins or inlets to prevent runoff from the bridge gutters eroding the fill slopes at the corners of a bridge.

At culvert inlets, determine the need for catch basins and the type of inlet and grates on an individual basis. Consider the amount of runoff to be collected, the capacity of the inlet under various slope and gradient conditions, and the amount and type of anticipated debris; slide material and sedimentation that may plug them. Determine the need for culvert inlets at the upstream approach end of bridges, and where there are curbs or guard walls. In all cases, drainage grates and drop inlets should be designed so that they do not encroach into the traveled way. Drainage grates adjacent the roadway should always be designed bicycle-safe. Where shoulder width, or a bike lane, adjacent to a curb is less than 5 feet [1.5 m], recessed drainage inlets or curb inlets should be used.

9.5.5.5 Downdrains and Pipe Anchors

Downdrains or chutes are generally used to convey the discharge water from the inlets to the embankment toe. Buried pipe downdrains are preferable because the flow is confined, erosion along the embankment slope is minimized, interference with maintenance functions is reduced and they are aesthetically pleasing. Downdrains may be used to convey drainage down high or steep embankments. Downdrain culverts may be used to reduce excessive excavation required to install a new culvert at the bottom of an existing fill. Also, consider downdrains where the culvert outlets on erodible soils. Do not use downdrains for culverts larger than 48 in [1.2 m].

Design the outlets of downdrains to control or minimize scour and erosion.

Pipe anchors should be specified for all above ground downdrain installations. Buried downdrains may require an anchoring system depending on specific site and slope conditions.

9.5.5.6 Storm Drains

Storm drain systems and urban drainage systems require design by or in consultation with the hydraulic engineer. Furnish layouts, lines and grades and topographic mapping and land features for each drainage area. Include detailed storm drain system drawings in the plans.

For further information, see Section 7.3.4.

9.5.5.7 Underdrains and Horizontal Drains

Coordinate with the Geotechnical Unit for design recommendations or conceptual designs for underdrain systems and horizontal drains based on field observations and exploration of subsurface conditions. Incorporate the recommendations in the detailed roadway design and provide detailed drawings as part of the PS&E.

9.5.5.8 Riprap Slope Protection

Obtain recommendations from the hydraulic discipline for the class, thickness and cross section of riprap for slope protection along streams and lakes, and for ditch and channel lining. Incorporate these recommendations and data in the roadway design and PS&E preparation. The location, quantity, surface dimensions, class, thickness and typical section of riprap slope protection should be shown in the plans and specifications. Refer to FLH standard drawings for typical outlet protection details. See Section 7.3.2 for more information on channel stabilization.

Place riprap around culvert inlets and outlets, as necessary, to prevent erosion and undercutting.

9.5.5.9 Energy Dissipators and Outlet Detention Basins

In areas of erodible soils, consider energy dissipators at the outlet of downdrains and culverts with high outlet velocities and in channels at points where the grade flattens. Energy dissipators may be in the form of riprap outlet basins, stilling wells, weirs or concrete structures. These features may be needed for temporary or permanent stormwater management. For more information, see Section 7.3.5.

9.5.6 SOIL EROSION AND SEDIMENT CONTROL

Erosion and sediment control are important considerations in the development of the design of a highway facility. **It is the policy of FLH that highways be designed and constructed to standards that will minimize erosion and sediment damage to the highway and adjacent properties.** See *Green Book* Section 3.6.1.

It is FLH standard practice to determine the need for various types of soil erosion and sediment control features, develop their proposed design, and include the appropriate items of work in the contract. Refer to 23 CFR 650 Subpart B. Also refer to Section 7.5.4 for stormwater management guidance. Roadway construction projects with soil disturbance exceeding 1 acre [0.4 hectare] requires filing a Notice of Intent (NOI) with the U.S. Environmental Protection Agency (EPA) and preparation of a Storm Water Pollution Prevention Plan (SWPPP) including erosion and sediment controls. The type and extent of erosion and sediment control measures will depend on the soils, proximity of adjacent streams or lakes, cut and fill slope magnitudes, topography, hydrology and other factors. Coordinate the design of soil erosion and sediment control features and incorporate input from hydrology and hydraulics, geotechnical, construction and environmental discipline specialists. The techniques for addressing temporary soil erosion and sediment control are commonly described as Best Management Practices (BMP's). Sources of BMPs are:

- *Best Management Practices for Erosion and Sediment Control*, FHWA (Report No. FHWA-FLP-94-005), 1995.
- US Environmental Protection Agency, National Menu of Stormwater BMPs, *Construction Site Stormwater Runoff Control*,
- AASHTO Center for Environmental Excellence (CEE), Construction Practices for Environmental Stewardship, *Erosion and Sedimentation Control*, and
- NCHRP Synthesis 430, Cost-Effective and Sustainable Road Slope Stabilization and Erosion Control, TRB, 2012.
- NCHRP Synthesis Report 70, Design of Sedimentation Basins, TRB, 1980.

Additional references are State regulatory agencies BMPs and State DOT stormwater and erosion and sediment control manuals; refer to the CEE reference above for links to a number of such manuals.

9.5.6.1 Developing Erosion and Sediment Control Plans

The erosion control plans describe the location and type of controls to be implemented temporarily during construction and at the completion of earthwork and drainage construction. The controls should address erosion from the initial clearing stage to the final site stabilization.

The plans should reference FLH *Standard Drawings* and Division Details detailing the construction and installation of the particular control. Special resources (e.g., wetlands, surface waters) must be clearly identified on the plan along with protection measures. Any known problems including highly erodible soils, unstable slopes, etc., should also be identified while developing the plans. In addition, the plans should typically include basic drainage information (e.g., drainage patterns, drainage areas) and the size and location of drainage structures.

As appropriate, include a narrative in the PS&E or supporting documents to assist in plan implementation. The narrative should address issues that may not be clearly conveyed with a drawing. This may relate to construction sequences, maintenance on the controls, stabilization timing or other critical factors. The narrative may consist of brief notes and comments while an in-depth discussion may be provided in the Storm Water Pollution Prevention Plan (SWPPP).

9.5.6.2 Erosion and Sediment Control Phases

Erosion control plans should address the different stages of construction:

- Initial clearing and grubbing,
- Intermediate grading and drainage, and
- Final stabilization of the site.

The initial phase should address the perimeter controls required during the initial clearing and grubbing stage to prevent sediment from leaving the site. The intermediate grading and drainage phase should reflect the controls required during earthwork construction. This includes the point from grubbing operations until final grade is reached. The third phase of erosion control is the final stabilization of the site and installation of the permanent controls.

Consider the need for initial perimeter controls such as:

- Filter barriers,
- Diversion structures, and
- Settling structures.

Consider the need for intermediate controls such as:

- Temporary slope drains,
- Temporary channel linings,
- Mulching,
- Temporary and permanent turf establishment,
- Check dams,
- Settling and detention structures, and
- Inlet and outlet protection.

Consider that turf establishment or stabilization may be performed in incremental stages on cut and fill slopes, and may need additional quantity for multiple applications.

The last phase of erosion control consists of final site stabilization. This includes final stabilization of the slopes and waterways, stabilization of outfalls and other disturbed areas. Consider the need for final controls such as:

- Permanent turf establishment,
- Channel linings,
- Temporary slope drains,
- Check dams, and
- Outlet and inlet protection.

Both temporary and permanent erosion control measures must be considered during the design and all necessary features incorporated into the contract plans and specifications.

Temporary control measures are those features temporarily installed for use during construction activities. Upon project completion they are generally removed and disposed. The design for temporary control measures (e.g., silt fences, brush barriers, diversion channels, sediment traps, check dams, slope drains, berms) are contained in the *Best Management Practices for Erosion and Sediment Control Manual*, FHWA-FLP-94-005.

Division Standard Details detailing the more common temporary control devices are available and should be included in every project plans set containing construction activities that could possibly affect soil degradation or water quality.

Permanent control measures are those features installed as part of the highway to minimize scour, sedimentation, erosion, etc., during the facility life. Refer to the roadway drainage features described elsewhere in this chapter.

See HEC 22 for details and information relative to permanent inlets, downdrains, grates, curbs, gutters and other similar roadway drainage designs useful in controlling erosion. Chapter 7 lists additional information sources applicable to the design of debris control structures, riprap or slope protection installations, energy dissipator systems, ditch, channel linings, and similar structures.

9.5.7 PARKING AND REST AREAS

On FLH projects, parking and rest areas are typically constructed for the scenic, recreational and cultural enhancement of the highway facility. Coordinate the parking area design with the partner agency and if appropriate with local officials and business owners to identify acceptable locations for parking and to determine the geometry, capacity, design vehicle type and other related requirements. Information on rest area design is provided in the *Guide for Development of Rest Areas on Major Arterials and Freeways*, AASHTO, 2001.

Design parking and rest areas to accommodate persons with disabilities. Refer to the *Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities (ADAAG)* for the applicable standards. The *Green Book* contains information on sidewalk curb ramps in Section 4.17.3. Refer to Section 9.3.16.3 for accessibility requirements applicable to the design of parking areas and passenger loading zones.

Refer to Section 9.3.9.3 for design of parking lanes, and Section 9.3.9.9 for parking pullouts.

Determine the appropriate design vehicle and design parking areas to accommodate all circulation and parking maneuvers. Design intersections within the parking area to provide safe traffic movement. See Section 9.3.19 for parking lot layout considerations.

9.5.8 ROADWAY APPURTENANCES

Refer to Section 8.5 for design of traffic barriers and end treatments, and to Section 8.7 for design of signs, traffic signal installations and traffic control devices.

9.5.8.1 Highway Lighting Systems

As applicable, consider providing illumination to facilitate traffic operations and to improve traffic safety during nighttime hours. Where used, design highway lighting to enable the driver or pedestrian to better recognize important details in the roadway or parking area quickly, accurately and confidently. Coordinate the selection of lighting hardware and components with the maintaining agency to ensure compatibility. An engineer with expertise in this specialty should design highway lighting systems.

Refer to Section 8.7.3 for warrants and design of highway lighting systems. Also, refer to the *Roadway Lighting Design Guide*, AASHTO, 2005.

9.5.8.2 Fencing

Design fencing to separate highway users from livestock encroachment, and to separate pedestrian activity from vehicular travel where applicable. Coordinate the needs for wildlife passage or restriction in the fencing design. Generally, fencing is designed to replace an existing fence and is usually constructed on the right-of-way line through private lands. Some States have laws requiring fence for all State highway right of way. Check the applicable State or local regulations during the design process. Coordinate with the Right of Way unit to address fencing in the right-of-way negotiations and documents. Fencing type and location must agree with the right-of-way documents, or otherwise be agreed by the property owner as a right-of-way consideration for the project.

When the right-of-way line has many abrupt irregularities over short distances, fencing runs should have continuous alignment, but should never encroach upon private land. Minimize the number of different fence types on a particular project.

Fence type selection depends on the character and density of adjacent development and cost of installation and maintenance. In general, chain link fence should be installed in urban and suburban areas, and woven wire or high-tensile fence in rural areas. Consider chain-link fence where the following situations exist adjacent the highway:

- Along steep embankments or drop-offs such as a box culvert headwall, that are adjacent to a pedestrian facility or sidewalk or bicycle path,

- Industrial areas,
- Residential developments or where development is expected to occur,
- Military reservations,
- Schools and colleges,
- Recreational and athletic areas, playgrounds, and
- Other locations where a high level of protection to prevent encroachment on the right-of-way is necessary, or is requested by the maintaining agency.

Chain link fence should not be located where it restricts sight distance, particularly on curves. Also consider that chain link fence may increase snow drifting in some areas, and may collect waste paper and trash.

Generally, provide a 6 ft [1.8 m] high chain link fence if needed to prevent encroachments in urban or suburban areas, and to discourage climbing over the fence. A 4 ft [1.2 m] height may be used if conditions are less critical or if a lower height is needed to allow sight distance, or to meet right-of-way agreement considerations. In some locations it may be appropriate to consider improving the aesthetics of chain link fence by adding a colored epoxy coating or privacy slat inserts.

Wire fencing types apply in all rural areas and in some suburban and urban areas where developments along the right of way are infrequent and future development is not anticipated. The fencing may consist of barbed wire, woven wire and other metal fabric types. Woven wire and high tensile wire fence may not be adequate to retain livestock, and such applications should be specifically designed and coordinated with the property owner and addressed during right-of-way negotiations.

Determine the fence height and wire spacing, which may vary depending on the primary purpose of the fence (e.g., controlling cattle, sheep, or wildlife). Wire fencing may need to be as much as 10 ft [3.0 m] high if necessary to control elk and deer. In some western States, the special design of the wire spacing and height is important to minimize potential hazard for deer, elk or antelope crossings.

Metal right-of-way fencing can interfere with airport traffic control radar. When fencing in the vicinity of an airport, review the FAA permit to determine if the fencing will create radar interference. An alternate type of fencing may be appropriate in this case.

Provide gates, where required, and at the locations stated in the right-of-way agreements or as agreed to during the development of the project. Also provide gates, and locks if required, where needed for access by maintenance personnel. Designate the type, size and location of gates on the plans.

9.5.8.3 Cattle Guards

The design of cattle guard substructures must be concrete, timber or steel. The width and type may need to be documented in a right-of-way agreement or be agreed to during the project plan-in-hand review.

At a minimum, cattle guard widths should be shoulder-to-shoulder, or traveled way widths plus 8 ft [2.4 m] whichever is greater.

Cattle guard wing guards are usually not crashworthy and should be placed outside the clear zone, or treated as an exception to the roadside design.

9.5.9 RIGHT-OF-WAY AND UTILITY CONSIDERATIONS

Refer to Chapter 12 for Right-of-Way and Utility guidance. Also see *Green Book* Section 3.6.4.

The existing right-of-way should be considered and evaluated as a design constraint and should act as a design control similarly to all other environmental, social, economic, aesthetic and cost control factors. There may be certain projects where property values or the land's intrinsic values are so high or that its acquisition is so contentious that designing within either the existing right of way or a specified right of way limit may be necessary.

Right-of-way limits may be established following the completion of the highway design and determination of construction limits, including all earthwork, drainage, approach roads, walls, structures, and all other features affecting physical disturbances are determined.

The minimum right-of-way width is the horizontal distance from the centerline to the edge of construction limits for clearing. It is always desirable to provide some additional area to accommodate minor changes during construction and to provide space for normal construction and maintenance operations.

Refer to Chapter 12 for the standard minimum widths and the desirable distance from the clearing limit to the right-of-way line.

The clear zone recovery area should receive consideration when establishing new right-of-way limits. Good engineering judgment is essential in this area to determine when taking a prudent right of way equals the need for a portion of the theoretical recovery area.

The right-of-way should provide for maintenance, control of access, utilities, and future widening, control of adjacent drainage and vegetation for ensuring sight distance and aesthetics. The same land is often desirable for dwellings, farming, commercial or recreational purposes. Hence, right-of-way is seldom ideal but is usually a compromise.

It is not mandatory to provide right-of-way for new utilities. However, it is the usual practice to accommodate them when they do not conflict with the primary function of the roadway. Construction often causes the relocation of utilities located with the existing right-of-way. It is a requirement that the new right-of-way must provide areas for their relocation or the development of easements specifically to accommodate the utility.

Poles or other surface utility relocations should be beyond the clear zone area or behind guardrail. Design underground utilities such they are placed outside of the roadway, either in the foreslope, ditch, backslope, between the construction limits and right-of-way, or preferably outside the right-of-way line within a utility easement. Easements for pole lines usually require a minimum of 16 ft [5 m] of width to accommodate the cross arm and anchor systems and to provide for control of vegetation under the wires.

Right-of-way limits should be outside drainage control structures, channel changes, riprap, stilling pools, etc., constructed above or below the roadway allowing space to maintain or repair them. The right-of-way should extend at least 10 ft [3.0 m] beyond these facilities. It is preferable to obtain right-of-way (fee title) to cover these installations but in some cases a permanent maintenance easement may suffice. A permanent maintenance agreement will often cost nearly the same to acquire and administer as to acquire the right-of-way outright, but may be advantageous to the acquiring and highway-owning agency if the right-of-way acquisition is very contentious.

States, counties and other cooperating agencies generally have established standard widths for highway right-of-way. Contact the highway-operating agency to determine the standard minimum widths and any other applicable criteria.

9.5.10 ENVIRONMENTAL PROTECTION AND ENHANCEMENTS

Coordinate with the environmental discipline for the design of environmental protection and enhancements that are included in commitments made as part of the environmental document. Such enhancements may also be requested and appropriately added as part of the final design process, in addition to commitments included in the environmental document. Enhancements may include special features and details for wildlife connectivity, fish passage and accommodations for wildlife crossings, adjustment of horizontal and vertical alignment to avoid sensitive areas, to fit topographical features, and to protect scenic and visual quality. Enhancements to the roadway cross section may include:

- Adjustment of the typical slope ratio to enhance new slopes or protect existing ones;
- Use of curb and closed drainage systems to minimize the width of roadside ditches;
- Use of retaining walls;
- Riparian enhancements and wetland or wetland buffer restoration or creation;
- Slope design for viewshed and scenic enhancement and vegetation management;
- Selection of aesthetic traffic barriers and to allow visibility of the roadside;
- Preservation of significant roadside features such as rock outcrops and vegetation;
- Use of landscaping for screening or earth berm buffers;
- Preservation and retrofitting of historical features such as culverts, walls, curbs;
- Incorporation of historical features at interpretive facilities, rest areas, overlooks; and

- Use of architectural landscape design details.

Refer to the FHWA "Critter Crossings" and the Forest Service "Wildlife Crossings Toolkit" for wildlife crossings guidance and design references. Refer to the FWS "FishXing" for fish passage through culverts guidance and design references. Also refer to *Management and Techniques for Riparian Restorations: Roads Field Guide. Vol. I and II*, FS, 2002.

9.5.11 CONSTRUCTION CONSIDERATIONS

Construction considerations include work sequencing and constructability. If a route is to be constructed in phases due to programming of funds or other considerations, coordinate closely with the Planning and Programming Unit to develop the highway design and PS&E for implementing the most effective strategy and sequence of projects to deliver the overall route.

9.5.11.1 Construction Sequencing

Consider construction sequencing in the design of features that may need to be constructed in a specific order to enable traffic management through the work zone, utility accommodation, environmental restrictions, earthwork, drainage, structural considerations or other factors. At a minimum, the design must reflect an orderly sequence of construction such that all design and environmental commitments can be efficiently accomplished. Preferably, the design should demonstrate a comprehensive analysis and design details for a fully optimized construction sequence that appropriately balances the overall cost, time, resources, quality, stakeholder and public concerns and environmental protection.

As applicable, provide construction sequencing details, or applicable special contract requirements, or both, in the design and PS&E documents that depict the intended construction sequencing.

9.5.11.2 Constructability

Constructability refers to the practicality of the design to be bid, built and administered during construction. In order to receive fair and competitive bids the prospective bidders must clearly understand the design and the construction requirements. Avoid using unclear design requirements or nebulous notes, descriptions and requirements than cannot be readily quantified for basis of bidding and contract administration purposes.

Constructability also includes the consideration in the design for earthwork balance, availability of the materials and equipment needed to perform the work, construction access, ability to comply with any restrictions while performing the work, etc. Coordinate closely with the Construction Unit throughout the design process to include input for developing the design and contract provisions and to facilitate a thorough review of the design and PS&E.

9.6 PLANS SPECIFICATIONS AND ESTIMATE (PS&E) DEVELOPMENT

This section prescribes procedures and policies for the preparation of the plans, specifications and cost estimate (PS&E) and supporting design documentation for performing the work to construct a highway facility. The following addresses the PS&E format and decisions made for PS&E preparation, within the constraints imposed by earlier environmental and engineering studies and decisions.

Coordinate with other technical disciplines and cooperating agencies as applicable to obtain specific information, input, design data and other contributing portions of the design documents for inclusion in the completed PS&E.

Also, refer to the FHWA FAPG 23 CFR 630B, *Guidelines for Preparation of Plans, Specifications and Estimates*.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.1 PS&E PACKAGE

Provide the following items for a standard PS&E assembly:

- Plans,
- Specifications including the Standard Specifications (FP-XX) and the Special Contract Requirements (SCRs),
- An engineer's estimate and unit cost analysis to perform the construction,
- An estimated construction schedule and contract time analysis,
- Design data that is made available to the bidders (e.g., GEOPAK output reports, hydraulic data, geotechnical data, cross sections), and
- Supporting information for the geometric design and PS&E, construction stakeout and control, and engineering data for construction management.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.2 ALTERNATIVE PS&E DEVELOPMENT AND CONTRACTING OPTIONS

When applicable, provide the following design and PS&E development options:

1. **Design-build.** Design-build is a project delivery method that combines the final design and construction together under the same contract. Normally, the decision to select a project for design-build will be made during the planning and programming phase. For design-build, typically develop the highway design and PS&E to no more than a preliminary (30 percent) level for contracting. Refer to Chapter 4 for guidance on requirements for development of the preliminary design package. Coordinate closely with the Acquisitions Unit for special guidance on the development of the design and PS&E documentation for design-build projects. For additional information on design-

build refer the AASHTO *Guide for Design-Build Procurement*, 2008 and "Public-Private Partnerships" from FHWA.

2. **Alternative Bid Schedule Packages.** Alternative bid schedules provide several increments of the design and PS&E package within the same solicitation documents. Include all necessary details, quantities, specifications and cost estimates for the entire project package as well as for one or more lesser increment packages, such that any one of the alternative bid packages may be awarded depending on the funding available and the amount of the bids received. The design of the lesser packages must be fully compatible and able to be constructed within their lesser scope, such that the alignment, earthwork balance, roadway geometry including connections with the existing roadways, environmental commitments and other design requirements are fully provided for within each of the alternative bid schedules. Provide alternative bid schedules for design package increments that are estimated to cost:

    a. Approximately 10 to 15 percent below the program amount,

    b. At the program amount, and

    c. Approximately 10 to 15 percent above the program amount.

3. **Options.** When applicable, provide a base design and PS&E package, with provision for additional work to be included in the project either at the time of award, or possibly at some later time, depending on the funding available at these respective times and the amount of the bids received. Options may be developed for increasingly additive work, or for one or more additional project features that are independent of each other, within the contract. The PS&E must be very clear regarding what is included within each option, to avoid potential contract administration conflicts if a particular option is exercised or not.

9.6.3 PS&E DEVELOPMENT AT VARIOUS STAGES OF DESIGN

Develop the PS&E to an increasing level of detail during each stage in a project's iterative design process. The following are the PS&E development requirements for each major point in the design process.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.3.1 Conceptual Studies and Preliminary Design

Refer to Chapter 4 for the design development activities at the conceptual and preliminary design phase. The plans and cost estimate are typically developed to the 30 percent level for preliminary design.

9.6.3.2 Intermediate Design

During the intermediate design phase, the PS&E package should be developed to the 50 percent level. The intermediate design PS&E package should include cross-sections, major pay items with their associated quantities, major design details (e.g., intersections, turnouts, large culverts, guardrail, walls), and any items affecting permits and right-of-way (ROW) acquisition (e.g., erosion control plan). The completed intermediate design, with review comments incorporated and revisions, should enable the development of final right-of-way plans and descriptions, final structural designs, final retaining wall designs, final hydraulic and geotechnical designs and for all major elements that other technical disciplines will develop or finalize as applicable for later inclusion in the PS&E.

Consider the following information to develop the intermediate design PS&E package:

- Summary of comments provided at the preliminary design (30 percent) review,
- Preliminary Engineering Study Report, and
- Preliminary design plan and estimate.

Activities required to develop the intermediate design PS&E package include:

- Document the resolutions to the preliminary field review comments and revise the PS&E package accordingly.
- Update the design exception portion of the Highway Design Standards Form (see Section 9.1.3).
- Incorporate interdisciplinary, cross-functional team (CFT) (e.g., hydraulic, geotechnical) and cooperating agency recommendations into the plans.
- Develop design drawings and quantities required for environmental permitting.
- As needed, provide design information to the Right-of-Way Specialist for the development of the draft right-of-way plans and easement plats.
- As applicable, for projects exceeding $5 million in construction costs, perform a Value Engineering (VE) study. Incorporate any approved VE recommendations into the PS&E package.
- Refine the preliminary cost estimate (from the preliminary design) to reflect all intermediate design changes.
- Prepare a draft set of special contract requirements, as needed. This is recommended, but not required, at this point.

Following completion of the intermediate design PS&E package, perform an intermediate design (i.e., 50 percent) review as described in Section 9.6.4.2.

9.6.3.3 Intermediate Design Revisions

During this phase, revise the PS&E package to sufficient detail to apply for applicable permits, to allow for preliminary roadway staking and to prepare final right-of-way and utility plans, as applicable.

Consider the following information to perform the intermediate design revisions:

- NEPA document,

- The summary of comments provided at the intermediate (i.e., 50 percent) design external review, and
- The intermediate design PS&E package.

Activities required for the intermediate design revisions include:

- Document the resolutions to the intermediate external review comments and revise the PS&E package accordingly,
- Incorporate any environmental commitments from the NEPA document,
- Update the Highway Design Standards Form and document any design exceptions (see Section 9.1.3.4), if not completed previously.
- Finalize construction limits,
- Prepare draft environmental permit applications as needed. Develop the plans to sufficient detail to enable preparation of applications for permits,
- Provide revised cross-sections and staking data (e.g., slope stakes, centerline) to the survey discipline, if staking for Plan-in-Hand (PIH) review will be required, and
- Provide the revised intermediate PS&E package to the right-of-way specialist, as applicable, for development of final right-of-way and utility plans. See Chapter 12, Right-of-Way and Utilities.

9.6.3.4 Plan-in-Hand (PIH) PS&E

During this phase, develop the PS&E package to the 70 percent level. The Plan-In-Hand (PIH) PS&E should include semi-final plans representing a draft of each plan sheet, except certain special plan sheets (e.g., structural design details) to be included in the final plans. Develop all major design elements (e.g., grading, detail sheets of parking areas and road intersections, drainage, structures, erosion control, traffic control, cross-sections) a draft set of special contract requirements and a complete construction estimate including all pay items that are shown on the plans with their associated quantities. Verify that the proposed right-of-way and utility plans provide for all the final design and construction requirements so that acquisition of the right-of-way and utility adjustments, as applicable, may be expediently accomplished.

Information used to develop the PIH PS&E includes the revised intermediate PS&E package (revised in accordance with Section 9.6.3.3).

Activities required to develop the PIH PS&E package include:

- Develop a proposed set of special contract requirements,
- Determine all pay items to be used in the contract and calculate the associated quantities,
- Provide quantity tables and a summary of quantities in the PS&E package,
- Further develop the plan sheets to adequately support the work items called out in the plans,

- Compile a complete engineer's estimate for all work items called out in the plans, and
- Update the Highway Design Standards Form and document any design exceptions (see Section 9.1.3.4), if not completed previously.

Following development of the PIH PS&E package, perform a PIH (i.e., 70 percent) design review according to Section 9.6.4.3.

9.6.3.5 Final Design

During this phase, revise the PIH PS&E package according to the PIH field review comments and develop the PS&E package to the 95 percent level.

Consider the following information to develop the final (i.e., 95 percent) PS&E package:

- The summary of comments provided at the PIH field review.
- The Plan-in-Hand (PIH) PS&E package.

Activities required for development of the PS&E package include:

- Document the resolutions to the PIH field review comments and revise the PS&E package accordingly.
- Provide documented comments resolutions to the attendees of the PIH field review.
- Incorporate all final design details into the plan sheets.
- Finalize the special contract requirements.
- Finalize the proposed construction schedule to determine the contract time or anticipated construction completion date.

Following completion of the final (i.e., 95 percent) design PS&E package, perform a final PS&E review according to Section 9.6.4.4. Following that review, advance the package to 100 percent and prepare all documentation to submit to the Acquisitions Unit as described in Section 9.6.4.5.

9.6.4 REVIEWS

Perform office reviews or on-site field reviews at milestone phases applicable to the specific project to ensure that the design and PS&E reflect and are consistent with contextual values and with Federal, State and local stakeholder's goals, objectives and standards. As appropriate, conduct multi-disciplinary and multi-agency inspections, as well as specialized meetings with a single discipline to resolve a specific problem. Include all cooperating agencies and appropriate FLH Division staff, and other appropriate stakeholders in each milestone review.

Before reviews, perform a check of the highway design and PS&E, using the applicable quality control process and design file documentation. Check the overall technical soundness of the work and appropriate application of design and PS&E standards. When applicable, after revisions from the initial check are completed a senior highway designer or Highway Design Manager (HDM) should perform a secondary review using the applicable quality control process and design file documentation. After revisions from the quality control checks are completed, the interdisciplinary project team and partner agency reviews the PS&E with the intent to:

- Evaluate how all work products of each function fit within the design and PS&E as a whole,
- Ensure that the design and PS&E conforms to the overall project scope, and
- Ensure that the design and PS&E incorporates commitments made to partners and regulatory agencies.

Prior to conducting field reviews, provide the participants with the appropriate information (e.g., plans, specifications, cost estimate, exhibits, visualizations) sufficiently in advance for them to schedule their time to perform a comprehensive review of the information and to formulate their input or questions, prior to the onsite meeting. To expedite the field review, arrange in advance to provide an appropriate level of stakeout (e.g., marking or flagging the centerline, proposed slope stakes, structural foundations), as applicable.

During reviews communicate the proposed design to the cooperating agencies and other stakeholders, and solicit comments from all participants to ensure that the design is being developed with regard to its context, and in compliance with the intended scope and social and environmental commitments. Provide an opportunity for free and open discussion that encourages early and amicable resolution of controversial issues that may arise during the development of the design and PS&E package, among the interdisciplinary project team, cooperating agencies, and other stakeholders.

During field reviews verify data and check the design as developed in the office against field conditions to identify any discrepancies and minimize conflicts and changes during construction.

In all cases, document the conclusions reached at the field reviews and distribute to the interested parties.

The following sections describe reviews for various phases of the design development.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.4.1 Preliminary Design (15 or 30 Percent) Review

The preliminary design review covers the preliminary design and results in evaluation and resolution of the major design features for a project (e.g., horizontal and vertical alignments, typical section, and access control). It typically represents a level of design detail sufficient to support the environmental analysis, documentation and decisions, which is typically some level within the 15 to 30 percent range of development. The preliminary design review typically includes both an internal review and an external (i.e., partner agencies and stakeholders) review, and will typically include an on-site field review. These may be held separately or concurrently.

The purpose of the review is to evaluate and resolve the roadway geometry, safety considerations, and environmental impact mitigation and cost effectiveness of the proposed improvement, to support completion of the environmental document and decision-making process. The review should also identify the revisions needed to bring the roadway design, plans and estimate to a full 30 percent stage. The field review should also include verifying the mapped features and spot-checking the topography, particularly in areas of narrow roadbed bench width or constrained right of way.

The level of detail for the preliminary design review depends on the scale of proposed improvements and may be different for RRR projects than for reconstruction or new construction projects. The information available for the review (deliverables) includes detail maps or plans and profiles showing preliminary alignments and plotted cross sections of the mainline and major intersecting roadways for all alternatives being considered and preliminary construction cost estimate. Provide exhibits and visualizations of the project alternatives, if available. The plans and cost estimate are typically developed to the 15 percent level for an initial line and grade review, if applicable, and to 30 percent level for preliminary design.

As part of the review, it is essential to identify and document any exceptions to standards, along with any associated hazards or risks so that all parties are aware of the potential consequences of the decisions. See Section 9.1.3.

9.6.4.2 Intermediate Design (50 Percent) Review

The result of the intermediate design review is the determination of the design features affecting the limits of disturbance for a project (e.g., horizontal and vertical alignments, cross sections, major approach roads, intersections, parking areas, earthwork, and type, size location of structures and retaining walls). On some projects, an intermediate design review may not be necessary to complete the design.

The information provided for the review includes:

- The 50 percent plans containing detail plans and profiles showing alignments, grades, construction limits,
- The plotted cross sections,
- Draft Special Contract Requirements, and
- The engineer's cost estimate.

The level of detail of the review depends on the scale of construction proposed (e.g., RRR to new construction).

The purpose of the review is to resolve all aspects of the roadway geometry and design features that affect the physical disturbances, safety considerations, environmental impact mitigation and cost of the proposed improvement, to ensure that the design and PS&E:

- Is context sensitive,
- Minimizes or avoids resource impacts,
- Mitigates environmental impacts (wetlands, etc.),
- Addresses safety,
- Has correct roadway geometrics,

- Is cost-effective and constructible,
- Integrates into the design the environmental mitigation and stipulations, and
- The PS&E package is being developed with appropriate design and drafting standards.

The extent of all proposed construction limits for the roadway footprint is typically a key issue for most Federal land management agencies that requires resolution at this stage.

For the review, identify and document any exceptions to standards and the associated safety risks so that all parties are aware of the ramifications of the decisions.

The review may consist of an office review, or a field review at the project site, or both. The external review should preferably occur after an internal review is performed, and preferably after the PS&E package has been revised as necessary based on comments from the internal review. Provide copies of the plans, cross-sections and Special Contract Requirements to the external agencies sufficiently prior to performing the external review. For Forest Highway projects, the external review will typically include interdisciplinary project team members and cooperating agency representatives. For Park Roads projects, the attendees will typically include interdisciplinary project team members, Park representatives and Denver Service Center representatives, as requested. Prepare additional presentation materials and visualizations as necessary to convey design information at the external review. Following completion of the external review, prepare a report summarizing accomplishments and decisions made during the review.

9.6.4.3 Plan-In-Hand Design (70 Percent) Review

The PIH design review consists of a review of the 70 percent (semi-final) plans and specifications for the proposed project. The primary purpose of this review is to resolve all the design elements and other special conditions for finalization and inclusion in the PS&E package. The information required for the review is:

- Semi-final plans (all anticipated plan sheets, completed to 70 percent stage)
- Plotted proposed cross sections,
- The draft Special Contract Requirements, and
- The current engineer's cost estimate.

Since the line and grade, construction limits, drainage features and other roadway design geometry has been reviewed and presumably resolved at earlier stages, this review is primarily focused on final design and specification details, finalization of minor roadway appurtenances and construction sequencing details.

At this stage, the design should conform with all of the governing criteria, including input from geotechnical and hydraulic reports, environmental documents, safety requirements and other matters pertinent to the project. Resolve those items affecting the plans or Special Contract Requirements, or make arrangements for obtaining the necessary data and decisions for their resolution.

For the review, identify and document any exceptions to the standards, and the associated safety risks, so that all parties are aware of the ramifications of the decisions.

The review normally consists of a field review at the project site. The external review should preferably occur after an internal review is performed, and preferably after the PS&E package has been revised as necessary based on comments from the internal review. Provide copies of the plans, cross-sections and Special Contract Requirements to the external agencies sufficiently prior to the external review. Typically, the review includes similar participants as the Intermediate Design (i.e., 50 percent). Review described in Section 9.6.4.2. Prepare additional presentation materials and visualizations as necessary to convey design information at the external review. Following completion of the external review, prepare a report summarizing accomplishments and decisions made during the review.

After the review has been completed, revise the PS&E package to resolve the comments of the participants. Document resolutions and provide to the attendees of the field review. If necessary, update the Highway Design Standards Form and document the approval of any design exceptions.

Following the review, the designer should have all input necessary to prepare the final plans, Special Contract Requirements and complete the engineer's estimate for the project.

9.6.4.4 Final PS&E (95 Percent) Review

This consists of the final PS&E review phase, both internally and externally. In some cases, the internal and external reviews described below are combined and done simultaneously. After revising the plans and Special Contract Requirements to show changes from the previous reviews, the PS&E package is typically distributed internally for a final review by Division staff specialists to ensure consistency with programming, environmental, geotechnical, hydraulics, bridge or other project requirements. A 95 percent PS&E Review comment resolution meeting should be held, if comments need to be discussed and reconciled. After the PS&E is reviewed internally and the comments addressed, or concurrently if necessary, the PS&E package should be distributed externally to the highway facility owner and Federal land management agency for review and concurrence, and may also be distributed to other stakeholders and interested agencies for their review and comment. Depending on the thoroughness of the previous reviews, an on-site inspection may or may not be required. In either case, resolve all comments received concerning the proposal so that the project may proceed to solicitation for construction.

Incorporate the recommendations from any final geotechnical reports and permit requirements, and stipulations from right-of-way and utility agreements. Ensure that all necessary permits, agreements and other requirements for advertisement of the project are completed and are addressed in the PS&E. Provide the title sheet of the plans to the agency and individuals listed in the signature block for signature, or obtain a letter of approval for the signature.

9.6.4.5 PS&E Approval and Authorization (100 Percent)

This consists of final approval, sign-off of the PS&E and authorization for solicitation of the contract package. The purpose of this activity is to advance the PS&E package to the 100 percent level so that the PS&E is ready for advertisement, and to deliver the PS&E and associated documents and necessary data to the Acquisitions Unit. During this activity the plans are signed and all specifications, estimates, certifications and other documentation are approved. The funding authorization and obligation documents are also approved. The completion of this activity allows the solicitation of the contract package.

Information needed to perform the PS&E approval and authorization (100 percent) includes:

- The summary of comments provided from the final PS&E (i.e., 95 percent) review.
- The final design PS&E package.

Activities required for the PS&E approval and authorization include:

- Document the resolutions to final (i.e., 95 percent) PS&E review comments and revise the PS&E package accordingly.
- Finalize any remaining details necessary to complete the PS&E package and compile supporting documentation for approval.
- Perform a final QC/QA review. This review typically evaluates the completeness of the documentation, forms and PS&E package before submittal to Acquisitions. Revise the documentation, forms and PS&E package as necessary.
- Obtain all required signatures and approvals of the PS&E, funding authorization and obligation documents. Minor design revisions may be necessary to resolve any final comments or conditions from the approving officials.
- Deliver the final PS&E package and supporting documentation to the Acquisitions Unit.

9.6.4.6 Value Engineering

FHWA Order 1311.1A, *Value Engineering*, describes policy relating to value engineering in design and construction and the review of designs and standards. **It is FLH policy to employ VE when there is a reasonable potential for a significant ratio of savings to the cost of the VE analysis.** A VE study should be considered on all projects where there is a reasonable potential for a ratio over 5:1 of implemented savings to VE cost, or with an estimated construction cost over $10 million, or are complex, or include major structures.

As applicable, perform a VE study and apply recognized value engineering techniques by a multi-disciplined team to:

- Identify the functions of the designed products or services,
- Establish a worth for those functions,
- Generate alternatives through the use of creative thinking, and
- Provide the needed functions to accomplish the original purpose of the project, reliably and at the lowest life-cycle cost without sacrificing safety, quality and environmental attributes of the project.

VE is typically applied at the intermediate stage of design; however, studies are applicable as early in the design process as feasible.

Prepare a report of the study findings and recommendations. Document the VE results and probable cost savings, if any, from implementation of the VE study recommendations into the highway design.

For guidance on VE practices refer to Value Engineering from FHWA. Also, refer to AASHTO *Guidelines for Value Engineering*, 2nd Edition, 2001.

For Park Roads and Parkways projects a value analysis may be required. Refer to the NPS Value Analysis Report Template for performing these analyses.

9.6.5 PLANS

Provide plans consisting of an organized series of drawings containing the necessary engineering data about the location, character and dimensions of the work, including layouts, roadway geometry, cross sections, structures and related details. The plans should not encompass material that is more appropriately included in the specifications. The plans, together with the specifications, should contain all of the data required for the contractor to submit a bid, stake and construct the project.

Project plans should be prepared using the guidance provided in the following sections and the Division Supplements.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.5.1 Format

It is FLH standard practice to prepare all plan sheets using an approved CADD system. MicroStation from Bentley Systems, Inc. is the current FLH standard CADD system. Rare exceptions (e.g., conceptual drawing, architectural renditions, emergency projects) may be necessary to accommodate special needs of internal sections or cooperating agencies. When manual drafting becomes necessary, it should be accomplished in a manner that duplicates the appearance of CADD drafting to the extent possible.

The standard size of plan sheets should be approximately 11 in by 17 in [279 mm by 432 mm]. The standard size plan sheets should provide approximately a 1.4 in [35 mm] margin for the binding on the left edge, a 0.3 in [7 mm] margin on the right edge and a 0.3 in [7 mm] margin on the top and the bottom. This accommodates an effective sheet size of approximately 10.4 in by 15.3 in [265 mm by 390 mm]. For plotting purposes, the useable sheet dimensions may be slightly reduced (e.g., 10.7 in by 16.7 in [271 mm by 423 mm] with 1.1 in [27 mm] left margin and 0.2 in [5 mm] margins on the right, top and bottom). Margins may be reversed for double-sided (duplex) printing.

When applicable, provide abbreviated “book size” plan sheets, which may be as small as 8.5 in by 11 in [216 mm by 279 mm], and may be used provided they give sufficient information to describe and construct the project. Consider abbreviated plans for very low complexity projects such as minor emergency relief, safety improvements, and RRR.

Refer to Division Supplements for CADD plan sheets format and for the organization of plans. Consider the complexity of the work and provide the format accordingly.

9.6.5.2 Drafting Standards

Refer to Division Supplements for drafting standards applicable to each Division.

The following primary drafting requirements apply:

- Adhere to the applicable drafting standards for uniformity and quality,
- Use care in laying out details and locating text on plans to clearly relate the text to the applicable details,
- Provide sufficient notes on plan drawings to clarify the drawing and provide necessary information for a complete understanding of the work,
- Notes must be clear, concise, descriptive and as brief as possible to convey the message,
- Do not duplicate instructions or requirements covered in the Specifications on the plans,
- Use the correct text font, style and size, with proper spacing between figures, symbols and words, and
- Use the correct line level, line style, color, and weight and in the correct relationship to other lines on the plans.

The following general drafting guidelines apply to all plans:

- Do not use “Station” or “Sta” as a prefix to station numbers. Any numbering including a plus sign (e.g., 92+95) is understood to be a station number;
- Use a Note for general information that is relevant to the entire sheet. Do not use the term “General Notes.” When possible, place Notes on the right hand side of the sheet;
- When placing text on plan sheets, do not crowd other information. Carefully choose a place for the notes that is as close as possible to the point of application;
- Use standard cross-section indicators;
- Do not use the letters “I,” “O,” “N” or “Z” as cross-section indicators. “I” and “O” resemble symbols shown on drawings and “N” and “Z” are the same shape, but oriented 90 degrees. When at the end of the alphabet, use AA, BB, etc.;
- Write numbers with commas separating millions or thousands (i.e. 99,999 rather than 99999 or 99 999);
- Do not draw hidden contours under a structure with long dashes. Make dashes 0.12 in [3 mm] long with 0.06 in [1.5 mm] spaces between. Show hidden lines of structures with the same symbol;
- Avoid running hatching, lines or patterning through words or figures. Do not use the border lines of the sheets as a basis for establishing angle of parallel hatching lines. It is

desired to gradually change the direction of hatching at angle points in the section to maintain a 45-degree angle with the neat line of the structure;

- Use abbreviations on plan and profile sheets only where there is not enough space to spell out the word. In instances where the meaning of abbreviation appears doubtful, the word should be spelled out;
- Do not capitalize abbreviations unless the word or words represented are ordinarily capitalized, or unless the abbreviation itself has become established as a capital letter, such as N for north; and
- Use a period following each part of an abbreviation that represents a single word. This aids in quick interpretation of an abbreviation (e.g., “a.m.”, not “am”). The exception to a period following an abbreviation is with units of measure where periods are not used.

Minor deviations from the guidelines for the plans may be acceptable provided the primary requirements above are followed.

9.6.5.3 Organization of Plans

The *Guidelines for Preparation of Plans, Specifications and Estimates*, FAPG 23 CFR 630B, provides guidelines in the preparation of plans, specifications and estimates. The guidelines are presented in a non-regulatory supplement attachment to FAPG, Subchapter G, Part 630, Subpart B.

As applicable, follow the guidelines in the *FAPG* for the following subject areas in the organization of plan sheets:

1. Title Sheet,
2. Typical Sections,
3. Summary of Quantities,
4. Tabulation of Quantities,
5. Plan and Profile,
6. Bridges,
7. Drainage Facilities,
8. Traffic Control Plan,
9. Standard Drawings, Division Standard Details, and Special Details,
10. Environmental mitigation,
11. Cross Sections,
12. Contiguous projects, and
13. Right-of-Way Plans (if not provided separately).

The *FAPG* guidelines permit latitude in the arrangement of plan sheets provided the intent of the plans is clear. Determine an arrangement that best fits the needs within the *FAPG*.

Refer to the Division Supplements for arrangement and organization of plan sheets and for example sample plan sheets. The following sections provide guidelines for the plans.

9.6.5.3.1 Title Sheet

The Title Sheet serves to identify the location and limits of the project so bidders can find it in the field. Descriptive terms appearing on the Title Sheet should be readily identifiable by the topography or culture or by using State highway maps.

Details that help to clarify the limits of the work or provide data needed to conveniently bid the work are encouraged. Additional details that may help the bidders include:

- Locations of material sources described in Section 105;
- Locations of disposal areas, staging areas, stockpile sites; and
- Off-project mitigation work.

The *Guidelines for Preparation of Plans, Specifications and Estimates*, FAPG 23 CFR 630B, recommends that the scales used on the plans show on the Title Sheet. Considering the number of scale variations found in a typical project, a scale legend could be confusing and difficult to cross-check. Therefore, the Title Sheet exhibits show a bar scale only for the map appearing on that sheet.

A completed Title Sheet should contain the following data:

- Proper title and project designation.
- Statement of the project length.
- The State, county, city or town (and, where applicable, the National Forest, National Park, etc.).
- Key map of the State with designator showing project location.
- The location or route map showing project location with beginning and ending stations or termini, and the corresponding mileposts consistent with program's road inventory data for the route.
- Index of sheets comprising the plans.
- Design classifications (e.g., the current average daily traffic (ADT), design year ADT, design hourly volume (DHV), directional distribution (D), percent of trucks (T), design speed (V) and maximum superelevation rate (e)).
- Distance from the project to nearest city, town, etc.
- Provisions for dates and signatures of the approving officials.
- Standard Specifications applicable to the project.
- Units of measurement applicable to the project (i.e. US Survey Foot, International Foot, or meter; see Section 5.3.2.5)

The location or route map should be prepared using a scale ratio of 1:100 000 or larger and show the project area, the nearest towns appearing on a State highway map, other roads, railroads, major streams, etc. In instances where sufficient information cannot be placed on the route map to adequately identify the project work, additional vicinity maps should be prepared on separate sheets and placed following the Title Sheet.

The large number of symbols and abbreviations used within FLH precludes placing the information on the Title Sheet. Therefore, a separate Plan Symbols and Abbreviations Sheet should be used and typically follows the Title Sheet in a set of plans.

When a special symbol is required that is not included, show it in a legend on either the first plan sheet where the symbol appears or on the left side of the first Plan and Profile Sheet. Abbreviations not shown may be placed on the plans similar to the way symbols are placed, or may be added to the contract as a Special Contract Requirement under Subsection 101.03 of the Specifications.

The symbols and abbreviations should not be changed on a project-to-project basis, but if necessary may be supplemented with additional project-specific items. When a change is required for a Division's needs, change the master file so all future projects will have the same symbols and abbreviations. This prevents the need to check all the symbology on the sheet for every project.

For complex projects consider providing a supplemental sheet showing the overall total project site plan, including contractor staging areas, material stockpile or storage areas, construction access, water or material sources, disposal sites, and other locations of interest to the contractor.

9.6.5.3.2 Typical Sections

The Typical Section Sheet shows the shape of the finished surface and shoulders, and represents the appearance of the completed project. It must be specific enough to describe the proposed work, its location and the material needed. Ensure that all references to materials, bid item names and numbers are consistent with the summary of quantities and bid schedule.

For combined roadway and bridge projects, the typical section for the bridge may be shown with other bridge design information. All plans should show typical sections for the project including those for bridges only and those where abbreviated plans are used. On projects requiring more than one Typical Section, the limiting stations for each section should show. This may require additional plan sheets for clarification of the work.

Identify all functional elements of the typical section to a relative scale. Show widths in feet [meters] and show thickness or depth in inches [millimeters]. Show the thickness of each element in the pavement structure in inches [millimeters].

Use notes or tables on the Typical Section Sheet to describe varying pavement structure thicknesses. These may occur due to differing soil conditions, traffic volumes or other roadway characteristics.

For stage construction projects, identify the ultimate typical section. Clearly distinguish the work to be performed under the contract and the future stage construction work.

Include tables or notes to illustrate curve widening, relationship of slope ratios to cut and fill heights, slope rounding and other special treatments.

Identify the profile grade on the Typical Section Sheet at the point where it is carried relative to superelevation.

Use supplemental typical sections to show variations in special ditches, clearing widths, rock cuts, etc. Also use supplemental typical sections to detail curbs, median treatments, slope protection, channel changes, etc. Place these supplemental typical sections on the Typical Section Sheet or on a following sheet. List the stations where the typical sections apply. Place a note on the Plan and Profile Sheet describing the site-specific work and referencing the appropriate typical section. On abbreviated plans, supplemental typical sections may be placed on the plan sheet at the locations where the work is proposed.

9.6.5.3.3 Summary of Quantities

The Summary of Quantities tabulates, combines, and summarizes quantities of the various construction items. This summary informs prospective bidders where to locate work within the plan sheets, the basis of plan and bid schedule quantities, and expands on contract bid schedule information. It also serves as a checklist to the designer to ensure that all elements of the design receive consideration.

This is generally one of the last plan sheets prepared in final form. All the pay items are listed in numerical order and identified by appropriate descriptions using the engineer's estimate program. The bid schedule quantities duplicate those in the contract. Items of work paid for under the contract quantity provision of Section 109 should be identified when preparing the engineer's estimate.

In the preparation of the Summary of Quantities Sheet or the Tabulation of Quantities Sheets, always spell out the pay unit the way it is shown in the FLH master pay item list. Symbols for pay units are expressed without periods (e.g., ft [m], sqft [m2], cuyd [m3], lb [kg], etc). Conform with the information shown on the Plan Symbols and Abbreviations Sheet for consistency of plans.

9.6.5.3.4 Tabulation of Quantities

A Tabulation of Quantities Sheet consists of a detailed summary of an item of work or several items of work usually presented in a tabular or table format. It provides bidders with more detailed information on the location and extent of the work required than can be shown on the Summary of Quantities Sheet. Ensure that all references to quantities, bid item names and numbers are consistent with the summary of quantities and bid schedule. The following provides a description of typical Tabulation of Quantities Sheets:

1. **Drainage Tabulation**. The Tabulation of Drainage Quantities Sheet lists all culvert and related drainage data. Show the location of the drainage installation under the station heading. Show related data in the row across the sheet under an appropriate column heading. Total the figures in the various columns to obtain the quantities shown on the Summary of Quantities Sheet for the appropriate culvert item.

The Tabulation of Drainage Quantities Sheet may be developed using a spreadsheet format. The designer may modify the sheet layout to address specific project requirements.

Where maximum cover is the controlling factor in acceptable culvert pipe selection, provide this information on the plans. Where environmental factors control acceptable culvert pipe selection, provide this information. The primary purpose of the Summary of Drainage Quantities Sheet is to present all available options for potential bidders to evaluate in preparing their estimate for the project.

Where maximum cover is the controlling factor on acceptable culvert pipe, the designer has the option of specifying the thickness, class or type of culvert on the summary or simply tabulating the controlling information and having the contractor or supplier determine the thickness, class or type.

2. **Other Tabulations**. A Tabulation of Quantities Sheet should be referenced to the location or description of the work in the plans. Use a separate plan sheet for the tables or place the tables on the same sheet as the details for the work. Separate sheets are required when the tabulation is supported by work detailed on FLH standards or Division standard details.

   Consider placing a tabulation of pavement structure quantities table referenced to the Typical Section Sheet in groups of the required work that is easy to comprehend and check.

   Tabulation of quantity tables referenced to the Plan and Profile Sheets for items of work (e.g., removal of individual trees, roadway obliteration, roadway excavation, turf establishment) aids the bidders in precisely locating the work areas and determining the effort required to perform the work. Tabulations for items of work (e.g., guardrail, fences) may be referenced to the Plan and Profile Sheets or the Special and *Standard Drawings* detailing the installation of those work items.

   A sheet tabulating all the items required, that can be referenced to the detail sheets for a major parking area, a roadside development area, a scenic overlook or other special work may assist bidders as well as internal checking. This also applies to traffic control plans, signing plans, landscaping plans and other work.

9.6.5.3.5 Plan and Profile

Prepare plan and profile sheets at a scale that is adequate to show the necessary details as governed by the topography and the complexity of the work. Profiles have the same horizontal scale as the plan, but the vertical scale should have an exaggeration of 5 or 10 times the horizontal scale.

Plans should have a horizontal scale of 1:600, 1:1200 or 1:2400 [1:500, 1:1000 or 1:2000] when prepared on the standard sheet size. Larger or smaller scales can be used depending on the amount of detail to be shown.

When laying out Plan and Profile Sheets, avoid dividing major structures, highway intersections, interchanges or grade separations between sheets. Increasing stationing should run from left to right. Typically roadway stationing increases from south to north and from west to east. If the direction of mileposts or road inventory data conflict with this, use the milepost or road inventory direction.

Leave about 10 in [250 mm] or more of blank space before the beginning of the project on the first Plan and Profile Sheet and a similar blank space after the end of project on the final Plan and Profile Sheet. Except for the first and last sheet, attempt to place a consistent station range on each sheet and always break sheets at even station numbers.

Show a prominent North arrow for orientation on each sheet.

Show all boundary lines, State, county, city, township and section lines. Show ties to section corners that fall off the sheet by breaking the line and showing the corner with the tie distance. Describe found corners and show their coordinates. At the bottom of the plan portion of the sheet, show township, range and meridian. Streams, lakes, swamps, estuaries, etc., must also be shown.

Show the station and coordinates of the beginning of the project and the end of the project on the first and final Plan and Profile Sheets, as appropriate. Identify them as State grid or other system.

On the plans, show the elevation datum used for the project.

Show the designed centerline prominently and comply with the following, as applicable:

- If the designed line (L line) is not staked, and a preliminary control line (P line) is staked, show as a light line. Label the P line as “P Line as staked” and the L line as “Line to be constructed.” Where the preliminary control line consists of a series of survey control points to be used by the contractor during the construction staking operation, label the control points by number and show the coordinates and elevation either on the plans or on a separate tabulation sheet.
- If the L line is staked, do not show a P line on the Plan and Profile Sheets. Where control points are provided for the contractor’s staking operation, label the control points by number and list the coordinates and elevations either on the plans or on a separate tabulation sheet.
- If an L line is visibly staked at the time of bidding, but another line is designated in the plans for construction, make the staked line dashed and label it as “Line as staked” and make the other line solid and label it as “Line to be constructed.”

On all sheets, show the cut and fill slope limits, construction limits (when applicable), access control lines, easements and right-of-way lines. Within the right-of-way, show all cultural features affecting construction or requiring relocation (e.g., utilities, fences). Identify all ownerships for right-of-way purposes. Show all existing and proposed drainage structures. Show any cultural features adjacent to the right-of-way that may be affected by the project.

Curve data consisting of delta angle, radius of curve, tangent length, length of curve and superelevation should be shown. Curve widening may also be shown at this location. For spiral transitions, the spiral angle and length of spiral should be shown. Identify every 100 ft [100 m] station along the centerline. Bearings or azimuths of all tangents should be shown.

Show the location of borings, test pits or other sites where subsurface investigations have been made on the plan portion of the Plan and Profile Sheet, or on special plan detail sheets, as applicable. Do not show actual boring log or test results on the plan-profile. Use separate plan sheets for this data, if applicable, or reference the materials investigation reports.

On the profile portion of the Plan and Profile Sheets show the profile grade and existing ground lines. Show gradients on the profile to at least three, preferably four decimal places, grade elevations to three decimal places and natural ground points to two decimal places.

Show vertical and horizontal clearances for railroads, highways and streambeds under proposed and existing structures.

Identify and show type and clearance, if known, under and over utility lines within the right-of-way.

In addition to profile data, the quantity and limits of the following items may be shown by arrow diagram at the bottom of the Plan and Profile Sheet.

- Turf establishment;
- Clearing and grubbing;
- Embankment, where it occurs;
- Roadway excavation, where it occurs; and
- Earthwork balance points.

At the top of the profile portion of the sheet, the designer may show information (e.g., curbs, fences, guardrail) at the proper stations and identify them appropriately. These items may show instead on separate sheets using tables, tabulations or other appropriate formats.

Show profiles of connecting roads, waterlines, road approaches, etc., on the Plan and Profile Sheet. Offset their location on the plan if they obscure the main profile or show them on a separate plan sheet.

Show bridges and major structures to be constructed on the Plan and Profile Sheet in outline only, with a note to see the appropriate drawings.

Show irrigation facilities requiring minimum service interruptions during construction of the project.

Show all culverts on the Plan and Profile Sheets.

Abbreviated plans are acceptable on rehabilitation type work, emergency relief work or other types of work where Plan and Profile Sheets would not clarify the required construction.

The work areas can be identified along the route by stations, mile [km] posts, and etc., with a written description of the work to be performed at each site.

The description is used to identify work details, specify quantities, and reference applicable Special Details, Standard Drawings, or Division Standard Details elsewhere in the plans. The information may be placed in a tabular format or may be included as descriptive text at the specific work locations as shown on a straight-line diagram or graph. Any plan format that is clear, concise and adequately details the work is generally acceptable.

9.6.5.3.6 Bridge Plans

The Structural Design Unit designs most bridges and other large structures. The designer will usually receive a complete set of bridge plans and accompanying draft Special Contract Requirements for insertion into the PS&E assembly. The bridge plans and roadway plan-profile sheets, and other plan sheets, must be crosschecked for compatibility and to ensure that stationing, gradients, elevations and other geometric details are identical. The notes on the bridge plans and the draft Special Contract Requirements must be reviewed and checked to eliminate any potential conflict with other provisions of the contract. Transfer quantities on the bridge plans to the summary sheet and assign item numbers as appropriate. Resolve any differences found during the review and number the bridge plans for insertion into the final package.

9.6.5.3.7 Cross Section Plans

When cross section plans are included in the contract plan assembly, show sufficient information on each of the sections to accurately determine the extent of the proposed work. Use a scale that is appropriate for the work.

9.6.5.3.8 Temporary Traffic Control Plans

A Temporary Traffic Control Plan is required for all projects. Also refer to Section 9.6.6.2.4 for development of a Transportation Management Plan.

The plan sheets for the Temporary Traffic Control Plan are applicable FLH Standard Drawings, or Division Standard Details, or project-specific Special Details, or combination thereof, that graphically portray all temporary traffic controls required to assure safe travel through the project construction zone. Such temporary traffic controls include provisions for pedestrians (including those with disabilities), bicyclists, and motor vehicles. All pay items related to temporary traffic control may be tabulated on this Sheet or have a separate tabulation sheet.

Temporary Traffic Control Plans may range from simple line diagrams for low-volume rural roads to complex plan sheets detailing every stage of the project work on high-volume urban highways. Guidance on Temporary Traffic Control Plans is provided in the *MUTCD*. Also refer to *Green Book* Section 3.6.6.

9.6.5.3.9 Permanent Signing and Marking Plans

When applicable, show permanent signing, pavement markings, delineation and other permanent traffic control devices on separate plan sheet details for clarity and ease of use. Refer to Section 8.7.1 for additional guidance on preparation of signing and marking plans. Adhere to guidance on permanent signing and marking that is provided in the *MUTCD*.

9.6.5.3.10 Erosion and Sediment Control Plans

The plan sheets for the erosion and sediment control plan may include Special Drawings, or Division Details, or both, that detail the measures required to protect resources and to comply with permit stipulations. The plan sheet details should reflect Best Management Practices (BMP); comply with *Erosion and Sediment Control on Highway Construction Projects*, 23 CFR 650 Subpart B; and be in agreement with the stipulations in the National Pollutant Discharge Elimination System (NPDES) permit.

9.6.5.3.11 Landscaping and Revegetation Plans

When applicable, show permanent landscaping features on separate plan sheet details for clarity and ease of use. As applicable, include the following details:

- Removal or salvage of plan materials,
- Site plan and layout of landscaping and vegetative items, plant list with quantities and symbology,
- Grading plan showing existing and proposed contours, applicable spot elevations,
- Special grading details and typical slope treatments, and
- Planting details showing typical plant installation details, irrigation details, etc.

9.6.5.3.12 Environmental Mitigation

Commitments for environmental mitigation features that are contained in the environmental documentation should be detailed as necessary and included in the project plans as Special Details, or Division Details, or both.

Plan sheets for wetland replacement or mitigation are Special Drawings that detail all work required to ensure successful mitigation. These may range from simple sketches to elaborate contour grading and planting plans to conform to the commitments in the environmental document. Pay items may be tabulated on these sheets or on separate sheets.

9.6.5.3.13 Major Drainage Facilities Plans

Plan sheets under this subject area would include details of large culvert installations conforming to the requirements listed in Section 7.3.1. Headwalls, inlet and outlet treatments, fish passage requirements, energy dissipators, catch basins, manholes and other drainage installation can also be detailed under this subject area. The drainage plan sheets should be numbered and placed in the plans in logical order as appropriate.

9.6.5.3.14 Material Source Reclamation Plans

FLH standard practice is that government designated material sources require rehabilitation under an approved reclamation plan, and applicable environmental documentation as described in Section 3.5.

The reclamation plan must set forth measures to return the land to the most appropriate function following use of the source. The site may be reclaimed in a series of stage reclamation efforts when several projects designate the same source. Side borrow sites within the right-of-way do not require a reclamation plan.

The reclamation plan provides that reclamation measures, particularly those relating to control of erosion, be conducted simultaneously with surface mining. When this is not possible, initiate reclamation measures at the earliest possible time after completion or abandonment of mining on any segment of the site area.

As applicable, the reclamation plan should include the following:

- A vicinity map describing site boundaries as shown on the right-of-way or sundry site boundaries and enough information to locate the site on quadrangle or county maps.
- Existing water forms and ground contours. Existing contours are optional unless the design or permit process requires them.
- Proposed finished ground contours and cross sections needed to show finished slopes.
- Statement of the proposed subsequent use of the land. Include any local zoning and planning requirements, any indications of whether the site is intended for use by other contractors or maintenance forces in the future and whether or not stage reclamation applies. For stage plans, provide interim reclamation measures that ensure an orderly depletion and restoration of the site. Scheduled staged use to reclaim the largest possible surface area under the final reclamation plan.
- Manner and type of revegetation and other surface treatment of disturbed areas.
- Preservation or establishment of visual screening and vegetative cover to screen the view of the operation from public highways, public parks and residential areas.
- Proposed practices to protect adjacent surface resources. This includes prevention of slumping or landslides on adjacent lands.
- Slopes that are blended with adjacent terrain to meet future use requirements. In all cases, provide for adequate safety.
- Method of preventing or eliminating conditions that create a public nuisance, endanger public safety, damage property or are hazardous to vegetative, animal, fish or human life in or adjacent to the area.
- Method of controlling contaminants and disposing of surface mining refuse.

- Method of diverting surface waters around the disturbed areas.
- Method of restoring stream channels and stream banks to a condition minimizing erosion, siltation and other pollution.
- Planned lakes, ponds or other bodies of water that would be beneficial for residential, recreational, game or wildlife purposes.
- Restoration of any borrow, quarry or pit site. Sites resulting in a lake or wetland involve careful planning and must take into consideration all factors impacting the fauna and flora.
- Proposed stockpiles of 11,000 tons [10,000 metric tons] or more.
- Permanent buildings and any protective stipulations required.
- Photographs whenever possible.

The FLH Division will cooperate with other governmental and private agencies to provide land reclamation of the sites used for the described purposes.

Reclamation plans for sources located on Federal Lands require coordination with and approval by the agency responsible for administration of the land in accordance with the appropriate Memorandum of Understanding.

Reclamation plans for sources on private lands usually require coordination and approval by a State agency, or local agency if applicable, with responsibility for issuing and administering material removal operating permits.

9.6.5.3.15 Right-of-Way and Utility Plans

On occasion, right-of-way plans or utility plans may be too complicated to incorporate on the Plan and Profile Sheets, and may be prepared as a separate plans set with only the pertinent information (e.g., ownerships, existing and proposed right-of-way lines) shown on the roadway plans. Refer to Chapter 12 for guidance on preparation of right-of-way plans.

9.6.5.3.16 Contiguous Projects

A general plan or layout of contiguous construction projects may be beneficial to potential bidders in determining the cost of work on FLH projects. This is particularly true where another agency is constructing a project that will affect FLH contractors. It is essential that the relationship between the projects be well detailed on the plans.

There are instances where as-built plans should be included in the contract plan package. If a bridge or other structure is scheduled for salvage, a set of the as-built plans will greatly assist a contractor in determining the most effective method to disassemble the structure.

9.6.5.4 FLH Standard Drawings, Division Standard Details and Special Details

Arrange the FLH Standard Drawings, Division Details and project-specific Special Details in an order that best clarifies the work to be accomplished.

9.6.5.4.1 FLH Standard Drawings

The Office of Federal Lands Highway (FLHO) issues Standard Drawings for use in the Federal Lands Highway programs. Standard Drawings, together with the Specifications, contain all appropriate information that is necessary to describe the details of the proposed work. The FLHO maintains the Standard Drawings and supersedes or withdraws those drawings that become obsolete or ineffective.

FLH Standard Drawings cover various design elements that have been approved by FLHO for use on a nationwide basis. FLH Standard Drawings have a fixed format and each drawing has its own unique identification number. FLH Standard Drawings are usually incorporated into the contract plan assembly and not issued as a separate booklet.

The Functional Discipline Teams periodically review FLH Standard Drawings and Division Standard Details for consistency with FLH Standard Specifications and with FLH policies, and industry best practices.

A FLH Functional Discipline Team or FLHO may propose new FLH Standard Drawings or revisions to existing FLH Standard Drawings at any time. Functional Discipline Teams submit their proposals for consideration as summarized below. When it is determined that FLH Standard Drawings should be developed, adopted or revised, the FLHO or Functional Discipline Teams will agree upon a responsible Functional Discipline Team to perform the preparatory work.

The responsible Functional Discipline Team will develop or modify FLH Standard Drawings on the CADD system. The responsible Functional Discipline Team will then submit proposed new or revised FLH Standard Drawings to the FLHO. Any Special Contract Requirements for the FLH Standard Drawings should accompany the distribution. Normally, the submission to the FLHO should be in electronic format. The responsible Functional Discipline Team will coordinate the review and comment of proposed FLH Standard Drawings with the other Functional Discipline Teams and the FLH Divisions.

The following process shall be used for approval of proposed new FLH Standard Drawings and revisions to approved FLH Standard Drawings:

- On behalf of the FLHO the responsible Functional Discipline Team will make distribution of the proposed new or revised FLH Standard Drawings to the Headquarters and Division offices and others as appropriate, with a request for comments.
- The responsible Functional Discipline Team will consolidate and review the comments received and make the appropriate revisions, with coordination of the other Functional Discipline Teams and the FLH Divisions.

Upon disposition of comments, the responsible Functional Discipline Team will resubmit the Standard Drawings to the FLHO. The submissions should include a summary of the disposition of comments. If needed, additional distributions will be made by the FLHO in accordance with these procedures. If additional distributions are not required, approval will be given to the responsible Functional Discipline Team to finalize and date the title block of the FLH Standard Drawings. The approval date or revision date to be included on FLH Standard Drawings will be provided with FLHO approval.

The responsible Functional Discipline Team will distribute electronic versions of the CADD files to each Division. The files will also be posted in a centralized location for use by all offices and industry.

The FHLO will distribute a complete list of the FLH Standard Drawings with the latest approval or revision dates with the approval memorandum noted above. Each Division shall ensure that links to the latest approved FLH Standard Drawings are provided in their CADD files.

In FLH Standard Drawings, the lettering will be sentence-case italicized True Type Verdana excluding titles and subtitles that will be vertical. Standard letter size will be 0.08 in [2 mm]. Minimum letter size will be 0.05 in [1.25 mm]. Use minimum letter size sparingly to ensure clear and readable plans at the scales proposed for standard size plans and letter sized abbreviated plans. Additional information is available in Division Supplements.

9.6.5.4.2 Division Standard Details

These drawings are used on a repetitive basis within each Division. They should be placed in the plans as applicable to clarify the work required.

Each Division will provide links to their current Standard Details in their CADD files.

9.6.5.4.3 Special Details

Special Details are project specific details necessary to properly describe the work. Special Details include plan sheets detailing grade crossings, turnouts, retaining walls, dikes and ponds, waste or borrow areas, stage construction plans, permanent striping and signing plans, road approaches, material source locations and other work.

When a Division office must modify Standard Drawings or Division Standard Details for specific projects, they become special details and they no longer have typical standard drawing title blocks. To prevent confusion, title blocks for special details must be clearly distinguishable from the Standard Drawing title blocks.

Standard plans prepared by a State DOT or other outside agencies that are incorporated into the contract should be treated as Special Details for insertion into the plans package.

A FLH Special Details Database is maintained, which may be helpful for development and sharing of project-specific special plan details and the associated specifications and unit costs.

9.6.6 SUPPORTING INFORMATION

Supporting information includes all information that documents the development of the geometric design, the preparation of the PS&E, and design information needed for layout and control of the construction work, and to support the construction management.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.6.1 Computation of Quantities

Determine the contract items and appropriate pay units needed for the work. All computations for estimating quantities are a part of the supporting data. Keep the computations in support of a contract item together and the items listed in numerical sequence.

Clearly distinguish and define any estimated quantities that are computed and shown for information only, to be included in other items of work and not measured or paid for separately.

Some work may not be paid for directly, e.g., small quantities that would be difficult or uneconomical to measure. Limit the no-payment work to types of work that can be clearly differentiated from pay items, or that can be clearly described and are not ambiguous for inclusion under the contract as incidental to the bid items, and clearly define it on the plans and in the Special Contract Requirements (SCRs) so that bidders can adequately include it in their cost estimates under other contract items.

A lump-sum item can is used where the work required consists of a number of inter-related, small quantity items to obtain a specified end result or the work can be described in complete detail in the SCRs. Identify the breakdown of the work required when a number of items are included in the lump-sum item.

When several methods may be used to measure the work, coordinate early with the Construction Unit to verify the most appropriate method to estimate, measure and pay for the work.

Follow the requirements of the Standard Specifications, *FP-XX*, as amended by the project SCRs, for the method of measurement and basis of payment used in the computation of design quantities. Coordinate with the Materials Unit and the Construction Unit for guidance in selecting the appropriate pay items, application rates, unit weights, and other design assumptions for quantity computations.

9.6.6.2 Design Documentation

In addition to the PS&E preparation, provide all required additional information supporting the development of the geometric design and PS&E. The following sections provide applicable guidance for the design documentation.

9.6.6.2.1 Design Files

As applicable, provide the following general information that should be contained in the project design files, which may not be described specifically in the other sections below:

- Pertinent correspondence, reports, memoranda, project agreement, emails, etc., relating to the development of the design and related design considerations;
- Design technical information regarding design criteria and design decisions;
- Highway Design Standards Form (Section 9.1.3);
- Environmental document and commitments pertaining to the highway design;
- Pertinent right-of-way documentation, agreements, certification;
- Utility agreements;
- Pertinent technical reports and recommendations from other disciplines;
- CADD files and summary documentation for archival and retrieval;
- Calculations for design quantities, properly organized and checked; and
- Review comments and documentation regarding their disposition.

9.6.6.2.2 Design Exhibits

As applicable, develop exhibits for use at design reviews, stakeholder meetings, public meetings, etc. Such exhibits should be designed and formatted for presentation to a non-technical audience, and should enable clear understanding of the design concepts and features and should foster interactive communication and constructive feedback from those viewing the exhibits.

For additional guidance on developing and utilizing design exhibits refer to the FHWA report: *Public Involvement Techniques for Transportation Decision-Making*.

9.6.6.2.3 Visualization and 3D Modeling

As applicable, the latest visualization technology should be used to facilitate communication and understanding of project design goals and solutions with stakeholders and the general public. Computer three-dimensional (3D) modeling and imaging should be used to depict and evaluate the design aspects in addition to the traditional orthogonal views of plan, profile and cross-sections. Visualization and electronic media and graphics presentations should be used to assist designers, as well as the interdisciplinary project team, stakeholders and the public to better comprehend, evaluate and communicate complex roadway design features than by using traditional two-dimensional (2D) roadway drawings.

In addition to using modeling and imaging presentations that depict how the proposed facility will appear within the existing conditions, consider using dynamic, real-time techniques to simulate and analyze the operational characteristics of the facility.

The FHWA Visualization in Planning site and TRB Visualization in Transportation Site provides information on visualization techniques and their applications for highway projects. Also refer to the FLH Visualization Guide.

9.6.6.2.4 Transportation Management Plan

The Work Zone Safety and Mobility Rule requires consideration of the safety and mobility impacts of work zones during project development, and the implementation of a Transportation Management Plan (TMP) to manage these impacts during project delivery. The TMP includes development of a plan for Temporary Traffic Control (TTC) measures and devices, applicable public information and outreach, and operational strategies. The scope, content, and level of detail of the TMP varies based on the anticipated work zone impacts of the project. Refer to Section 9.6.5.3.8 for preparation of TTC plans.

As applicable, prepare transportation management plans and reports that are required and the responsibility of the FLH or the client agency. The transportation management plans and reports may precede or may be in addition to the PS&E, and may be required for submittal to State DOTs or local governments, community relations, public information efforts, etc.

9.6.6.3 Permits

As applicable, include all permit requirements into the design and PS&E documents. The specific permits and their requirements may be included within the special contract requirements for direct incorporation within the contract documents, as applicable. Refer to Section 3.3.3 for guidance on commonly required permits.

9.6.6.4 Design Data for Construction Engineering

Document and provide all necessary design and related information that will be made available to the prospective bidders during the advertisement period, and to the contractor after award. Such information may include materials reports, geotechnical reports, earthwork reports, permits, specifications that are referenced but not directly shown within the solicitation documents, and traffic management plans.

For projects with retaining wall systems that require engineering by the construction contractor, the information that may be needed by prospective bidders or the construction contractor includes the subsurface investigation, structural requirements and geotechnical design data. The data should include:

- Shear strength and consolidation properties of foundations materials,
- Shear strength and unit weight of backfill,
- Design life (minimum service life) – typically 75 years,
- Safety factors for overturning, sliding and stability of temporary slopes,
- Allowable foundation bearing pressure and minimum embedment depths,
- Maximum tolerable differential settlement,
- MSE internal design requirements,
- External loads,

- Drainage requirements,
- Backfill requirements, and
- Facing requirements.

9.6.6.5 Stakeout Data and Construction Controls

As applicable, provide information necessary for survey, stakeout and field control of construction work. This may include supplemental engineering data not provided on the plans such as survey data, coordinate geometry data, structural data, slope stake and grade finishing notes, clearing and seeding reports, superelevation reports, design cross section data, and other design information. Provide sufficient copies for the design file, the construction project management engineer, and the construction contractor both in hard copy and electronic format, as applicable.

When converting cross-section based roadway designs to 3D design surface models for construction control, provide the intended level of precision. The model precision is affected by the length of chords (breaklines) connecting like points between cross sections, and the resultant offset from the chords to curved design elements. Deviations to the chord offsets should be well within the staking tolerances for construction survey listed in Table 152-1 of the FP, such that any deformations in the 3D surface model are negligible and have no discernable effect on the intended roadway geometry. For construction control, the 3D design surface model should use sections (pattern lines) spaced at 10 ft [2.5 m] maximum intervals, and at superelevation transitions, roadway widening, special ditch transitions, and inlet catch basins where culverts are designed in cuts. In sharp horizontal or vertical curves, closer spaced sections should be used. A 3D design surface model should be prepared for major public road approaches similar as for the mainline. Minor road approaches and other minor features built with standard drawings or typical details need not be modeled. All limitations in the 3D design model data should be described in the special contract requirements.

9.6.6.6 Information for the Construction Branch

As applicable, provide pertinent design information to the construction project engineer, including the following:

- Design special considerations narrative;
- PE package and hold file;
- Quantity support calculations and related drawings;
- Environmental commitments, including those that are not performed by or the responsibility of the contractor;
- Agreements;
- Permits;
- Pertinent correspondence and reports;
- Pertinent meeting minutes and design field trip reports;

- Technical discipline reports applicable to construction; and
- Survey and stakeout information.

9.6.7 CONSTRUCTION SCHEDULE AND CONTRACT TIME

Determine the anticipated construction schedule including reasonable times for completion of construction activities and total contract time. Factors that determine contract time include materials, equipment, manpower, costs and constraints (i.e., weather, regulations, traffic, utilities, user convenience).

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.8 ENGINEER'S ESTIMATE

Prepare an engineer's estimate of cost for each project as part of the PS&E development associated with each stage of the project's design process. The estimate should become more detailed and complete at each subsequent stage. For each estimate type, document the estimate basis, assumptions, calculations, and uncertainties, as described in the following sections. In addition to the estimated unit costs and total cost for construction, the engineer's estimate includes, as separate line items, the estimated costs for preliminary engineering, construction engineering, right-of-way acquisition, utility relocation and other anticipated contingencies.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.8.1 Preliminary Engineering Cost Estimate

Design engineering costs can be based on a percentage of the construction cost estimate, for various types of projects and design activities. More detailed cost estimates are based on the estimated labor hours and direct costs to perform each activity of the preliminary engineering work, or may be based roughly on the estimated number of plan sheets.

9.6.8.2 Construction Engineering Cost Estimate

Construction engineering (inspection and construction management) costs can be based on a percentage of the construction cost estimate, for various types of projects and construction activities. More detailed cost estimates are based on estimated equipment (office trailer, laboratory trailer, vehicles, inspection equipment, etc.) and labor hours and direct costs to perform the construction engineering work.

9.6.8.3 Right-of-way Acquisition and Utility Relocation Cost Estimate

Estimated costs can be based on consideration of the number of parcels, acreages, appraisal costs, right-of-way considerations, and the type and extent of individual utility adjustments. Refer to Chapter 12 for guidance and detail on estimating these costs.

9.6.8.4 Construction Cost Estimates

For each type of construction cost estimate, document the supporting calculations thoroughly and appropriately, as described in the following sections.

9.6.8.4.1 Class C Construction Cost Estimate

A Class C construction cost estimate is based on cost per mile of similar scope construction work, and adjusted for estimated rate of inflation and local conditions. It is normally developed for planning, programming, and conceptual studies.

9.6.8.4.2 Class B Construction Cost Estimate

A Class B construction estimate is based on the estimated quantities and unit costs for the major high cost categories of work, and either cost per mile or percentage of total construction costs for minor categories of work. It should be developed in the preliminary design (15 and 30 percent) phase and updated at the intermediate design (50 percent) phase of design detail. Consider the following major items for development of estimated quantities and unit costs:

- Clearing and grubbing per acre [hectare],
- Roadway excavation per cubic yard [cubic meter],
- Minor drainage per mile [kilometer],
- Aggregate base, subbase or surfacing per ton [metric ton],
- Asphalt or concrete paving items (type) per ton [metric ton],
- Major structures, including any bridges and retaining walls, per square yard [square meter], and
- Large culverts per each.

Miscellaneous minor items may be grouped into categories as a lump sum or percentage of the total construction (include mobilization, construction survey and staking, temporary traffic control, guardrail, signing, striping, erosion and sediment control, fences, revegetation, landscaping, etc.) based on historical data of similar projects.

9.6.8.4.3 Class A Construction Cost Estimate

The Class A construction cost estimate (Engineer’s Estimate) is a listing of all items of work in the contract, showing quantity, unit of measurement, unit cost and total cost of each. The total amount of all items of work, including appropriate incentive payments, makes up the construction estimate. Contingencies, construction engineering, project agreement costs and other costs added to the construction estimate makes up the program amount. A Class A construction cost estimate should be provided for the plan-in-hand (70 percent) design phase, and the unit prices verified and updated for the final (95 percent) design phase.

When a contract is financed by multiple funds, and expenditure of a fund is limited to a particular section, a separate estimate, summary sheet and bid schedule are necessary for each section. When a contract is financed by more than one type of fund, but expenditures are not limited to a particular section, only one bid schedule is necessary, supported by a combined estimate and summary sheet.

For the plan-in-hand (70 percent) phase of development, typically a 5 percent contingency should be added to the overall construction cost estimate. For final (95 percent) phase of development all pay items, quantities, and any pay items incentives should be known and specified, and no separate contingency amount is included for the final estimate. An allowance may be included within the tabulations of individual bid item quantities listed on the plans to address approximated quantities potentially needed to fit the project site conditions.

Retain confidentiality of the unit price analysis and construction cost estimate at all times to maintain the integrity of the bidding and procurement process.

9.6.8.5 Development and Update of Prices

FLH standard practice for developing and updating estimated prices for construction includes the following:

- Develop unit prices that consider the location, timing and characteristics of the work to be performed.
- Estimated unit prices may be based on historical data (i.e., bid prices for previous contracts), or on actual costs, or both.
- For major items of work identify and analyze the primary factors and risks affecting the cost of the work (e.g., local labor rates, equipment rates, unusually small or large quantities, transportation distances, interest rates, time allowance, competition levels, material shortages).
- Document the methods and assumptions used to establish each unit price, including the primary unknowns and risks that are taken into consideration.
- Perform periodic reviews of the unit prices and construction cost estimate during the design process, at each major project development phase, to confirm it is accurate and fully reflects the project scope and current market conditions.
- Before communicating unit prices or a construction cost estimate to program partners, confirm that the unit price analysis is current, and update if necessary.

Unit prices for the engineer’s estimate should reflect the actual cost to the contractor of doing business, including a reasonable profit. Consider the two common methods to determine this cost; historical costs (bid-based estimating) and actual costs (cost-based estimating). With either method, the designer should strive to predict the expected overall low bid, and develop unit prices that will at least equal, or slightly exceed this amount. Develop unit prices for each defined pay item using either historic bid data that is factored for the project conditions, or cost-based pricing (using costs for equipment, labor, material, and production rates applicable for the project conditions), or use both methods for comparison, as appropriate for each pay item.

1. **Bid-Based Estimating**. Use historical bid data as a basis for estimating current costs. Consider the bids received for like items on recent (within the past two to five years), representative projects built under similar conditions that fairly represent the contractor's cost plus a reasonable profit. Consider the average of the low bids received on previous projects in similar locations, factored for project conditions and cost indices, as a basis for the anticipated minimum overall cost for current projects. However, do not use solely the lowest bids for analysis of historic unit prices, due to the variability in bids and costs for the individual bid items.

   Consider that the lowest bid for a project may not represent a consistent distribution of costs among the bid items, and that the low-bidder's prices on each individual item may not represent the lowest or most reasonable cost for every item. Therefore, it is recommended to use the average of the unit prices from the lowest three bidders to verify that the low-bid unit price is reasonable and consistent. Use the lowest three bidder's prices from representative past projects, and modify them to fit the conditions on the project, and adjust for increases in the overall cost of construction over time using an inflation index. Consider factors that may have a direct bearing on the historical bid prices in relation to the current project, including the following:

   - Availability of construction material,
   - Proximity of access roads and railroads,
   - Distance from towns and travel speed,
   - Timing of construction,
   - Inflation indices, and
   - Amounts of quantities.

   The historical bid price approach, tempered with engineering judgment, is recommended for estimating the minor items of work on a project. For major items of work, it is recommended to also consider the cost-based estimating approach, in addition to the bid-based estimating approach, to verify the unit price analysis is reasonable.

2. **Cost-Based Estimating**. Consider the cost-based approach for some items of work, especially major items such as roadway excavation, base and plant mix material, bridge material, etc. The actual costs to construct these items should be analyzed to ensure that all factors that bear on the cost of the item receive consideration. Use current labor, equipment and materials costs, production rates, as well as overhead and profit to develop cost-based unit prices.

When updating costs used in the engineer's estimates, consider the effects of inflation on pay items, wage rates, equipment rates and material costs. Use current inflation trends in highway construction prices. Several cost inflation indexes are available to track short and long-term construction pricing trends, including:

- FHWA *Price Trends in Federal-Aid Highway Construction Projects*
- American Road and Transportation Builders Association (ARTBA) Price Index
- State DOT Price Indices

When updating historic bid prices or other cost data, use an inflation time period that begins at the year and month the historic bid or cost data originates from, and ends in the year and month of the proposed project's anticipated construction completion.

9.6.8.6 Assessment of Cost Estimate Uncertainties and Risks

For each estimate type, identify and assess the potential price uncertainties and risk factors associated with the estimate. Use an interdisciplinary approach to identify project cost risks and uncertainties early, and evaluate these identified risks to establish cost ranges and appropriate contingencies. Anticipate potential external cost influences and incorporate them into the overall assessment.

After the proposed quantities, unit prices and estimated costs are determined; determine a project cost range and probability. Evaluate the potential risks for deviations in the construction quantities, as well as their unit costs. Consider cost impacts of potential project risks such as:

- Limited number of available or qualified contractors to perform the type of work,
- Changes in construction market conditions or competing work opportunities,
- Changes in labor or materials availability,
- Uncertainties in costs for construction materials supplied to the project,
- Uncertainties in site conditions, in-situ materials, utilities, weather, stream flows,
- Changes in traffic conditions and traffic maintenance requirements,
- Changes in construction time restrictions, access, or hauling limitations,
- Delays in construction permitting,
- Delays in funding availability,
- Delays in right-of-way acquisition, PS&E completion, or contract award.

Describe the type of estimate, its key assumptions, and its uncertainties, whenever a cost estimate is communicated. When communicating prices or a construction cost estimate for programming purposes, also convey the extent of cost unknowns, risks and variability that should be considered with the estimate amount.

9.6.9 SPECIFICATIONS

Prepare all necessary Special Contract Requirements relating to an individual project to describe the work with clarity and precision in a clear logical format. FLH standard practice is to follow the format and guidelines described in the FLH *Specification Writer's Guide*.

The *FLH Specifications Procedures* provides information primarily for FLH internal use in developing new specifications and coordinating them with the plans and estimate; and FLH procedures for specification review and evaluation.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.10 CONTRACT ASSEMBLY

A standard contract assembly or solicitation package consists of several main parts:

1. **Solicitation, Offer and Award (SF 1442)**. This contract form, after being signed by the contractor and contracting officer, consummates the contract and makes it legal and binding on all parties.
2. **Solicitation Provisions**. The *Federal Acquisition Regulations* (FAR) define the scope of the contract and sets forth bidding requirements.
3. **Bid Schedule**. A list of all pay items in the contract to be completed by bidders with their offered bid prices for the work. The bid schedule is prepared from data obtained from the engineer's estimate.
4. **Contract Construction Clauses**. FAR clauses regulating and controlling contractor construction activities.
5. **Labor Standard Clauses**. All laborers and mechanics working on the project are covered by Federal regulations (i.e., *Davis-Bacon Act*), that includes a minimum wage schedule.
6. **Special Contract Requirements**. The amendments and supplements to the Standard Specifications necessary for the construction of the project.
7. **Plans and Drawings**. The plans and drawings necessary to detail and identify the work. These also include FLH Standard Drawings, Division Standard Details, and Special Details that may be applicable.

The Federal Lands Highway offices use these seven subdivisions in their contract solicitations (advertised or negotiated). The solicitation generally contains all the necessary forms and contract documents that a bidder needs to make the Government an offer for the construction of the highway facility.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.11 QUALITY CONTROL AND QUALITY ASSURANCE

Ensure that all design work is performed in accordance with an approved quality control and quality assurance (QA/QC) plan, and provide documentation of the completed QA/QC activities related to design. Refer to Division Supplements for specific FLH Division requirements. The established QA/QC process may be supplemented by a project-specific quality plan described in Section 9.6.11.1, as applicable. For design work performed by A/E consultant, the A/E firm should have an established process for the formulation, implementation, and administration of their firm's QA/QC program, but which may need to be supplemented to meet the FLH quality requirements of the project.

The design QA/QC plan should include the following general components:

- A project-specific quality plan that designates individual responsibilities;
- Comprehensive quality control (QC) during the design and PS&E production;
- Independent quality assurance (QA) monitoring; and

- Evaluation and feedback of the QA/QC procedures.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

9.6.11.1 Project-specific Quality Plan

As may be applicable for each project, provide a project-specific QA/QC plan to supplement the standard, established QA/QC process. The project-specific quality plan should identify any special QA/QC activities, and individual roles and responsibilities for preparation, performance, and maintenance of applicable quality activities. The project-specific quality plan together with the established QA/QC process should address all quality expectations and applicable quality requirements for design of the particular project. The plan should:

- Reference standard, established QA/QC procedures applicable to design of the project, including applicable quality requirements;
- Reference special technical aspects and level of effort vital to the quality of the project,
- Identify a schedule of milestones for significant quality control (QC) activities, including;
  - ◊ QC activities, description and when in the design process they occur;
  - ◊ Checks, back checks, and any anticipated QC audits, if applicable
  - ◊ Approximate duration and anticipated level of effort for each QC activity;
- Identification of the responsible individual(s);
- Identify those individuals responsible for performance of the quality assurance (QA) activities sufficient to verify and ensure adherence with applicable QC requirements;
- Analyze the level of risk associated with above efforts, and assess the potential impacts for each activity identified as having a high level of risk, obtain applicable approval or endorsement of risks, and incorporate applicable measures to mitigate the risks; and
- Provide for periodic review and updating, if necessary, of the design QA/QC activities and those responsible during the life of the project.

9.6.11.2 Quality Control

Quality control (QC) applies to internal design work as well as externally outsourced A/E consultant or sub-consultant work. Perform quality control using an established QC plan during the design and production of:

- Highway geometric design,
- Manual and computer-generated design calculations,
- Engineering drawings,
- Specifications,
- Quantities calculations,
- Construction cost estimate and unit price analysis,
- Technical documents, studies and reports,
- Incorporation of environmental commitments and technical discipline recommendations,
- Permit applications, permitting requirements and their incorporation, and
- Construction stakeout data and reports.

The established QC plan should include the following essential elements:

- Guidelines are provided for using a standard checking and back-checking markup system, review checklists, and other QC control tools and documents;
- All design work is checked by the originator before completion of a task to provide continuous QC during the design and PS&E production work;
- All documents and supporting calculations developed for each stage of design development and review are fully checked by a qualified individual other than the originator before being issued. The QC checker should ensure each document meets an established level of quality, typically identified through using a checklist;
- QC checks identify, incorporate, track and verify the markups and review comments;
- Back checking of review markups to assure that the completed design reflects input received during checks and various iterative reviews used to control the work and evolution of the design, and reflects the intent of the review recommendations;
- QC checks involve subject matter experts for the specific technical discipline;
- QC checks involve the project manager in overall quality control overlapping multiple disciplines;
- QC checks ensure that the design and PS&E products conform to applicable policies and design standards, FLH standard practices, and are accurate and of high quality;
- The QC checks made and their date and responsible person(s) performing the check are recorded; and
- Documentation of the quality control checks made by the originator, reviewer(s), project manager, and others, as applicable is maintained during the life of the project. Refer to Section 9.6.11.4.

9.6.11.3 Quality Assurance

Perform independent quality assurance (QA) checks of the design and PS&E as necessary to:

- Verify that the established quality control (QC) checks have been performed;
- Assure that the completed work conforms with the established QC procedures;
- Ensure that the design and PS&E conform to applicable policies, standards, FLH standard practices, and are accurate and of high quality;
- Verify that design solutions and products meet the overall expectations of FLH, and the FLH Division, and the needs of the partner agency and project stakeholders;
- Comply with legal, regulatory and contractual requirements;
- Assure technical features are consistent with the project scope and intent, and each individual feature is properly integrated into the overall project; and
- Appropriately balance risk between various project constraints, using professional engineering judgment and endorsement of FLH management and partner agency as applicable.

9.6.11.4 Documentation of QA/QC Activities

Throughout the highway design and PS&E development, maintain evidence that applicable QA/QC procedures have been performed. Documentation of QA/QC activities should include notes from reviews, checked plans, specifications, and estimates showing review markup, checked computations showing review markup, and updated CAD files and design notes demonstrating conformance with the applicable QA/QC procedures.

The design QA/QC documentation should address:

- The documents, tracking, file management and retention of QA/QC checks and records;
- Designation of the line of design engineering responsibility;
- Certification of QC checking performed in accordance with an established plan;
- For A/E consultants, sealing and signing of A/E consultant-prepared documents such as:
    - ◊ Engineering drawings,
    - ◊ Specifications,
    - ◊ Construction cost estimate,
    - ◊ Engineering reports and formal technical memorandums,
    - ◊ Construction staking data and reports, and
    - ◊ Other formal technical recommendations or deliverables.

9.6.11.5 Evaluation of QA/QC Procedures

At the conclusion of each project, conduct an evaluation of the QA/QC procedures that were used, to identify and document any significant design problems encountered, areas for process improvement, lessons learned, outstanding quality issues, and to identify any deficiencies in the established QA/QC plan that was used. Refer to Chapter 13 for design feedback processes.

Chapter 10 – STRUCTURAL DESIGN

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CHAPTER 10

STRUCTURAL DESIGN

10.1 GENERAL

The purpose of this chapter is to provide standards, guidance and techniques for designing bridges, retaining walls, tunnels, large span culverts and other structural items. Also see Chapter 1 for general policies and guidance. The goal of a structural design is to produce a structure that:

- Serves the purpose for which it is intended;
- Is capable of co-existing within its immediate environment without causing adverse impacts (i.e., visual, physical); and
- Is economical from both a maintenance and construction point of view.

Structural design requires a solid understanding of the techniques of structural analysis and the behavior of a structure under various loading conditions. Structural design also requires knowledge of concrete, steel and timber material properties.

Awareness of factors related to other engineering fields (e.g., hydraulics, soils) is necessary to ensure that the structure functions without affecting or being affected by its environment in a detrimental way. Finally, the importance of aesthetic appeal must be recognized to make the structure an extension of nature rather than an intrusion on nature.

The Federal Lands Highway Bridge Office (FLHBO) employs a staff of professional structural/bridge engineers who develop plans and specifications for projects and occasionally oversee the actual construction.

Since structural elements do not normally comprise the entire highway project, the structural engineer will generally function as part of a design team.

The Project Manager has the overall responsibility for seeing that all aspects of the project are addressed.

However, the structural designer must obtain supporting data from the environmental, geotechnical, survey and hydraulics staff and coordinate the structural design with these technical units. The structural engineer is responsible for the following:

- Developing bridge type, size and location (TS&L);
- Designing bridges, retaining walls and other structures;
- Preparing complete PS&E's for structures;
- Providing technical assistance to construction staff;
- Checking contract shop drawings; and
- Providing technical assistance to other agencies as requested.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

10.1.1 BRIDGES

Bridges are the most common major structure encountered in highway engineering and the most varied in design. Bridges range from simple designs (e.g., a timber deck on stringers that are supported at each end) to very complex designs (e.g., segmental, cable-stayed, suspension bridges). Span lengths can vary from 20 ft [6 m] to hundreds of feet [meters]. Each bridge location is different and in most cases it is necessary to custom-fit a bridge structure into its surroundings. This generally precludes the use of wholly standardized plans and specifications in the design of bridges and requires that each bridge be handled individually.

Structural engineering work consists of designing new structures and repairing or rehabilitating existing ones. Bridges include both simple and continuous span structures constructed of reinforced concrete, prestressed concrete, steel, timber or a combination of these materials. Span lengths generally range from 20 ft [6 m] to approximately 200 ft [60 m]. As a general rule, slab-type superstructures (i.e., cast-in-place, precast, prestressed units) are economical for span lengths up to 50 ft [15 m]. Conventional composite superstructures consisting of a deck slab supported by steel stringers or concrete beams are commonly used for spans up to 100 ft [30 m]. For span lengths ranging between 100 ft and 150 ft [30 m and 46 m] a prestressed concrete bulb-tee or composite steel plate girder can be used. Structures with span lengths greater than 150 ft [46 m] require special consideration.

Bridge rehabilitation includes repairs, reconstructs, replaces or retrofits of various structural components, such as railing system, joints, deck, superstructures, substructures, etc. The most common bridge rehabilitation involves the repair of concrete decks that have been damaged by corrosion of the steel reinforcing in the deck. The type of repair needed depends on the level of concrete and steel deterioration. A deck that is severely deteriorated may have to be entirely replaced, whereas one that is moderately deteriorated could be made usable by removing and replacing all unsound materials. For decks in the initial stages of deterioration, one preventive solution may be to install a cathodic protection system to stop further corrosion.

10.1.2 SPECIAL DESIGNS

The structural engineer may occasionally become involved with certain types of bridges or other structures that differ from those normally handled and would therefore be considered special designs. This category includes major bridges having exceptionally long spans and/or requiring unique design and construction techniques. Examples are cable-stayed bridges, segmental bridges and long-span box girder bridges. Designing these types of structures often requires specific expertise. For this reason, the Office of Infrastructure often reviews projects of this type and is available to provide assistance upon request.

In general, certain structures (e.g., box culverts, sign supports) lend themselves to a standardized design. This enables the roadway designer to handle these types of structures with little or no assistance from the structural engineer. Occasionally, standard designs or plans are not entirely applicable to the conditions encountered and a modified or custom design is necessary.

An example of a modified standard design would be a box culvert that is required to have dimensions larger than what are detailed in the standard plans. The structural engineer would then be responsible for developing plans and specifications for the structure. It is therefore important that the structural engineer understand the principles governing the design of these structures and also that the engineer recognize the factors that influence their design.

In addition to the structure itself, the structural engineer is sometimes called upon to design structural components for guardrails, sign supports, lighting supports, pedestrian screening, etc.

The following provides brief descriptions for the design of retaining walls, tunnels and culverts:

1. **Retaining Walls**. The retaining wall as a highway structure serves one of two functions:
   - To maintain the stability of a roadway embankment in fill areas, or
   - To prevent unstable material from sloughing off onto the roadway surface in cut areas.

   The design of retaining walls is normally carried out by the structural engineer.
2. **Tunnels**. Because of their high construction costs, highway tunnels have limited use and should only be considered when other more cost-effective alternatives are not practical. The successful design of a tunnel is dependent upon a comprehensive geologic study performed by qualified geotechnical engineers to determine the presence of faults, badly fractured rock, seams, water, etc. It is vital that the structural engineer work closely with the geotechnical engineers to determine requirements for lining, drainage and methods of excavation.
3. **Culverts**. Culverts with clear spans greater than 10 ft [3 m] are generally described as large culverts and are in most instances designed for a specific site condition by a structural engineer. While these structures are described as culverts, they are in most cases not used as drainage structures, but are used to pass farm livestock, farm machinery, industrial equipment or people through an earth embankment. Typically, these large culverts are low profile steel arch superspans with spans from 20 ft to 40 ft [6 m to 12 m], rigid frame reinforced concrete box structures with spans in the 13 ft to 18 ft [4 m to 5.5 m] range and precast prestressed concrete low profile arch structures with spans in the 29.5 ft to 40 ft [9 m to 12 m] range.

10.2 GUIDANCE AND REFERENCES

The FLH Program includes a wide variety of bridge types, site conditions and design loadings. Accordingly, the bridge engineer relies on a wide variety of references for assistance, as described in the following subsections.

10.2.1 PROFESSIONAL ASSISTANCE

The primary source of professional assistance is the FLH Bridge Engineer and senior structural engineers within the design office. These individuals can provide not only technical guidance, but also can explain the correlation between theory and specifications.

Additional professional assistances are available from the Office of Infrastructure, Bridge Technology in the Federal Highway Administration, Washington, DC, the Federal Highway Administration Resource Center and the Office of Research Development and Technology at Turner-Fairbank Highway Research Center, Virginia.

On FLH projects that become part of State highway systems upon completion of construction, State highway departments are also a source of excellent professional assistance.

As a matter of good office practice, all outside contacts should be informally discussed with the FLH Bridge Engineer prior to making contact and the items discussed should be documented in the design notes or in the design files.

10.2.2 DESIGN SPECIFICATIONS AND GUIDELINES

The primary design specification for all highway bridges on public roads in the United States is the *LRFD Bridge Design Specifications* published by American Association of State Highway Transportation Officials (AASHTO) unless approval to use the AASHTO *Standard Specifications for Highway Bridges* is granted by the FLH Bridge Engineer. The *LRFD Bridge Design Specifications* is the primary design specification for all FLH bridges. AASHTO *LRFD Specifications* set forth minimum requirements that are consistent with current practice and certain modifications may be necessary to suit local conditions. AASHTO *LRFD Specifications* apply to ordinary highway bridges, but supplemental specifications may be required for unusual types and for bridges with spans longer than allowed in the AASHTO *LRFD Specifications*.

Interim Specifications are published yearly by AASHTO and have the same status as the *LRFD Specifications*. *Interim LRFD Specifications* are revisions that have been approved by at least a two-thirds majority of the members of the AASHTO Subcommittee on Bridges and Structures. FLHBO policy is to apply *Interim Specifications* to all design projects started after the issuance of the *Interim Specifications*. *Interim Specifications* shall not apply to projects retroactively.

The following AASHTO specifications, including current revisions, apply to all FLH bridge projects:

1. LRFD Bridge Design Specifications, AASHTO, current edition.
2. Standard Specifications for Highway Bridges, AASHTO, current edition.
3. Guide Specifications for Horizontally Curved Steel Girder Highway Bridges, AASHTO, current edition.
4. *Guide Specifications for Fracture Critical Non-Redundant Steel Bridge Members*, AASHTO, 1978 (with all current *Interim Specifications*).
5. *Standard Specifications for Moveable Highway Bridges*, AASHTO, 1988.
6. *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, AASHTO, current edition.
7. *Bridge Welding Code*, AASHTO/AWS D1.5, current edition.
8. *Guide Specifications for Design and Construction of Segmental Concrete Bridges*, AASHTO, current edition.

The following specifications offer insight to and clarification of many of the AASHTO *Specifications*:

1. Building Code Requirements for Reinforced Concrete and Commentary, ACI 318M, American Concrete Institute, current edition.
2. *Ontario (Canada) Highway Bridge Design Code and Commentary*, Ministry of Government Services, Toronto, Ontario, current edition.
3. *AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings and AISC Code of Standard Practice*, current edition (found in *Manual of Steel Construction*, American Institute of Steel Construction).
4. *National Design Specification for Wood Construction and Design Values for Wood Construction*, National Forest Products Association, current edition.
5. *Design Standard Specifications for Structural Glued Laminated Timber*, American Institute of Timber Construction, current edition.
6. *Structural Welding Code-Steel*, American Welding Society, current edition.
7. *Manual for Railway Engineering*, American Railway Engineering and Maintenance of Way Association (AREMA), current edition.

10.2.3 DESIGN EXAMPLES

Engineers with minimal experience should rely on the design notes and project plans of previous bridge projects. Care should always be exercised to select projects designed and checked by experienced structural engineers. Also, previous notes should not be followed in a cookbook manner, but rather, they should be used in conjunction with current AASHTO *LRFD Bridge Design Specifications*.

Design engineers should always review new projects with the project Team Leader before work is started. At this time, a similar example project to be used for guidance can be selected and discussed.

10.2.4 TECHNICAL REFERENCES

State-of-the-art bridge design involves the practical application of the principles of many varied disciplines. The following references are listed to provide entry-level structural engineers with theoretical background and assistance in practical bridge design. These references should not necessarily be considered FLHBO policy. Experienced structural engineers may also find the listing useful for a personal library.

10.2.4.1 Structural Analysis

The following references apply to structural analysis:

1. Moments, Shears, and Reactions for Continuous Highway Bridges, American Institute of Steel Construction.
2. Timoshenko, S., *Strength of Materials*, 2 volumes, 3rd ed., New York. D., Van Nostrand Company, 1958.
3. Roark, Raymond J. and Young, Warren C., *Formulas for Stress and Strain*, New York, McGraw-Hill Book Company, 1975.
4. Wang, Chukia K., *Statically Indeterminate Structures*, Chukia K. Wang, New York, McGraw-Hill Book Company, 1953.
5. Gaylord Jr., Edwin H. and Gaylord, Charles, *Structural Engineer Handbook*, 2nd ed., New York, McGraw-Hill Book Company, 1979.
6. Gere, James J. and Weaver Jr., William, *Analysis of Framed Structures*, Princeton, NJ. D. Van Nostrand Company, 1965.
7. Gere, James M., *Moment Distribution*, Princeton, NJ, D. Van Nostrand Company, 1963.
8. *Continuous Concrete Bridges*, 2nd ed., Portland Cement Association.
9. *Handbook of Frame Constants*, Portland Cement Association, 1958.
10. Carpenter, Samuel T., *Structural Mechanism*, Salt Lake City, John Wiley and Sons, 1960.
11. Ketter, Robert L.; Lee, George C.; and Prawel, Sherwood P., *Structural Analysis and Design*, New York, McGraw-Hill Book Company, 1979.

10.2.4.2 Reinforced Concrete

The following references apply to reinforced concrete:

1. *ACI Manual of Concrete Practice*, American Concrete Institute, current edition..
2. *Design of Highway Bridges: Based on AASHTO LRFD, Bridge Design Specifications,* Richard M. Barker, Jay A. Puckett, current edition.
3. *CRSI Handbook*, Concrete Reinforcing Steel Institute, current edition.
4. *AASHTO LRFD Strut-and-Tie Model Design Examples*, Portland Cement Association (PCA).
5. FHWA/NHI LRFD Design Example for Prestressed Concrete Superstructure Bridge with Commentary.
6. *Manual of Standard Practice*, Concrete Reinforcing Steel Institute, current edition.
7. *Reinforcing Bar Detailing*, Concrete Reinforcing Steel Institute, current edition.
8. Hurd, M.K., *Formwork for Concrete*, American Concrete Institute, current edition

10.2.4.3 Structural Steel

The following references apply to structural steel:

1. Design *of Highway Bridges: Based on AASHTO LRFD, Bridge Design Specifications,* Richard M. Barker, Jay A. Puckett, current edition.
2. *FHWA/NHI LRFD Design Example for Steel Superstructure Bridge with Commentary*
3. Fischer, John W., *Bridge Fatigue Guide*, American Institute of Steel Construction, 1977.
4. Fischer, John W., *Fatigue and Fracture in Steel Bridges*, Salt Lake City, John Wiley and Sons, 1984.
5. *FHWA/NSBA* Three-Span Continuous Composite I-Girder Steel Bridge Design Example.

10.2.4.4 Prestressed Concrete

The following references apply to prestressed concrete:

1. LEAP Software LRFD Bridge Design Books with design examples (2), LEAP Software, current edition.
2. *Post-Tensioning Manual*, Post-Tensioning Institute, current edition.
3. *Post-Tensioned Box Girder Bridge Manual*, Post-Tensioning Institute, current edition.
4. *Precast Segmental Box Girder Bridge Manual*, Post-Tensioning Institute and Prestressed Concrete Institute, current edition.
5. *Design of Highway Bridges: Based on AASHTO LRFD, Bridge Design Specifications,* Richard M. Barker, Jay A. Puckett, current edition.
6. *PCI Bridge Design Manual, Volumes One and Two*, current edition.

7. *PCI Design Handbook, Precast and Prestressed Concrete*, Prestressed Concrete Institute, current edition.

10.2.4.5 Timber

The following references apply to timber:

1. *Timber Bridges: Design, Construction, Inspection and Maintenance*, US Department of Agriculture, US Forest Service, current edition.
2. *Timber Construction Manual*, American Institute of Timber Construction, Salt Lake City, John Wiley and Sons.
3. *Weyerhaeuser Glulam Wood Bridge Systems*, Weyerhaeuser Company, 1980.
4. *Design of Highway Bridges: Based on AASHTO LRFD, Bridge Design Specifications,* Richard M. Barker, Jay A. Puckett, current edition.
5. *Timber Design and Construction Handbook*, Timber Engineering Company, New York, McGraw-Hill Book Company, 1956 (out of print).
6. *National Design Specification (NDS) for Wood Construction*, American Forest and Paper Association, current edition.

10.2.4.6 Foundations

The following references apply to foundations:

1. Bowles, Joseph E., *Foundation Analysis and Design*, New York, McGraw-Hill Book Company, 1988.
2. Terzaghi, Karl and Peck, Ralph B., *Soil Mechanics in Engineering Practice*, Salt Lake City, John Wiley and Sons, 1967.
3. *Bridge Substructure and Foundation Design*, Petros P. Xanthakos, current edition.
4. *Manual on Design and Construction of Driven Pile Foundations*, DOT, FHWA, 1985.
5. *Design of Highway Bridges: Based on AASHTO LRFD, Bridge Design Specifications,* Richard M. Barker, Jay A. Puckett, current edition.
6. *FHWA/NHI LRFD Design Example for Steel Superstructure Bridge with Commentary*.
7. *Design of Piles and Drilled Shafts Under Lateral Load*, DOT, FHWA, 1987.
8. *Steel Sheet Piling Design Manual*, US Steel, Updated and reprinted by DOT, FHWA, July 1984.
9. FHWA/NHI LRFD Design Example for Prestressed Concrete Superstructure Bridge with Commentary (Available on the H Drive).
10. *LEAP Software LRFD Bridge Design Books with design examples (2),* LEAP Software, current edition.

10.2.4.7 Seismic/Dynamic Analysis

The following references apply to seismic and/or dynamic analysis:

1. Newmark, Nathan M. and Rosenblueth E., *Fundamentals of Earthquake Engineering*, Englewood Cliffs, NJ, Prentice-Hall, 1971.
2. Weigel, Robert L., *Earthquake Engineering*, Englewood Cliffs, NJ, Prentice-Hall, 1970.
3. *Seismic Design of Highway Bridges - Workshop Manual*, DOT, FHWA, Office of Research and Development, Implementation Division, January 1981.
4. *Caltrans SEISMIC Bridge Design Specification and Commentary*, California Department of Transportation, Office of Structure Design, current edition.
5. *Seismic Analysis and Design of the AISI LRFD Design Examples of Steel Highway Bridges*, AISI.

10.2.4.8 Miscellaneous Topics/Design Manuals

The following references discuss topics that were not discussed in the above sections:

1. LRFD, Bridge Construction Specifications, AASHTO, current edition
2. *Bridge Design Practice - Load Factor*, California Department of Transportation, current edition.
3. *California Falsework Manual*, California Department of Transportation, Division of Structures, current edition.
4. *California Trenching and Shoring Manual*, California Department of Transportation, current edition.
5. *Construction Handbook for Bridge Temporary Works*, FHWA, current edition.

10.3 INVESTIGATION

In the development of structural design plans and specifications, the structural engineer will be confronted with data and comments obtained from several different types of investigations and reviews. This information may include bridge safety inspection structural condition data reports, bridge site survey information and several levels of field review. Also refer to Section 4.3 for general guidance when beginning the investigation.

10.3.1 BRIDGE SITE PLANS

A bridge site plan is developed when a new or replacement bridge is required. The purpose of the site plan is to provide the structural engineer with a graphic representation of the topography at the site so the required type, size and length of bridge can be determined for the site.

Bridge site topography can have a significant effect on the method of construction. The structural engineer must be aware of the possibilities and limitations that are presented by the existing conditions. Topographic maps assist the designer in determining quantities of excavation for estimating purposes.

The site plan shows the contours of the terrain as well as roads, streams or other significant features in the immediate area of the proposed bridge. Survey teams taking extensive topographic field measurements collect this data. The plans should be drawn using a scale appropriate for the total length of the proposed bridge. Contours are generally drawn at 1 ft or 3 ft [0.5 m or 1 m] intervals.

10.3.2 HYDRAULIC ANALYSIS

In cases where a bridge crosses a river, stream or flood plain, it is usually necessary to perform a hydraulic investigation and analysis. This is generally accomplished concurrently with the development of the site plan since hydraulic information is needed in deciding what type of structure is practical for the crossing. The structural engineer is interested in the high water elevation and flow velocity for flood conditions with a specified frequency of occurrence.

Typically, bridges are designed to handle a 50-year flood, which is a flood of a magnitude that it is expected to occur no more frequently than once in 50 years. For some large, high-cost structures, the design might be based on a 100-year flood to lessen the risk of flood damage. For detailed information with regard to the hydraulic design of bridges, see Chapter 7.

10.3.3 GEOTECHNICAL INVESTIGATION

Geotechnical investigations should be performed after the site plan has been developed and preliminary determinations have been made regarding the type and length of the proposed structure and the location of the foundations for the structure. The purpose of the investigation is to identify the composition of the underlying stratum, determine whether the preliminary location is acceptable as a foundation site and determine what type of foundation design is most appropriate.

Most often the investigation consists of extracting and analyzing core samples of the substratum. Core drilling is normally performed to the depth necessary to reach solid rock. For small bridges on flat terrain, a single core is sometimes sufficient. For bridges longer than approximately 100 ft [30 m] or bridges located on hilly terrain, a more comprehensive study is typically needed. It is desirable to obtain at least one core at each foundation site.

After analyzing the data, the geotechnical engineer should provide a report containing recommendations for the type of foundation needed along with allowable bearing capacities and any other pertinent information. The structural engineer receives a copy of this report to assist in developing the final design of the foundations. For detailed information with regard to the geotechnical design of bridges, see Chapter 6.

10.3.4 BRIDGE INSPECTION PROGRAM

All bridges located on public roads are required by law to be inspected at regular intervals not to exceed two years. The inspections must be in accordance with the *National Bridge Inspection Standards and Guidelines* as set forth in Title 23, CFR, Part 650, Subpart C.

The FLH Bridge Office administers a bridge inspection program for the National Park Service and other Federal agencies. Bridge structures are reviewed for condition and structural adequacy.

Basic data that can be found in a typical inspection report includes the following:

- Photographs of the roadway and profile view of the bridge;
- A written description and photographs of deficiencies found during the inspection;
- Basic physical dimensions of the bridge; and
- A structural load capacity rating, where applicable.

In many instances, data found in these reports is the basis for the development of preliminary bridge repair plans.

10.3.5 DECK SURVEY

A deck survey is performed to assess the structural condition of the bridge deck. The information is used by the structural engineer to determine if the deck can be repaired and the most suitable method of repair, where applicable.

A deck survey may be composed of several types of investigations, which can be classified as either destructive or nondestructive. Half-cell potential readings and delamination readings are non-destructive since they provide information without actually disturbing the deck.

Destructive methods (e.g., taking chloride samples, deck cores) are generally used only when non-destructive methods yield data that indicates the potential or presence of severe internal deck deterioration. Chloride samples are taken to determine the level of chloride contamination in the deck.

Deck cores allow a visual inspection of the deck condition below the surface. Also, split-tensile tests can be performed on the cores to give an indication of the strength of the existing concrete.

10.3.6 BRIDGES WITHIN RESURFACING, RESTORATION, OR REHABILITATION (RRR) PROJECTS

Decisions are made to retain or replace any bridge within the limits of a non-freeway resurfacing, restoration, or rehabilitation (RRR) project. See the applicable chapter of the AASHTO *Green Book*. When a bridge requires replacement, design a new bridge in accordance with AASHTO LRFD structural standards for bridges. Select widths consistent with current standards to which the highway may be upgraded in the near future. Review recent bridge inspection reports to determine if the bridge is structurally and functionally adequate.

When a bridge is to remain in place, determine which treatment, if any, is required for operational and structural adequacy.

The following conditions require that no work or minor rehabilitation be performed for a RRR project:

- The bridge clear roadway width is equal to or greater than the minimum surfacing or approach traveled way widths.
- The bridge crash records indicate that crash problems do not exist and the approach is gradually narrowed to meet the bridge clear roadway width in advance of the bridge. Where crash problems exist; make an analysis to determine the necessary corrective action (e.g., providing improved transitions, rehabilitation, widening, replacement).
- The bridge railings, including the approach rail, meet or are made to meet adequate strength and geometric standards. In all cases where a structure is to remain in-place, check the bridge rail for adequacy.
- A reasonable or adequate alternative route does not exist and the load carrying capacity is sufficient to carry school buses and vital service vehicles.

Consider major rehabilitation for the following conditions:

- Deck replacement, to the extent practical, is designed in accordance with current AASHTO LRFD Bridge Design Specifications unless approval to use the AASHTO Standard Specifications for Highway Bridges is granted by the FLH Bridge Engineer;
- Rehabilitation meets current AASHTO LRFD safety standards;
- Bridge railing is to be upgraded to current standards (NCHRP 350); and/or
- The approach roadway width does not meet current AASHTO geometric standards and the bridge is to be widened to meet the geometric standards for the highway if it were reconstructed. The decision to rehabilitate or replace may be decided by established cost guidelines or may be subjective. However, when the total cost of rehabilitation is expected to exceed 50 percent of the cost of reconstructing the structure to current standards, consider replacing the structure.

Vertical clearances at existing underpass structures will require adjustment when the clearance after resurfacing work is less than the minimums required. Do not reduce surfacing depths or eliminate surfacing in the vicinity of the bridge to avoid pavement removal or structure modification.

All signing and markings for bridges shall be in accordance with the *MUTCD*.

10.3.7 FIELD REVIEWS

Two levels of field reviews are generally required in the development of plans for bridge repair, replacement or new construction. The first field review is designed to involve the responsible agencies in the design concepts and parameters that will be used in the development of plans and specifications for the given project. Basic information to be supplied by the structural engineer at this review is a proposed bridge type, size and location (TS&L) drawing for replacement and new bridge projects. Drawings depicting proposed repair methods shall be provided for bridge repair projects.

The second level of field review, commonly known as a plan-in-hand review, should be performed when the bridge drawings are approximately 70 percent complete. The purpose of this review is to verify that all items covered in the drawings will be compatible with the existing field conditions and to confirm that all design, safety and specific client agency needs are properly addressed in the final design documents.

10.4 DESIGN PROCESS

The design process involves two stages. The initial or preliminary design effort establishes the proposed structure type and layout. The final design effort develops detailed contract plans to be used to construct the facility. Both of these stages require the skills of a structural engineer.

In the preliminary design process, a structure is selected which economically fulfills the structural, functional, aesthetic and other relevant requirements of a given site. Coordinate the structure selection with the overall project preliminary design process, see Section 4.5.2.12.10.

The development of the preliminary plan requires the consideration of many different factors. The following are some of the more common of these factors:

1. **Economic**. When preparing the preliminary plan, consider the initial and maintenance costs.
2. **Site Requirements**. The following factor should be considered when reviewing the project site:
    - Topography,
    - Horizontal and vertical alignment,
    - Superelevation,
    - Deck geometrics, and
    - Proposed or existing utilities.
3. **Hydraulic**. Consider the following factors when preparing the hydraulic design:
    - Stream flow (i.e., Q_{50}, Q_{100});
    - Risk assessment;
    - Passage of debris;
    - Scour;
    - Pier and bank protection;
    - Permit requirements;
    - Deck drainage; and
    - Culverts (as alternatives).
4. **Structural**. Factors to be considered with regards to the structural aspects of a project include:
    - Span ratios,
    - Horizontal and vertical clearances,
    - Limitations on structural depth,
    - Future widening,
    - Slope treatment,
    - Foundation and groundwater conditions,
    - Anticipated settlement,
    - Eliminate deck joints if feasible, and
    - Use high performance materials (i.e., HPC, HPS) when possible.

5. **Environmental**. Consider the following environmental factors for the preliminary planning stage:
   - Aesthetics and compatibility with surroundings,
   - Similarity to adjacent structures, and
   - Extent of exposure to the public.
6. **Construction**. During the preliminary stage, consider the following factors for future construction:
   - Access to site,
   - Time for construction,
   - Detours or stage construction,
   - Extent of falsework and falsework clearances,
   - Erection problems, and
   - Ease of construction.
7. **Safety**. Consider the following safety factors for the project:
   - Traffic convenience,
   - Density and speed of traffic,
   - Approach guardrail type and connection to structure, and
   - Bridge rail type (crash tested rails).
8. **Other**. Consider any recommendations resulting from interdisciplinary team studies or special requests by an owner.

In making the recommendation for type of structure, full consideration should be given to the above factors. Economy is generally the best justification for a selection. However, some of the above considerations may outweigh differences in cost. In the final analysis, the owner must be satisfied that the proper structure has been selected.

The final design process begins with the approval, by all interested parties, of the bridge TS&L drawing. Using the information shown on the drawing, and following the design specifications, the structural engineer makes a comprehensive analysis and design of the bridge. This design is then the basis for the preparation of detailed contract plans to be included in the complete project plans.

The final design of bridges requires meticulous attention to details and a high degree of responsibility. Irresponsible design can result in construction difficulties, reduced service life of the structure and higher maintenance costs. In the extreme case, poor design can result in the collapse of the bridge either during construction or in service.

It is FLHBO policy that a complete and independent check is made of all structural design work. This means that one structural engineer designs the bridge and a second structural engineer performs an independent structural analysis of the bridge.

The information that is provided in the following sections applies to both preliminary design and to final design.

10.4.1 GENERAL FEATURES

The FLH Program involves a wide variety of bridge types from single lane forest development roads to high volume urban arterials. The general features, including widths, clearances, railings and approaches of these structures are normally controlled by the roadway standards of the client agency. All necessary general features should be shown on the bridge TS&L and should be agreed upon before final design begins.

10.4.1.1 Bridge Widths and Clearances

Single-lane bridges should be a minimum of 14 ft [4.3 m] wide, face-of-rail to face-of-rail.

Multiple lane bridges should be as wide as the approach roadway plus the offset to the face of the approach guardrail.

Vertical clearances for interchange structures should meet AASHTO *Specifications* or be consistent with other bridges on the route.

10.4.1.2 Bridge Railings and Approach Railings

Railings meeting both the geometric and structural requirements of AASHTO *LRFD Specifications* and NCHRP 350 should be provided for all bridges

The use of approach railing on all bridges is required. The approach railing should be connected to the bridge railing system with connecting details that will develop the full strength of the approach railing.

All concrete parapet-type bridge railings should be detailed with joints as follows:

- At the point of maximum positive movement of all spans,
- At or near the centerline of all piers,
- In between the above locations so that the length of rail segments does not exceed 25 ft [7.6 m], and
- At bridge expansion joints.

At these locations, joints should be detailed normal to the rails or radial on curved bridges. Joint filler material should be a minimum 0.5 in [12 mm] thick. Reinforcement should not extend through the joint.

Joints for special design concrete railings should be located as necessary to control cracking due to flexure or temperature changes.

At the ends of the bridges, between the superstructure and substructure elements, railing joints should be compatible with deck joints, expansion assumptions, etc.

All steel bridge railings should have joints located as described above. Joints should be designed to allow movement that maintains the full strength of the railing.

10.4.1.3 Hydraulic Considerations

Most bridges are designed to pass, without damage, 50-year flood design (Q_{50}) flows; however, the effects of 100-year flood design (Q_{100}) flows should be evaluated. Normally, there are only minor differences between these two flows and most structures will pass both without damage. For details concerning other hydraulic considerations for scour, clearances and slope protection, see Chapter 7.

10.4.2 LOADS

For loads and load factors, see Chapter 3 of the AASHTO *LRFD Bridge Design Specifications*.

10.4.3 DECKS, RAILS, DECK JOINTS AND DRAINS

The roadway surface of bridges that support and contain vehicular traffic consists of the deck, rails, deck joints and drains. This surface must not only provide a good riding surface but also must also provide durability against abrasive deterioration and repetitive cycles of loading in flexure and shear.

10.4.3.1 Deck Design

Transversely reinforced concrete slabs are the most commonly used bridge deck and are a significant portion of bridge design in terms of dollar investment.

These slabs also make-up the one portion of the bridge that has the most common and expensive maintenance problems. Heavy wheel loads, excessive use of deicing salts, studded tires and poor construction control are contributing factors to structure damage.

Edge support for transversely reinforced slabs is normally provided by steel or concrete cast-in-place end diaphragms. These diaphragms are often placed only between girders. Caution should be exercised to provide an edge support on slab overhangs where a substantial length of overhang might exist and where moments due to wheel loads might be a major portion of the total moment requirement. Cast-in-place decks on structural steel superstructures are another place where edge support might not naturally be provided. Edge support should be designed for each condition to be capable of carrying a wheel load.

Placement of transverse slab reinforcing on skewed bridges is a subject of some debate. A reasonable rule used by many designers, however, places the reinforcement on the skew for up to 20 degrees, and for 20 degrees or greater, places the reinforcing normal to the roadway with variable length bars at the skewed ends. For reinforcement placed on the skew, the span should be increased to the skewed length and the area of reinforcement increased for the spacing normal to the skew. For skew angles greater than 30°, additional reinforcement shall be placed in the slab end zones at abutments and conventional deck joints.

The AASHTO *LRFD Specifications* require a 2 in [50 mm] cover over the top reinforcing steel and a 1 in [25 mm] cover over the bottom reinforcement in deck slabs. Both the positive moment bottom reinforcement and the negative moment top reinforcement should be designed. It is common practice to make the top and bottom reinforcement the same to avoid confusion during construction. It is FLHBO policy that the cover over the top and bottom reinforcing steel in deck slabs shall be 2.5 in [65 mm] and 1.5 in [40 mm] respectively, and all reinforcing steel connecting to the deck slabs shall be epoxy-coated. The purpose is to ensure that a minimum of covers of concrete would be provided over all reinforcing steel. It is also recommended to use low permeability High Performance Concrete (HPC) when possible. Both recommendations, combined with the use of epoxy-coated reinforcing steel, should be used when appropriate.

10.4.4 RAIL DESIGN

Bridge railings are an extremely important part of any structure and should be carefully designed and detailed. Railing loads are specified in AASHTO *LRFD Bridge Design Specifications*. The application of these loads to the deck overhang is also covered in the AASHTO *LRFD Specifications*.

The method of connection of rails to decks should allow for ease of deck construction, for alignment and for ease of rail repair or replacement.

10.4.5 DECK JOINT DESIGN

The designer should carefully consider accommodating all bridge movements for deck joint designs.

These movements include but are not limited to the following:

- Temperature expansion and contraction,
- Concrete shrinkage and creep,
- Live load rotation,
- Effects of prestressing, and
- Foundation movements.

Deck joints should be avoided whenever possible since they are often sources of maintenance problems due to leakage of roadway water and contaminants as well as improper performance.

When possible, jointless, integral or semi-integral abutments should be used to eliminate deck joints at the ends of bridges. The following are some rough guidelines for providing for superstructure movements at abutments:

1. **Integral Abutments**. Integral abutments are constructed as a rigid connection of the deck and beams to a single row pile supported substructure. There are no expansion joints at the abutments. The length of an integral abutment structure shall be measured between the abutments centerlines. For integral abutment structure up to 325 ft [100 m] long, an expansion joint should be provided at the end of each approach slab (sleeper slab is required). The use of integral abutment should be investigated for integral abutment structures over 325 ft [100 m] long.
2. **Semi-Integral Abutments**. For rigid abutments, and for flexible abutments with more that 75 ft [23 m] of contributory length, allow superstructure movement to occur against the approach fill, but permit movement between superstructure and abutment with an expansion bearing. Semi-Integral abutments are similar to conventional abutments with the exception of the girders extending over the bridge seat and are embedded in a backwall that hangs off behind, but is not connected to, the abutment stem. The maximum expansion length to the nearest fixed bearing should not exceed 230 ft [70 m]. An expansion joint should be provided at the end of each approach slab (sleeper slab is required).
3. **Jointless Abutments**. For jointless abutments where spans contributing to expansion at the abutment in question are less than 100 ft [30 m] long, no provision for expansion is required. For spans with more than 100 ft [30 m] spans contributing to expansion at the abutment in question and are more than 100 ft [30 m] long, an expansion joint should be provided at the end of each approach slab (sleeper slab is required).
4. **Conventional Abutments**. Conventional abutments with an independent backwall type abutment with deck joint designed for all movements should be used when the use of jointless, integral or semi-integral abutments is not feasible.

The above guidelines should be used with careful consideration of bearing protection from contaminants as well as provision for approach fill drainage and abutment details.

Deck joints between abutments are not desirable for the reasons mentioned. In general, they should only be used to separate different superstructure types, relieve frame-type restraint forces or when the designer feels the provision for movement is critical.

For movements of less than 4 in [100 mm], the designer can select any of a number of proprietary joints according to the manufacturer's recommendations. It is recommended that on skewed joints, an interlocking type strip or gland seal be used. The joint should be detailed so drainage is properly handled at curbs, sidewalks, parapets, etc. On the plans, the joint width setting at the temperature anticipated during construction should be shown as well as adjustments for other construction temperatures.

For movements more than 4 in [100 mm], a special design is required.

10.4.5.1 Deck Drains

Every bridge should be analyzed for deck drainage considering width of bridge, superelevation or crown, profile grade, wingwalls, rail type and geographic location. Consideration should be given to locating bridge deck drains between toes of embankments and installing drainage structures, catch basins, etc., off the bridge.

Deck drains over abutment fill slopes should be avoided. These drains have caused severe erosion on many previous projects. Where deck drains must be provided over abutment fill slopes, the plans must include an erosion control measure to be built at the time of bridge construction.

10.4.5.2 Analysis of Bridge Structures

The analysis of bridge structures begins with an approved TS&L drawing and the AASHTO *LRFD Bridge Design Specifications*. Using these two documents, the design engineer begins by making a preliminary estimate of the members and end conditions. This assumed structure is then analyzed for the design loads and only the critical sections are designed. This design is then compared with the assumed (estimated) sections.

If necessary, the structure is modified and the new structure is again analyzed. This process continues until the optimum design is attained. At this point, the entire structure is designed for all sections and the plans can be produced.

Typically, the design is monitored at each stop for consistency, economic feasibility and practicality of construction. The designer must never forget the original purpose of the structure and the objectives of the FLHBO partners.

10.4.5.3 Preliminary Sizing and Structure Modeling

The preliminary sizing of the bridge members is aided by previously similar designs as well as the depth-to-span criteria listed under Sections 10.4.5 through 10.4.8. This is a critical point in the design process since a wise choice here will reduce the analysis/design iterations mentioned. Experience is invaluable at this stage, so assistance from the FLH Bridge Engineer and the senior structural engineers is highly recommended. On certain structures, final design of the deck and traffic rails is now possible. This will help to finalize a portion of the dead load.

Structural analysis is the determination of displacements and stresses due to the known loads. For analysis purposes, the bridge structure must be idealized or modeled as to how the various parts interact to carry the loads to the supports.

In all structural analysis, the following three fundamental relationships must be satisfied:

- Equilibrium,
- Compatibility of displacements, and
- Consistency of displacements with the respective stress/strain relationships.

The simplest structure type to analyze is the determinate structure, which needs only the equations of equilibrium for complete solution.

The indeterminate structure requires compatibility and stress/strain relationships in addition to the equilibrium equations for complete solution. This requires significantly more effort than the determinate structure.

For each member in the bridge structure, the designer must decide whether a simplified determinate model will be adequate or whether a more complicated, time consuming indeterminate model is required. For example, a pile cap is often analyzed for 0.8 times the simple span moment to approximate the moments from a more difficult indeterminate solution, and the simple span shears are increased by 20 percent to account for continuity. By contrast, a bridge to be built at a high seismic location must be modeled with a sophisticated three-dimensional mathematical model to permit the required dynamic analysis.

Structure modeling for bridge members and complete structures can only be briefly introduced in this chapter. The inexperienced structural engineer is referred to the many references listed in Section 10.2 as well as professional assistance from the sources listed in the same section.

The engineer should always make certain that the modeling assumptions adequately represent the members or structures' true behavior for the particular design being conducted.

10.4.5.4 Simplified Methods of Analysis (Hand Method)

Before the development of computer structural analysis aids, many techniques for hand analysis were developed. These hand analysis techniques continue to be valuable tools for the structural engineer. These techniques serve to train inexperienced engineers in the structural theory behind the computer programs. They also provide a means to check and understand the results of computer analyses.

Moment distribution is a simple, fast and accurate method of analyzing continuous girders and frames. It was first taught by Professor Hardy Cross in 1924 and continues to be the bridge engineer's most powerful hand analysis tool. Two excellent references are the *Manual of Bridge Design Practice*, 3rd edition by Caltrans and *Moment Distribution* by J.M. Gere. Moment distribution can easily accommodate the frequent variable moment-of-inertia member types encountered by use of aids for stiffness and carryover factors as well as fixed-end moments for various loadings. The analogous column procedure can be used to develop these for members and loadings not covered by the aids.

For computation of deflections, the moment area and conjugate beam procedures prove very useful. Another deflection computation method that can be extended for calculation of buckling loads and beam-column problems is Newmark's method. These methods are described in *Structural Mechanics* by Samuel Carpenter and *Structural Analysis* by Harold Laursen.

Moments, Shears and Reactions for Continuous Highway Bridges by AISC provides complete moments, shears and reactions for certain continuous beam type members. It provides coefficients for determining influence lines that can be used for both dead and live loads.

The elastic center method can be used to analyze arches and rigid frames. It is described in *Structural Mechanics* by Samuel Carpenter, Section 14 of *Manual of Bridge Design Practice*, 3rd Edition, by Caltrans and *Analysis of Arches, Rigid Frames and Sewer Sections* by the Portland Cement Association.

For indeterminate frame type structures, the following procedure for hand analysis has proven helpful:

1. **Calculate Stiffness**. From assumed member sizes, calculate stiffness and carryover factors.
2. **Perform Moment Distributions**. Perform moment distributions for unit fixed-end moments at all member ends individually and tabulate the results.
3. **Calculate Dead and Live-Load Moments**. Calculate dead load and live load moments and shears at critical superstructure sections using the above unit distributions multiplied by the fixed-end moments for dead and live loads.
4. **Check Critical Superstructure Sections**. Check the critical superstructure sections for adequacy for the assumed member sizes. (If not adequate, a change at this point will not require much effort.)
5. **Design Superstructure**. When critical superstructure sections are adequate, design the substructure. (Changes at this point to the substructure members will not waste much previous effort and reanalysis can be done.)
6. **Compute Dead Load Moments and Shears**. When substructure design is complete, compute dead load moments and shears for the superstructure at all tenth-point locations.
7. **Develop Influence Lines**. Develop and draw influence lines for moments at the tenth points. Live load moments and shears can be obtained semigraphically from these.
8. **Produce Moments and Shears**. Finally, produce the required envelopes of moments and shears for the completion of the superstructure design.

10.4.5.5 Refined Methods of Analysis (Computer Method)

The computer has become an invaluable aid to the bridge engineer. It permits better analysis in much less time than hand methods. It provides the engineer more flexibility to change member sizes and investigate different support conditions, various loading conditions and various modeling assumptions, than possible with time-consuming hand analyses.

Use of this greater analysis power removes the tedium of hand analysis and allows much more flexibility, but demands that the responsible engineer become familiar with each program, its capabilities and limitations, and verify the results of each analysis. This responsible use of computer tools is essential to maintain professional control of a bridge analysis and design project. The computer cannot substitute for an engineer’s education, experience, judgment and responsibility.

It is FLHBO policy to encourage the responsible use of state-of-the-art computer tools for analysis and design of bridge structures.

Some recommendations for responsible use of this tool are as follows:

- Determine program authors, original purpose and history of usage and revisions in order to evaluate the authenticity of reliability, available technical support for and the maturity of the program;
- Obtain complete user documentation as well as sample problem input and output;
- Strive to become familiar with and understand the program's flow and internal algorithms to the greatest extent possible;
- Obtain training and technical support from program authors or experienced users;
- Obtain education in unfamiliar program analysis techniques;
- When using very complicated programs for the first time, obtain a check run from the same program by the author or an experienced user;
- Always correlate the program output results (at least at critical sections) to a rough hand analysis in which you have confidence;
- When reasonable correlation does not exist, determine the cause and pursue better correlation or understanding before using the program further;
- Document helpful notes on input, usage, problem areas, correlation results, etc., for aiding novices and repeat users; and
- Avoid becoming overconfident with any program and always verify its results.

A very real danger exists in irresponsible computer usage. Engineers should spend their early career development time learning not just the usage of computer programs, but also the structural theory fundamentals.

In the FLH Bridge Office, engineers are taught the classical hand analysis techniques described previously along with proper computer usage. Development of these hand skills has shown to provide an excellent theoretical as well as practical application base for the development of responsible bridge engineers.

The following are some excellent computer programs:

1. **Bridge Design System (BDS)**. An orthogonal plane frame analysis system applicable to a wide variety of bridges.
2. **CONSPAN.** A comprehensive program for the AASHTO Standard and LRFD design and analysis of simple- and multiple-span precast and prestressed bridge beams.
3. **Structural Analysis Program (SAP)**. A large, general-purpose, elastic finite element program for static, dynamic and nonlinear analysis.
4. **RC-PIER.**An integrated tool for the AASHTO Standard and LRFD analysis and design of reinforced concrete bridge substructures and foundations.

5. **CONBOX.** Specifically developed for the analysis and design of post-tensioned and cast-in-place reinforced concrete box girder and slab bridges constructed on falsework.
6. **LARSA**. Analyzes steel, concrete segmental, composite and cable-stayed bridges.
7. **Bridge Rating and Analysis of Structural Systems (BRASS)**. Analyzes and designs reinforced concrete box culverts; steel, timber, reinforced concrete or prestressed girders; and, reinforced concrete piers. The program is a comprehensive system for rating simple and continuous truss and girder floor beam stringer type bridges.

10.4.6 REINFORCED CONCRETE DESIGN

Almost every bridge designed in the United States today uses reinforced concrete in some element. This may be footings, substructure elements (e.g., piers, abutments), retaining walls, girders, decks or rails. Many bridges consist entirely of reinforced concrete. Since its introduction over 150 years ago, concrete has been the most widely used construction material in the history of civilization. The major advantage in the use of concrete for bridges is its ability to be used in a wide variety of configurations and to have variable content.

10.4.6.1 Structural Types

The following is a list of the more common types of reinforced concrete bridge structures. Each design has distinctive characteristics and attributes.

1. **Reinforced Concrete Slab Bridge**. The following applies:
   a. **Structural**. Refer to Section 2.5.2.6.3 of the AASHTO *LRFD Bridge Design Specifications* for the span-to-depth ratios.
   b. **Appearance**. Neat and simple; desirable for low, short spans.
   c. **Construction**. Details and formwork simplest.
   d. **Traffic**. May be impeded by falsework if cast-in-place due to reduced clearances. Guardrail should protect falsework openings for traffic lanes.
   e. **Construction time**. Shortest of any cast-in-place construction.
   f. **Maintenance**. Very little except at hinges. Future widening may be difficult.
2. **Reinforced Concrete T-Beam Bridge**. The following applies:
   a. **Structural**. Refer to Section 2.5.2.6.3 of the AASHTO *LRFD Bridge Design Specifications* for the span-to-depth ratios.
   b. **Appearance**. Cluttered in view from bottom; elevation is neat and simple.
   c. **Construction**. Requires good finish on all surfaces; formwork is complicated.
   d. **Traffic**. May be impeded by falsework if cast-in-place due to reduced clearances. Guardrail should protect falsework openings for traffic lanes.

e. **Construction time**. More than for slabs due to forming, but not excessively long.

f. **Maintenance**. Low, except that bearing and hinge details may require attention.

3. **Reinforced Concrete Box Girder Bridge**. The following applies:

a. **Structural**. Refer to Section 2.5.2.6.3 of the AASHTO *LRFD Bridge Design Specifications* for the span-to-depth ratios. High torsional resistance makes it suitable on curved alignment.

b. **Appearance**. Neat and clean lines from all views; utilities, pipes and conduits can be concealed.

c. **Construction**. Rough form finish is satisfactory on inside surfaces; formwork is complicated.

d. **Traffic**. May be impeded by falsework due to reduced clearances. Guardrail should protect falsework openings for traffic lanes.

e. **Construction Time**. More than for slabs or T-beams due to staging of concrete placement, but still not excessively long.

f. **Maintenance**. Low, except that bearing and hinge details may give some trouble. Future widening may be difficult.

4. **Rigid-Frame Bridges**. The following applies:

a. **Structural**. Integral rigid negative-moment knees greatly reduce the positive span moment and overturning moment at foundation level.

Single rigid portal frames will adapt to narrow water channels, railways, subways and divided or undivided highways underneath.

Double-span rigid frames suitable for divided multilane highways underneath with sufficient small or medium width for triple-span support rigid frames (with or without side spans) are possible to accommodate multilane, divided highways with a wider center mall or median.

Advantage of variable moment of inertia can be easily incorporated. Preliminary proportioning can start with a thickness at the knee equal to approximately twice that at the crown.

b. **Appearance**. Graceful and clean; well adjusted to stone facing.

c. **Construction**. Usually requiring curved formwork for variable depth.

d. **Traffic**. May be impeded by falsework due to reduced clearances. Guardrail should protect falsework openings for traffic lanes.

e. **Construction Time**. Similar to that of other types.

f. **Maintenance**. Low, except for potential backfill settlement. Limited flexibility for future widening.

5. **Arch Bridges**. The following applies:

   a. **Structural**. Horizontal reactions created by an arch greatly reduce the otherwise large, positive moment in the center. Constant depth for small spans and variable moment of inertia for medium and long spans. Spans as long as 1000 ft [300 m] have been built. Rise-to-span ratio varies with topography. Thickness at spring lines usually is slightly more than twice that at the crown. Filled spandrels are used only with short spans.

   b. For medium and long deck spans, open spandrels with roadways carried by columns are the rule. In a through-arch, the center deck usually is carried by hangers and side decks by columns. Use long single spans over deep waterways and shorter multiple spans over wide, shallow waters with rock bottoms.

   c. **Appearances**. Graceful and attractive, especially over deep gorges, ravines or a large waterway.

   d. **Construction**. Either falsework or cantilever methods can be used.

   e. **Traffic**. When traffic cannot be diverted, the cantilever method may be used instead of falsework.

   f. **Construction Time**. Usually longer than for other structures. Use prefabricated blocks and post-tensioning when shorter time is desired.

   g. Maintenance. Low.

10.4.6.2 General Requirements and Materials

Concrete to be used for nonprestressed structures will normally have a 28-day compressive strength (f'_c) of 4 ksi to 5 ksi [28 MPa to 35 MPa]. The strength required will be based on the member use and product availability from local sources. Poor quality local aggregates often limit the strength of available concrete.

All reinforcing steel should conform to Section 709 of the *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-XX*.

10.4.6.3 Analysis

All members of statically determinate or indeterminate structures should be designed for the maximum effects of all loads as determined by elastic analysis. Instead of elastic analysis, any acceptable method may be used that takes into account the nonlinear behavior of reinforced concrete, when subjected to bending moments approaching the ultimate. The FLH Bridge Engineer should approve the use of these more exact methods of analysis on a case-by-case basis. Consider the following:

1. **Expansion and Contraction**. When designing and detailing reinforced concrete structures, the design engineer should always keep in mind the degree of restraint in members of the bridge. Highly restrained members will almost always crack due to

shrinkage or temperature changes. Carefully located construction joints can reduce shrinkage stresses. Stresses due to temperature changes can be controlled by adjusting the stiffness of the structure and by the location of joints.

Creep and shrinkage of concrete are time-dependent deformations and must be included in the design of bridge structures. Short-term loading (live loads) on a concrete bridge induces elastic deformations. Dead loads or superimposed dead loads, however, are long-term effects that must be considered.

Creep of concrete is the phenomenon in which the deformation continues with time under constant load. This response can be related to the initial elastic deformation or strain.

Shrinkage is defined as the volume change in the concrete with respect to time.

10.4.6.4 Design

The AASHTO *LRFD Bridge Design Specifications* should be used on all new construction projects unless approval to use the AASHTO *Standard Specifications for Highway Bridges* is granted by the FLH Bridge Engineer. On rehabilitation projects, the use of the AASHTO *Standard Specifications for Highway Bridges* will be decided on a case-by-case basis by the FLH Bridge Engineer.

10.4.6.5 Specifications, Design Aids and Policies

The technical references listed in Section 10.2.4 will clarify and guide the usage of the AASHTO *LRFD Bridge Design Specifications*. The AASHTO *LRFD Yearly Interims* are necessary since bridge design is dynamic in nature (i.e., research and development of new technologies force changes in both design specifications as well as construction methods).

10.4.7 STRUCTURAL STEEL DESIGN

Although true structural steel was used for the eye-bars of suspension bridges in the early 1800’s, it was not until about 1870 that the first all steel bridge was constructed. Today, there is a wide variety of steels available for bridge design. The bridge engineer needs to have a working knowledge of the physical properties of these steels in order to make a proper selection.

10.4.7.1 Structural Types

The following is a list of the more common types of structural steel bridges. Each design has distinctive characteristics and attributes:

1. **Composite Wide Flange Beam**. The following applies:

   a. **Structural**. This structure type has low dead load that may be of value when foundation conditions are poor. Refer to Section 2.5.2.6.3 of the AASHTO LRFD Bridge Design Specifications for the span-to-depth ratios. Larger sizes of wide flange beams may not be available in many areas.

   b. **Appearance**. Can be attractive. Best for simple spans.

   c. **Construction**. Details and form work simple. Partial length cover plates welded to bottom flange will improve economics.

   d. **Traffic**. Minimal traffic problems; limited to short periods of time for erection and installation of protection nets if required.

   e. **Construction Time**. On the job, very short, but procurement of steel may cause delay.

   f. **Maintenance**. Painted steel structures require routine maintenance depending on environmental conditions. Weathering steel eliminates the need for painting. The savings in initial and future maintenance painting offsets its higher cost. Weathering steel should be carefully considered in desert climates, coastal areas or in areas subject to heavy use of deicing salts. Weathering steel may cause straining of concrete piers and abutments.

2. **Composite Welded Girder**. The following applies:

   a. *Structural*. This structure type has low dead load, which may be of value when foundation conditions are poor. Refer to Section 2.5.2.6.3 of the AASHTO LRFD Bridge Design Specifications for the span-to-depth ratios. Can be adapted to curved alignment. Competitive with precast concrete girders.

   b. *Appearance*. Can be made to look attractive. Girders can be curved to follow alignment.

   c. *Construction*. Details and formwork simple. Transportation of prefabricated girders may be a problem.

   d. *Traffic*. Same as for composite wide flange beam.

   e. *Construction Time*. Short time on the project, but procurement and fabrication of steel may cause delay.

   f. *Maintenance*. Same as for Composite Wide Flange Beam.

3. **Structural Steel Box Girder**

   a. *Structural*. Use multiple boxes for spans up to 200 ft [60 m] and single box for longer spans. Use depth-span ratio of 0.045 for continuous spans, and 0.060 for simple spans. More expensive than steel “I” girder. More economical in the upper range of usable span and where depth may be limited. Steel box girder superstructure is an option for spans ranging between 200 ft and 300 ft [60 m and 90 m]. Its high torsional resistance makes it suitable on curved alignment.

   b. *Appearance*. Generally pleasing. Better than steel or precast concrete girders.

c. *Construction*. Very complicated welding and welding details. Because of the many opportunities for welding and detail errors that can give rise to fatigue failures, the steel box should only be used in very special circumstances.

d. *Traffic*. Erection requires substantial falsework bents at splice locations.

e. *Construction Time*. Procurement of steel and extensive fabrication requires considerable time.

f. *Maintenance*. Same as for composite wide flange beam.

4. **Steel Railroad Structure**. The following applies:

a. *Structural*. Reinforced concrete deck preferred. Steel plate deck may be used. Deck type structures are more economical than through girder structures. Depth-span ratio is 0.10 for deck type (not including the 2 ft [0.61 m] from top of rail to bottom of ballast). Through girder structures requires substantial deck thickness from top of rail to bottom of ballast. Depth-span ratio of through girders is 0.13.

b. *Appearance*. Can be attractive.

c. *Construction*. Details simple. Shop Fabricated.

d. *Traffic*. Minimal traffic problems.

e. *Construction Time*. Same as for Composite Welded Girder.

f. *Maintenance*. Same as for composite wide flange beam.

10.4.7.2 General Requirements and Materials

All structural steel should conform to Section 717 of the *Standard Specifications For Construction of Roads and Bridges on Federal Highway Projects, FPXX*. The use of High Performance Steel (HPS) should be considered where possible.

In general, bolts for structural steel bridges shall be fabricated from ASTM A 325M (Type 1) (AASHTO M 164M) steel and should be used with painted steel. Type 3 bolts conforming to ASTM A 325M (AASHTO M 164M) should be used with weathering steel.

The use of high strength ASTM A 490M (AASHTO M 253M) bolts should be used only when necessary.

10.4.7.3 Design

In the past, steel bridge design was relatively simple. Usually, the structure was only required to span an obstacle by the simplest and most direct means. Material stresses were kept quite low. Today, however, steel bridges are required to match the highway alignment, which often results in curved structures. Economic considerations require the use of steels to their maximum, resulting in very high material stresses. This means that the design details for steel bridges are of utmost importance. Current specifications become very complex and should be carefully adhered to for all steel bridge design. Consider the following:

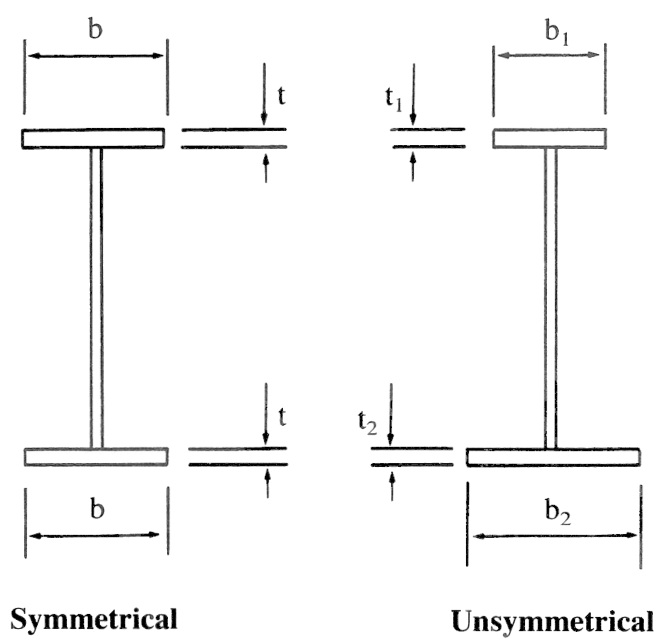
1. **Fatigue and Fracture Considerations**. Refer to Section 6.6 of the AASHTO *LRFD Bridge Design Specifications* for the fatigue and fracture design provisions.

2. **Efficient Girder Depths**. The first step in the design of a steel bridge is to determine the most efficient web depth. The determination of this depth is based on several parameters. Girders may be classified as either symmetrical or unsymmetrical as shown in Exhibit 10.4-A. Usually the weight and cost of a girder should decrease as the girder depth increases. Very deep girders with small flanges may become unstable and difficult to fabricate, transport and erect. The additional cost due to difficult fabrication, transportation and erection, which can easily overweight the cost savings due to the steel weight reduction. An economical web is a web that does not require stiffeners. Transverse stiffeners can be eliminated or reduced by thickening the web.

   In addition to being classified as symmetrical or unsymmetrical, steel members can be further categorized as follows:

   - Compact,
   - Noncompact,
   - Braced,
   - Unbraced,
   - Transversely stiffened, and/or
   - Longitudinally stiffened.

Exhibit 10.4-A GIRDER CLASSIFICATION



3. **Deflection**. The contract drawings should show the design camber necessary to compensate for deflection due to dead load, superimposed dead load and for vertical curvature required by the profile grade.

4. **Splices**. Field splices should be bolted splices and designed by the AASHTO *LRFD Bridge Design Specifications*. Field splices are generally located near points of dead

load contraflexure. Field welded splices of primary structural members should be avoided.

5. **Diaphragms, Cross Frames and Lateral Bracing**. Diaphragms and cross frames should placed as stated in Section 6.7.4 of the AASHTO *LRFD Bridge Design Specifications*. The need for lateral bracing should be investigated in accordance with Section 6.7.5 of the AASHTO *LRFD Bridge Design Specifications*.

6. **Composite Deck Design**. Concrete deck slabs should be made composite with steel girders for the entire length of simple spans. For continuous spans, if shear connectors are not provided in the negative moment region, additional shear connectors should be placed in the region of the points of permanent dead load contraflexure (for detailed explanation, refer to AASHTO LRFD Section 6.10.10). This is generally achieved with welded stud or channel shear connectors.

10.4.7.4 Specifications, Design Aids and Policies

The technical references listed in Section 10.2.4 will clarify and guide the usage of the AASHTO *LRFD Bridge Design Specifications*. The AASHTO *LRFD Yearly Interims* are necessary since bridge design is dynamic in nature (i.e., research and development of new technologies force changes in both design specifications as well as construction methods).

10.4.8 PRESTRESSED CONCRETE

The first prestressed concrete bridge in the United States was constructed in 1949. Since 1960, most bridges in the United States with a span range of 60 ft to 120 ft [18 m to 36 m] have been constructed with prestressed concrete. In the late 1970's, post-tensioned continuous or cantilever bridges with spans of 150 ft to 660 ft [45 m to 200 m] have gained in popularity.

10.4.8.1 Structural Types

The following list of features of the more common structures provides information to assist in the preliminary selection and sizing of members:

1. **Cast-in-Place Concrete Slab**. The following applies:

   a. **Structural**. Used for spans up to 66 ft [20 m]. Recommended for conditions where very low span-to-depth ratio is required. Can be used for either simple or continuous spans. The depth span ratio is 0.030 for simple and continuous spans. More expensive than reinforced concrete slabs.

   b. **Appearance**. Same as reinforced concrete slabs.

   c. **Construction**. More difficult than reinforced concrete slabs.

   d. **Traffic**. May be impeded by falsework due to reduced clearances. Guide rail should protect falsework openings for traffic lanes.

e. **Construction Time**. Shortest of cast-in-place construction; longer than precast slabs.

f. **Maintenance**. Very little.

2. **Precast Prestressed Concrete Slab**. The following applies:

a. **Structural**. Adjacent prestressed concrete slabs can be used to a maximum span of about 55 ft [17 m]. Not recommended for long multi-span structures because of difficulties in camber control resulting in undesirable riding qualities. Economical where many spans are involved or in areas remotely located from concrete batch plants.

b. **Appearance**. Same as reinforced concrete slab.

c. **Construction**. Details and formwork very simple. Shop fabrication methods employed.

d. **Traffic**. Very little interference except during erection.

e. **Construction Time**. On site, very short. Very little time required for plant fabrication.

f. **Maintenance**. Very little.

3. **Precast prestressed Concrete Girder**. The following applies:

a. **Structural**. Prestressed concrete box beams can span up to 120 ft [37 m]. Prestressed concrete I-beams and bulb-tee beams can span up to 150 ft [46 m]. For longer spans, spliced prestressed concrete girders should be considered. Refer to Section 2.5.2.6.3 of the AASHTO *LRFD Bridge Design Specifications* for the span-to-depth ratios. Feasibility to transport and erect girders longer than 130 ft [40 m] should be investigated. Precast prestressed concrete girders are competitive with steel girders and very economical in areas near precasting plants.

b. **Appearance**. Similar in appearance to T-beams. Straight girders on curved alignment can look awkward.

c. **Construction**. Require careful handling and transporting after fabrication. Fabrication plants nationwide cast a wide variety of sections in addition to standard AASHTO sections.

d. **Traffic**. Same as prestressed slabs.

e. **Construction Time**. Same as steel girders. Fabrication may require additional time.

f. **Maintenance**. Very little except at hinges or joints.

4. **Cast-in-Place Box Girder (Post-Tensioned)**. The following applies:

a. **Structural**. Requires detailed stress analysis. Refer to Section 2.5.2.6.3 of the AASHTO *LRFD Bridge Design Specifications* for the span-to-depth ratios. High torsional resistance makes it desirable on curved alignment. Dead load deflections minimized. Desirable for simple spans over 150 ft [46 m]. Long-term shortening of structure must be provided for. About the same as conventionally reinforced box girder. Used for spans up to 600 ft [180 m].

b. **Appearance**. Better than conventional box girder because of shallow depth. All other qualities of conventional box girder exist. Excellent in metropolitan areas. Can be used in combination with conventional box girders in long structures with varying span lengths to maintain constant structure depth.

c. **Construction**. Same as conventional box girder.

d. **Traffic**. May be impeded by falsework due to reduced clearances. Guardrail should protect falsework openings for traffic lanes.

e. **Construction Time**. Longest for any prestressed concrete structure due to delay before tensioning is allow to proceed.

f. **Maintenance**. Very little except at joints or hinges.

10.4.8.2 General Requirements and Materials

Concrete in prestressed members is subject to higher stress levels than concrete in nonprestressed, reinforced members. Therefore, on all projects under the jurisdiction of FLH, the minimum compressive strength at the time of initial prestress must be f'_{ci} = 3.6 ksi [25 MPa] (post-tensioned members).

Prestressing steel strands are available in diameters from 0.25 in to 0.6 in [6.4 mm to 15.2 mm], in grades of 250 ksi or 270 ksi [1720 MPa or 1860 MPa], and as either stress-relieved or low-relaxation. The grade or strand indicates the ultimate strength and the type of strand (i.e., stress-relieved or low-relaxation) and defines the manufacturing process and prestress loss characteristics. Only low-relaxation prestressing steel strands should be used unless approval to use other prestressing steel strands is granted by the FLH Bridge Engineer.

The specifications should allow a prestressing firm to change the size and pattern of the strands if desired. Any changes should be redesigned by the manufacturer and checked by the government. These changes should be shown on the fabrication plans and submitted for approval.

Properties and strengths of seven-wire, grade 270 ksi [1860 MPa] strand are shown on Exhibit 10.4-B.

10.4.8.3 Analysis

Stresses are introduced into the concrete opposite to the stresses resulting from loads acting on the structure. The stresses are introduced in a manner that allowable stresses will not be exceeded. Compressive stresses are induced in the face of the member where tensile stresses tend to develop due to loads. These induced stresses result from a compressive force that is transmitted to the concrete from the prestressing steel.

Exhibit 10.4-B PROPERTIES OF PRESTRESSING STRAND

(US Customary)

Seven-Wire-Strand, f′S = 270 ksi					
Nominal Diameter, in	3/8	7/16	1/2	9/16	0.600
Area, in^2 [A^*_S]	0.085	0.115	0.153	0.192	0.217
Weight, lb/ft	0.29	0.40	0.52	0.65	0.74
0.7 f'_S A^*_S, kips	16.1	21.7	28.9	36.3	41.0
0.75 f'_S A^*_S, kips	17.2	23.3	31.0	38.9	44.0
0.8 f'_S A^*_S, kips	18.4	24.8	33.0	41.4	46.9
f'_S A^*_S, kips	23.0	31.0	41.3	51.8	58.6

Note: f'_s = Ultimate strength of 270 ksi

Exhibit 10.4-B PROPERTIES OF PRESTRESSING STRAND

(Metric)

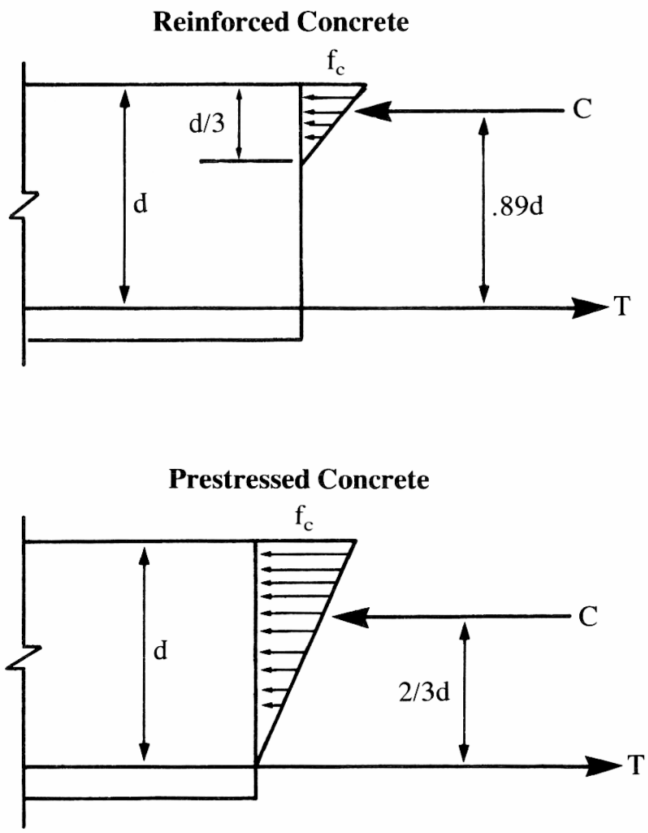
Seven-Wire-Strand, f′S = 1860 MPa					
Nominal Diameter, mm	9.5	11.1	12.7	14.3	15.2
Area, mm^2 [A^*_S]	54.8	74.2	98.7	123.9	138.7
Mass, kg/m	0.43	0.60	0.79	0.97	1.12
0.7 f'_S A^*_S, kN	71.6	96.5	128.6	161.5	181.0
0.75 f'_S A^*_S, kN	76.5	103.6	137.9	173.0	193.5
0.8 f'_S A^*_S, kN	81.8	110.3	146.8	184.2	206.8
f'_S A^*_S, kN	102.0	137.9	183.7	230.4	258.4

Note: f'_s = Ultimate strength of 1860 MPa

Prestressed concrete makes full use of the compressive strength of the concrete and the tensile strength of the prestressing steel. Ordinary reinforced concrete does not use the concrete to its full advantage. For comparison purposes (using the same allowable concrete stress), see Exhibit 10.4-C. The resulting moment for the reinforced concrete section is calculated in the normal manner, and the resisting moment shown for the prestressed section is approximately the net resisting moment for applied loads after prestressing.

As shown in Exhibit 10.4-C, a prestressed section with beams of the same depth can resist more than twice the moment that the reinforced concrete section can resist. Furthermore, the allowable stress can be doubled for the prestressed section, thus making the resisting moment over four times that of the reinforced concrete section. The prestressed section makes use of the entire concrete area; however, the reinforced section uses about one-third of the area while two-thirds is being used to hold the reinforcing steel away from the working section, resist shearing stresses and develop the bond between the concrete and reinforcing steel.

Exhibit 10.4-C CONCRETE BEAM STRESSES



Two advantages of a prestressed concrete structure are the reduction of both concrete and steel quantities. Other advantages of a prestressed concrete structure are as follows:

- A considerable reduction in depth of section, not only relative to reinforced concrete, but also relative to structural steel.
- A reduction in the cracking of concrete within a known range of load. This results in greater durability under severe conditions of exposure.
- A prestressed structure that has maximum rigidity under working loads and maximum flexibility under excessive overloads.
- The capacity to support a load in excess of the design load in which cracks appear but disappear completely on removal of the excess load.
- A definite reduction in diagonal tension. An important factor in reinforced concrete but often less severe in prestressed concrete.
- Use of pretested structural materials. During the prestressing operations, the steel is tested to a stress that will never again be reached under design loads. The same

applies to the concrete, in many cases. This type of in-place testing is impossible in ordinary reinforced concrete structures.

- Added flexibility for construction.

There are two methods of applying a prestressing force. Pretensioning is tensioning of the steel that is done before the concrete is cast in the forms. Post-tensioning is tensioning that is done after the concrete has been cast and has attained the required strength. In the former, the force is transmitted by the bond between the steel and concrete. The initial prestress is immediately reduced due to the deformation and shrinkage of the concrete. Gradually, these losses are increased by further shrinkage and creep of the concrete. In post-tensioning, the elastic shortening losses are lower than in pretensioning. Like pretensioning, there is a gradual loss due to the shrinkage and creep of the concrete and the creep of the steel. Consequently, for equivalent members, the pretensioning method requires a greater initial prestressing force to compensate for the larger losses.

Pretensioning is practical only within factory or mass production facilities, since permanent anchorages are required to take the reaction of the stressed wires until the concrete attains the required strength.

Several methods of stressing and anchoring “post-tensioned” steel are in use. The methods used most commonly in the United States at present are illustrated in the *Post-Tensioning Manual.*

Design prestressed concrete members to meet the requirements of Chapter 8 of the AASHTO *LRFD Bridge Design Specifications*.

Expansion and contraction are important design parameters and require consideration. Bearings and joints for prestressed bridges must accommodate the movement from prestress shortening in addition to temperature changes. In framed structures, the stresses resulting from these movements must be included in the design.

The prestress shortening to be expected can be calculated by Equation 10.4(1):

$$\Delta = \frac{PL}{AE}$$ Equation 10.4(1)

where:

P = total prestressing force, lbs [kN]
L = one half of the length between piers, ft [m]
A = cross sectional area of the superstructure, ft^2 [m^2]

E = elastic modulus of superstructure concrete, lbs/ft^2 (kN/m^2)

10.4.8.4 Specifications, Design Aids and Policies

The technical references listed in Section 10.2.4 will clarify and guide the usage of the AASHTO *LRFD Bridge Design Specifications*. The AASHTO *LRFD Yearly Interims* are necessary since bridge design is dynamic in nature (i.e., research and development of new technologies force changes in both design specifications as well as construction methods).

10.4.9 TIMBER

Timber bridges, properly designed and treated with modern preservatives, will give many years of minimal-maintenance service. Their use is normally limited to low-volume, secondary-road bridges and pedestrian bridges.

The following are the most common bridge components that use timber:

- Piling,
- Beams or girders,
- Decks, and
- Rails and posts.

As can be seen, it is possible to construct entire bridges of timber; however, this is rarely done. Rather, timber is combined with other elements (e.g., steel girders, concrete substructures) to produce the most economical and maintenance-free structure possible.

With the exception of temporary structures, all exposed timber should be pressure treated. The most common species of timber used are Douglas Fir and Southern Pine. Hardware is normally galvanized.

10.4.9.1 Substructures

Timber pilings are displacement piles that normally function as friction piles. When used as point bearing piles or when difficult driving conditions are encountered, reinforced pile tips should be considered. AASHTO *LRFD* Section 8.4.1.3 gives guidance on the design of timber piles as a structural member. Timber piling should not be used in soils where large boulders or cobbles exist. Timber piling is most economical when used for relatively shallow foundations. Timber-pile bents should not be used in streams that carry heavy drift and debris.

10.4.9.2 Superstructures

The most common type of timber superstructure is the longitudinal girder, simple-span bridge. Straight girders are most economical for short spans of 20 ft to 60 ft [6 m to 18 m]. Spans up to 100 ft [30 m] are possible using glue laminated girders, but may not be economical depending on location, live load and vertical clearance requirements.

A second common type of timber superstructure is the truss bridge. This may be either a bowstring truss or a parallel-chord truss. Bowstring trusses are of two general types:

1. The pony truss for spans from 50 ft to 100 ft [15 m to 30 m], and
2. The through span truss for spans longer than 100 ft [30 m].

Commonly, top and bottom chords are glue-laminated members and web members are sawn timber. Steel rods are used in tension members in the web. When water clearance allows, the parallel chord truss may be used as a deck span, thus enabling pier heights to be greatly reduced. The parallel chord truss may also be used in a through span. The practical span range for either system is 100 ft to 250 ft [30 m to 75 m].

For long, clear-span timber bridge construction, the deck-arch bridge has been used. With this type of construction, pier height is held to a minimum and yet the bridge is well above high water. The deck arch is practical for spans from 60 ft to 300 ft [18 m to 90 m], and is particularly suitable when rock canyon walls can reduce the foundation sizes for arch abutments. All present designs for timber-arch bridges should specify laminated construction.

10.4.9.3 Decks

Timber decking is the most common use of timber in current bridge construction. In the past, the most common type of deck was nail-laminated decking using nominal 2 in [50 mm] dimension lumber fastened with through-nailing of the laminations and toe-nailing of the laminations to longitudinal stringers.

Today, most decks are glue-laminated timber systems that allow longer deck spans. These glue-laminated deck systems are plant fabricated in panels and may be designed for either transverse or longitudinal decking. This has necessitated the development of improved connection systems to connect the deck panels to the superstructure. Many current systems are detailed in timber design publications and manuals. The designer should carefully select and analyze these connection systems for strength, ability to resist shrink or swell of timber members and for resistance to loosening due to vibration or deflection.

Few deck connection systems provide true lateral support to the compression flanges of supporting girders. This lateral support must be considered partial lateral support at diaphragms or cross-frames in most cases.

Most timber deck designs should include wearing planks (sometimes called running planks) to protect the primary decking from tire wear. These wearing planks are nailed to the lower deck and are replaced as required.

All timber decking should be pressure treated to extend decking life.

Timber decks may also be protected by an asphalt concrete overlay. Detailed mix designs for these overlays are available from the American Institute of Timber Construction.

For some designs, this overlay can be used to provide a crown section for roadway drainage. It is not practical to crown decks constructed entirely of timber.

10.4.9.4 Rails and Posts

Timber rails and posts are commonly used for railings on pedestrian bridges due to the ability of timber to produce an aesthetically pleasing appearance. These railings normally use glue-laminated timber for the rails and either glue-laminated or sawn timber for the posts. Do not use creosote treated timber for pedestrian rail systems.

Timber rail system used on FLH bridges should meet the NCHRP 350 and AASHTO *LRFD Specifications*. Timber rail systems, intended for vehicular traffic, almost always incorporate a heavy timber or concrete curbing and a steel backing plate for the timber rail elements. The rails are usually glue-laminated timber and posts may be either glue-laminated or sawn timber. As with all rail systems, timber railings must be carefully designed, with particular attention paid to connection, joints and splices.

10.4.10 BEARINGS

Bridge bearings serve several purposes, the first of which is to transmit vertical loads from the superstructure to the substructure. These bearings must also transmit lateral forces, longitudinal or transverse in direction, between the superstructure and the substructure. In addition, these bearings should take care of girder rotation.

Fixed (sometimes called pinned) bearings transmit both longitudinal and transverse forces. Expansion bearings generally transmit only friction or longitudinal shear forces from the movement of the bearing during longitudinal expansion or contraction. Expansion bearings also usually transmit transverse lateral forces from the superstructure to the substructure.

Numerous types of bearings are available. The following are the most common bearings in current use:

- Elastomeric bearing pads come in several configurations. Plain pads of 1 in [25 mm] thickness are used for fixed bearings in conjunction with lateral-load transfer devices such as keys in construction joints, shear lugs or anchor bolts. These 1 in [25 mm] pads allow rotation of girders and provide distribution of loads between slightly uneven bearing surfaces.
- Laminated pads of thicknesses up to a maximum of about 4 in [100 mm] are used for expansion bearings. These bearings may have either steel shims or fabric shims, usually spaced at 0.5 in [12 mm] increments. Laminated pad bearings usually are used with transverse lateral load transfer devices. They are usually designed for horizontal movement in one direction only.
- Steel-shim laminated bearings with other than integrally molded edge protection have been found to be unsatisfactory in use. Laminated bearings not molded as a single unit under heat and pressure are susceptible to bond failure between the layers.

  The durometer hardness of the elastomer should be specified on the plans. This hardness should be based on the lowest anticipated service temperatures.

Geometric proportions (i.e., shape factors) are given in the AASHTO *LRFD Specifications* to ensure stability of the bearings. Bearing design is controlled by compressive stress, shape factor, hardness and compressive strain. Bearing thickness is controlled by movement requirements.

- Sliding bearings are a configuration normally consisting of a combination of a thin elastomeric pad (to allow rotation and to control the distribution of the bearing loads), steel bearing plates and a TFE (Teflon) surface moving against either another TFE surface, or against a stainless steel surface. These bearings have very low friction valves. They are used for moderate-span steel structures. Lugs to transfer lateral forces are often incorporated into the design of bearing.
- Pot bearings are bearings used in high load situations, or where the thermal movements are excessive for elastomeric bearings. They incorporate an elastomeric material-confined material. The fluid-type action distributes the load evenly on the base plate. These bearings may be designed with TFE sliding surfaces to allow movements.
- Roller and rocker bearings are bearings generally used for longer-span steel bridges. They are normally either painted or galvanized, even when used with weathering steel superstructures. Small diameter rollers do not perform satisfactorily due to corrosion and should not be used. These bearings can be designed for either fixed or expansion bearings.

All bearings should be accessible for inspection and maintenance. For bearings that are designed for longitudinal movement, the plans should include, in tabular form, the required settings throughout the probable temperature range at the time of erection or construction.

The designer should keep construction procedures in mind and carefully detail bearing seats. Difficult profile grade geometry and skew effects often will require the use of grout pads under bearings. These grout pads are cast after the abutment or pier seat is complete and allow exact bearing location to be achieved. Because it is unreinforced, the thickness of the grout pad should be limited and the grout pad should be recessed into the bearing seat.

Together with deck joints, bridge bearings are a source of major structural problems and often are the cause of serious damage to other parts of the structure. Bearings must be engineered and designed to allow free movement and to transmit superstructure loads. Careful analysis should be made of all bridge bearings. A standardized bridge bearing that fits all conditions does not exist.

10.4.11 FOUNDATIONS AND SUBSTRUCTURES

The substructure is that part of the structure that serves to transmit the forces of the superstructure and the forces on the substructure itself onto the foundation.

The foundation is that part of a structure that serves to transmit the forces of the structure onto the natural ground.

If a stratum of soil suitable for sustaining a structure is located at a relatively shallow depth, the structure may be supported directly on it by a spread foundation. If the upper strata are too weak, the loads are transferred to more suitable material at greater depth by means of piles or piers.

The design of the structural elements for foundations, substructures and retaining walls shall be in accordance with AASHTO *LRFD Bridge Design Specifications*.

Some of the items that are determined by evaluation of site investigations and/or by current practice are as follows:

- Bearing capacities of foundation soils,
- Settlement of foundation soils,
- Ability of piles to transfer load to the ground, and
- Lateral earth resistances.

In stability analyses should be performed as required in Chapter 10 of the AASHTO *LRFD Bridge Design Specifications*.

10.4.11.1 Capacity of Shallow Foundations

A shallow foundation is a term applied to footings having a depth-to-base width ratio of 1 or less.

Two things control the capacity of a shallow foundation:

1. The ability of the soil to support the loads imposed upon it, known as the bearing capacity of the soil.
2. The amount of total or differential settlement that can be tolerated by the structure being considered.

10.4.11.2 Capacity of Deep Foundations

A pier is a structural member of steel, concrete or masonry that transfers a load through a poor stratum onto a better one. A pile is essentially a slender pier that transfers a load either through its tip onto a firm stratum (point bearing pile) and/or through side friction onto the surrounding soil over some portion of its length (friction pile).

In general, the bearing capacity of a single pile is controlled by the structural strength of the pile and the supporting strength of the soil. The smaller of the two values is used for design.

Piles driven through soft material to point-bearing may be dependent upon the structural strength of the pile for their bearing capacity.

The supporting strength of the soil is the sum of the following two factors,

1. The bearing capacity of the area beneath the base, and
2. The frictional resistance on the contact surface area for the length of the pile.

For point-bearing piles, factor “1” is of primary significance while for friction piles, factor “2” is of primary significance.

Structural sections of piles are to be designed using the provisions for the material being used and satisfying the minimum requirements specified in the AASHTO *LRFD Specifications*. A pile load test is probably the best method available for determining the bearing capacity of an individual pile. The tests are quite expensive, however, and on small jobs, the cost of their use cannot be justified.

10.4.11.3 Substructure Analysis and Design

In the design procedure, the allowable bearing determinations are performed by the geotechnical engineer prior to completion of the approved layout for final design. Consider the following:

1. **Reinforced Concrete Columns**. Since these are the most common substructure elements for transferring superstructure loads to the foundations, discussion of other types will not be included. Reinforced concrete columns are designed according to the AASHTO LRFD specifications.

   Commonly used shapes are round, rectangular, rectangular with rounded ends and rectangular with large chamfered corners. Flares and tapers are often required. The designer should obtain help from the FLH Bridge Engineer and/or the senior structural engineers in determining the type and trial dimensions. The final design should provide adequate strength to cover all factored axial load plus axial or biaxial moment combinations magnified for slenderness as necessary. See Chapter 5 of the AASHTO *LRFD* for additional information on reinforced concrete column design.

2. **Drilled Shafts**. For design requirements, see Chapter 5 and Chapter 10 of the AASHTO *LRFD Bridge Design Specifications*.

3. **Spread Footings**. For design requirements, see Chapter 5 and Chapter 10 of the AASHTO *LRFD Bridge Design Specifications*.

4. **Pile Footings**. For design requirements, see Chapter 5 and Chapter 10 of the AASHTO *LRFD Bridge Design Specifications*.

5. **Seals**. Seals are required for cofferdam construction of foundation portions below water where the water head and soil permeability are too great to be controlled by pumping, diversion of water, etc. The need for seals is usually determined during the preparation of the preliminary bridge layout. A rough guide is that seals are required for heads of water more than 10 ft [3 m] deep. The designer calculates the depth of seals for spread footings at 0.43 times the water head at time of construction. A minimum depth of seal should be 24 in [600 mm]. The factor 0.43 is the ratio of the unit weight of water 62.4 lb/ft^3 [1000 kg/m^3] to the unit weight of plain concrete 145 lb/ft^3 [2320 kg/m^3].

   For pile footings where uplift resistance of the piles can be counted on, the seal depth may be reduced to 0.25 times the water head.

These foundation recommendations should be presented in a report along with the foundation investigation information.

10.4.12 RETAINING WALL DESIGN

Retaining walls should be designed according to Chapter 10 and Chapter 11 of the AASHTO *LRFD Bridge Design Specifications* unless approval to use the AASHTO *Standard Specifications for Highway Bridges* is granted by the FLH Bridge Engineer.

10.4.12.1 Aesthetic Considerations

The type of face treatment for retaining walls is decided on a case-by-case basis according to degree of visual impact. The wall should blend in with its surroundings and complement other structures in the vicinity. Top of walls are usually on smooth flowing curves as seen in elevation.

The profile of the top wall should be designed to be as pleasing as the site conditions permit. All slope changes at the top of the wall should be rounded with vertical curves at least 20 ft [6 m] long. Small dips in the top of the wall should be eliminated. Sharp dips should be improved by using vertical curves, slopes and steps or combinations thereof. Side slopes may be flattened or other adjustments made to provide a pleasing wall profile.

Where walls are adjacent to highways, frontage roads or city streets, special surface texturing, recessed paneling or provisions for landscaping shall be considered.

10.4.12.2 Footings

For economy and ease of construction of reinforced concrete retaining walls, consider the following criteria for layout of footing steps:

- Distance between steps should be in multiples of standard plywood sizes.
- A minimum number of steps should be used even if a slightly higher wall is necessary. Small steps less than 12 in [300 mm] in height should be avoided unless the distance between steps is 95 ft [29 m] or more. The maximum height of steps should be held to 4 ft [1.2 m]. If the footing thickness changes between steps, the bottom of the footing elevation should be adjusted so that the top of the footing remains level.

10.4.12.3 Wall Joints

For cantilevered and gravity walls, joint spacing should be maximum joint spacing of 30 ft [9 m] for contraction joints and 90 ft [27 m] for expansion joints. For counterfort wall, joint spacing should be a maximum of 33 ft [10 m] on centers. For tieback walls, joint spacing should be 23 ft to 33 ft [7 m to 10 m] on centers for cast-in-place walls, but for precast units, the length of the unit would depend on the height and thereby the weight of the unit. Odd panels for all type of walls should normally be made up at the ends of the walls. For cast-in-place construction, a minimum of 1 in [25 mm] premolded filler should be specified.

No joints other than construction joints should be used in footings except at bridge abutments and where the change from a pile footing to a spread footing occurs. In these cases, a 1 in [25 mm] premolded expansion joint through the wall and a construction joint with shear keys through the footing should be used. In addition, dowel bars should be placed across the footing joints parallel to the wall elements to guard against differential settlement or deflection of the footings.

The maximum spacing of construction joints in the retaining wall footing should be 118 ft [36 m]. The footing construction joints should not line up with the expansion joints in the wall.

10.4.12.4 Drainage

Gutters should be used behind walls in areas where there is a necessity to carry off surface water or to prevent scour. Low points in the vertical wall alignment or areas between return walls must be drained by downspouts passing through the walls.

The standard plans show typical drainage details. Special design of surface water drainage facilities may be necessary depending on the amount of surface water anticipated.

Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent buildup of hydrostatic pressures and unsightly continuous flow through weep holes.

All concrete retaining walls should have 4 in [100 mm] diameter weep holes located 8 in [200 mm] above final ground line and spaced about 13 ft [4 m] apart. In case the vertical distance between the top of the footing and final ground line in front of the wall is greater than 10 ft [3 m], additional weep holes should be provided 8 in [200 mm] above the top of the footing.

Weep holes can get clogged and the water pressure behind the wall may start to increase. In order to keep the water pressure from increasing, it is of utmost importance to have free draining gravel backfill and underdrains.

10.4.12.5 Other

Make provisions to relocate or otherwise accommodate utilities conflicting with the retaining wall. Any modifications of a standard wall to accommodate utilities should be specially designed.

Show all special wall details (e.g., sign bases, utility openings, drainage features, fences, concrete barriers) on the applicable sheet of the wall plans or on a separate plan sheet and include with the wall plans. Cross reference details between the various plan sheets on which they are shown.

10.5 APPROVALS

This section briefly discusses the steps taken by the division bridge staff to acquire client approval of proposed bridge structure type, size and location for a given project. Steps taken to obtain such approvals must be both timely and contain adequate detail to maintain assigned program schedules.

10.5.1 BRIDGE TYPE, SIZE AND LOCATION (TS&L)

The first step in acquiring partner's approval of a proposed structure is to develop one or more drawings that depict the bridge type, size and location for each site.

The highway design/location staff furnishes data required to develop a bridge site plan. A site plan includes the following:

- A plan view showing the horizontal alignment of the roadway and the ground contours of the surrounding area,
- The vertical alignment of the roadway within the limits of the bridge site, and
- The roadway typical section to be used at the site.

After determining approximate span lengths and superstructure depths, the bridge opening shall be checked for adequacy.

For stream crossings, a hydraulic analysis shall be made for the site.

For roadway crossings, vertical clearance above the underpass roadway shall be checked. Once the appropriate clearance checks have been made, the profile grade can be adjusted for final TS&L development.

Once developed, the TS&L drawing is then distributed to the partner agency for review and approval. Upon receipt of this approval, the structure design and contract plan development can begin. Also see Section 4.10.3.

10.5.2 DESIGN STANDARDS AND EXCEPTIONS

There are many publications available to the design engineer to aid in the development of engineering design calculations for highway structures. Deviations from specific minimum values therein are permissible only after due consideration is given to all project conditions (e.g., maximum service and safety benefits, type and purpose of improvement and compatibility with adjacent sections of unimproved roadway).

Exceptions to design standards are to be documented during the TS&L development stage. All responsible agencies should be made aware of each exception, agree to the need for the exception and be fully aware of any safety and environmental impacts resulting from the deviation. Also refer to Section 9.1.3 for documentation of exceptions to standards for structural capacity, width, horizontal clearance, and vertical clearance.

10.5.3 PLANS, SPECIFICATIONS AND ESTIMATE

Upon completion of the final plans, specifications and estimate (PS&E) for a structure, all documents are to be forwarded to the highway design staff for inclusion with the roadway portion of the project.

The plans and specifications should address and adequately describe the design features incorporated into the structure, the construction requirements necessary to facilitate the building of the structure and an estimate of construction costs of the project.

The estimate should reflect the anticipated cost of the project based on an analysis of previously bid items of work for structures of similar type and construction and geographic location.

Detailed plans for bridges should contain the following drawings and data:

- Site plan;
- Location and log of each foundation sounding or boring;
- Profile of the crossing;
- Typical cross section;
- Sectional drawings, as needed, to detail the structure completely;
- Quantities of materials required;
- Reinforcing bar list and bar bending diagram;
- Design loadings, working stresses, classes of concrete and grades of steel;
- Drainage area and applicable runoff of hydraulic properties;
- Design and construction details not otherwise covered in the *Specifications*; and
- References to applicable standard or industry specifications.

10.6 STANDARD FORMAT

A standard format is required in all plans and specifications. Standard formats have been established for drafting plan sheets, writing contract specifications and establishing contract unit-bid terms. Document storage and retrieval procedures for work developed on the Computer Aided Drafting and Design (CADD) System have been developed. See Section 9.6.5 for additional guidelines.

10.6.1 PLANS

Standard formats for plans are described in Section 9.6.5.1. A majority of this information is also stored on the CADD system for ready use and reproduction. Drafting standards are described in Section 9.6.5.2. Refer to Division Supplements for applicable information on plans format such as sheet border size, title block and project identification data, and appropriate line weights, lettering fonts and commonly used symbols and details.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

10.6.2 SPECIFICATIONS

There are three major types of specifications used in a contract and they are:

- *Standard Specifications*, *FP-XX*
- Supplemental Specifications, and
- Special Contract Requirements.

See the definition for contract document hierarchy in Section 104.04 of the FP-XX.

Each Division office maintains a file of Special Contract Requirements (SCRs) that have been developed for addressing unique or specialty work that may be required due to a project's geographical location or special design features that would not be covered in the *Standard Specifications* or Supplemental Specifications. Refer to Section 1.2.5 for applicable Division Library of Specifications (LOS).

When it becomes necessary to develop Special Contract Requirements, they shall be written in the same format as the *Standard Specifications*. Also refer to Section 9.6.9.

10.6.3 ESTIMATE

An engineer's estimate is developed in the preliminary PS&E stage of plan development based on an average cost per square foot [square meter] of bridge deck. As the structural design proceeds toward the final PS&E stage, a revised cost estimate is developed based on a unit price analysis for all items of work to be accomplished under the project.

One source of data that can be used for estimating purposes is past contract unit-bid prices for similar type work within the same geographical area. Caution is urged when establishing unit prices from past records.

When estimating, the engineer must consider the current economic environment and be aware of regional cost trends and industry pricing data.

Estimates should be realistic and should be based on a reasonable cost analysis for the work to be accomplished. Unrealistic estimates (e.g., too high, too low) have a detrimental impact on future project planning and programming.

Also refer to Section 9.6.8.

Chapter 11 – PAVEMENTS

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LIST OF EXHIBITS

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CHAPTER 11
PAVEMENTS

11.1 GENERAL

This chapter identifies the pavement related policies, standards, guidance, and references approved for use in developing designs for roads and bridges in the Federal Lands Highway Programs. Refer to Section 1.1.1 for definitions of policy, standards, criteria and guidance. The intent of this chapter is to present the above information in a concise and clear manner. The chapter is not a step-by-step instructional "how-to" guide. However, where appropriate, procedures, instructional aids, AASHTO guidelines, publications, and manuals are referenced. Users of this chapter are expected to be knowledgeable in the pavement discipline and familiar with most references and concepts included. Federal Lands Highway (FLH) projects are typically developed by an interdisciplinary team (IDT) led by a project manager. This interdisciplinary team may also be referred to as a cross-functional team (CFT). It is critical that the pavement discipline representative on the IDT is fully engaged in project planning, scoping, PS&E reviews, and other project development activities. Additionally, the pavement discipline representative on the IDT should plan work and develop recommendations in close coordination with the IDT.

Compliance with all policies and standards in this chapter is essential to ensure consistency in project development for all Federal Lands Highway projects. Although policy cannot be compromised, flexibility of standards is sometimes necessary to meet project-specific objectives. (See Section 11.1.3 for exceptions and variances to standards).

As changes in policies, standards, or criteria occur, updates to this chapter will be made as described in Section 1.1.2

The information presented in this chapter is the standard practice for pavement engineering that will be applied to all projects developed and delivered for the Federal Lands Highway Programs.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

11.1.1 REFERENCES

The publications listed in this section provided much of the fundamental source information used in the development of this chapter. While this list is not all-inclusive, the publications listed will provide the designer with additional information to supplement this manual.

1. FP-XX — *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects*, FHWA, current ed.

2. Field Materials Manual — FLH *Field Materials Manual*, Publication No. FHWA-FL-91-002.

3. Standard Drawings — Federal Lands Highway Standard Drawings, current edition.

4. NRC-HMA Handbook — *Hot Mix Asphalt Paving Handbook*, National Asphalt Pavement Association, 2000. Available for purchase at the NAPA online store.

5. NHI 131033 — *Construction of Portland Cement Concrete Pavements Participants Manual*, National Highway Institute Course No. 131033, FHWA HI-96-027, 1996.

6. AGDPS — *Guide for Design of Pavement Structures and 1998 Supplement*, AASHTO, 1993. Available for purchase at the AASHTO online bookstore.

7. AGDPS Supplement — *Supplement to the AASHTO Guide for Design of Pavement Structures, Part II, Rigid Pavement Design and Rigid Pavement Joint Design*, AASHTO, 1998.

8. NCHRP 1-37A — *Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, Design Guide NCHRP 1-37A, TRB, 2004.

9. 23 CFR 626 — Code of Federal Regulations, Title 23, Part 626, *Pavement Policy*

10. FAPG 23 CFR 626 — Federal Aid Policy Guide (FAPG) for section 23 CFR 626, Non-regulatory supplement, 1999.

11. AASHTO GTDP — Guidelines for Traffic Data Programs, AASHTO, 1992.

12. FLH FWD Backcalculation and Data Collection Guide, February 2007.

13. DARWin-ME — DARWin-ME, Pavement Design and Analysis software, AASHTOWare

14. Special Report 83-27 — *Revised Procedures for Pavement Design Under Seasonal Frost Conditions*, US Army Corps of Engineers, September 1983

15. LTPPBind — LTPPBind, asphalt binder selection software, FHWA

16. FHWA-NHI-131026 — *Pavement Subsurface Drainage Design*, NHI Training Course, 1999.

17. DRIP 2.0 — *DRIP 2.0 – Drainage Requirements in Pavements User's Guide*, FHWA-IF-02-053, 2002.

18. FHWA-CFL/TD-05-004 — FLH Context Sensitive Roadway Surfacing Selection Guide, 2005

19. FHWA-RD-75-48 *A Review of Engineering Experiences with Expansive Soils in Highway Subgrades*, Report No. FHWA-RD-75-48, June 1975.

20. FHWA-RD-77-94 *An Evaluation of Expedient Methodology for Identification of Potentially Expansive Soils*, Report No. FHWA-RD-77-94, 1977.

21. FAA-RD-76-66 *Design and Construction of Airport Pavements on Expansive Soils*, Federal Aviation Administration Report, January 1976,

22. EM 1110-3-138 *Pavement Criteria for Seasonal Frost Conditions - Mobilization Construction*, Army Corps of Engineers Engineering and Design Manual EM 1110-3-138, April 1984.

23. FHWA-RD-97-083 *Design Pamphlet for the Determination of Design Subgrade in Support of the 1993 AASHTO Guide for the Design of Pavement Structures*, Report No. FHWA-RD-97-083, 1997

24. ACPA American Concrete Pavement Association

25. ACPA – TB200P *Concrete Engineering of Streets and Local Roads Reference Manual*, (ACPA), 2002 or latest update.

26. FHWA-NHI-131060 *Concrete Pavement Design Details and Construction Practices*, NHI Training Course, 2001.

27. FHWA-NHI-131008 *Techniques for Pavement Rehabilitation*, Reference Manual, NHI Training Course, 1998.

28. BARM Basic Asphalt Recycling Manual (BARM), Copyright 2001, Asphalt Recycling and Reclaiming Association (ARRA).

29. Gravel Roads (LTAP) *Gravel Roads Maintenance and Design Manual*, South Dakota LTAP and FHWA, 2000.

30. Forest Service 9977 1207 SDTDC *Dust Palliative Selection and Application Guide*, USDA – Forest Service, San Dimas Technology and Development Center, 1999.

31. AASHTO TF-28 *Guidelines and Guide Specifications for Using Pozzolanic Stabilized Mixture (Base Course or Subbase) and Fly Ash for In-Place Subgrade Soil Modifications*, Task Force 28 Report, AASHTO-AGC-ARTBA Joint Committee, 1990.

32. AASHTO TF-38 *Report on Cold Recycling of Asphalt Pavements*, Task Force 38 Report, AASHTO-AGC-ARTBA Joint Committee, 1998.

33. T 5040.30 FHWA Technical Advisory T 5040 .30, *Concrete Pavement Joints*, November 30, 1990.

34.	AASHTO GVWD	*Guide for Vehicle Weights and Dimensions*, AASHTO Subcommittee on Highway Transport, 2001.
35.	AASHTO R 13	*Conducting Geotechnical Subsurface Investigations*, ASTM designation is D 420, (a more limited treatment of methodology as compared to AASHTO MSI-1 as discussed in Section 6.3).
36.	ACAA	American Coal Ash Association
37.	ACAA Fly Ash Publication	*Soil and Pavement Base Stabilization with Self-Cementing Coal Fly Ash*, American Coal Ash Association (ACAA), 1999.
38.	FHWA-IF-03-019	*Fly Ash Facts for Highway Engineers*, Report No. FHWA-IF-03-019, 2003
39.	PCA	Portland Cement Association, *Soil-Cement and Roller-Compacted Concrete Pavements*.

11.1.2 PAVEMENT PHILOSOPHY: CRADLE TO GRAVE

In order for a pavement to perform for its intended service life, it must be *designed* properly, *constructed* properly, and finally *maintained* properly. This chapter focuses primarily on the process necessary to provide a quality pavement design. The requirements to achieve quality construction are covered in the *FP-XX* and the *Field Materials Manual*. Other good sources for quality construction guidance include the *Hot-Mix Asphalt Paving Handbook* (NRC-HMA Handbook) and the NHI 131033, *Construction of Portland Cement Concrete Pavement*s, course participant's manual. See Section 11.7 for guidance on pavement preventive maintenance. FLH Standard Drawings are available for the pavement typical section details, jointing details for PCCP, and pavement transition details.

The standard design process used by FLH is the *1993 AASHTO Guide for Design of Pavement Structures (AGDPS)* and the 1998 Supplement (*AGDPS Supplement*) that pertains only to rigid pavement design. The *AGDPS* design process is an empirical design process that uses index-type values for inputs, and a design equation that is based upon observed performance. Empirical design processes are often calibrated for only a small set of varying conditions. The equation for the *AGDPS* was based upon field observations from the AASHO Road Test completed in the late 1950's. The conditions at this road test included one subgrade soil type (an A-6 silty clay), one climate condition, 18-kip [80 kN] equivalent single axle loads (ESAL) of about 1,200,000, and a flexible pavement structural section consisting of an asphalt concrete surface, crushed limestone base, and a gravel subbase. Rigid pavements were also evaluated in a similar manner at this same site. Environmental effects such as thermal cracking or frost heave were not addressed. Project conditions for FLH projects often vary from the conditions described above. It is important for the pavement engineer to understand the basis and background of the *AGDPS*.

Currently, new pavement design procedures that are more mechanistic-based are being developed and validated (such as *NCHRP 1-37A*). As these procedures mature and are standardized, it is anticipated that they will be adopted by FLH as a new standard. Pavement engineers are encouraged to become familiar with the new procedures, test methods, and inputs of mechanistic-empirical pavement design. Refer to Section 11.9 for additional information

An excellent source for state-of-the-art guidance, information, and publications is the FHWA Pavements website. Research information, workshop availability, and information about upcoming events and meetings are included on this website.

11.1.3 DESIGN EXCEPTIONS AND VARIANCES

Deviation from pavement service life standards cited within this chapter (see Section 11.2.1.1) will require justification, approval and documentation as a formal technical standard exception (See Section 9.1.3, for a description of the design and technical standard exception process). Significant deviations from other standards, criteria, and guidance cited within this chapter will be justified and documented in the project file.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

11.1.4 QUALITY CONTROL AND QUALITY ASSURANCE

Quality control and quality assurance procedures (QC/QA) will be incorporated and executed in all pavement investigations, analysis, and designs. Those responsible for pavement activities will follow their Division policy and provide signed documentation as evidence of conforming to the procedures throughout the duration of the pavement activities.

11.1.5 DOCUMENTATION AND DELIVERABLES

The type and nature of documentation and deliverables required will vary depending upon the project. **It is the policy of FLH that the pavement activities for a project be properly documented in a project file and eventually archived.** It is important that this project documentation is accurate, comprehensive, and presented in a user-friendly format. Typical project documentation will include formal reports and memos, but informal correspondence such as emails and meeting notes may also be included.

Typical projects will include the pavement discipline deliverables described in the following sections. In addition to the timely delivery of these reports, memos, and documents, it is critical that the pavement engineer is engaged in PS&E reviews and field reviews.

11.1.5.1 Pavements Project Start-Up Information

Include as much of the following information as possible:

- As-built plans including date of original construction
- Existing or archived pavement and/or geotechnical reports and other historical documentation
- Maintenance and rehabilitation history of the road
- Preliminary field investigation needs
- Unique, pavement-related project issues, if applicable
- RIP / PMS information
- Project constraints that may affect pavement recommendations
- Basic climate and geology information
- Local material availability (consult with Materials Engineer)

Also refer to Section 4.5.2 for information included in the Project Scoping Report.

11.1.5.2 Preliminary Pavements Recommendation

The recommended pavement structure is generally required by the 30% design stage. In most instances the field investigation and a pavement design analysis as required by 23 CFR 626 is completed. Coordinate the pavement recommendations with the project's cross-functional team. Briefly summarize the following data and information:

- Field investigation, including pavement, base, and subgrade conditions and quality.
- Material testing results.
- Design criteria used.
- Design alternatives considered and evaluated.
- Design alternative recommended.
- Recommended follow-up testing or additional information gathering.

Also refer to Section 4.10.1 for information included in the Preliminary Engineering Study Report.

11.1.5.3 Final Pavements Recommendation

This deliverable is needed by at least the 70% design stage, but may be required at an earlier design stage, refer to Division Supplements. This document is made available to construction contractors during the bidding phase. Comprehensively document and support design recommendations, to a level commensurate with the project scope and risk, with the following:

- General project information
- Approval sheet (i.e. QC/QA documentation)
- Procedures and results
    - ◊ Summary of the performance history of the pavement as documented in the Pavements Project Start-Up Information deliverable above.

- ◊ Pavement distress data
- ◊ Traffic load and growth projection evaluation with estimated percentages of vehicle classifications
- ◊ Relevant geometric site conditions (e.g. pavement and bench width, steep grades, etc.)
- ◊ Relevant climatic and environmental information (e.g. frost depth, annual rainfall, etc.)
- ◊ Pavement drainage characteristics
- ◊ Tabular summary of sampling and testing (e.g. boring / coring logs, test pit information, material source quality, FWD results, DCP results, lab test results, visual descriptions, etc.)
- ◊ Values or inputs determined by engineering judgment.

- Analysis
  - ◊ Pavement design methodology and inputs
  - ◊ Economic evaluation (e.g. comparative cost analysis of alternatives, LCCA, etc.)
- Pavement Design and Materials Recommendations
  - ◊ Structural section including material type
  - ◊ Pavement rehabilitation method, if applicable
  - ◊ Needed subexcavation, patching, crack sealing, underdrains, or other application that will resolve problems with wet and/or weak subgrade soils.
  - ◊ Auxiliary pavement items including, as applicable, prime/tack coat, asphalt binder grade, emulsified asphalt grade, stabilizing/recycling agents, antistrip additive type, cement type, gradations for base and surfacing material, and any other information that is needed to assure that the appropriate material type and quantity is used.
  - ◊ Address special construction issues related to pavements including but not limited to material haul distance, the need for special contract revisions, lift thickness, curing time, traffic control, and steep grades
- Support Information. Include the following when applicable and appropriate (generally as attachments or appendices):
  - ◊ Site map(s) with sampling and testing locations
  - ◊ Material testing reports
  - ◊ Field notes, logs, FWD data, etc.
  - ◊ Calculations and/or design software reports
  - ◊ Photos (photographically document and represent typical and atypical project conditions, features, and materials)

11.1.6 APPLICABLE LAWS AND REGULATIONS

23 CFR 626 establishes FHWA policy affecting pavement design. **All Federal Lands projects will conform to FHWA policy.** The following is the CFR definition and policy statement:

> "Pavement design means a project level activity where detailed engineering and economic considerations are given to alternative combinations of subbase, base, and surface materials which will provide adequate load carrying capacity. Factors which are considered include: materials, traffic, climate, maintenance, drainage, and life-cycle costs."
>
> "Pavement shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost effective manner."

The FHWA Federal-Aid Policy Guide (*FAPG*) provides standards and guidance for the interpretation of policy. FAPG 23 CFR 626 provides the basis for many of the standards recommended in this chapter.

Other FAPG sections that contain relevant guidance include:

- FAPG 23 CFR 660A – Section 7 on Forest Highway project development
- FAPG 23 CFR 660E – Attachment 3 for Guidance for design of military Transport-Erector Routes

In addition to the FAPG's above, the Park Roads and Parkways Program Implementation Manual also contains relevant guidance.

11.2 PAVEMENT DESIGN VARIABLES

There are numerous pavement design inputs and processes that may vary from project to project. A project's context, risk, and scope will help determine the specific design inputs and processes to use. This section provides an explanation of the design variables involved and guidance on how they are applied.

11.2.1 REQUIRED DESIGN INPUTS

In order to complete a pavement design in accordance with the *AGDPS* and *AGDPS Supplement*, numerous inputs must be determined. The following subsections describe the inputs necessary for the completion of a pavement design.

11.2.1.1 Pavement Performance

The initial and terminal serviceability of the pavement are required inputs. Serviceability is a measure of the functional level of service at a given point in time of the life of a pavement. In the *AGDPS*, the serviceability of a pavement is expressed in terms of the present serviceability index (PSI). The scale for PSI ranges from 0 to 5. A rating of 0 represents a pavement that is impassable and a rating of 5 represents a pavement that is perfectly smooth. The initial serviceability value of a pavement is an estimate of what the PSI will be immediately after construction. The terminal serviceability is the lowest acceptable PSI prior to a structural rehabilitation. An increase in the delta or difference between the initial and terminal serviceability, will result in a decrease in the required thickness or structural number value. **The following serviceability standards apply for typical FLH projects:**

- Use an initial serviceability of 4.2 for flexible pavements and 4.5 for rigid pavements;
- Use a terminal serviceability of 3.0 for roadways with an ADT of 5000 or greater;
- Use a 2.5 terminal serviceability for roadways with an ADT between 500 and 5000; and
- Use a 2.0 terminal serviceability for roadways with less than 500 ADT.

In addition to serviceability, the pavement service life, or period of performance, (e.g. 25 years) for a pavement must be established. An increase in the period of performance will generally result in an increase of the required pavement thickness or structural number value. **The following pavement service life (period of performance) standards apply:**

- For reconstruction projects (4R) use a minimum 25-year period of performance for flexible pavements (HACP) and a 35-year period of performance for rigid pavements (PCCP);
- For rehabilitation projects that increase structural capacity (3R), use a minimum 20-year period of performance regardless of pavement type;
- For preventive maintenance projects (i.e. surface treatments) there is no period of performance design requirement; and

- On aggregate surfaced roads use a period of performance for both reconstruction and rehabilitation projects that corresponds with the expected frequency of future rehabilitation/resurfacing treatments, which is typically 5 to 10 years.

Deviation from the above pavement service life standards will require justification, approval and documentation as a formal design exception (see Section 9.1.3, for a description of the Design Exception process).

11.2.1.2 Traffic

Accurate cumulative load estimates expressed as 18-kip [80 kN] equivalent single axle loads (ESAL) are very important to pavement structural design. Load estimates should be based on vehicle counts and classification, truck weight data, and anticipated growth in truck volumes and weights. The concepts described in the FHWA *Traffic Monitoring Guide* and the AASHTO *Guidelines for Traffic Data Programs* (AASHTO GTDP) contain procedures for obtaining accurate traffic data.

The *AGDPS* contains procedures for converting mixed traffic (with different axle configurations and weights) into design traffic equivalent single axle loads (ESALs). Part of these procedures involves converting expected axle loads and configurations into an equivalent number of ESALs. Standard load equivalency factors are used to complete this conversion, generally by developing a truck factor for each particular truck classification. AASHTO's *Guide for Vehicle Weights and Dimensions* (AASHTO GVWD) includes schematics of truck configurations as well as weight limits, and it can be used as a resource for developing truck factors.

Attaining good estimates of the daily truck traffic and truck class distribution is essential for completing a cost effective pavement design. Poor estimates of truck traffic can lead to premature failures and unplanned repair expense. However, achieving good estimates of traffic loading is not simple and generally requires a significant investment. Traffic data may exist at some project locations. Consult with local State DOTs or use the NPS Traffic Data website. The pavement and traffic engineer must balance cost and risk when determining the level of investigation needed for gathering traffic data.

For most FLH projects, it is recommended to calculate design ESALs using estimated truck factors. It is important to use representative truck factors for each truck classification that is expected to use the roadway. Refer to Exhibit 11.2–A for the 13 FHWA vehicle classifications with common truck factor ranges.

Exhibit 11.2–A FHWA VEHICLE CLASSIFICATIONS AND TRUCK FACTORS FOR FLEXIBLE PAVEMENTS

FHWA Class	Description	Truck Factor[1]
1	*Motorcycles.* This class includes all two or three wheeled motorized vehicles.	n/a

FHWA Class	Description	Truck Factor[1]
2	*Passenger cars*. This class includes all sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers.	0.0004 to 0.0008
3	*Pickups, Vans.* This class includes all 2-axle, 4-tire single unit vehicles other than passenger cars.	0.0004 to 0.004
4	*Buses.* This class includes all vehicles manufactured as passenger-carrying buses. These vehicles will typically have a 2-axle, 6-tire configuration or 3 or more axles.	0.75 to 1.75
5	*2-Axle, 6-Tire Single Unit Trucks*. Vehicles with a single frame that have 2-axles and dual rear tires characterize this class. Typical vehicle types include recreation vehicles, motor homes, and delivery vehicles.	0.3 to 0.7
6	*3-Axle, Single Unit Trucks*. All vehicles with a single frame and 3-axles make up this class. Typical vehicle types include large recreation vehicles and motor homes, garbage trucks, and dump trucks.	0.5 to 1.5
7	*4-Axle or More, Single Unit Trucks.* This class includes all vehicles on a single frame with 4 or more axles. This is a relatively uncommon vehicle class.	1.0 to 2.0
8	*4-Axle or Less, Single Trailer Trucks.* This class includes all vehicles with 4 or less axles consisting of two units (tractor and trailer). Typical vehicle types include freight hauling trucks.	1.5 to 2.0
9	*5-Axle Single Trailer Trucks*. This class includes all 5-axle vehicles consisting of two units (tractor and trailer). This class represents a very common truck on highways. It includes freight hauling trucks and logging trucks.	2.0 to 2.3
10	*6 or More Axle Single Trailer Trucks*. This class includes all vehicles with 6 or more axles consisting of two units (tractor and trailer).	2.0 to 2.3
11	*5 or Less Axle Multi-Trailer Trucks*. This class includes all vehicles with 5 or less axles consisting of three or more units.	3.0+
12	*6-Axle Multi-Trailer Trucks*. This class includes all 6-axle vehicles consisting of three or more units.	3.0+
13	*7 or More Axle Multi-Trailer Trucks*. This class includes all vehicles with seven or more axles consisting of three or more units.	3.0+

[1]Common values or ranges of truck factors for flexible pavements. Calculate project specific factors or refer to Division Supplements for more specific guidance.

The following standards apply:

- If design traffic ESALs is calculated to be less than 50,000, use 50,000 ESALs for design purposes when designing paved roads.
- Use a directional distribution of 60 percent, unless a traffic study warrants the use of some other value.
- For aggregate surfaced roads, use a minimum of 10,000 ESALs (per AGDPS).

If traffic growth projections are not available, use 2 percent for volume and 0 percent for loads, or engineering judgment. For high volume roadways, conducting a traffic study is recommended. In regards to lane distribution, use Exhibit 11.2–B taken from the *AGDPS* as guidance if measured distributions for multi-lane highways are not available.

Exhibit 11.2–B LANE DISTRIBUTION FACTORS

Number of Lanes in Each Direction	% of 18-kip [80 kN] ESAL in Design Lane
1	100
2	80 – 100
3	60 – 80
4	50 - 75

11.2.1.3 Subgrade Soil Characterization

The stiffness or strength of the subgrade soil has a significant impact on the structural requirements of a pavement and is one of the most sensitive inputs within the flexible pavement design equation. The definitive material property used to characterize soil stiffness in the *AGDPS* is the resilient modulus for flexible pavement design. The resilient modulus value is directly input into the design equation. For rigid pavement design, the elastic k-value on the top of the subgrade is the soil property used to characterize soil stiffness. **The following standards apply for determining the soil stiffness or strength:**

1. **Flexible Pavement.** Determine the soil resilient modulus using one of the following methods:
    a. Direct measurement by AASHTO T 307
    b. Backcalculation using FWD data collected in accordance with the FLH FWD Backcalculation and Data Collection Guide
    c. Completing soil index testing, either AASHTO T 193 (CBR) or AASHTO T190 (R-Value), and applying an established correlation from a local DOT, *AGDPS*, or *NCHRP 1-37A*.
    d. Completing dynamic cone penetrometer (DCP) testing according to ASTM D 6951 and applying an established correlation from a local DOT, *AGDPS*, or *NCHRP 1-37A*.

Additional guidance on determining the design resilient modulus input (i.e. effective annual resilient modulus) is included in Section 11.3.2.1.1.

2. **Rigid Pavement.** Determine the effective modulus of subgrade reaction (k-value) according to the process outlined in subsection 3.2.1 of the *AGDPS Supplement*.

In selecting a method to determine resilient modulus, the pavement engineer should consider the size, scope, and risk of the project. Standards and guidance for field investigation, sampling, and evaluation is provided in Section 11.3.1.

In areas with exceptionally soft or expansive soils, consideration of unique design elements such as installation of positive flow subsurface drainage, chemical treatment of soil, use of geosynthetics, or overexcavation should occur. In areas with frost-susceptible soils, consideration should be given to removing all or a portion of this soil and replacing with nonsusceptible soil or granular material.

11.2.1.4 Materials

Quality pavement materials and construction are essential. All materials specified should meet the requirements of the *FP-XX* and its supplements, and the applicable Division's library of specifications (LOS), and applicable project-specific SCRs. More specific guidance for materials is provided is Sections 11.3.2.3, 11.4.2.2, and 11.5.2.4.

Consider the following guidance for material property values and layer coefficients:

1. Rigid Pavement.

   a. PCC Elastic Modulus determination – use ASTM C469 or correlations included in the *AGDPS* or DARWin-ME software. Typical values will range from about 2,500,000 psi [17,000 MPa] to 6,000,000 psi [41,000 MPa]. 4,200,000 psi [29,000 MPa] was the value from the AASHO Road Test.

   b. PCC Modulus of Rupture determination – use AASHTO T 97 results as a basis, but remember to use the mean value expected during construction. 690 psi [4.8 MPa] was the average for the AASHO Road Test.

   c. Base modulus determination - use ASTM C469 or correlations included in the *AGDPS* or DARWin-ME software. 25,000 psi [172 MPa] is a typical value used for granular base and this was also the measured value at the AASHO Road Test. For a treated base, see Table 14 in the *AGDPS Supplement*.

   d. Slab/base friction coefficient – use Table 14 in the *AGDPS Supplement*

3. Flexible Pavement Layer Coefficients: Typical ranges are provided in Exhibit 11.2–C. Refer to the Division Supplements or testing data and analysis performed during project development to determine a specific input value. Site-specific material properties will often affect layer coefficient values. For additional resources, consult the *AGDPS*, which contains charts and equations that aid in determining layer coefficients.

Exhibit 11.2–C LAYER TYPES AND COEFFICIENTS

Layer Type	Layer Coefficient Range	Comments
HACP	0.40 – 0.44	Bid items 401 and 402.
HACP	0.38 – 0.40	Bid items 403 and 404.
Cold Asphalt Mix	0.25 – 0.35	Bid items 408 and 417.
Cold In-Place Recycling	0.25 – 0.30	Bid item 416.
Full-Depth Reclamation (FDR) – Pulverizing	0.10 – 0.12	Bid item 303. This range is appropriate for material with less than 25% passing the #200 [75 µm] sieve.
FDR – Cement	0.15 - 0.22	Bid item 304. Refer to Figure GG.9 of Volume 2 of the *AGDPS*. This layer coefficient is highly influenced by the in-situ material properties, compressive strength, and other factors.
FDR – Bituminous	0.20 - 0.25	Bid item 418. This layer coefficient value is highly influenced by the in-situ material properties, and other factors.
Treated Base	0.18 – 0.30	Bid item 302 and 309. Refer to Figure GG.9 and GG.10 of Volume 2 of the *AGDPS*.
Crushed Aggregate Base	0.12 – 0.14	Bid item 301. This range is appropriate for material with R-values greater than 80.
Subbase or Minor Aggregate Base	0.10	Bid items 301 and 308. This value is appropriate for material with R-values greater than 65.
Select Borrow	0.06 – 0.08	Bid item 204. This range is appropriate for material with R-values greater than 55.
Chemically Stabilized Subgrade	0.08 – 0.12	Bid item 213. To use 0.08, it is expected that the 28-day unconfined compressive strength is at least 100 psi [690 kPa].

11.2.1.5 Environment Considerations

The *AGDPS* considers two main environmental factors:

1. Temperature affects the stability of asphalt, asphalt oxidation rates, thermal-induced cracking, contraction and expansion of Portland cement concrete pavement (PCCP), and curling and warping of PCCP.
2. Rainfall will influence the properties of the subgrade soil, base, and surfacing material.

In addition, freezing and thawing of the subgrade soils and pavement layers remains a major concern for pavement engineers.

For frost-susceptible soils use the guidance provided in the AGDPS for identifying these soils, determining frost depth, and developing design solutions. An additional resource for seasonal frost conditions is Special Report 83-27.

The following standards apply:

1. **Flexible Pavement.** For the selection of appropriate asphalt cement, use the software program LTPPBind (LTPP models) with a 95% or greater reliability for both high and low temperatures. In determining the design resilient modulus for subgrade soil, consider seasonal variations in rainfall and saturation in order to calculate an annual effective subgrade resilient modulus.
2. **Rigid Pavement.** Average annual wind speed, temperature, and precipitation are required to determine the effective temperature differential (TD) for the PCC slab. Use the guidance and equations provided in the *AGDPS Supplement* to develop the TD value.

11.2.1.6 Drainage

Water and pavement layers are not good for each other. Maintaining positive drainage within the pavement structure is an important design consideration. Pavement engineers need to consider the effects of moisture on the performance of the pavement. Note that subsurface drainage needs as related to slope stability, intercepting springs, and other such items, is covered by the Geotechnical chapter in Section 6.4.9.2. .

When appropriate use drainage coefficients (m_i) for flexible pavement design as outlined in the *AGDPS*. As a basis for comparison, the m_i value for the conditions at the AASHO Road Test in northeastern Illinois was 1.0. For specific design alternatives (i.e. drainable bases with edge drains) and additional technical information use FHWA-NHI-131026 and the software program DRIP 2.0 for guidance. Note that the *AGDPS Supplement* does not incorporate the drainage coefficient, C_d, into the rigid pavement design equation.

11.2.1.7 Additional Rigid Pavement Design Inputs

The following standard applies to rigid pavement design: Use the *AGDPS Supplement* to optimize or select the following inputs associated with the particular dimensions of the slab:

- Joint spacing (L)
- Lane edge support adjustment factor (E)
- Base thickness (H_b)
- Joint Layout

11.2.2 DESIGN RELIABILITY AND RISK

Reliability is defined by the *AGDPS* as follows:

> "The reliability of a pavement design-performance process is the probability that a pavement section designed using the process will perform satisfactorily over the traffic and environmental conditions for the design period."

The pavement engineer needs to consider risk and reliability during the design process. The *AGDPS* has incorporated reliability concepts that allow the designer to vary the level of risk based on various classes of roads or other factors. As long as the standards and guidance of this chapter are followed it is recommended *that mean values be used as opposed to conservative values* for each of the design inputs. It is important to note that the design equations were developed using actual variations and mean values.

The following standards apply:

1. Use the following design reliability on FLH projects:
   a. 75 percent on roadways with less than 2500 ADT;
   b. 85 percent on roadways with 2500 to 5000 ADT; and
   c. 90 percent on roadways with ADT greater than 5000.
2. For the overall standard deviation of the design process (S_o), use 0.49 for flexible pavement design and 0.39 for rigid pavement design. These are "default" values recommended by the *AGDPS* to use when no formal study on local conditions has been completed.

11.2.3 ENGINEERING ECONOMIC EVALUATION

When multiple pavement design alternatives exist, a construction cost analysis should be completed. Pavements are long-term investments and on high volume routes additional costs that occur over the pavement life should be considered including maintenance costs and user costs. However, most FLH projects are on low-volume roads and a rigorous economic analysis of alternative strategies, materials, and user costs is typically unnecessary. If the alternatives are not structurally equivalent, minimum design standards are not met, and/or the alternatives have different maintenance requirements, completing a life cycle cost analysis (LCCA) may be appropriate. Refer to the FHWA *Final Policy Statement on LCC Analysis* published in the Federal Register September 18, 1996 for the requirements. The goal of LCCA is to identify the long-term economic efficiency of competing pavement designs.

When a LCCA evaluation is needed, the following documents and manuals provide excellent guidance:

- FHWA Memorandum *National Highway System Designation Act – Life Cycle Cost Analysis Requirements*, April 19, 1996.

- FHWA's Interim Technical Bulletin: *Life Cycle Cost Analysis in Pavement Design*, FHWA-SA-98-079, September 1998.
- FHWA's Demonstration Project 115: *Probabilistic Life Cycle Cost Analysis in Pavement Design*.
- RealCost LCCA software and User's Manual.

The FHWA policy on alternate bids for alternate pavement types is addressed in 23 CFR 635.411(b). This section requires the use of alternate bids "When…more than one…product…will fulfill the requirements…and these…products are judged…equally acceptable on the basis of engineering analysis and the anticipated prices…are estimated to be approximately the same." FLH does not encourage the use of alternate bids to determine the mainline pavement type, mix type, or rehabilitation method, primarily due to the difficulties in developing truly equivalent pavement designs.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

11.2.4 PREVENTIVE MAINTENANCE

Pavements will generally not reach their intended service life without some form of maintenance. Reactive maintenance, while necessary at times, is much less cost effective than preventive maintenance. AASHTO defines preventive maintenance "as the planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system without increasing structural capacity." Examples of preventive maintenance treatments include chip seals, slurry seals, crack sealing, micro-surfacing, and friction courses.

An October 8, 2004 memorandum issued by the FHWA states, "Timely preventive maintenance and preservation activities are necessary to ensure proper performance of the transportation infrastructure." Research and experience has shown that when properly planned and applied, preventive maintenance treatments are the most cost effective way to extend the service life of pavements. An agency can improve the condition of their roadway network without an increase in funding through the implementation of a pavement preservation program. In other words, establishing a pavement preservation program offers a way of increasing the return of investment on roadway construction projects.

The FHWA memo titled Pavement Preservation Definitions discusses the components of pavement preservation and clarifies pavement preservation terminology.

11.2.5 ROADWAY SURFACING TYPE SELECTION

On projects in environmentally or historically sensitive areas or on projects where stakeholders have differing views and opinions on the purpose and need of the roadway project, the use of FHWA-CFL/TD-05-004 may be beneficial. This Guide includes a step-by-step process for selecting a surfacing type amongst a group of diverse stakeholders. This Guide also includes a catalog of all surfacing types that includes descriptions of the surfacing performance, appearance, constructability, costs, and numerous other factors. To go along with this catalog is a photo album that contains photos and design details of the surfacing types.

11.3 FLEXIBLE PAVEMENT DESIGN

11.3.1 FIELD RECONNAISANCE AND INVESTIGATION

There are two major phases in pavement design:

1. Field investigation and data gathering
2. Analysis of data through a design process

This subsection provides standards and guidance for field investigations. It is important to complete a well-planned field investigation that fits the scope, needs, and budget of the project. Coordinate the field reconnaissance, data gathering and investigation with other discipline scoping activities during the conceptual studies and preliminary design phase. Also refer to Section 4.3.2.15.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

11.3.1.1 Climate, Terrain, and Pavement History

Research and document the typical climate conditions for the project site including average annual rainfall, temperature ranges, and climatic zone of the project area. This information will help to determine drainage coefficients, timeframes for suitable construction, and the need for special measures to combat frost heave and/or thaw-weakening conditions.

Gather historical reports, scoping reports, archived files, RIP data, Visidata, and other such information to become familiar with the terrain of the project area, traffic volume, project context, areas of wetlands or springs, and general geology. Maximize the use of this information in developing the field investigation plan.

Gather information about the history of the existing surfacing including maintenance, rehabilitation, re-occurring problematic areas, original construction date, and as-built plans. The local facility managers are often excellent sources for this information. Again, maximize the use of this information in developing the field investigation plan.

11.3.1.2 Existing Pavement and Roadway Conditions

Determine typical surfacing/pavement distress and probable failure mechanisms, as appropriate. Use the Distress Identification Manual for the Long-Term Pavement Performance Program (LTPP), Publication No. FHWA-RD-03-031, to define and quantify distress.

If there is the potential that the pavement structural section may be salvaged and reused, measure pavement and bench widths at numerous locations (i.e. at every boring location) to characterize the range of widths. Also retain representative surfacing, base, and subbase samples for classification, gradation, and, if appropriate, strength testing.

Measure and record the thickness of the pavement structural layers (i.e. asphalt pavement, aggregate base, subbase) at a minimum of every 0.5 mile [0.8 km]. It may be necessary to have additional depth measurements if the structural layers will be salvaged. Record visual condition of pavement structural layers. In particular note whether there is evidence of such occurrences as asphalt stripping, excessive weathering, contamination by fines, and sulfate damage.

Record the roadway drainage conditions and determine the drainage coefficient (m_i) value. Using engineering judgment and information gathered from Section 11.3.1.1 above, estimate the quality of drainage. Exhibit 11.3–A, taken from the *AGDPS*, provides guidance.

Identify low clearance areas that may be problematic for construction equipment.

Identify existing features such as manholes, utilities, bench width, curb and gutter, and walls that may affect the pavement design or construction of the pavement.

Exhibit 11.3–A QUALITY OF DRAINAGE

Quality of Drainage	Water Removed Within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very Poor	Water will not drain

11.3.1.3 Subgrade Soil Conditions

The strength of the subgrade soil has a significant influence on the eventual pavement design. It is critical that the strength of the subgrade soil is properly quantified. Additionally, swelling soils, springtime thaw-weakening conditions, and frost heave will impact pavement performance and these conditions should be investigated as appropriate. Complete subsurface investigations in conformance with the sample retention, safety, boring closure, and logging methods described in Section 6.3 and AASHTO R 13, Conducting Geotechnical Subsurface Investigations. Always attain the necessary utility clearances and access permits prior to any investigation.

Coordinate with the geotechnical engineer on the project cross-functional team (CFT) for sampling and testing soil from areas that will be excavated during construction and used to construct embankments below the pavement structure. Consider the properties of this excavated material in determining design soil strength values.

Complete shallow borings, generally to a depth of 5 ft [1.5 m] below top of subgrade, a minimum of every 0.5 mile [0.8 km]. Photograph, log and visually classify the material. As appropriate, retain samples for classification, in-situ moisture content (retain sample in waterproof baggy), moisture-density relation, and strength testing per Section 11.2.1.3. A DCP may be used in lieu of or to supplement soil strength testing. Although not typically used on new or reconstruction projects, the FWD may also be used in lieu of or to supplement soil strength testing.

Investigate areas that may have unsuitable material within 5 ft [1.5 m] of the top of finished subgrade. Estimate limits and quantities for subexcavation. Recommend design details for the subexcavated area using Section 11.3.2 as guidance. It is important to provide positive drainage of the area by daylighting the backfill material to a foreslope or providing underdrains.

On projects where continuous or long stretches of unsuitable material (such as weak, wet, and/or high plasticity soils) exist, subexcavation may become cost prohibitive. Retain representative soil samples for follow-up analysis of potentially cost effective alternatives such as stabilization by chemical treatment, and/or stabilization by geosynthetics.

On projects where expansive soil may exist beneath the pavement structure, retain representative samples for follow-up testing according to AASHTO T 258 and T 92 and retain samples for investigating remedial methods to control swell. For additional guidance consult FHWA-RD-75-48, FHWA-RD-77-94, and FAA-RD-76-66.

Frost heave is the raising of a surface due to the formation of ice lenses in the underlying soil. At a minimum, pavements will be designed to prevent interruption of traffic due to bumps caused by differential heave. The past history of roadway performance in the area may provide a good indication of whether or not frost heave needs to be investigated. Additionally, a ground water table within 5 ft [1.5 m] of the surface is another signal of potential frost heave action. Refer to guidance in the *AGDPS*, EM 1110-3-138, and Special Report 83-27 for testing and investigation procedures.

Thaw weakening is related to frost heave above. It occurs as the gradual melting of ice lenses leaves soil unconsolidated and saturated. Support capacity can be greatly reduced during the thaw-weakening period. If annual load restrictions are not applied by the road-owner or are not practical, the pavement will be designed to account for the effects of thaw-weakened subgrade soil. Refer to Special Report 83-27 for testing and investigation procedures. Additional sources of information include the following:

- Technical Report ERDC/CRREL TR-00-6, *Thaw Weakening and Load Restriction Practices on Low Volume Roads*, 2000
- *Using TDR and RF Devices to Monitor Seasonal Moisture Variation in Forest Road Subgrade and Base Materials*, Gordon L. Hanek, et at, USDA Forest Service, 2001, and
- *Guidelines on the Use of Thermistor and TDR Instrumentation for Spring Thaw Road Management on Low-Volume Asphalt Roads*, USDA Forest Service publication number 0177 1805 – SDTDC, 2001.

It is not FLH standard practice to include drainable bases with an edge drain system on projects. However, designing a drainable base with an edge drain system or providing some other form of positive drainage of the pavement layers may be necessary to achieve long-term pavement performance in special cases. Using the materials of FHWA-NHI-131026, NCHRP 1-37A (Part 3, Chapter 1) and the software program DRIP 2.0, as guidance, evaluate whether or not special drainage measures are necessary and cost effective.

Exhibit 11.3–B provides a summary of the general soil characteristics that are evaluated on projects for pavement design purposes. Note that additional, more specialized testing may be necessary when expansive or frost susceptible soil exists.

The following standard applies: The number and frequency of samples submitted for testing will vary from project-to-project due to differing conditions and scope. At a minimum, representative soil samples from every mile will be tested for soil characteristics.

Exhibit 11.3–B SUMMARY OF GENERAL SOIL CHARACTERISTICS TO EVALUATE FOR PAVEMENT DESIGN

Characteristic	Test(s)
Strength	R-Value – AASHTO T 190 CBR – AASHTO T 193 Resilient Modulus – AASHTO T 307 FWD – FLH FWD Backcalculation and Data Collection Guide DCP – ASTM D 6951
Classification	AASHTO M 145 (AASHTO Soil Classification) ASTM D 2487 (Unified Soil Classification System)
Moisture Content (in-situ)	AASHTO T 255 or T 265
Moisture-Density Relation	AASHTO T 99, method C AASHTO T 180, method D

11.3.1.4 Project Constraints

In addition to investigating and documenting the soil, pavement, performance, terrain, and climate conditions discussed above, there are often other issues that can affect the pavement design and/or cost of the pavement. Investigate and/or document the project constraints as appropriate. A list of potential project constraints to consider is included below. This list may not be all encompassing.

- Can the road be closed to traffic or must traffic be maintained through the construction zone?
- What types of pavement materials are available locally? Will there be a substantial haul distance for materials?
- Are there project-funding constraints?
- Is there a lack of local contractors or certain construction equipment to perform the work?
- Will there be construction restrictions due to environmental issues?
- Limitations on grade raise?

11.3.2 DESIGN STANDARDS AND GUIDANCE

Use the methodology of the *AGDPS* for pavement design. Sections 11.2.1 and 11.2.2 contain standards and guidance for all the required design inputs. Additional guidance is provided below for designing layer thickness, specifying material types, and designing for problematic subgrade soils.

11.3.2.1 Subgrade Soil

Proper characterization and preparation of the subgrade are two of the most critical items in achieving a long-lasting pavement. Without an adequate foundation, pavement performance will suffer. Technical guidance is provided below to help determine the design soil strength as well as identify problem soils and minimize their effects.

11.3.2.1.1 Design Strength

For determining the design resilient modulus of the subgrade soil, it is important that an *annual average* resilient modulus or what is referred to as the effective soil resilient modulus is estimated as opposed to using a worst-case resilient modulus value. Inherent variability of soil conditions within a project is addressed by using the reliability and standard deviation values discussed in Section 11.2.2, and thus any value above an average value could result in an overly conservative design. Guidance for determining the effective soil resilient modulus is provided in the *AGDPS* and FHWA-RD-97-083. Equations for correlating index soil tests to resilient modulus are provided in the *AGDPS*, *NCHRP 1-37A*, and *AGDPS Vol. II*. Correlations equations developed by individual State DOTs may also be considered and used as appropriate.

11.3.2.1.2 Unsuitable (weak) Soil

There are projects where small areas of weak or compressible soils may exist amongst much stronger, more predominant soil. If these areas are small and localized, they will not significantly affect the pavement design. However, to avoid localized failures in these areas, it is recommended that a minimum of 2 ft [0.6 meters] of the unsuitable soil be removed (subexcavated) and replaced with select borrow or aggregate base. It is also recommended to place a geosynthetic fabric at the bottom of the subexcavation to provide separation and additional strength. De-watering the subexcavated area by daylighting the backfill material to a foreslope or providing some other form of positive drainage (i.e. underdrain) is important, especially in wet areas.

11.3.2.1.3 Swelling Soils and/or Soils with High PI (> 15)

Swelling or expansive soils can be very damaging to pavements. At a minimum, pavements should be designed to remain serviceable and safe under swelling and expansive soil conditions for the required performance period. Deformations or bumps caused by heaving or shrinking of the soil can be a safety issue and damaging to vehicles. These soils can also cause constructability problems such as difficulty in achieving compaction due to the pumping action of the soils. Construction equipment can also get bogged down in these soils especially in wet conditions. Even if swelling is not expected to occur due to the particular project conditions, these soils are weak and generally require a substantial pavement structural section. For additional guidance consult FHWA-RD-75-48 and FAA-RD-76-66.

The following is a list of potential treatments of expansive and/or high plasticity soils beneath the pavement structure (not intended to be all inclusive):

- When the expansive soil layer is just a few feet thick, remove the layer and replace with a select borrow material.
- Subexcavate the expansive soil to a suitable depth (see Exhibit 11.3–C) and backfill with an impermeable soil that is not expansive. A variation of this treatment is to include a waterproof membrane such as a plastic sheet, geosynthetic, or asphalt cement that completely lines the subgrade from backslope to backslope. When a waterproof membrane is used, it may not be necessary to backfill with impermeable material.
- Chemically stabilize the soil with lime or Portland cement. When an adequate quantity of lime is added and mixed with expansive soil, it can reduce the PI, and create a nearly impermeable, stable, and non-expansive layer. Chemical stabilization is a widely used method for controlling expansive soils. Refer to Exhibit 11.3–D on Soil Stabilization for additional guidance.

In general, the rational of the treatments is to keep the moisture content of the swelling soils constant. Swelling can be prevented if the moisture level of the expansive soils stays relatively constant. The pavement engineer must be judicious in the treatment selection. Not all of the treatments will be appropriate for every project. Cost /benefit analysis, project scope, and risk should all be considered.

Exhibit 11.3–C GUIDANCE ON SUBEXCAVATION DEPTH OF EXPANSIVE SOILS

Plasticity Index (PI)	Liquid Limit (LL)	Depth of Subexcavation
15 – 25	< 50	2 ft [0.6 m] *
25 – 35	50 – 60	2 – 4 ft [0.6 m – 1.2 m] *
> 35	> 60	4 – 6 ft [1.2 m – 1.8 m] *

*Traffic volume, project significance, and results of AASHTO T 258 and T 92 should influence subexcavation depth.

11.3.2.1.4 Frost-Susceptible Soils

For frost-related pavement problems to occur, three conditions must be present:

1. Frost-susceptible soils
2. Freezing temperatures that penetrate into the soil, and
3. A source of water.

Frost susceptible soils can lead to two pavement performance problems:

1. Heaving or deformation of the pavement due to the formation of ice lenses in the underlying soil, and

3. Pavement fatigue damage due to thaw-weakened subgrade of the springtime or any freeze-thaw cycle period.

Because thawing of the frozen subgrade occurs top-down, free water becomes trapped in the upper subgrade resulting in reduced bearing capacity of the soil (sometimes as low as 20% of the normal modulus during the summer). Pavements should be designed to remain safe and serviceable under frozen subgrade conditions for the required performance period. Usually the "complete protection" design approach of removing and replacing all frost-susceptible soil for the entire depth of frost is cost prohibitive. A more limited approach of permitting some frost penetration into the natural subgrade will generally keep surface roughness to an acceptable level.

The following resources can be used to determine frost design soil classification, frost depths, and design of treatments:

- EM 1110-3-138
- National Climatic Data Center (NCDC)
- *NCHRP 1-37A*
- PCase Software (Pavement-Transportation Computer Assisted Structural Engineering), use the MODBERG module for frost depth estimation, US Corps of Engineers
- USDA's County Soils Reports.

Design of treatments for frost susceptible soils generally involve two steps:

1. Assuring there is adequate pavement layer structure to account for the loss of bearing capacity during the spring thaw, and
2. Removing and replacing highly frost susceptible soil for a portion of the expected frost penetration.

Highly frost-susceptible soils include silts and some clays.

11.3.2.1.5 Soil Stabilization or Improvement

For long-term pavement performance and good constructability, an adequate foundation is very important. As stated in *NCHRP 1-37A*, stabilization of soils is usually performed for two reasons:

1. For construction expediency, to dry wet soils, and facilitate the compaction of the upper layers. In this case the improved or marginally stabilized soil is not considered as a structural layer

2. To strengthen a weak soil or combat swelling soils. In this case the significantly strengthened and stabilized soil is given some structural value in the pavement design process.

It is the responsibility of the pavement engineer to provide a pavement structural design that meets the performance criteria of the project at the lowest cost. On some projects soil stabilization may be an economical solution where fair to poor soils exist or where the combination of climate and soil conditions dictate the need for construction aids or expediency. Exhibit 11.3–D provides guidance on when and how to incorporate soil stabilization into the overall pavement structure. It is important to note that "bridging over" the problematic soil by providing a thick layer of select borrow or aggregate is a feasible option in most cases. However, when acceptable and inexpensive local aggregates are not available, this option can be cost prohibitive. In these cases, soil stabilization can be an economical alternative.

Exhibit 11.3–D TYPES OF SOIL STABILIZATION

Stabilization Type	Common Uses	Evaluation and Comments	Resources
Lime	♦ Increase strength of cohesive, clayey soils (application rates of 3 to 8 percent). ♦ Reduce or eliminate PI. (Use of lime is only recommended when PI of soil is > 10 and has > 25% passing #200 [75 μm] sieve.) ♦ Reduce swell potential of expansive soils. ♦ Drying wet subgrade (application rates of 1 to 3 percent). ♦ Improve constructability and workability of soil.	♦ Complete preliminary analysis using AASHTO M 216, ASTM C 977, and ASTM D 5102 to determine feasibility. ♦ Unconfined compression strengths of 100 psi [690 kPa] after a 28-day cure are desired (to be considered a structural layer). ♦ Sulfates in soil can have a detrimental impact when mixed with lime. Refer to the Technical Memorandum - Guidelines for Stabilization of Soils Containing Sulfates	National Lime Association Lime-Treated Soil Construction Manual NCHRP 1-37A Evaluation of Structural Properties of Lime Stabilized Soils and Aggregates Consideration of Lime-Stabilized Layers in M-E Pavement Design

Stabilization Type	Common Uses	Evaluation and Comments	Resources
Lime-Fly Ash (Class C and F)	♦ Increase strength of plastic and non-plastic soils (application rates 8 to 20 percent fly ash and 2 to 6 percent lime). ♦ Versatility for use on a broader range of soils (i.e. silts and sands). ♦ Improve constructability and workability of soil.	♦ Complete preliminary analysis using ASTM C 593 and ASTM D 5239 to determine feasibility. ♦ Different sources of fly ash will have different properties and may react differently with the soil. ♦ Unconfined compression strength results should be similar to what you would expect when using cement (> 200 psi [1.4 MPa]).	American Coal Ash Association (ACAA) Fly Ash Facts for Highway Engineers, FHWA-IF-03-019 ACAA Fly Ash Publication AASHTO TF-28
Fly Ash (Class C, self-cementing	♦ Increase strength of plastic and non-plastic soils (application rates of 10 to 20 percent). ♦ Drying wet subgrade. ♦ Improve constructability and workability of soil.	♦ If stabilization (increased strength) is desired, complete preliminary analysis using ASTM C 593 and ASTM D 5239 to determine feasibility. ♦ Different sources of fly ash will have different properties and may react differently with the soil. ♦ Unconfined compression strengths of 100 psi [690 kPa] after a 28-day cure or 50 psi [345 kPa] after a 7-day cure are desired (to be considered a structural layer).	American Coal Ash Association (ACAA) Fly Ash Facts for Highway Engineers, FHWA-IF-03-019 ACAA Fly Ash Publication AASHTO TF-28

Stabilization Type	Common Uses	Evaluation and Comments	Resources
Cement	♦ Increase strength of plastic and non-plastic soils (application rates of 3 to 12 percent). ♦ Used to treat clayey soils with a PI less than 20. ♦ Improve constructability and workability of soil.	♦ If stabilization (increased strength) is desired, complete preliminary analysis using ASTM D 1633, AASHTO T134, T 135, and T 136. ♦ Unconfined compression strengths of 200 psi [1.4 MPa] after a 7-day cure are desired (to be considered a structural layer).	Soil-Cement Laboratory Handbook (PCA publication) Properties and Uses of Cement-Modified Soil (PCA publication IS 411.02) Soil-Cement Construction Handbook (PCA Publication)
Asphalt	♦ Increase strength of granular, cohesionless soils (i.e. sand) ♦ Waterproofing subgrade.	♦ Not a common treatment. ♦ Similar to a prime coat, with more thickness.	
Geosynthetics /Geogrids	♦ Reinforcement of weak soils ♦ Provide construction expediency in saturated soil conditions.	♦ Some guidelines are included in AASHTO PP-46, AASHTO M 288, and ASTM D 4439.	NCHRP 1-37A (Part 2, Chapter 1)

11.3.2.1.6 Borrow Material

The better soil (i.e. more granular, lower PI material) obtained from excavated or other areas along the project should be used in the upper part of embankment or fill areas. Soil that has strengths below the design strength should not be used in the upper 2 ft [0.6 m] of embankments and fills.

11.3.2.2 Required Structural Number (SN) and Designing Layer Thickness

After all of the design inputs have been estimated or determined, calculate the required structural number (SN) by using the flexible pavement design equation or flexible design nomagraph included in the *AGDPS*. The AASHTO DARWin-ME software can also be used to calculate the SN.

Once the SN is determined, it is necessary as stated in the *AGDPS* "to identify a set of pavement layer thicknesses which, when combined, will provide the load-carrying capacity corresponding to the design SN." It is important to note that there is not a single unique solution for the pavement layering system that will meet the design SN. The pavement engineer will need to consider several factors when trying to optimize the layering system. These factors include material costs, traffic, construction constraints, subgrade soil characteristics, historical performance, and maintenance constraints. A typical pavement structural section for FLH includes a HACP top layer over a crushed aggregate base and/or subbase over a prepared subgrade. However, layers consisting of treated aggregate bases, chemically treated subgrade, and select borrow may be advantageous to use under certain project conditions.

In general, historical performance has shown when a granular layer such as an aggregate base or subbase course contributes to at least 35 percent of the design SN the pavement performs satisfactorily. This is especially true over fine-graded subgrade soil. The benefits of a granular layer include improved drainage, improved frost protection, and more uniform foundation for the placement of asphalt pavement.

The following standards apply:

- Recommend design layer thickness in ½ in [13 mm] increments, rounding up.
- Regardless of the SN required it is impractical and sometimes uneconomical to place base and asphalt courses of less than some minimum thickness, the following are minimum pavement layer thicknesses for reconstruction (4R) projects:
  - ◊ HACP, 2 in [50 mm]
  - ◊ Aggregate Base or Subbase, 4 in [100 mm] (a stabilized subgrade may be used in lieu of this requirement)

11.3.2.3 Selecting Material Types

The use of quality materials that meet the strength, durability, and consistency criteria used to develop the pavement design is important to achieve a durable and long-lasting pavement. The following, which references specifications from the *FP-XX*, provides guidance for specifying material types of the various pavement layers. Refer to the Division Supplements for design application rates and unit weights to use for estimating purposes:

11.3.2.3.1 Asphalt Mix (HACP)

Either Section 401 (Superpave) or 402 (Hveem or Marshall) are specified on most projects. Selection of 401 or 402 is usually based on the mix design commonly used by the local State DOT or what is the most practical within the region of the project. Typically either a ½ in or ¾ in [13 mm or 19 mm] nominal maximum aggregate size is specified, but refer to Division Supplements for specific guidance on gradation and mix type.

Section 403, allows for a Hveem, Marshall, Superpave, or other State DOT asphalt concrete mixture to be used. Section 403 is commonly specified on small projects when it is impractical to accept material statistically (i.e. < 4000 tons [tons] HACP)

Section 404 is generally only used for sidewalks, paved waterways, and other areas that don't receive significant traffic loading.

Section 405, open graded friction course (OGFC), is specified as a riding surface only when splash and spray, tire-pavement noise, and/or wet pavement skid resistance is identified as a significant project issue. In areas where freezing temperatures occur, caution should be employed when specifying an OGFC because durability can be an issue with these mixes in cold climates.

11.3.2.3.2 Asphalt Binder

When specifying Section 401 or 402 asphalt concrete mixes, use the software program LTPPBind (LTPP models) and select an asphalt binder grade with a 95% or greater reliability. Verify that the selected asphalt cement grade is locally available. An asphalt binder grade is typically not specified when using 403 or 404 asphalt mixes. For pavements with multiple asphalt layers, a different grade may be specified for layers below the surface course as long as 95% reliability is met for the layer depth. However, the practicality and economic considerations of specifying multiple grades should be evaluated. Generally, at least 10,000 tons [tons] of mix in the lower layer is needed to have a significant cost impact.

11.3.2.3.3 Additives for HACP mixes

Refer to Division Supplements for specific guidance on usage, types, and application rates for additives such as lime.

11.3.2.3.4 Untreated Aggregate Base and Subbase

Section 301 (Untreated Aggregate Base) is specified on most projects when base and/or subbase is part of the pavement structure. Refer to Division Supplements, for specific guidance on gradation designation.

Section 308 (Minor Aggregate) is typically specified on projects when small quantities (i.e. < 4000 tons [tons]) make it impractical to accept material statistically.

FLH does not have a standard specification for permeable base. If permeable base is necessary on a project, it is recommended that a bound permeable base be used as opposed to an unbound permeable base. Unbound permeable bases can be difficult to compact and will often not provide a stable construction platform to complete paving operations. Refer to FHWA-NHI-131026 for guidance.

On some projects it may be economical to use a select borrow material as a lower subbase layer, especially when there is a readily available material source near the project location. Typically Section 204 is used to pay for this material.

11.3.2.3.5 Treated Base

Section 302 (Treated Aggregate Courses) or 309 (Emulsified Asphalt-Treated Base Course) can be specified when advantageous or cost effective for the project conditions. Some conditions that may warrant the use of a treated base include very high traffic loading, necessity to improve properties of lower quality aggregates, and bridging over poor subgrade.

11.3.2.3.6 Stabilized or Reinforced Subgrade

Section 213 (Subgrade Stabilization) or 207 (Earthwork Geotextiles) can be specified when advantageous or cost effective for the project conditions. Refer to Section 11.3.2 for additional guidance on usage, stabilizer type, and application rate.

11.3.2.3.7 Prime Coat, Tack Coat, and Fog Seal

Section 412 (Tack Coat) is specified on all projects with multiple lifts of HACP. Typically, the contractor is given the option to choose from the following emulsified asphalt grades: CSS-1, CSS-1h, SS-1, and SS-1h.

Section 411, Prime Coat, is typically specified on all projects with an aggregate base course beneath the HACP. Refer to Division Supplements and *Guidelines for Using Prime and Tack Coats* for additional information and guidance. If a specific prime material is specified in the contract, verify that the material is readily available, allowed by the local county or jurisdiction, and formulated to penetrate.

Refer to Division Supplements, to determine whether or not Section 409 (Fog Seal) is required on the project.

11.4 STRUCTURAL DESIGN OF AGGREGATE SURFACING

Most pavement and materials practitioners will agree that it is acceptable and practical to have an aggregate surfaced road when the ADT is less than 50. However, it is much more difficult getting agreement among practitioners on where the upper ADT threshold should lie for an aggregate surfaced road. Factors such as the type of traffic and function of the road are also important to consider when determining the suitability of aggregate surfacing.

11.4.1 FIELD RECONNAISANCE AND INVESTIGATION

There are two major phases in structural design of aggregate surfacing:

1. Field investigation and data gathering, and
2. Analysis of data through a design process.

This subsection provides standards and guidance for field investigations. It is important to complete a well-planned field investigation that fits the scope, needs, and budget of the project.

The following standard applies: Complete the field reconnaissance and investigation procedures as discussed in Section 11.3.1.1, 11.3.1.2, 11.3.1.3, and 11.3.1.4, albeit with an intensity and scope suitable and efficient for the project needs.

Generally structural performance issues related to frost heave, expansive soils, and subsurface drainage are not mitigated on aggregate surfaced roads. Coordinate these issues with the project cross-functional team.

11.4.2 DESIGN STANDARDS AND GUIDANCE

It is FLH standard practice to use the aggregate thickness design procedure included in the *AGDPS* and Gravel Roads (LTAP) manual. It is also acceptable to use the procedure in the Forest Services' *Aggregate Surfacing Design Guide* (Report number J669, February 1990) or *Earth and Aggregate Surfacing Design Guide for Low Volume Roads* (Report number EM-7170-16 or FHWA-FLP-96-001, October 1995). Both of these guides were developed for the Forest Service and specific inputs or process is not discussed in this chapter.

Additional design inputs not addressed in the guidance and standards in Section 11.2 include the following:

- Allowable Rutting: Typical values fall between 1.0 and 2.0 in [25 and 50 mm].
- Aggregate Loss of Surface Layer: This value is highly dependent upon the climate, traffic level, and frequency of maintenance / grading performed. The loss of ½ in [13 mm] of gravel per year can be used if specific information is not available.
- Length of Season: Estimate this variable using the table and figures in the *AGDPS* or from trusted climatic data from other sources.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

11.4.2.1 Designing Layer Thickness

The structural layers of an aggregate surfaced road will generally consist of an aggregate surfacing layer (with a gradation and plasticity that will provide binding and stability) over a prepared subgrade. If the existing subgrade soil is weak and/or traffic loading is relatively large, it may be economical to use additional structural layers such as geotextile reinforcement, soil stabilization, or select borrow.

Aggregate surfaced roads are inherently dusty. The use of dust palliatives should always be considered. In addition to reduced dusting, dust palliatives can provide stabilization and reduce the frequency of blade maintenance. Dust palliatives reduce the loss of fines, which leads to reductions in the loss of larger aggregates and reductions of distresses such as washboarding. The Gravel Roads (LTAP) and Forest Service 9977 1207 SDTDC contain additional guidance.

The following standards apply:

- Recommend design layer thickness in ½ in [13 mm] increments, rounding up.
- Regardless of the calculated thickness design results, it is impractical and sometimes uneconomical to place aggregate surfacing less than some minimum thickness. The minimum aggregate surfacing layer thickness for reconstruction (4R) projects is 6 in [150 mm].

11.4.2.2 Selecting Material Types

The use of quality materials that meet the strength, durability, and consistency criteria used to develop the aggregate surfacing structural design is important to achieve a durable and long-lasting pavement. The following, which references specifications from the *FP-XX*, provides guidance for specifying material types of the various pavement layers. Refer to Division Supplements, for design application rates and unit weights to use for estimating purposes.

11.4.2.2.1 Aggregate Surfacing and Subbase

Section 301 (Untreated Aggregate Base) is specified on most projects when aggregate surfacing is part of the structural section. Typically, at least the top 6 in [150 mm] of the structural section will meet the requirements of Section 703.05 (c) to provide binding and stability. Refer to Division Supplements, for specific guidance on gradation designation.

Section 308 (Minor Aggregate) is typically specified on projects when small quantities (i.e. < 4000 tons [tons]) make it impractical to accept material statistically.

On some projects it may be economical to use a select borrow material as a lower subbase layer, especially when there is a readily available material source near the project location. Typically Section 204 is used to pay for this material.

11.4.2.2.2 Stabilized or Reinforced Subgrade

Section 213 (Subgrade Stabilization) or 207 (Earthwork Geotextiles) can be specified when advantageous or cost effective for the project conditions. Refer to Section 11.3.2 for additional guidance on usage, stabilizer type, and application rate.

11.4.2.2.3 Dust Palliatives

Section 306 is specified on projects requiring a dust palliative. It contains specifications for the more traditional dust palliatives such as salts, lignin sulfides, and emulsified asphalts.

11.5 RIGID PAVEMENT DESIGN

FLH designs and builds few mainline Portland cement concrete pavements (PCCP) due to the predominant low-volume traffic conditions on most FLMA routes. However, it is common for FLH to design and build PCCP at spot locations such as low-water crossings, bus parking/turnarounds, entrance station kiosks, and boat ramps. The thickness design in these spot locations is usually governed by minimum thickness requirements as opposed to traffic loading. Regardless, a design methodology and required design inputs for PCCP are presented in this chapter.

11.5.1 FIELD RECONNAISSANCE AND INVESTIGATION

There are two major phases in pavement design:

1. Field investigation and data gathering, and
2. Analysis of data through a design process.

This subsection provides standards and guidance for field investigations. It is important to complete a well-planned field investigation that fits the scope, needs, and budget of the project.

Generally, the field reconnaissance and investigation procedures included in Section 11.3.1 are to be used. However, if existing PCCP is going to be removed or salvaged, and replaced with new PCCP, note the following exceptions:

- Existing Pavement and Roadway Conditions
    - ◊ If good quality as-built information exists, coring of the PCCP for determining layer thickness can be eliminated. However, coring of the PCCP and base should still occur, as needed, for forensic analysis and/or for determining salvage value.
    - ◊ Determine whether steel reinforcement and/or steel dowels exist within the PCCP.
- Subgrade Soil Conditions
    - ◊ Characterization of soil subgrade for determining k-value should be evaluated by FWD analysis (or historical reports). This will reduce the amount of time-consuming and relatively expensive coring operations.

11.5.2 DESIGN STANDARDS AND GUIDANCE

When traffic loading dictates, use the methodology of the *AGDPS Supplement* for jointed plain concrete pavement (JPCP) design. Otherwise use the minimum thickness requirements listed in Exhibit 11.5–A below.

Sections 11.2.1 and 11.2.2 contain standards and guidance for all the required design inputs of the AGDPS process. Additional guidance is provided in the following subsections for design checks, slab and base minimum thickness values, joint design, use of reinforcement/dowels, material types, and subsurface drainage.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

11.5.2.1 Designing Slab and Base Thickness

Review the guidance provided in Exhibit 11.5–A to evaluate whether or not it is necessary to complete a thickness design using the *AGDPS Supplement*.

Exhibit 11.5–A MINIMUM THICKNESS FOR PCCP AND BASE

Traffic Level, 18 kip [80 kN] ESALs (or function of PCCP)	PCCP in [mm]	Base in [mm]	Comments
Greater than 1,000,000	8.0 [200]	4.0 [100]	Evaluate acceptability of minimum thickness using *AGDPS Supplement*
500,000 to 1,000,000 (or Low-Water Crossings, and Boat Ramps)	8.0 [200]	4.0 [100] (untreated)	No design necessary. Evaluate need for treated base/subgrade and increased thickness when building over A-7 soils (fat clays)
Less than 500,000	6.0 [150]	4.0 [100] (untreated)	No design necessary. Evaluate need for treated base/subgrade and increased thickness when building over A-7 soils (fat clays)

11.5.2.2 Design Checks

When it is necessary to use the *AGDPS Supplement* for thickness design and dowels are not being used at the transverse joints, it is good practice to check that the stresses created at the top of the slab when an axle load is at the joint are not excessive. Complete the "joint load position cracking" check as described in the *AGDPS Supplement*.

When it is necessary to use the *AGDPS Supplement* for thickness design, complete a "joint faulting" check as described in the *AGDPS Supplement* after the required slab thickness is determined. As stated in the *AGDPS Supplement*, "Slab thickness should not be increased in an effort to improve the joint load transfer design, because slab thickness has only a minimal effect on joint faulting." The *AGDPS Supplement* suggests other potential adjustments to reduce faulting including using or increasing the diameter of dowels, and/or selecting a different base type.

11.5.2.3 Joint Design, Use of Dowels, Use of Reinforcement, and Other Details

The guidance and details provided below is meant for use on typical FLH projects such as rural roads or city streets. It may or may not be appropriate for high volume highways. The guidance was developed using the *AGDPS* and the ACPA's *Concrete Engineering of Streets and Local Roads Reference Manual* (ACPA – TB200P). For guidance on higher volume roads refer to FHWA Technical Advisory T 5040.30, Concrete Pavement Joints and FHWA-NHI-131060.

11.5.2.3.1 Joint Design

Use a maximum transverse joint spacing of 15 ft [4.6 m] for 8 in [200 mm] slab thickness or greater, and a maximum joint spacing of 12 ft [3.7 m] for 6 in [150 mm] slab thickness.

Use a slab width to length ratio that does not exceed 1.25. Avoid joint intersection angles less than 60°.

The use of expansion joints is generally not necessary with the above transverse joint spacing. However, the use of isolation joints is critical at intersecting roads, drainage structures, or other fixed objects.

Longitudinal joints should be placed at the centerline to aid in delineation of traffic lanes.

Additional guidance for joint layout along roadways, intersections, and parking areas is provided in the ACPA *Design and Construction of Joints for Concrete Streets* and *Intersection Joint Layout* publications included in ACPA – TB200P.

11.5.2.3.2 Use of Dowels

Consider using dowel bars to minimize faulting when Class 9 semi-tractor trailer traffic exceeds 50 per day or when the 18 kip [80 kN] ESALs exceed 1 million.

If dowel bars are required, use a 14 in [350 mm] long, ¾ in [19 mm] diameter dowel for a 6 in [150 mm] slab, and a 17 in [430 mm] long, 1¼ in [32 mm] diameter dowel for an 8 in [200 mm] slab.

Place dowels at 12 in [300 mm] centers along the joint.

11.5.2.3.3 Use of Reinforcement

It has been well established that distributed steel or wire mesh can serve to hold cracks tightly together, but the steel in the amount needed for holding cracks together does not add to the structural strength of the pavement. As a result, if proper joint layout and geometry is accomplished, no intermediate cracking should occur and distributed steel can be omitted.

When long and narrow slabs, irregular shaped slabs, or unsupported/untied edges are necessary, it is good practice to place small diameter reinforcement (i.e. #3 [#10] bars spaced on 12 in [300 mm] centers both longitudinally and transversely) 2 in [50 mm] below the surface.

Using reinforcement may be advantageous when the slab functions as a low-water crossing, boat ramp, or any riding surface where highly erodible or saturated conditions exist.

Use deformed tie bars to tie longitudinal joints when there is no curb or other firm lateral restraint. Curbing that is tied to the mainline slab will also keep the longitudinal construction joint tight. Never place tie bars within 15 in [380 mm] of transverse joints or they may interfere with joint movement.

11.5.2.3.4 Other Details

For information and details on joint sealant, deformed bar length and sizes, typical sections, joint types, etc., refer to the 501 series of standard drawings and specials. For guidance on surface texture, refer to FHWA Technical Advisory T 5040.36, Surface Texture for Asphalt and Concrete Pavements.

11.5.2.4 Selection Material Types

The use of quality materials that meet the strength, durability, and consistency criteria used to develop the pavement design is important to achieve a durable and long-lasting pavement. The following provides guidance for specifying material types of the various pavement layers:

- Rigid Pavement (PCCP) – From the *FP-XX*, Section 501 is typically used to specify concrete pavement.
- Untreated and Treated Base; Stabilized and Reinforced Subgrade – Specify as indicated under Section 11.3.2.3.

Refer to Division Supplements, for design application rates and unit weights to use for estimating purposes.

11.6 PAVEMENT REHABILITATION

The *AGDPS* defines pavement rehabilitation as "any work that is undertaken to significantly extend the service life of an existing pavement through the principles of resurfacing, restoration, and/or reconstruction." The AASHTO Highway Subcommittee on Maintenance defines major rehabilitation as "…structural enhancements that both extend the service life of an existing pavement and/or improve its load-carrying capability." This second definition better fits the focus of this section.

11.6.1 REHABILITATION METHODS: FLEXIBLE PAVEMENTS

In addition to institutional knowledge, three primary resources were used to develop the standards and guidance included in this subsection:

- FHWA-NHI-131008
- ARRA's Basic Asphalt Recycling Manual (BARM)
- *AGDPS*

11.6.1.1 General Field Reconnaissance and Investigation

Generally, the field reconnaissance and investigation procedures included in Section 11.3.1 are to be used. Additions and variances to those procedures are included below. With a reconstruction project (4R), the pavement engineer is primarily concerned with properly characterizing the subgrade soil conditions. With a pavement rehabilitation project (3R), the pavement engineer is still concerned about the subgrade strength but also has to consider how best to rehabilitate the existing pavement structure. Due to the additional variables, the pavement investigation for rehabilitation projects is generally more time-consuming and intense.

Identify and document whether or not steep grades exist (> 8 percent). Identify and document if the road has a curvy alignment and the number of sharp curves (radius < 40 ft [12 m]). These factors can affect cost and feasibility of some rehabilitation methods.

Identify stonewalls, low clearances, utilities, and other obstacles that may affect the selection of a rehabilitation method.

When as-built, rehabilitation, and maintenance information is not available, measure and record the thickness of the pavement structural layers at least every ¼ mile [400 m]. It is good practice to vary coring/boring locations transversely across the pavement. If the pavement thickness has significant variability, additional measurements or use of ground penetrating radar (GPR) may be necessary. Typical areas where variation in pavement depths may occur include patched/repaired areas, over culverts, shoulders vs. mainline, and wetland areas.

Record the visual condition of the pavement structural layers. In particular record the type of material/mix, whether there is evidence of stripping or raveling, approximate maximum aggregate size, and contamination by fines. It may be prudent to retain samples for follow up evaluation of properties such as moisture susceptibility.

When the rehabilitation scope includes recycling and/or reclamation, retain bulk samples of the asphalt pavement, base, and subgrade from test pits or large diameter coring. Multiple test pits will often be necessary as it is important that the full range of material types and conditions be sampled. Use this material for completing preliminary mix designs, gradations, and/or classifications. The results of this laboratory testing will help determine the feasibility and selection of the rehabilitation method.

When the rehabilitation scope includes recycling and/or reclamation, it is very important to quantify and characterize all of the materials and structures that will be encountered within the depth of recycling. If a contractor encounters unexpected buried manholes, paving fabric, shallow utilities, cobbles, and/or boulders, not only will FLH be culpable, but the project construction may also be delayed.

Follow Section 11.3.1.3 for subgrade soil condition investigation except when the scope of the rehabilitation includes just an overlay or a mill and overlay. In this case use a FWD to estimate the modulus values of the pavement layers and subgrade soil. Follow the testing and analysis guidance provided in the FLH FWD Backcalculation and Data Collection Guide. Using correlations equations from the *AGDPS*, the structural coefficient of the individual layers and/or overall SN can be estimated.

11.6.1.2 Design Standards and Guidance

Unless otherwise indicated, use the methodology of the *AGDPS* for pavement design. Additionally, Module 3-11, Identification of Feasible Alternatives in FHWA-NHI-131008 provides specific criteria and guidance for selecting rehabilitation methods.

For HACP overlays or mill and overlays the preferred practice is to use FWD deflection data and the backcalculation software program MODTAG to estimate layer moduli values and correlate these values to structural coefficients for the completion of a component design. The inputs and process discussed in Section 11.2 and 11.3 would apply. A secondary option is to use FWD deflection data and the backcalculation analysis included with the DARWin-ME software program. In this case, the overlay design program included with the DARWin-ME software would also be used.

When providing a rehabilitation recommendation, it is important that the pavement engineer considers the type of pavement deterioration, physical project constraints, costs of several alternatives, disruption of traffic, constructability, climate, and other pertinent issues. On most projects there is more than one feasible rehabilitation alternative, it is incumbent upon the pavement engineer to complete a comprehensive analysis of these factors before putting forth a recommendation. The following subsections and links present standards, guidance, and criteria to use for determining a cost effective and appropriate pavement rehabilitation method.

The following standard applies: For an HACP layer to be assigned a structural value (or coefficient), it must be at least 1½ in [38 mm] thick.

11.6.1.3 HACP Overlays

As indicated in FHWA-NHI-131008 the general purpose of an HACP overlay is to improve the functional or structural performance of an existing pavement. So it is important that the need for an overlay be accurately identified and the condition of the existing pavement properly characterized.

This subsection primarily covers the use of structural overlays, but it is important to recognize that thin and ultra-thin overlays are commonly used to correct functional deficiencies such as roughness, hydroplaning, and surface friction. Refer to Section 11.7 for use of thin overlays as a preventive maintenance treatment or to correct functional deficiencies.

Do not use overlays on pavements that have high severity fatigue, block, transverse and/or longitudinal cracking throughout the project area. Pavements nearing the end of their service life are better candidates for reclamation and recycling alternatives. Do not use overlays on pavements that are stripping and are moisture sensitive.

Closely evaluate the cost effectiveness and service life of an overlay on a pavement that exhibits moderate severity fatigue, block, transverse, and/or longitudinal cracking throughout the project area. If an extensive amount of pre-overlay repair is needed to achieve the required service life, recycling and reclamation alternatives may be more cost effective.

Pavements that are rutted (and not moisture sensitive), with low severity cracking distress, and relatively infrequent locations of higher severity distress, are good candidates for an overlay. Appropriate pre-overlay repairs should be completed prior to the overlay. According to both the *AGDPS* and FHWA-NHI-131008, the amount of pre-overlay repairs is one of the most significant factors affecting the future service life of the overlay. Exhibit 11.6–A contains a list of common pre-overlay repairs.

Advantages of overlays include:

- Very common treatment with a large availability of contractors that can complete the work
- Construction is relatively simple and can be completed with minimal disruption to traffic.
- When used appropriately, life-cycle costs are competitive

Limitations of overlays include:

- The greater the deterioration of the existing pavement, the lower the cost effectiveness.
- Increased risk of premature cracking or other failures, due to pre-existing conditions.

For material type selection, refer to Section 11.3.2.3.

Exhibit 11.6–A TYPICAL PRE-OVERLAY REPAIRS

Distress Type	Suggested Repair
Fatigue cracking and/or potholes	Saw cut and remove all distressed pavement. Replace with a suitable bituminous mixture. Depending upon whether the distress is related to the asphalt mix or the subgrade, subexcavation according to Section 11.3.2.1 may also be necessary.
Thermal and longitudinal cracks	Seal cracks < 0.75 in [19 mm] in width with a suitable material. Wider cracks may have to be filled with a sand-asphalt mix or other suitable material and may require reflection cracking control measures.
Rutting	Place a leveling course of HACP or remove ruts by milling.
Heaving, depressions, bumps	Investigate cause and treat the *cause*, not just the symptom.
Distress related to poor drainage conditions	Improve or correct drainage conditions.

11.6.1.4 Asphalt Pavement Milling

Asphalt pavement milling uses a self-propelled milling machine with drum-mounted carbide steel cutting teeth to chip off the surface of a pavement. With a milling operation, the depth of removal, longitudinal profile, and cross-slope can be controlled. The resulting grooved or textured asphalt surface is suitable for an overlay, once it is cleaned, broomed, and tack coated.

Generally, all milling operations precede an overlay or recycling process. Rarely is the milled surface used as the permanent riding surface. The most common use of milling for FLH is to eliminate grade raise or restore pavement elevation to the curb reveal. Other common uses of milling include removal of rutting, restoration of cross-slope geometry, and improve smoothness.

Single pass milling depths can be very shallow (i.e. ½ in [13 mm]) using micro-milling or relatively thick (> 4 in [100 mm]) using high capacity milling machines.

Milling should not be used to mitigate full-depth cracks, unless the full-depth of asphalt pavement is milled.

Constructability issues to consider include determining overhead clearances for the milling machine and identifying buried utilities such as abandoned manholes or other castings within the pavement layers to be milled.

When an HACP overlay is to follow the milling operation, it is necessary to have enough remaining pavement structure to support the paving equipment and operations. Generally, on a low-volume road, no less than 2 in [50 mm] of asphalt pavement should remain in-place. If the stability and durability of this lower depth asphalt pavement is questionable, a mill and overlay rehabilitation should not be recommended.

Advantages of milling include:

- Efficient way to restore required geometry, smoothness, and eliminate grade raises.
- Minimal traffic disruption.
- Millings can be recycled.

Limitations of milling include:

- Production levels may be reduced on steep grades or on sharp curves.
- If millings are not recycled locally, they may have to be hauled a long distance for storage/disposal.

Use Section 413 of the *FP-XX* to specify the cold milling operation. Refer to the *ARRA Basic Asphalt Recycling Manual* (*BARM*) for additional guidance and information on milling.

11.6.1.5 Full Depth Reclamation (FDR)

The *ARRA Basic Asphalt Recycling Manual* (*BARM*) describes FDR as a "…rehabilitation technique in which the full thickness of the asphalt pavement and a predetermined portion of the underlying materials (base, subbase, and/or subgrade) is uniformly pulverized and blended to provide an upgraded, homogeneous base material." There are three general categories of FDR:

1. Mechanical stabilization which includes just pulverizing, grading, and compacting,
2. Chemical stabilization which includes pulverizing, adding cement to stabilize, grading, and compacting, and
3. Bituminous stabilization which includes pulverizing, adding foamed asphalt or emulsified asphalt as a stabilizing agent followed by grading and compacting.

FDR is a versatile and cost effect rehabilitation option. The FDR process can accommodate some widening (~ 2 ft [0.6 m]), grade or geometry corrections, high traffic volumes, variable materials, curb and gutter, and pulverization depths up to 12 in [300 mm]. There are numerous good references and resources to use when evaluating the suitability of using of FDR. The following are recommended:

- *ARRA Basic Asphalt Recycling Manual* (*BARM*)
- *Soil-Cement Laboratory Handbook*, PCA
- *Wirtgen Cold Recycling Manual*, Wirtgen Group
- *Guide to Full-Depth Reclamation with Cement*, PCA (item code EB234, date 2005)

Use FDR to treat pavements with significant distress and to increase structural capacity of pavements nearing the end of their service life. FDR requires a wearing surface such as HACP.

FDR does not address localized subgrade or drainage problems. These areas should be identified during the pavement investigation with solutions developed to address the cause.

Constructability issues include:

- Determining overhead clearances for reclaimer/pulverizer,
- Identifying buried utilities such as abandoned manholes or other castings within the pavement layers to be pulverized,
- Assure no boulders or oversize rocks are within the depth to be pulverized,
- Determining feasibility of lowering manholes or other utilities within the roadway to accommodate pulverizing operation.

Collect bulk samples of the pavement layers per Section 11.6.1.1 to evaluate material properties and complete a preliminary mix design if necessary. Use the results to determine suitability, estimate application rates, and estimate structural coefficient values to use. Exhibit 11.6–B provides additional guidance.

Exhibit 11.6–B FDR EVALUATION GUIDANCE

FDR Method	Typical Application Rate of Stabilizer	Target Strength	Test Method	Comments
Mechanical (Pulverization)	N/A	R-Value > 70 CBR > 40	AASHTO T 190 AASHTO T 193	--
Chemical (Cement)	3% – 9%	400 psi [2.8 MPa] (but always less than 800 psi [5.5 MPa])	AASHTO T 134 ASTM D 1633	♦ > 45% passing #4 [4.75 mm] sieve desired for formation of aggregate matrix. ♦ Consider evaluating durability according to AASHTO T 135 and T 136.
Bituminous (foamed asphalt or emulsified asphalt)	2% - 5%	> 50%, TSR > 45 psi [300 kPa], Wet Tensile Strength	AASHTO T 245 AASHTO T 283	♦ 5% < passing #200 [75 µm] < 25% ♦ Non-plastic or low plasticity soils ♦ Typically 1% cement is added for improved strength ♦ For foamed asphalt evaluate half-life and foaming ability of asphalt binder.

Advantages of FDR include:

- Recycles materials and conserves resources.
- Versatile.
- Eliminates reflective cracking and other distresses.
- Substantial structural improvement with the introduction of stabilizers
- Cost effective when used appropriately.

Limitations of FDR include:

- Requires a riding surface.
- Stabilization processes require specialized equipment and experienced contractors.
- Some FDR methods require a cure time.

From the *FP-XX*, use Section 304 to specify FDR with cement, Section 303 to specify FDR with just pulverization, Section 408 to specify FDR with emulsified asphalt, and the 418 SCR to specify FDR with foamed asphalt. Refer to Division Supplements, for additional guidance on material selection and application rates.

11.6.1.6 Cold In-place Recycling (CIPR)

The *ARRA Basic Asphalt Recycling Manual* (*BARM*) describes CIPR as an asphalt pavement recycling process without the application of heat. CIPR uses a number of pieces of equipment that form a recycling “train”. The equipment in this train includes tanker trucks, milling machines, crushing and screening units, mixers, pavers, and rollers. With this train, all material processing is completed on grade including the mixing operation. For FLH the typical recycling depth is 3 or 4 in [75 or 100 mm]. However, recycling depths of 5 or 6 in [125 or 150 mm] may be possible with the addition of cementitious additives such as Portland cement to provide early strength gain. A 2 in [50 mm] depth is considered the minimum depth for recycling.

Just like FDR, CIPR can be a very cost effective rehabilitation alternative when appropriately used. FLH has had good long-term performance on CIPR projects. Generally, CIPR is best suited for higher-class rural roads with few curves, adequate geometry, and pavement thickness exceeding 5 in [125 mm]. However, CIPR has been used effectively on roads with many curves, where widening was necessary, and where thin asphalt pavement was present (the complete asphalt pavement thickness was recycled). There are numerous good references and resources to use when evaluating the suitability of using of FDR. The following are recommended:

- *ARRA Basic Asphalt Recycling Manual (BARM*).
- *Report on Cold Recycling of Asphalt Pavement*, AASHTO TF-38.
- *Techniques for Pavement Rehabilitation, Reference Manual*, FHWA-NHI-131008.

Use CIPR to treat most types of pavement distress. Ideal pavement candidates are old, cracked, and have at least fair base and subgrade support. CIPR requires a wearing surface such as HACP.

Localized failures caused by wet, unstable subgrade or heaving/swelling of the subgrade should be identified during the pavement investigation and addressed separately from the CIPR operation.

If the existing pavement exhibits asphalt stripping, CIPR is not recommended without the use of cement, lime, and/or fly ash.

Do not use CIPR on projects where the recycling train cannot be supported, such as a thin pavement structure over a weak, clayey soil.

Constructability issues include:

- Determining overhead clearances for the recycling train
- Identifying utilities such as manholes or other castings within the pavement layers to be recycled,
- Long steep grades (>8%) will reduce production,
- Many sharp curves may make CIPR impractical
- Heavily shaded areas will require longer curing times. Curing time will vary from 3 days to 2 weeks depending upon weather conditions and materials used.

If there is a concern about being able to achieve a quality mix, retain representative core samples to evaluate gradation, asphalt content, stripping, penetration, and viscosity. Also, if necessary, complete a preliminary mix design to determine the suitability and emulsified asphalt type and quantity required.

Emulsified asphalt application rates typically range from 1 to 2 percent.

Advantages of CIPR include:

- Wide variety of distress types can be treated with CIPR.
- Reflective cracking can be significantly reduced.
- Recycles materials and conserves resources.
- Cost effective when used appropriately.

Limitations of CIPR include:

- Cure time
- The several constraints discussed above.
- CIPR requires specialized equipment and experienced contractors

From the *FP-XX*, use Section 416 to specify CIPR. Refer to Division Supplements, for additional guidance on material selection and application rates.

11.6.1.7 Hot In-place Recycling (HIPR)

HIPR consists of:

1. Heating and softening the existing asphalt pavement so it can be scarified or hot rotary milled to a specified depth,
2. Mixing the loosened asphalt concrete with a recycling agent and possibly virgin asphalt and
3. Placing and compacting the mixture with conventional asphalt paving equipment.

FLH does not have a specification for HIPR and has not completed a HIPR project. Refer to the *ARRA Basic Asphalt Recycling Manual* (*BARM*) and FHWA-NHI-131008 for guidance and criteria.

HIPR can be a cost effective alternative when completed on pavements with appropriate conditions.

11.6.1.8 Whitetopping

Whitetopping is a pavement rehabilitation technique that involves construction of a portland cement concrete overlay on top of HACP.

FLH does not have a specification for whitetopping and has not completed a whitetopping project. Refer to the following references for guidance and criteria:

- FHWA's Technical Brief, *Conventional Whitetopping Overlays* (Publication No. FHWA-IF-03-008)
- ACPA's *Whitetopping – State of the Practice* (Engineering Bulletin EB210P)
- NCHRP Synthesis 338 *Thin and Ultra-Thin Whitetopping*
- *Synthesis of Current Minnesota Practices of Thin and Ultra-Thin Whitetopping*

11.6.2 REHABILITATION METHODS: AGGREGATE SURFACED ROADS

FLH primarily performs three types of rehabilitation methods on aggregate surfaced roads:

1. Mechanical stabilization which includes reshaping and reconditioning the existing gravel material and/or adding additional surfacing aggregate,
2. Chemical stabilization using dust palliatives or other materials, and
3. Upgrading the aggregate surfacing to a bituminous surfacing.

Sometimes combinations of above alternatives are used.

Aggregate surfaced roads are inherently very low volume roads with construction budgets commensurate with their significance. It is critical for the pavement engineer to optimize the use of local materials without sacrificing service life.

11.6.2.1 Mechanical Stabilization

With mechanical stabilization an additional layer of aggregate surfacing can be applied to increase structural capacity, restore geometry, improve drainage, and correct surface distress such as rutting. Mechanical stabilization also includes reshaping and reconditioning the existing aggregate material with a rotary mixer/reclaimer and/or motor grader. On many projects these two processes are combined. The use of geocells, geogrids, and other geosynthetics are also forms of mechanical stabilization that may be cost effective under the right conditions.

Complete field investigations according to Section 11.4 and 11.6.1.1, as needed. Complete structural surfacing design according to the methodology of Section 11.4.

It is impractical and sometimes uneconomical to place surfacing aggregate with a thickness less than 3 in [75 mm].

Identify localized subgrade or drainage problems and develop appropriate solutions.

Advantages of mechanical stabilization:

- Relatively simple construction using readily available equipment.
- Provides the opportunity to restore or rejuvenate existing surface aggregate.
- Low initial cost

Limitations of mechanical stabilization:

- Frequent maintenance required.
- Loose particles can cause vehicle damage

Refer to Section 11.4.2.2 for selecting material types. Additionally, the Gravel Roads (LTAP) provides guidance on construction methods and material selection.

11.6.2.2 Chemical Stabilization (using dust palliatives)

Recent research by FLH and other agencies has indicated that with a slightly higher application rate and a more aggressive method of incorporation, the use of dust palliatives can increase the strength and durability of an aggregate surfacing. It has been well established that the use of dust palliatives will reduce the loss of fines, which in turn reduces the frequency of maintenance operations.

Chemical stabilization can occur as a single activity using the *in situ* aggregate surfacing or it can be used in conjunction with the addition of new aggregate.

Complete field investigations according to Section 11.4 and 11.6.1.1, as needed. Complete structural surfacing design according to the methodology of Section 11.4. Note that the compatibility of stabilizing agents with the existing soil and aggregate is critical. Additional references to consult are Forest Service 9977 1207 SDTDC and FHWA-CFL/TD-05-004.

Chemical stabilization will not address localized subgrade or drainage problems. Identify these areas during the field investigation and develop appropriate solutions.

Advantages of chemical stabilization:

- Reduced dusting and surface erosion.
- Reduced frequency of maintenance intervals.
- A reduction of the loss of aggregate.
- Increased structural capacity

Limitations of chemical stabilization:

- Many products are proprietary
- Lack of objective performance data with many products
- Certain products can impact water and plant quality

The *FP-XX* Section 306 is typically specified on projects requiring a dust palliative. However, if stabilization is desired this specification may have to be modified on a project-by-project basis to fit the needs of the stabilization/dust palliative product. Refer to Division Supplements, for additional guidance.

11.6.2.3 Upgrading to Paved Surface

When ADT values approach 150 to 200 on an aggregate surfaced road, many practitioners and agencies promote upgrading the road to a paved surface such as HACP. There is no consensus or standardized guidance on when it is appropriate to upgrade a road to a paved surface. There are other factors besides ADT that will influence the decision on upgrading, including:

- Amount and type of truck traffic,
- Function of the road,
- Harshness of climate, and
- Subgrade soil conditions.

It is the responsibility of the pavement engineer to provide technical assistance to the project team on the above factors.

Complete field investigations according to Section 11.3 and 11.6.1.1, as needed. Complete structural surfacing design according to the methodology of Section 11.3. The scope of this rehabilitation method is similar to reconstruction.

Advantages of upgrading to a paved surface:

- Higher level of functionality and service,
- Reduced frequency of maintenance,
- All-weather accessibility, and
- Elimination of dusting.

Limitations of upgrading to a paved surface include:

- Higher construction costs,
- Repairing damaged sections is generally more expensive, and
- Potential safety issues with increased speeds.

Refer to Section 11.3.2.3 for selecting material types. Additionally, Gravel Roads (LTAP) provides guidance on “When to Pave a Gravel Road”.

11.6.3 REHABILITATION METHODS: RIGID PAVEMENTS

As was indicated in Section 11.5, FLH designs and builds few mainline Portland cement concrete pavements (PCCP) due to the predominant low-volume traffic conditions on most FLMA routes. Accordingly, FLH also completes few PCCP rehabilitation projects. As a result this subsection does not provide specific standards or guidance, but rather contains a list of the more common rehabilitation methods with suggested references to use for guidance.

The following are general references that cover most rehabilitation techniques:

- *Techniques for Pavement Rehabilitation Reference Manual*, FHWA-NHI-131008.
- NCHRP Web Document 35, Appendix B, *Pavement Rehabilitation Techniques*.
- FHWA and CPTP Tech Brief: Concrete Pavement Rehabilitation and Preservation Treatments, FHWA-IF-06-005, November 2005.
- *The Concrete Pavement Restoration Guide,* Technical Bulletin TB020P, ACPA 1997.

The following are more specific references for individual rehabilitation methods that can be used in conjunction with the general references listed above:

- **HACP overlays**
  - ◊ *Rubblization of Portland Cement Concrete Pavements* (TRB Circular E-C087)
  - ◊ *Ohio DOT’s Long Term Monitoring of Broken and Seated Pavements* (FHWA/OH-2002/024 or State No. 14670(0))
- **Partial Depth Repairs**
  - ◊ Partial Depth Repair of Concrete Pavements (FHWA Checklist Series #9)
  - ◊ FHWA web page on Partial Depth Repairs
  - ◊ FHWA Tech Brief: *Portland Cement Concrete (PCC) Partial-Depth Spall Repair* (FHWA-RD-99-177)
  - ◊ *Materials and Procedures for Rapid Repair of Partial-Depth Spalls in Concrete Pavement* (FHWA-RD-99-152)
- **Full-Depth Repairs**
  - ◊ FHWA web page on Full-Depth Repairs
  - ◊ Full-Depth Repairs of Portland Cement Concrete Pavement (FHWA Checklist Series #10)

- **Load Transfer Restoration / Dowel Bar Retrofit**
  - ◊ *Concrete Pavement Rehabilitation: Guide for Load Transfer Restoration* (FHWA-SA-97-103 or ACPA JPOOIP)
  - ◊ Washington DOT's *Ten-Year Performance of Dowel Bar Retrofit – Application, Performance, and Lessons Learned* (2003 TRB Annual Meeting Paper)
  - ◊ Dowel-Bar Retrofit for Portland Cement Concrete Pavements (FHWA Checklist Series #8)
- **Slab Stabilization and Slab Jacking** – use general references above.
- **PCC Overlays**
  - ◊ *Portland Cement Concrete Overlays – State of the Technology Synthesis* (FHWA-IF-02-045)
- **Grinding and Grooving**
  - ◊ FHWA's Concrete Pavement Rehabilitation Guide for Diamond Grinding

11.7 PAVEMENT PRESERVATION

At the time of this initial edition of the PDDM, FLH was in the early stages of developing planning, pavement management, and project development processes for pavement preservation programs for Federal Land Management Agencies (FLMAs). This is an emerging area of importance and some FLMA's are already using pavement preservation principles.

This section will be developed in the future. In the interim, use the information available on the following websites for guidance on field reconnaissance, treatment type selection, timing, and materials:

- FHWA Pavement Preservation webpage.
- The National Center for Pavement Preservation (NCPP) website.
- CalTran's Maintenance Technical Advisory Guide (MTAG)

11.7.1 PREVENTIVE MAINTENANCE TREATMENTS

(RESERVED)

11.7.2 FIELD RECONNAISSANCE AND INVESTIGATION

(RESERVED)

11.7.3 SELECTION OF TREATMENTS AND MATERIALS

(RESERVED)

11.8 PAVEMENT MANAGEMENT AND ROAD INVENTORY DATA

(RESERVED)

11.9 MECHANISTIC-EMPIRICAL PAVEMENT DESIGN

The *NCHRP 1-37A* project was funded to develop a substantially new process for designing pavements. This Mechanistic-Empirical Pavement Design Guide (MEPDG), as it has become known, was developed in 2004. To date, this process has not been adopted by AASHTO as a standard or a provisional standard. However, it is expected that in the future this design methodology will sooner or later be adopted by AASHTO.

Pavement engineers are not required but are encouraged to become familiar with the new methodology and complete "side-by-side" comparative designs using the MEPDG and *AGDPS* processes.

The FHWA has formed a Design Guide Implementation Team (DGIT) and this team conducts numerous workshops, videoconferences, and sponsors other activities. Refer to the DGIT webpage for a complete list and calendar of events.

A formal review of the products of *NCHRP 1-37A*, such as the MEPDG, was completed under *NCHRP 1-40D*. The review resulted in numerous improvements to the MEPDG and the development of Version 1.0 of the MEPDG software. It is anticipated that the MEPDG will offer FLH a better method for predicting pavement performance, developing pavement structural designs, and evaluating trade-offs in pavement thickness and materials types. FLH is formulating a long-term strategic plan for the use and/or implementation of the MEPDG.

Chapter 12 – RIGHT OF WAY AND UTILITIES

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CHAPTER 12

RIGHT OF WAY AND UTILITIES

12.1 GENERAL

This chapter provides the policies, standard practices and guidelines for obtaining and documenting the right-of-way and utility coordination requirements related to highway construction. Refer to Section 1.1.1 for definitions of policy, standards, and guidance. Statements of FLH Policy are shown in **bold type**. Statements regarding FLH Standard Practice are so indicated.

The land that a highway occupies is the right-of-way. It consists of the land owned by the operating agency or land that the operating agency has a right to use for roadway purposes. The rights required to support a roadway must include sufficient interest to provide for both the construction and continued maintenance of the facility. FLH has a stewardship role to assure that lands acquired or incorporated within one of its projects, or work required to accommodate railroad or utility interests within project right-of-way complies with prevailing Federal and State laws and regulations.

This chapter outlines the legal foundation necessary to define and acquire those real property interests identified as needed to build, reconstruct and maintain roads and highways. The chapter focuses on right of way issues and activities from the perspective of FLH programs. Content covers right-of-way discipline contributions to normal project development activities, including defining property rights needed for the highway, identifying how utilities and railroads are affected, preparing right-of-way and utility plans, and coordinating acquisition and utility adjustments through agreements and other means to obtain the property rights required to advance a highway project to construction.

Federal Lands Highway Division offices work with many different roadway owners and operating agencies, therefore only general guidelines are provided. It is not practical to prescribe detailed procedures and methods applicable to all situations relating to right-of-way, utilities and railroads. Information on how to perform basic procedures and fundamental steps for performing general right of way and utilities work are typically incorporated by references to other documents.

The following sections describe the legal provisions applying to the acquisition of land for public purposes. The relationships between Federal and State law regarding how real property is defined and acquired in support of highway development are identified. Statutes and regulations, in addition to those included in Section 1.2, related to right-of-way and utilities are referenced, and general guidance material identified. Links relevant to specific right-of-way activities are contained in the introductory section of the chapter that follow this introductory section.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

12.1.1 REAL PROPERTY UNDER FEDERAL, STATE AND TRIBAL LAW

Property rights law and the issues surrounding public use of private property flow from Amendments 5 and 14 of the U.S. Constitution. The Fifth Amendment provides in part that "… nor shall private property be taken for public use, without just compensation." The Fourteenth Amendment contains the due process clause that has been held to require that when a state or local governmental body, or a private body exercising delegated power, takes private property it must provide just compensation and take only for a public purpose.

The law relating to eminent domain is derived from the above two amendments of the Constitution. Eminent domain is an inherent right of organized government to take or appropriate property for a public use, provided just compensation is paid. The power of the government to take property is only exercised through legislation or through legislative delegation. The Fourteenth Amendment applies this delegation and control to the states. Within each state, the power can be delegated to local jurisdictions. Eminent domain can also be delegated through legislation to private corporations such as public utilities, railroad and bridge companies when they are promoting a valid public purpose.

The use of eminent domain requires payment of just compensation and that the taking of private property is for a public use. Federal, State, County and Municipal governments usually have established procedures in place to negotiate the purchase of private lands without having to resort to using their eminent domain authority. Each jurisdiction's eminent domain authority applies only to the lands within its boundaries.

At the Federal level, the policy and procedures related to acquisition of property are contained in the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended (Uniform Act). Each State has legislation that implements and in some cases expands on the minimum requirements established within the Federal legislation. The Federal legislation and regulations, and the related State laws will be discussed in more detail in the following sub-sections.

Tribal governments have their own sovereignty and operate under their own laws with land ownership maintained in trust through the Bureau of Indian Affairs. The unique situation when dealing with Indian tribes is discussed in Section 12.7.

12.1.1.1 Federal Laws and Regulations

The following Federal laws and regulations may apply when real property interests are required for highway right of way or related activities. Their application depends on the type of property required and how they may be affected by the proposed project.

Laws enacted by Congress are contained in the *United States Code* (USC). Listed Key code references relevant to land acquisition and utilities are listed below, but are not comprehensive.

1. **42 USC 61 – *Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970*** (The Uniform Act). The primary legislation related to Federal and

federally funded land acquisition programs. The Act and implementing regulations provide the basic requirements for projects using Federal funding and they are contained in 49 CFR 24. This act is not an addition to eminent domain law but a policy standard providing a set of required actions and benefits that pertain to acquisitions and displacements from a residential, farm or business where federal funds are used in any part of the project. The law is broken down into three sub-chapters. The first sub-chapter contains the broad requirements of the law, definitions, State certification requirements and designation of the Department of Transportation as the lead agency for the Act. (DOT has delegated the lead agency function to FHWA.) The second sub-chapter contains the relocation provisions outlining the benefits that are to be made available to persons displaced by federally funded projects and identifies the duties of the lead agency. The third sub-chapter contains the policy statement for uniform real property acquisition.

The Act also provides that relocation assistance and payment benefits are required to assist persons displaced by the acquisition of their property. The Act also consolidates a set of procedures agencies have to use when acquiring property. Both the acquisition and relocation provisions of the law are required if Federal funds are to be applied to any part of the project. The intent of the acquisition policies is to achieve the following objectives:

- Encourage and expedite the acquisition of real property by agreements with owners;
- Avoid litigation and relieve congestion in the courts;
- Assure consistent treatment for owners in the many Federal programs, and
- Promote public confidence in Federal land acquisition practices.

2. **23 USC 317 – *Highways on Federal Lands*.** This section contains the legislative authority for DOT to assist in transferring necessary interests in land needed for right-of-way across federally owned lands for federally assisted projects. Procedures related to obtaining right of way over federal land are addressed in Section 12.6.

3. **23 USC 323 – *Donations and credits*.** This section covers provisions relating to land donations in support of federally assisted projects and provide criteria allowing credits toward the State or local share for donated property.

Regulations issued by the agencies of the federal government to implement the laws passed by Congress are recorded in the *Code of Federal Regulations* (CFR). Actions by federal agencies to modify or update CFR materials are published for comment in the *Federal Register* (FR).

1. **49 CFR 24 – *Uniform Relocation Assistance and Real Property Acquisition for Federal and Federally-Assisted Programs.*** The implementing regulations for the Uniform Act are contained in this section of the Code of Federal Regulations. The regulation including the Appendix contains the Federal acquisition and relocation standards. The provisions in this rule and the Uniform Act apply to any project where privately owned real property is acquired. A summary of the acquisition and relocation requirements is included in Section 12.8.

2. **23 CFR 710 – *Regulations for Right-Of-Way and Real Estate*.** This part contains Implementing regulations governing program administration, project development, acquisition and management applicable to real property required for highway projects. See Section 12.9 for details.

3. **23 CFR 635 – *Construction and Maintenance*.** Regulations governing project construction activities including the status requirements regarding right of way and utilities prior to advertising and awarding construction contracts. See Section 12.9 for details.

4. **25 CFR 169 – *Rights-of-way over Indian Lands*.** The Bureau of Indian Affairs (BIA) regulations for obtaining easements over Indian lands covering the procedures, terms and conditions under which rights-of-way over and across tribal land, individually owned land and Government owned land may be granted. A general discussion on the subject is provided in Section 12.7.

The above referenced federal laws and regulations provide the basic requirements for State and local land acquisition practice. The FHWA Realty pages contain federal guidance and interpretation of how such laws are applied, including the following primary references:

1. ***Real Estate Acquisition Guide*.** This guide provides a comprehensive discussion of the various federal requirements related to implementing the Uniform Act and project development and administration contained in 23 CFR 710 related to right-of-way concerns. It was developed in 2004 and does not contain the most recent revisions of the Uniform Act regulations included in the January 2005 final rule. The basic content of the guide though is still appropriate. It was developed specifically to assist local governments cooperating in developing a federally funded project.

2. ***Right-of-Way Project Development Guide (PDG).*** This guide provides practical approaches to developing a right-of-way project. It concentrates on providing accepted approaches to deal with developing a right-of-way project including mini-case studies to demonstrate how States have handled a variety of right-of-way problems. This guide utilizes a simple narrative approach instead of using the regulatory language and CFR references to explain activities related to right of way acquisition programs. The guide covers valuation, negotiation and relocation procedures, plus contracting for right of way services and other administrative issues that are related to highway acquisition.

12.1.1.2 Statutory Interpretations and Precedents

The FHWA Office of the Chief Counsel has had occasions to interpret some of the provisions in 23 USC 107(d), which pertains only to the Interstate System, and 23 USC 317, which pertains to all Federal-aid Systems and FLH projects covered under Chapter 2 of Title 23. In some instances, representatives of other Federal agencies have been conferred with to determine an agreeable application of the statute. A number of these interpretations have been referenced earlier in this chapter, and some others are as follows:

1. In 23 USC 317(a), the phrase "lands or interests in lands owned by the United States" includes any interest in land owned by the United States, which interest is appurtenant to privately owned property. Examples include a leasehold interest, a reversionary interest,

a mineral interest, an easement right in, on and below the surface and a right to control or restrict the use of land. These interests may be relinquished or terminated under the cited statutory authority, for highway purposes.

2. The clause “for the right-of-way of any highway” in 23 USC 317(a) is interpreted to mean “with respect to,” or “in connection with,” or “with regard to” a highway. Accordingly, lands required as a maintenance site, stockpile site, or for scenic purposes, or for other construction projects and highway maintenance after the completion of the project, although not contiguous to the project, may be transferred under Section 317(a).

3. The phrase “such highway adjacent to such lands or interests in land”, appearing in the same section, is construed to mean “in the vicinity of” or “in the general area” of such land. Thus, land required as a source of borrow materials need not be contiguous to or actually abut the highway project. The land parcels may be, and very often are, located a considerable distance away from the project. This interpretation is supported by a decision of the Court of Appeals for the Ninth Circuit. The Court said that “adjacent to such land” must be given a broad interpretation and that eight to ten miles from the construction would be adjacent to, as contemplated in any reasonable interpretation of the statute. (*Southern Idaho Conference Assoc. of Seventh Day Adventists. v. United States*, 418 F.2d 411, 416 (9th Cir. 1968))

4. The words “as a source of materials” includes either transfer of land outright for continuous and unlimited withdrawal of borrow material or the transfer of the right to enter upon the land for the purpose of extracting a specific quantity of materials during a period of time. However, in the case of BLM lands, the quantity of material needed should be specified so that BLM may plan other uses of the site.

5. In 23 USC 317(b), the words, “under conditions” appearing in the clause “shall have agreed to the appropriation and transfer under conditions” do not include a condition whereby payment of a monetary consideration is required for the lands to be transferred. The following phrase “adequate protection and utilization of the reserve” can reasonably be interpreted to mean “adequate protection and utilization of the remainder lands”. Under this interpretation a monetary consideration may be required where a portion of a housing project is being transferred, and such transfer will adversely affect the agency's investment in the remainder property. The transferor agency should not be deterred in its mission or suffer a harm, without compensation, because of the transfer. However, it may receive a benefit from the road project to compensate for its loss of land.

6. The phrase “such land and materials may be appropriated and transferred” includes the conveyance of a determinable fee interest in the land, or such lesser interest as may be required by the SHA. This would include a highway easement for highway purposes.

7. The phrase “or its nominee,” appearing at the end of 23 USC 317(b), where lands may be transferred to the SHA, is interpreted to mean an official authorized by State law, another State agency, a city, town, county, or other political subdivision of the State.

8. 23 USC 317(c) says that if at any time the need for such lands or materials no longer exists, notice shall be given by the SHA to the FHWA. Further, there shall be an immediate and automatic reversion to the transferor agency. A recorded quitclaim deed or notice, suitable for recording, shall state that the need for the lands or materials no

longer exists. The FHWA Chief Counsel's position is that such reversion is immediate and effective when the land is no longer used for highway purposes, even though the State fails or refuses to give notice of that fact. Notwithstanding Section 317(c), GSA may require compliance with their Federal Management Regulation 102-75, as noted in Subpart 1.8(d), supra. (23 CFR 710.601; Federal Aid Policy Guide) But see Southern Idaho Conference of Seventh Day Adventists v. United States, supra, where land reserved for a material site under 23 USC 317, remains a material site until it is specifically canceled by the Secretary.

9. With respect to the possibility of a reversion, a clause which may be used in an instrument of transfer and which is required in General Service Administration conveyances is as follows:

> "In the event of a reversion, the acquiring agency shall be responsible for the protection and maintenance of the subject Premises from the date of notice of intent to revert title until such time as a quitclaim deed revesting title in the United States of America is recorded."

10. 23 USC 317 authorizes the transfer of any lands or "interests in lands" owned by the United States. Since the term "interest in lands" includes the control of access from adjoining lands, a transfer effected under Section 317 may properly include control of access to, from and between the land transferred and the remainder lands of the United States.

11. 23 USC 317 provides that the lands and materials transfer shall immediately revert to the grantor agency if at any time need for such property no longer exists. Since 23 USC 107(d) has no such requirement, lands transferred may possibly be given the State outright, although this has not been done. Since Section 107(d) states that "the Secretary may make such arrangements with the agency having jurisdiction over such lands as may be necessary", it is the policy of the FHWA to include standard reversionary provision in all Section 107(d) transfers. This policy fosters a consistent and amicable relationship with transferor agencies, whether effected under Section 317 or Section 107(d).

12. The provisions of 23 USC 317 authorize the transfer of borrow material sites required for the construction or maintenance of projects on a Federal-aid system. 23 USC 107(d), applicable only to projects on the Interstate System, does not specifically authorize the transfer of borrow materials sites. However, since the provisions of Section 317 are also applicable to Interstate highway projects, the authority contained in both sections of the statute may be relied upon in effecting the transfer of borrow material sites required for such projects.

13. It is the FHWA position that 23 USC 107(d) and 23 USC 317, were specifically enacted for highway purposes. Thus, these statutes take precedence over more general statutes, which may be considered inconsistent.

12.1.1.3 State Laws and Regulations

The above Federal references are the foundations for State laws and regulations that apply to land acquisition within their borders. While the federal laws and regulations provide the broad framework regarding property acquisition, the particulars lie in the laws, regulations or codes of the State where the project is located. State laws generally also govern the procedural policies of their county or municipal governments. For relocating or accommodating utilities or acquiring private land and relocating persons or property from proposed right of way, usually the State laws and regulations will apply. All States have parallel legislation to implement eminent domain provisions and address the policies and benefits required by the Uniform Act. Some provide benefits that exceed the federal minimums. For projects within their jurisdiction, the State procedures apply since all have already certified to FHWA that they have laws and benefits consistent with federal requirements. County and municipal governments must generally follow their respective State DOT approved procedures.

State law and regulation provide the framework for any required acquisition of privately owned lands identified as needed for a proposed project. See Section 12.8 for more detail on the steps required setting up the agreements and providing for land acquisition and if needed, relocations, prior to advancing a project to construction. State policies and regulations will also guide the relocation or accommodation of utilities affected by a proposed project and Section 12.4 includes necessary guidance materials. Section 12.5 contains similar information on the procedures required to work with railroads that may be affected by a project.

Acquisition of private property is based on the laws and procedures employed within each State. State Departments of Transportation (SDOT) have manuals and guidance materials, addressing the standards and procedures necessary to acquire property in compliance with the federal policy requirements of the Uniform Act. In addition, almost all States have programs and guidance material to assist local agencies in acquiring property for federally or state funded projects. A limited number of States prefer to acquire lands needed for local projects themselves when federal funds are involved in a project and in such cases it may be best to have the SDOT serve as the cooperating agency to handle right-of-way acquisition.

State and local custom regarding land titles, property records, right-of-way plans and other records need to be identified and matched with project development procedures.

Under provisions in 23 CFR 710, all States must maintain an up-to-date right-of-way operations manual that presents their existing practices and procedures for ensuring compliance with Federal and State real estate laws and regulations. Since all States have provided FHWA with assurances that they have laws and procedures enabling them to fully comply with the Uniform Act, project activity conforming to State standards and procedures can generally be accepted as complying with the provisions of the Uniform Act. State manuals are revised periodically, and procedures and guidance relating to right of way acquisition and utilities may be available on line. The FHWA Office of Real Estate Services web site maintains links to State Right-of-Way Manuals. Some states maintain similar referral information. For example, the Iowa DOT maintains links to other states' right of way materials.

In addition to FHWA and state sites, the AASHTO Right-of-Way and Utilities Subcommittee maintains a site that provides reports and a directory of members to aid in identifying appropriate contacts when working within different states.

12.1.2 RIGHT OF WAY AND UTILITIES PROCESS OVERVIEW

Right of way and utility related issues should be identified, considered and resolved as early as possible in the project Development process. Right of way and utility input at an early project stage can facilitate the design and NEPA processes by providing specialized information and expertise to the project team. For purposes of planning the Right of Way and Utilities process for a project, consider the following project development milestones with related key points.

Although the primary right of way and utility support (ROWUS) activities are concentrated in Stage 3 and 4 there are tasks or coordination activities in which they should be involved in all stages. For each of the stages the following brief outline identifies some key work areas where depending on project conditions ROWUS involvement might be appropriate.

The general right of way acquisition process is depicted in Exhibit 12.1–A and the utility relocation process is depicted in Exhibit 12.4–A.

12.1.2.1 Initial Right of Way Planning

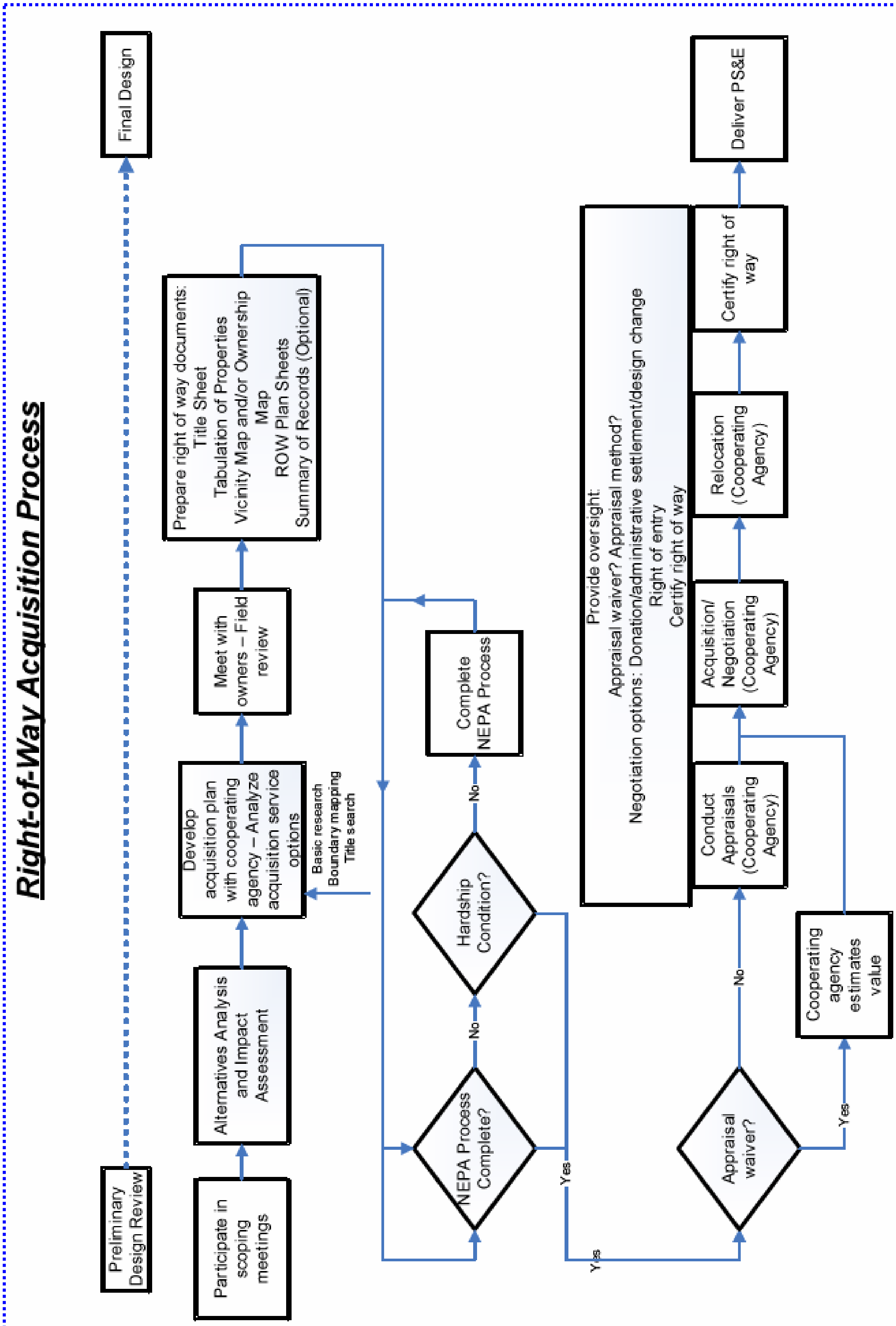
Right-of-Way activities can require an extended time commitment and affect project delivery schedules. It is essential that right-of-way considerations and issues be identified early in the project development process (refer to Chapter 4). The initial stage revolves around activities to set up the project and identify both the scope and stakeholders in the project. Identify the type and extent of right of way needed for the project and assess the capabilities of the cooperating agency that will be responsible for right of way and utility work. Any training or support services needed by the cooperating agency to acquire or work with affected utilities should be identified at this stage of the project. The following activities should be performed for this stage:

- Identify known utilities
- Develop contact list of utility interests
- Develop project agreement addressing utility issues

12.1.2.2 Preliminary Right of Way Activities

This stage includes the support for the development of alternatives and the NEPA process during which a range of effects on both the natural and human environment are evaluated. Provide support in developing surveys and ownership information, which can often identify critical locations where property interests may influence the selection of the preferred alternative. Communicate any feedback received from owners to the design unit, which may also influence preliminary design considerations. Input from the right-of-way specialist during the preliminary design process can be influential in determining the optimum alignment. Human impact on the environment can often be minimized and the time required to purchase or obtain

Exhibit 12.1–A RIGHT-OF-WAY ACQUISITION PROCESS FLOW CHART



the easements, deeds, permits or agreements shortened by identifying the local land holdings and the potential effects on property rights. The following activities should be performed for this stage:

- Facilitate the design and NEPA processes
- Preliminary right of way studies
- Identifying existing ownerships, existing rights and existing access
- Identify existing utility facilities
- Field investigations and surveys
- Locate and map all utilities within extent of project
- Secure title work
- Right of way impact and cost analysis relative to design alternatives
- Public Hearing involvement to provide right of way and utility information

12.1.2.3 Right of Way and Utilities Development and Engineering

This includes defining the specific properties and utilities affected by the preferred alignment. During this stage right of way plans are completed and the utility coordination work started. Coordinate the plan preparation process and develop plats and descriptions necessary to support project needs. Checklists covering Preliminary Research, Boundary Compilation and Documents detail the work done during this stage. Work activities during this stage are described in Sections 5.4.5, 9.5.9 and 12.2. Identify the type of ownership interests that might be affected by the project. For railroads and utilities, early coordination is essential since they need sufficient time to plan for and complete work necessary to fit final project design and construction needs. The review and approval process can take time even in situations when coordination is required to assure that no additional right-of-way is required.

Define the ownership of any additional right-of-way. Sections 12.6, 12.7 and 12.8 address in more detail the activities that will be required to obtain right-of-way when Federal, Tribal or privately owned property is involved in a project. The time required to obtain additional right-of-way can be directly linked to the number of ownerships affected, the cooperating agency involved and the complexity of the property interests affected.

The following activities should be performed for this stage:

- Property boundary ownership map/compilation
- Project proposed right of way takings
- Produce right of way documents
- Design accommodations for utilities
- Identify utility conflicts

12.1.2.4 Right of Way Acquisition

During this stage final right of way plans will be issued identifying the individual parcels and utility work related to the project. For Federal land parcels prepare a land transfer request on behalf of the cooperating agency. Where private land, or non-federal lands, and utilities work is required the cooperating agency will acquire the required property rights and coordinate the accommodation of affected utilities and railroads. Provide support services to the acquiring agency, as needed. Permits required by the project are also requested during this stage. Work activities during this stage are discussed in beginning in Section 12.4.

The following activities should be performed for this stage:

- Evaluate acquisition capabilities of cooperating agency
- Develop acquisition service contract
- Oversight and stewardship
- Develop utility conflict resolution or utility accommodation plan
- Develop right of way agreements
- Develop utility agreements

12.1.2.5 PS&E Development and Finalization

The PS&E development stage is when final design detail are developed and compared with mitigation commitment, as well as property acquisition commitments and consolidated into the construction proposal. Assure that ROW Certifications from the acquiring agency are accurate, and that the status of required utility adjustments is accurately reflected in the availability statement included in the contract proposal.

Although the ideal situation is that all property required for construction be available, and that all utility relocations be completed prior to the time the contract is advertised. When that is not the case the proposal must provide the contractor detailed information regarding when parcels will be available and when and where utilities work will have to be coordinated with project construction.

The following activities should be performed for this stage:

- Develop special contract requirements
- Process right of way and utility certifications
- Finalize utility related documents
- Utility facility specifications, SCRs, detail sheets, etc.
- Utility certification according to 23 CFR 635.309(b)
- Assure right of way and utility commitments are included in PS&E

12.1.2.6 Construction

During project construction there may be disputes with property owners or utilities that arise out of issues related to negotiated settlements, letter of consent or permit conditions, utility relocation agreements or any other property rights issue. When applicable, coordinate the dispute resolution involving land based issues.

Prior to construction provide notification to utility companies to participate in pre-construction conferences, and continue coordination throughout construction.

12.1.2.7 Recording

After the project construction is complete assure that ‘as built’ right of way plans are recorded when required and that any agreed final survey and monument placement be completed before finalizing project activity.

12.2 GUIDANCE AND REFERENCES

The references shown in this section provide additional information and guidance relevant to Right of Way and Utilities.

12.2.1 LAWS AND REGULATIONS

1.	Uniform Act	Title 42 USC, Chapter 61, *Uniform Relocation Assistance and Real Property Acquisition Policies for Federal and Federally Assisted Programs*
2.	23 USC 107(d)	Title 23 USC, Chapter 1, Section 107, *Acquisition of rights-of-way – Interstate System*
3.	23 USC 138	Title 23 USC, Chapter 1, Section 138, Preservation of Parklands
4.	23 USC 317	Title 23 USC, Chapter 3, Section 317, *Highways on Federal Lands*
5.	23 CFR 635	Title 23 CFR Part 635, *Construction and Maintenance*
6.	23 CFR 645	Title 23 CFR Part 645, *Utilities*
7.	23 CFR 710	Title 23 CFR Part 710, *Regulations for Right-Of-Way and Real Estate*
8.	25 CFR 162	Title 25 CFR Part 162, *Leases and Permits*
9.	25 CFR 169	Title 25 CFR Part 169, *Rights-of-way over Indian Lands*
10.	49 CFR 24	Title 49 CFR, Part 24, *Uniform Relocation Assistance and Real Property Acquisition for Federal and Federally-Assisted Programs*

12.2.2 GUIDANCE

1.	FHWA Realty	FHWA Real Estate Information
2.	Real Estate Acquisition Guide	FHWA *Real Estate Acquisition Guide For Local Public Agencies*
3.	PDG	*Project Development Guide (PDG)*, FHWA Office of Real Estate Services

4.	Program Guide	*Utility Relocation and Accommodation on Federal-Aid Highway Projects*, FHWA Office of Program Administration, Sixth Edition, January 2003
5.	Federal Acquisition Brochure	*Acquiring Real Property for Federal and Federal-aid Programs and Projects*, Publication No. FHWA-HEP-05-030, 2005

12.3 RIGHT OF WAY COORDINATION

It is essential when additional property rights are required to build a proposed project that the ownership and jurisdiction be identified and coordinated so that, as necessary, responsibilities can be assigned and included in an interagency agreement to advance project activity. The ownership and jurisdiction, along with the property interests needed for the project are also key components to developing a realistic delivery schedule.

The FHWA documents referenced in Section 12.2.2 provide guidance on implementation strategies to advance both property acquisition and utility relocation or accommodation. The general work flow of the right of way acquisition process is depicted in Exhibit 12.1–A.

12.3.1 INTERNAL COORDINATION

As applicable, perform the following internal coordination activities during Project Development:

1. **Coordination with Planning and Programming**. At the early stage of project planning and scoping identify potential impacts to existing facilities or features that could have a significant effect upon the design, right of way and utilities, and the cost of developing the project.
2. **Coordination with Preliminary Design.** It is important for the right-of-way specialist to be involved and participate in the early field reviews when it is expected the scope of the project may involve acquisition of additional right-of-way, relocation of utilities, irrigation facilities or railroads. The early involvement by the right of way specialist can add value to the design process by contributing perspective to the analysis and selection of route and design alternatives. Having a knowledgeable representative from the cooperating agency participate in early project activity is recommended. This individual may provide insight into the land holdings and uses that may be affected by project development. The preliminary engineering investigation and preparation of the Project Scoping Report are described in Section 4.5.2. Identifying potential right-of-way acquisition needs and determining if utilities, railroads or other public entities might be impacted by a project is a key component in assuring that sufficient time is available to meet project schedules.
3. **Coordination with Environment.** Throughout the planning, conceptual studies and preliminary design phases coordinate with the Environmental unit to identify and evaluate right of way and utilities impacts and issues for inclusion in the environmental process. Refer to Section 3.4.
4. **Coordination with Design.** Throughout the development of the design and PS&E it is important for the right-of-way specialist to be involved and participate in the determination of additional right-of-way, relocation of utilities, irrigation facilities or railroads. The continuous involvement by the right of way specialist during design can add value to the design process by identifying opportunities to minimize the amount of additional right of way acquisition and utilities adjustments, and related costs and schedule impacts.

5. **Coordination with Construction.** Prior to and during construction, coordinate the right of way and utility issues closely with the Construction unit, including follow-up on right of way and utility commitments, and subsequent acquisitions or utility adjustments related to construction activities, if necessary.

12.3.2 EXTERNAL COORDINATION

As applicable, perform the following external coordination activities during project development:

1. Coordination with land owners
2. Coordination with tribal authorities
3. Coordination with acquiring/maintaining agency, including assurance of:
    - Legal sufficiency of right of way acquisition documents;
    - Recordability. Each state and local jurisdiction has its own unique recording requirements, which must be identified and incorporated into the development of right of way documents; and
    - Expertise and resources for right of way acquisition.
4. Coordination with utilities, railroads, irrigation companies.
5. Coordination with State Agencies including State DOTs. It is important to identify the laws of the state within which a project is located since their standards of practice will control the form and process used for right-of-way acquisition and provide the policy related to utility accommodation and relocation when affected by a transportation project. .Right-of-way and utility operations are for the most part dependent on states laws and policies relating to real property and utility accommodation. Title and land transfer requirements enacted through State legislation dictates how official records are maintained. Although federal acquisition and relocation policies apply to any property acquisitions required by a federally funded project, all States have provided assurances that their laws and practices comply with the minimum federal requirements. Many states have programs that provide benefits exceeding the Federal minimums and therefore project activities, especially when dealing with private land acquisition need to match state standards.
6. Coordination with the Federal land management agency (FLMA) requirements

12.3.3 ENVIRONMENTAL CONSIDERATIONS

Consider the following environmental-related constraints in developing the Right of Way for the project:

- NEPA and Right of Way Acquisition;
- 23 CFR 771;

- Context Sensitive Solutions (CSS). The CSS approach will sometimes utilize nontraditional solutions involving real estate and may influence the designation of right-of-way. See Section 4.6.1. Also see the FHWA CSS website;
- Mitigation areas; and
- Hazardous materials, including
  - ◊ Due diligence requirements. Property acquired for right-of-way must be free of any hazardous material or contamination. Liability for any subsequent clean up or remediation will be at the expense of the right-of-way interest holder. In order to assure sufficient time is available for such actions it is imperative that the initial property scoping activities identify potential underground storage tanks and contaminated sites.
  - ◊ Certification on re-acquired land.

Right-of-Way acquisition cannot begin until after completion of the environmental document and approval of NEPA clearance, except under certain hardship and protective buying conditions as described in 23 CFR 710.503. Coordinate the right-of-way and utility activities with the environmental processes as described in Section 3.4.

Involvement by Realty staff or representatives from the cooperating agency is recommended in the environmental analysis process. Local knowledge and their active participation can identify environmental issues caused by, social or economic impacts, or other human factors that will be affected by the project. Additionally right of way involvement may contribute to environmental mitigation efforts

12.3.4 RIGHT-OF-WAY SERVICES

Right of Way services includes the following activities:

- Right of way engineering
- Right of way acquisition
- Interagency agreements

Refer to Section 2.4 for a description and samples of interagency agreements FLH uses to advance a highway project. On projects needing new right-of-way, or affecting utilities or railroad interests, the agency having responsibility for acquisition needs to be identified at an early stage of project development. The cooperative agreement developed for the project needs to spell out the property acquisition and relocation responsibilities attendant to advancing the project.

Since many rural counties where projects are being developed may not have a staff familiar with right-of-way practices the prospect for needing to contract for some or all of the right-of-way function exists. Refer to the FHWA *A Guide for Developing a Right-Of-Way Service Contract* for guidance on the contracting process. Contracting for such consultants, whether they deal with appraisal, acquisition, or relocation, must follow approved State or local (with State approval) procurement procedures. Cooperating agencies are encouraged to work with their state transportation agency to determine specific requirements.

FLH is responsible for assessing the capability of the right-of-way acquisition agency and fulfilling the stewardship role to assure acquisitions and relocations if required are conducted in compliance with federal and state standards. This will require pre-screening activities and consultation with the acquiring agency to develop an appropriate acquisition plan. Coordination between the local government and the State DOT may be necessary when local conditions warrant.

12.3.5 ESTABLISHING PROPOSED RIGHT-OF-WAY LIMITS

Sufficient right of way must be acquired to construct, operate and maintain the roadway and the appurtenant features. Right of way should provide for access for maintenance, utility accommodation, possible future widening, drainage structures, and in some circumstances control of access. It may be necessary to acquire temporary right of way for construction activities. Establish the following right-of-way limits and descriptions for development of the project:

- Existing right of way. Property records research and cadastral surveys should be developed following the guidance in Section 5.4.5 .
- Width of new right of way. States, counties and other cooperating agencies may have standard widths for roads and highway right-of-way and should be considered when establishing proposed right of way limits. A number of State roadway design manuals can be found online. Consult the appropriate State Roadway Design Manuals for design information.

Establishing proposed right-of-way widths can usually begin as soon as the earthwork design is substantially completed. This must include alignment, grade, drainage structures, driveways and approach roads and any other structure associated with the roadway. The right of way line must encompass the cut and fill catches as well as clearing limits and slope rounding (construction limits). It is recommended that additional right of way area be included to accommodate minor changes in construction and to allow access for typical maintenance operations.

As practical, apply the following recommended criteria for projecting right of way lines:

- Maintain a uniform right-of-way width through each ownership parcel for ease in locating fences and describing right-of-way.
- Keep changes of right-of-way width to a minimum. Consider keeping the minimum length of constant width along centerline to 200 ft [60 m]. Change widths when the right-of-way width needs changes by more than 15 ft [5 m] over a length of 200 ft [60 m].
- Limit changes in right-of-way widths to property lines, which will simplify the legal description of the right-of-way.

- Change right-of-way widths at even stations or at curve points. To make a symmetrical fence line, it may be necessary to change widths at 50 or 100 ft [20 m] points or other odd stationing.
- Changes in width should taper from point-to-point except at property lines. Use a minimum of 50 ft [15 m], preferably 100 ft [30 m], along the centerline to avoid abrupt angles in the right-of-way line. This makes it easier to build and maintain right-of-way fences and to mow and care for right-of-way plantings.
- Provide sufficient right-of-way width to accommodate stopping sight distances at intersecting road approaches and provide right-of-way to maintain these sight distances. This is mandatory at all grade crossings of railroads.

Sometimes there is a need to have drainage control structures, channel changes, riprap, stilling pools, etc., constructed above or below the roadway. It is desirable to have these structures within the right-of-way so there is no question of the right to maintain or rebuild them. The right-of-way should extend at least 10 ft [3 m] beyond these facilities. It is preferable to obtain right-of-way to cover these installations but in some cases a construction easement may suffice. Determine the required nature of these type right of way interests, such as the following:

- Fee
- Easement
- License or permit

12.3.6 RIGHT-OF-WAY PLANS

Refer to the *PDG* Section 5.3 Right-of-Way Plans and Section, 23 CFR 710.203(b)(1)(ii) and Division Supplements.

For Forest Highway (FH) and Public Lands Highways (PLH) projects, typically the county, as cooperating agency and maintainer of the roadway acquires right of way. Right of way document format must be adequate to meet the acquisition needs of the different acquisition agencies. The right-of-way staff should meet with the acquisition agency early in the design process to determine the format and style acceptable to all parties.

The following general topics also merit discussion and resolution during the preparation of the right-of-way plans:

- What are the document formatting and recordation requirements?
- How should property lines and ownerships be shown on the plan sheets?
- Can construction plans and right-of-way plans be combined?
  - ◊ For separate right-of-way plans, is it necessary to have profile grade plan sheets?
  - ◊ Are Federal-aid Plan and Profile Sheets adequate or are separate sheets necessary?

- What is the right-of-way fencing policy? How should fencing be depicted on the plan?
- When the agency acquiring the right-of-way is also responsible for utility relocation agreements, what additional requirements are necessary to complete the plans?
- What is the process for modifying right-of-way plans after the acquisition agency has given final approval to the plans?

The cooperating agency may request FHWA to furnish descriptions of the proposed right-of-way. Provide a metes and bounds description, if requested.

In some instances, the cooperators prefer to prepare their own right-of-way plans and only require a completed detail map with slope limits and all known property ties. In other areas, Federal Lands Highway Division offices are responsible for the acquisition of right-of-way. The following discussion provides the guidelines and recommendations that cover the preparation of plans.

Before developing the right-of-way plans, obtain title reports, copies of deeds and any other documents about existing right-of-way. In some cases, the acquisition agency will perform this function.

Examine the documents for easements or other encumbrances to reveal the existence and location of waterlines, conduits, drainage or irrigation lines or other features affecting construction.

Although not typical on FLH projects, a relocation plan may have been prepared during the conceptual stage of the project and is available to the right-of-way designer for information related to improved properties affected by the project. If the plan is outdated or significant changes have occurred within the project corridor, it may be necessary to request a supplemental relocation study. The study should show how occupancy needs are correlated with specific available and suitable housing. Typically, the right-of-way designer can request this information from the State or cooperator by working through the appropriate FHWA Federal-aid division office.

Resolving the right-of-way plan format and obtaining current title reports and other documentation opens the way to preparation of the actual right-of-way plans. Completed right-of-way plans generally consist of four elements:

- Title Sheet.
- Tabulation of Properties.
- Vicinity Map and/or Ownership Map.
- Right-of-Way Plan Sheets.
- Summary of Records (optional)

The basic information required on all right-of-way plans is found in FAPG NS 23 CFR 630B. The Division Supplements provide sample plans and activity checklists to assist in the development and review of right of way plans.

A standard construction type of title sheet, modified to reflect right-of-way criteria, may be used provided it is acceptable to the acquisition agency. All the information that normally shows on a construction title sheet can appear on the right-of-way Title Sheet.

Most projects require a vicinity map or total ownership parcel map. The map scale used should be suitable to show the entire project on one plan sheet. It should also show general information to depict the project in relation to surrounding communities, public and private road systems and other local features.

Many States use the vicinity map to show ownerships and parcel numbers. This is often shown in tabular form with column headings as follows:

- Parcel numbers.
- Recorded owner.
- Total assessed ownership.
- Right-of-way required.
- Existing right-of-way.
- Remainder (left and right).
- Easements (permanent and temporary).

Minor variations of this tabular format will occur depending on the acquisition agency's practices. It is usually permissible to place the parcel tabulation on a separate plan sheet if the vicinity map becomes too detailed. Some agencies show the parcel tabulation on the individual plan sheets rather than the vicinity map. It is difficult to go wrong if the vicinity map follows the format of the applicable agency manual. This is essentially true if the project is on a county road system or a State system.

In addition to the requirements of the vicinity map and other right-of-way documents, show the following data on the right-of-way plan sheets:

1. **Alignment.** Show the base line that legally describes the right-of-way as a continuous solid line for the full length of the project including alignment data. Existing or additional centerlines show as dashed lines with or without alignment data as appropriate. Tie the existing stationing to the new centerline by station and/or bearing equations.

2. **Control Features.** In addition to the culture tie requirements of Chapter 5, identify on the plans all Government subdivisions, platted subdivisions, donation land claims, National Park or Forest boundaries, Indian reservations or farm units.

   Show a minimum of one tie from the new highway centerline to an existing and recorded monument or Government subdivision, particularly the monument from which the title report originates. Compute the tie to a centerline intersection along the section subdivision line with a station, bearing and distance to the monument.

   Frequently, it is necessary to resolve the issue of appropriate evidence of property lines for purposes of right-of-way activities. The property line could be a fence, ditch, partial section boundary (1/16) or the line described in the property deed. Locate, reference and show on the plans all topographic features (e.g., fences, ditches, roads) relating to property usage and boundaries. These topographic features are shown on the plans as they actually exist in the field. The property line is determined and designated from this data for right-of-way requirements.

3. **Right-of-Way Details.** Right-of-way lines are continuous. These lines cross city streets, county roads, rivers, railroads, etc., and must match adjoining projects.

   Show enough detail to describe the right-of-way for its entire length from a centerline or from a metes and bounds description. Tie any existing right-of-way retained for the new project and describe it from the new centerline or by metes and bounds description. Ties to a previous centerline are not acceptable.

   Right-of-way may be established by deed, dedication or statute. The project scoping report should identify how the existing right-of-way was obtained, the owner, and the type of interest held.

   Right-of-way by usage or prescription may or not be legally supportable in a court of law, depending on the evidence and other factors. When a recorded (deeded) right-of-way does not exist, tie any physical evidence of the existing roadway and the maintained right-of-way, and the centerline of the existing road, to the new road alignment and/or the new right-of-way.

   Right-of-way widths and centerline stationing must be shown at the beginning and ending of each plan sheet and at all points of change in right-of-way width. Any easements required outside the right-of-way must show permit descriptions. These easements will accommodate intersecting roads and streets, land service, access and temporary roads, drainage areas, material storage areas, slope widening, utilities, railroads and other special uses.

   Show centerline stationing at the beginning and end of each easement. Mark each easement as temporary (T) or permanent (P). If the easement is irregular in shape, include distance and bearings for writing a description.

   Temporary construction easements give permission to use the land for a brief time (e.g., during construction). Determine a period of effective use or termination date of the temporary easement. Use permanent easements where parties other than the owner need to maintain a right to the land (e.g., a pipeline, an access road).

   Assign a parcel number to each recorded ownership for properties involved on each project. This includes all units of Government. As a rule, number parcels starting with the first tract crossed by the project and then continue in sequence through to the end of the project.

4. **Access Control.** FLH projects usually do not include access control which in most states is a compensable land right that must be specifically purchased and can create damages to the non-needed portion of a property. The highway-operating agency regulates control of access between a highway facility and all other property. In instances where access rights are acquired, access control lines and all approved points of entry or exit from the traffic lanes must be shown on the plans. An access control line

may or may not be coincident with the right-of-way line. Several types of access control, ranging from minimal to full control, may exist within the project limits.

When the access control agency permits individual road approach entries from adjacent properties, identify them on the plans by symbol or type including stationing, width and grade.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

12.3.7 PLANS FOR NATIONAL FOREST LANDS AND FEDERAL AGENCIES

When the acquisition agency and the Forest Service request that FHWA prepare right-of-way plans over National Forest Lands, the above plan preparation instructions apply. When the cooperator is a State highway agency, the right-of-way plans should comply with the Memorandum of Understanding (MOU) between the State and the Forest Service. When the acquisition agency is a county or other local Government entity, the State highway agency may assist the county in obtaining the appropriate easement deeds for the highway construction. The process will be expedited and function quite smoothly if the designer coordinates the procedures through the appropriate FHWA Federal-aid division right-of-way office.

Guidance in the *PDG* and in 23 CFR 710.601 provides information on the content requirements of the application, and the deed for conveying the lands or interests required. Other details on the transferring of lands can be found in the 1989 FHWA *Attorney's Manual for Public Land Transfer and Federal Condemnation*. The *Attorney's Manua*l provides systematic procedures for transferring federal lands as well as examples of the applications and the conveyance deeds. Although only limited copies of the manual are available, updated content may soon be available on the FHWA Office of Real Estate Services site.

12.4 UTILITIES

The term utility means all privately, publicly or cooperatively owned lines, facilities and systems for producing, transmitting or distributing communications, power, heat, petroleum products, water, steam, waste and storm water not connected with highway drainage. Other services that directly or indirectly serve the public and are also considered utilities include cable television, fire and police signal systems and street lighting systems. It also means the utility company is inclusive of any wholly owned or controlled subsidiary.

Irrigation districts or companies performing work at Federal expense should be treated as utilities.

12.4.1 REGULATIONS AND GUIDANCE

It is FHWA policy that utilities can occupy the right-of-way if they do not conflict with the integrity, operational safety or functional and aesthetic quality of the highway facility.

Two sections of Federal highway law in Title 23 of the United States Code (cited 23 USC) specifically address utilities:

- 23 USC 109(l) addresses the accommodation of utilities on the right-of-way of Federal-aid highways.
- 23 USC 123 addresses reimbursement for the relocation of utility facilities necessitated by the construction of a project on any Federal-aid highway.

23 CFR 645 and the Non-regulatory Supplement to 23 CFR 645A provide policy and guidelines on adjustments to utilities. The highway operating agencies have various degrees of authority to designate and to control the use of right-of-way acquired for public highway purposes. Their authorities depend upon State laws or regulations. Utilities also have various degrees of authority to install their lines and facilities on the right-of-way.

More information on relevant laws and regulations can be found on the FHWA Utilities Program website relating to utilities. Links to State web sites are included and provide a resource to state-specific policies.

12.4.2 ACCOMMODATION OF UTILITIES

It is in the public interest to permit utility facilities within the right of way of public roads and streets when such use does not interfere with primary highway purposes. The opportunity for such joint use avoids the additional cost of acquiring separate right of way for the exclusive accommodation of utilities. As a result, the right of way of highways, particularly local roads and streets, is used to provide public services to abutting residents as well as to serve conventional highway needs.

It is not mandatory to provide right of way for new utilities. However, existing rights must be recognized. Impacts to utility facilities or interests may be compensable under the Uniform Act.

It is FLH Standard Practice to accommodate existing facilities when they do not conflict with the primary function of the roadway. The roadway project can cause the relocation of utilities that are in conflict with the design or construction. It is required that the relocation be accommodated within the new right-of-way or the utility company be made whole for their relocation.

The FHWA's authority for allowing utility use and occupancy of the right of way of Federal-aid and direct Federal highway projects is contained in 23 CFR 1.23. The right-of-way must be devoted exclusively to public highway purposes. However, § 1.23(c) permits certain non-highway uses of the right-of-way which are found to be in the public interest provided such uses do not impair the highway or interfere with the free and safe flow of traffic thereon. As previously discussed above in “Public Interest Finding,” such a public interest finding has been made for utilities.

Refer to Chapter 2 of the *Program Guide* for additional details. See also the AASHTO *A Guide for Accommodating Utilities within Highway Rights-of-Way*, 4th Edition, 2005, and the AASHTO *A Policy on the Accommodation of Utilities within Freeway Right-of-Way*, 5th Edition, 2005, for more guidance.

12.4.3 UTILITY COORDINATION

Coordinate utility issues early in the project development process, with all affected entities, including:

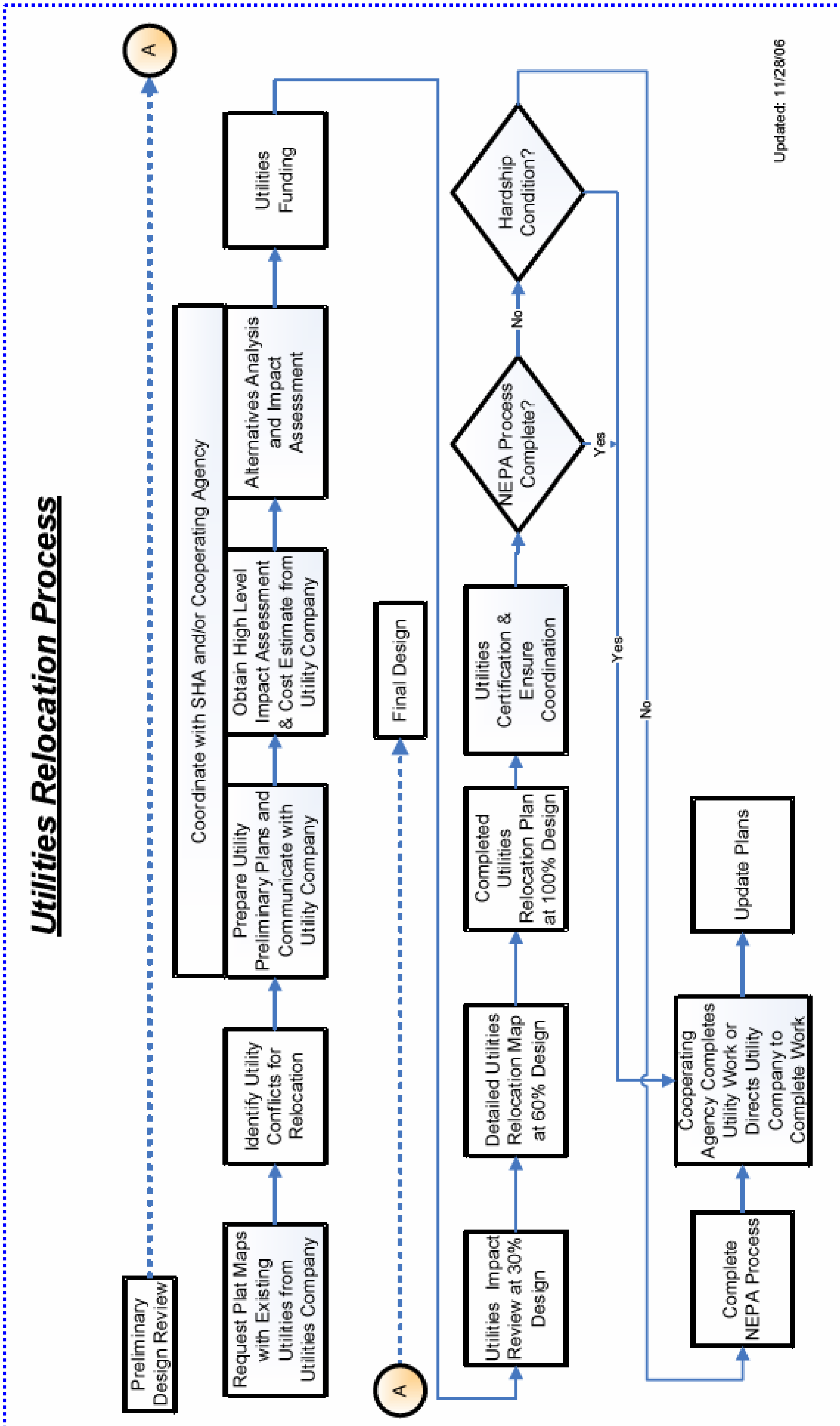
- Utility companies
- Cooperating agencies
- FLMAs
- State DOT or local agency for encroachment permits

The cooperating agency is typically responsible to work with the utilities located within the right of way and arrange to either accommodate them within the new right of way or relocate them to a location outside the new right of way. FLH will typically provide the initial maps and plans to assist the cooperating agency work with the affected utilities. The general flow of work is indicated in Exhibit 12.4–A.

Provide plans and contact all utility companies shortly after the preliminary design work begins. Outline the proposed construction project, its length, termini and other pertinent information that could affect the utility company (e.g., a tentative construction schedule). In some cases, a small-scale map may be helpful for describing project limits.

Request the utility companies to provide plat maps of the project area showing the location of all existing facilities above and below the ground level. The letter of request should also state that the utility company will receive construction plans later, showing existing utility facilities.

Exhibit 12.4–A UTILITY RELOCATION PROCESS FLOW CHART



During the preliminary or final design identify any utility conflicts, and provide the information to the utility company. The earlier an alert of potential conflicts can be identified the better for providing time to prepare for the accommodation or relocation necessary to complement project construction activity.

12.4.4 UTILITY AGREEMENTS AND RESPONSIBILITY FOR UTILITY RELOCATION

Early in the project development process, identify the roles and responsibilities of all parties regarding utility issues, and develop utility agreements which include the:

- Purpose of agreement,
- Parties to agreement,
- Terms of the agreement, and
- Financial liability and schedule.

After the preliminary design is established, identify the utilities that may require relocation or adjustment. Once the utilities have been identified, form a utility agreement with the utility company indicating scope of work and financial responsibilities. The utility agreements indicate responsibility for the utility adjustments.

This could be an agreement with a government, utility or a combination. When determining the responsibility for utility adjustments, identify each utility conflict on the preliminary plans. Color-coding and/or symbols can be helpful in making proper identifications. A tabulation sheet showing conflicts by utility companies is recommended.

Refer to the utility agreements to determine financial responsibility. If no utility agreement exists, use the following general guidance:

- When the utility occupies the existing highway right-of-way, applicable State law determines the portion of the utility relocation cost that is the responsibility of the Government.
- When the utility occupies Government land (e.g., land administered by the Forest Service, National Parks, Bureau of Land Management), relocation cost is usually borne by the utility. There are cases when the utility has occupancy rights that require the Government to share in the cost of adjustment, so check with the land management agency.
- When the utility facility is owned as part of the Federal property infrastructure, as in National Park areas, cost for relocation will be part of the project.
- Determine responsibility for design, ownership and future liability of the facility.

After establishing financial responsibility, show on preliminary utility plans the method used to make the required utility adjustment. One way to accomplish this is to identify and show on the plans at each location where conflict exists, the following information:

- Who is to move the facility (i.e., utility company, FHWA, State).

- Existing and proposed locations (i.e., stationing, left or right of centerline).
- Who will pay for the relocation (i.e., utility company, FHWA, State).

A system of symbols can show the same information. In addition, some method of noting joint use of utilities (i.e., power and telephone lines on the same poles) is desirable for use on the plans.

There will also be cases where the utility move will be a combination of utility and Government expense. This covers instances where the utility is on existing right-of-way and would only need to move a short distance for construction purposes. However, FHWA wants them to move a greater distance for other purposes (e.g., aesthetics, clear zone requirements). In all cases, the utility owner has to be "made whole" or compensated for impacts to the facility.

Send a letter and plans to the utility companies inviting them to a field inspection. Provide the utility companies with a copy of 23 CFR 645 and Non-regulatory Supplement Attachment for 23 CFR 645A along with the preliminary plans, if applicable. This is particularly applicable if the utility is a local entity and not familiar with their rights and obligations under FHWA policy and procedure. As applicable, include a statement that the company's preliminary engineering costs for plan preparation and estimating costs of the utilities to be removed, adjusted or relocated at FHWA expense are eligible for reimbursement after date of the letter.

At the field review with the utility company's representative, discuss areas of mutual interest and resolve any conflicts to the extent possible.

Document oral agreements made at the field review. The report should note the name and organization of those in attendance, the names of contacts during development of the utility plan and any problems pertaining to facility relocations. The utility should receive a copy of the plan and any problems pertaining to facility relocations. The utility should receive a copy of the report.

Invite the highway agency responsible for permitting the utility to use a portion of the right-of-way to all field reviews and keep them informed of all developments. When the utility is on Government land, involve the administrating agency in the utility relocation.

Following the field review, work with the utility's representative to determine the adequacy, practicality and economic reasonableness of the portion of the relocation eligible for reimbursement by FHWA. This involves checking the utilities' relocation plans and reviewing their work estimate for accuracy and cost effectiveness.

The evidence of the right-of-occupancy submitted by the utility requires a check to determine its validity. The evidence may be a letter giving the numbers and/or identifying the use permit or a statement that the utilities are on private right-of-way or easements. If there is any question, check the permits through the applicable agency. The utility right-of-way easement over private property can be checked through the county records of deeds or assessments.

On approval of the utility relocation plan, show the information on plan sheets and provide copies for the utility agreement, if applicable.

The Government requires a utility agreement when any portion of the relocation costs is eligible for reimbursement. When the relocation costs are borne by the utility, the right-of-way staff will furnish plans, coordinate activities and review the utility's proposal for compatibility with construction and safety requirements.

When the rough draft of the agreement is complete, obtain the contract number from the Planning and Coordination Unit and request that they obligate the required funds. When notified that funding is clear, complete the preliminary agreement including cost estimate and plans.

Send a copy of the utility package (include occupancy permits, when applicable) to the cooperating agency with responsibility for its use. The responsible agency is usually the State highway organization of the county. When the relocated utilities fall within the Forest Service boundaries, send a copy to the Forest Supervisor's Office for review. The FHWA Division Office may want the opportunity to review the package to ensure that the proposal does not conflict with policy agreed to with the State.

When all the review comments are resolved, complete the final agreement package. The original and two copies of the final agreement will require signatures before they can be forwarded to the utility. The utility should return two signed copies. Distribute the signed copies and all necessary confirmed copies in accordance with office procedures.

Prepare a utilities packet and provide the packet to the appropriate construction staff for forwarding to the project engineer. The Construction Unit is responsible for verifying the utilities work. When the utility performs the work before the award of the contract, the Right-of-Way Unit is responsible.

After completion of the utility relocation and Government verification of the work, make final payment to the utility company and record the work.

12.4.5 LOCATION OF UTILITIES

It is recommended to place utilities within the right of way but beyond or outside the construction limits.

If possible, locate facilities to minimize the need for utility adjustment on future highway improvements. Avoid interference with highway maintenance and permit access to the facilities for their maintenance with minimum interference to highway traffic. Follow roadside safety and clear zone requirements when making utility adjustments; refer to Chapter 8 for this guidance.

Locate facilities on uniform alignment as near as practical to the right-of-way line. Locate facilities providing access for maintenance of utility facilities. Where possible co-locate facilities within the same general corridor or trench.

For facilities crossing the highway, locate them at approximately right angles to the highway alignment whenever possible and, preferably, under the highway. It is recommended that placement of utility conduit be considered in the design and construction of the roadway for future placement of utilities under the roadway. Benefits to the project include elimination of future pavement cuts, preserving the integrity of the roadway, avoiding expensive directional boring, etc.

Avoid longitudinal placement of any facility within the roadway prism.

12.4.6 RETENTION OF EXISTING FACILITIES

Determine if existing utilities may remain in place during construction, and if so develop a utility accommodation plan including:

- Design accommodation requirements and specifications (e.g. clearance requirements, minimum depth of cover)
- Preserve in place protections and requirements, including:
  - ◊ Encasement protection
  - ◊ Effect of final grade on facility

Under certain conditions, AASHTO policy permits existing facilities encountered during highway construction to remain in place. Facilities deviating from this policy may remain on the highway right-of-way when it is in the public interest and will not adversely affect the highway or its users. This type of retention will be with the understanding that compliance is mandatory when the facility is reconstructed.

When crash history or safety studies show that existing facilities are hazardous, relocate or shield them regardless of prior agreements with the utility. Changes in operating conditions of existing facilities, other than for routine maintenance, require a new permit from the highway operating agency before initiating any work or change.

12.4.7 AESTHETIC CONTROLS

The design of facilities should minimize any adverse visual impact and should be planned to preserve attractive landscapes.

New utility installations, including those needed for highway purposes, are not permitted on highway right-of-way or other lands acquired by or improved with Federal funds within or adjacent to areas of scenic enhancement and natural beauty. These types of areas include public parks and recreational lands, wildlife and waterfowl refuges, historic sites as described in 23 USC 138, scenic strips, overlooks, rest areas and landscaped areas.

New underground utility installations must not cause the extensive removal or alternation of trees visible to the highway user or impair the visual quality of the area.

Avoid new aerial installations unless there is no feasible and prudent alternative to the use of these lands.

No service connections are permitted to cross freeways when a distribution line is available within a reasonable distance on the same side of the highway as the premises being served. Keep crossings of other highways and streets to a minimum.

Facilities to be located on or across highways having easements across federally owned land require the approval of the FLMA and the roadway maintaining agency.

State law may have requirements for placement of utilities along roadways.

12.4.8 UTILITY INSTALLATIONS ON HIGHWAY STRUCTURES

Accommodate utility attachments to bridge structures whenever possible. In those cases where alternate location is not practical, ensure that utility relocation needs are identified early in the roadway and bridge design process.

12.4.9 OVERHEAD POWER AND COMMUNICATION LINES

Above ground facilities must be located outside the clear zone. When circumstances warrant a lesser distance, facilities can be installed behind guard rail or other protective barrier or other design accommodations can be made. It is recommended to locate all facilities as near as possible to the right of way line.

Minimum vertical clearance for conductors must meet the requirements of the National Electrical Safety Code or applicable local codes. When codes conflict, use the code requiring the greater clearance.

12.4.10 UNDERGROUND ELECTRIC POWER AND COMMUNICATION LINES

The installation is recommended to be outside the construction limits and as near to the right-of-way line as practical while maintaining a uniform distance from the highway centerline.

Longitudinal installations located within the foreslope limits are acceptable if an installation outside the ditch line would be difficult or costly; or if the highway traverses a scenic area where an aerial installation would have negative esthetic impact.

Locate installations placed within the foreslope limits a uniform distance from the pavement edge and as near as practical to the inside edge of the ditch. Locate all crossings as normal to the highway alignment as practical. Avoid crossings in deep cuts, near footings of structures, at-grade intersections or ramp terminals, at cross drains and in wet rocky terrain.

The FHWA Subsurface Utility Engineering (SUE) website provides guidance in identifying and dealing with subsurface issues. The SUE also provides a reference regarding the National Consensus Standard (NCS) developed by The American Society of Civil Engineers (ASCE). The standard, ASCE C/I 38-02, *Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data* can be obtained from the ASCE bookstore.

12.4.11 IRRIGATION AND DRAINAGE PIPES, DITCHES AND CANALS

When crossing a roadway, water canals and irrigation ditches can pass through culverts or bridges. Bury irrigation line and pipe siphon crossings from right of way line to right of way line or from edge-of-clear zone to edge-of-clear zone.

Open channels or ditches should not be parallel to highways within the clear zone. It is preferable to locate these outside the right-of-way limits. Conversely, accommodate existing irrigation facilities through minor modification of design, thus eliminating them from being located within the right of way.

Maintain water flow to accommodate periods of mandatory operation. Provide temporary facilities as needed.

12.5 RAILROADS

Projects that cross or may affect land owned by a railroad require early action to start the process required to coordinate development of necessary agreements between the railroad, the cooperating agency and FLH. The following sections provide guidance on railroad-highway right of way issues.

12.5.1 REGULATIONS AND GUIDANCE

Most railroad impacts for projects involve grade crossings. When initiating a project to eliminate a grade crossing of a highway the rail traffic volume should be considered and for low volume lines a determination made whether abandonment of the railroad line is probable within a reasonable time. Such considerations can influence the scope of the crossing design.

Railroads and their rights-of-way are addressed in several sections of the USC. Title 16, Conservation; Title 25, Indians; Title 43, Public Lands; and Title 45, Railroads all contain provisions dealing with railroad rights-of-way. Title 23, Highways contains numerous references to railroads but the primary highway section dealing with railway–highway crossings is 23 USC 130*.*

The federal regulations related to railroads from the highway perspective can be found in *23 CFR 646*. Other federal programs that may be considered when project development affects railroads include safety consideration, rails with trails, and rails to trail programs in states with rail banking programs may also be considered during project development. Refer to Section 5.4.4.6 for survey guidelines for railroad-highway grade crossings. The FHWA Office of Safety maintains guidance documents relating to design and traffic control at highway-rail grade crossing.

Identifying rail ownership can be facilitated through State contacts. Both the Association of American Railroads (AAR) and Freightworld maintain link pages to member railroads.

12.5.2 RAILROAD AGREEMENTS

The processing of railroad agreements and the preparation of plans for railroad encroachment projects are usually time-consuming operations. Therefore, as indicated the coordination activities with the railroad and cooperating agency need to be started as early as possible in the project development process.

Railroad agreements are three party documents between the cooperating highway agency, the affected railroad company and the Federal Lands Highway Division. The responsibilities and obligations of each party must be spelled out in detail in the jointly signed agreement. If there is anticipated to be an interruption of service during the construction process it must be noted in the agreement. There is no rigid format for preparation of the agreement but items needed in every agreement are spelled out in FAPG NS 23 CFR 646B. Each railroad may have its own internal requirements.

In general, right of way is not acquired in fee from a railroad company. Instead, the highway cooperating agency acquires either a temporary or a permanent easement to cover land interests needed for highway construction.

The cooperating highway agency or the affected railroad may prepare the actual agreement. However, it requires review and approval by all three parties. The agreement must be executed prior to project advertising so that all parties, including the eventual contractor are aware of the agreed upon provisions.

Each State usually has a procedure and guide to clear their projects through the appropriate railroad channels. State requirements must be reviewed for compliance. Contact the cooperating highway agency for additional guidance.

Refer to Section 9.3.15 for highway design considerations and requirements, and for coordination of the highway plans preparation with the railroad agreement.

12.6 FEDERAL LANDS

Lands needed for road right of way or road related construction located on federally owned land is obtained by requesting a federal land transfer. Provisions in both 23 USC and 23 CFR provide the authority for a transfer of an easement interest between a Federal Land Management Agency and a non-federal roadway maintaining agency. Although these transactions are referred to as a land transfer, the conveyance does not involve a transfer of the fee simple interest to the property. Only specific property rights for permanent or temporary use are transferred by easement with the underlying fee ownership remaining with the Federal Land Management Agency. In some cases it may be more expedient to construct roadway under a special use permit issued by the FLMA.

Generally, compensation for land is not required, but some agencies may require fees based on a schedule to cover the cost of processing the transfer request. When initiating work with a Federal Land Management Agency the existing MOUs with that agency should be reviewed. The FLH request to the FLMA for their consent to transfer the easement should also request a waiver of all fees.

Land transfers require coordination and cooperation between multiple agencies. The coordination process is usually time-consuming, and proper recognition of that fact is very important for the successful completion of a project. If a project is expected to involve a land transfer, it is very important to identify and involve realty staff for all involved agencies early on in the project development process. Refer to the flow chart in Exhibit 12.6–A for the key steps in processing a land transfer.

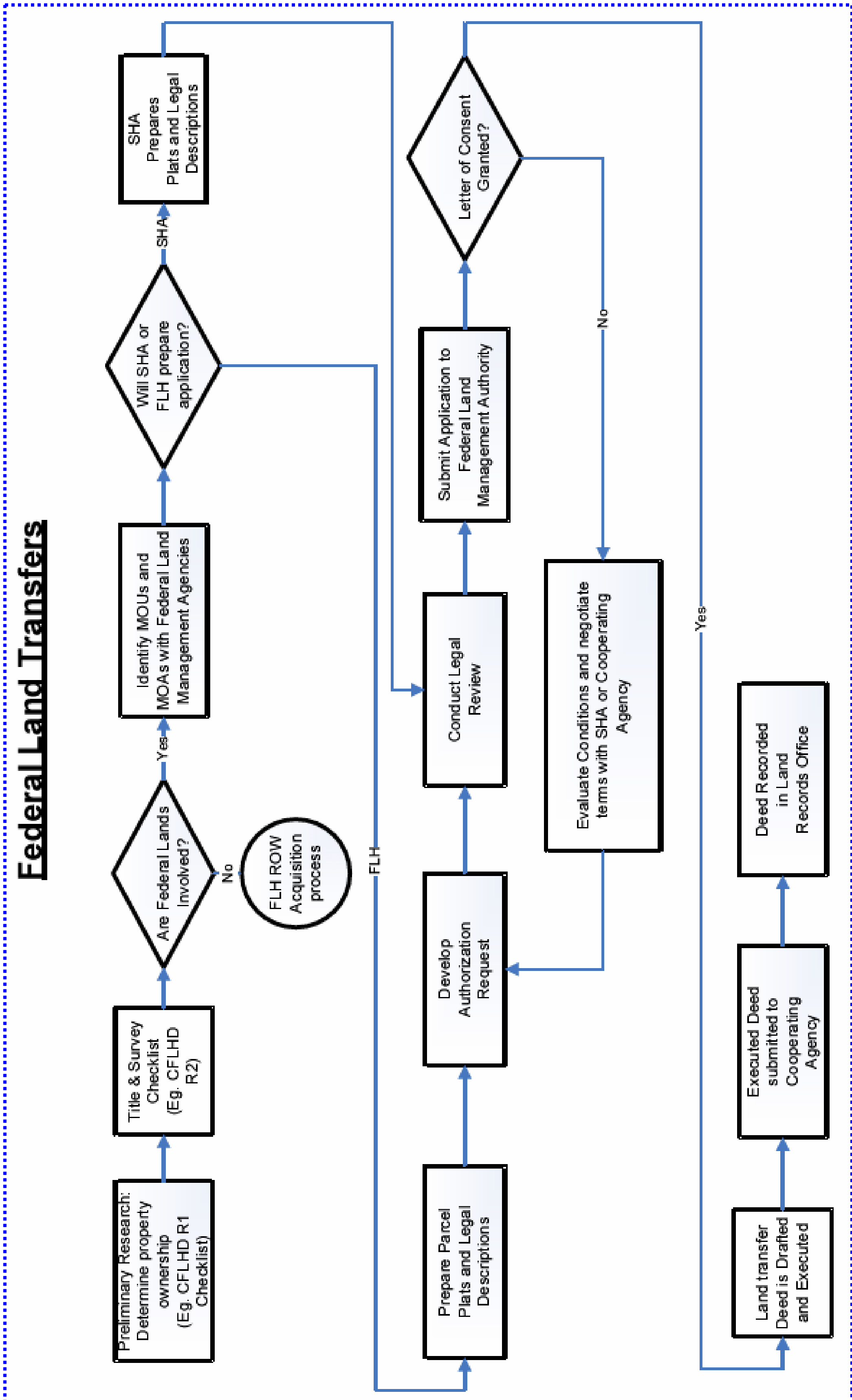
12.6.1 REGULATIONS AND GUIDANCE

23 USC 317 provides the authority for appropriation of lands or interests in lands owned by the United States, when identified as reasonably necessary for the right of way of any highway, or as a source of materials for the construction or maintenance of any such highway. The section provides for a filing and review process between the transportation agency and the land resource agency to identify any conditions that may apply to the land transfer. The section also provides that any transfer shall revert to the resource agency when the transportation need no longer exists.

23 CFR 710.601 contains the regulations related to making an application for a Federal land transfer. For FLH projects, the application material is normally prepared on behalf of the cooperating agency, processed through the land-owning agency, and then approved by the FLH Division Engineer.

The last guidance document issued by FHWA was the 1989 *Attorney's Manual for Public Land Transfers and Federal Condemnations, Environmental* Law and Right-of-Way Branch, Office of Chief Counsel, FHWA/USDOT, Pub. No. FHWA-CC-89-006. An updated online version of this document is pending

Exhibit 12.6–A FEDERAL LANDS TRANSFERS FLOW CHART



A summary report of findings related to improving interagency coordination required in securing public land transfers is available online at the FHWA Office of Real Estate Services.

12.6.2 FEDERAL LAND TRANSFER COORDINATION

During early project scoping, when project needs are identified and it is apparent that right of way or material sites will have to be obtained from a Federal land resource agency, steps need to be taken to alert the realty staff at the Federal Land Management Agency. Much of the environmental work is coordinated with the resource agency (see Section 3.2 for process and MOU or MOA with Federal resource agencies), but often these preliminary activities are not processed through the realty office of the Federal Land Management Agency and specific attempts may be required to assure all parties essential for the review and approval of a transfer are alerted early in the process. Offices and contacts for the primary resource agencies involved with FLH projects can be found using the following links.

1. U.S. Forest Service
2. National Park Service
3. U.S. Fish and Wildlife Service.

Early coordination regarding the potential land transfer is also needed with the state and the cooperating agency since deed form and filing documents must conform to any applicable State laws. In addition to the national MOUs and MOAs with the Federal resource agencies listed in Section 3.2, regional and state based agreements may also be in place. Real Estate contacts in the State FHWA Division Office or through the AASHTO State Right-of-Way Directory can identify those procedures and practices that apply.

The national MOUs and the State agreements provide the framework for land transfers. In locations where there are extensive public landholdings, more specific agency guidance manuals help provide more detailed information on document preparation and content requirements relating to the conveyance of property interests.

The preparation necessary to secure either a Letter of Consent or easement conveyance requires a commitment of resources for both the requesting and the Federal Land Management Agency. This preparation work includes preparation of surveys, land descriptions, and documents necessary to define the appropriate terms, stipulations, and conditions related to the Letter of Consent or easement conveyance.

12.6.2.1 Application to the Federal Agency

FLH projects affecting Federal resource agency land are developed in cooperation with the Federal land management agency and developed in accordance with the environmental process outlined in Chapter 3. A general understanding of the conditions and stipulation that may apply to a project should become known early on through the environmental process contacts with the agency. The agency staff that oversees the forest, park or refuge can also be particularly helpful in this respect. The work on the actual land transfer can begin once the alternate selection, preferred alignment survey, and mapping work are complete. The initial objective is to secure a letter of consent (similar to a right-of-entry) from the resource agency that will permit initiation of construction, with the easement deed conveyed based on "as built" conditions.

The following steps, unless otherwise determined by an agreement between the agencies, outline the process for obtaining a transfer or needed property rights for highway construction purposes.

1. Determine whether FLH or the SHA will prepare an application setting forth the need for the lands in accordance with 23 CFR 710 Subpart F (See also Federal Aid Policy Guide).

2. Prepare the application. The application must address the requirements set forth in 23 CFR 710.601. The application must also cover any applicable provisions in the SHA Right of Way Manual as approved by FHWA at the time of the request, and meet the requirements of the cooperating agency. The FLH Division Engineer coordinates a review of the application and accompanying materials by the FLH Right-of-way utilities support (ROWUS) staff and the appropriate FHWA Counsel. The application must be based on the eligibility of the project for the proposed transfer, and a determination that the land is reasonably necessary for the project.

   The application must include, at a minimum, the following information and certifications (See 23 CFR 710.601).

   - The purpose for which the lands are to be used.
   - The estate or interest in the land required for the project.
   - The Federal-aid project number or other appropriate references.
   - The name of the Federal land management agency exercising jurisdiction over the land and identity of the installation or activity in possession of the land.
   - The name of the cooperating agency that will have jurisdiction over the lands conveyed;
   - A map showing the survey of the lands to be acquired.
   - A legal description of the lands desired.
   - A statement of compliance with the National Environmental Policy Act of 1969 (42 USC 4332, et seq.) and any other applicable Federal environmental laws, including the National Historic Preservation Act (16 USC 470), and Section 4(f) (23 USC 138).

3. The FLH Division Engineer requests authorization from the Federal land management agency to allow the FHWA to effect the transfer of property under the FHWA statutory authority on behalf of the cooperating agency. To expedite the project, a Letter of Consent (interim right of entry) on behalf of the cooperating agency is routinely included in the request, since they are consenting to transfer the easement.

4. Upon receiving appropriate authorization from the Federal land management agency, the FLH, cooperating agency, and possibly the SHA review the conditions and negotiate mutually acceptable conditions with the Federal land management agency. The deed or appropriate instrument of transfer is then drafted by FHWA Counsel or the SHA. Deeds effecting the transfer shall contain certain clauses required by FHWA and 49 CFR 21.7(a)(2), relating to nondiscrimination and the agreed upon conditions. All deeds shall be certified by an attorney licensed within the State as being legally sufficient, as required by 23 CFR 710.601(f).

5. The proposed deed, along with any comments from the Federal land management agency, conditions of transfer, and the recommendations of FLH will be coordinated with the cooperating agency. All accompanying data shall be reviewed at this time. This includes the request for authorization to transfer, the responses of the Federal land management agency, the conditions of transfer, the proposed deed with the legal property description, and findings that the land is reasonably necessary for the proposed highway project.

6. Coordinate the resolution of any remaining issues with the cooperating agency and the Federal land management agency, and review the final documents. This review shall include a determination that the proposed deed and transfer conditions, easements, etc., are adequate and acceptable.

7. Upon a determination that the documents are adequate and acceptable, the FLH Division Engineer executes the deed and transmits it to the cooperating agency or the SHA for execution and recording. The FLH Division distributes executed copies of the deed to all interested parties and coordinates remaining administrative matters.

8. Upon notice by the SHA that the executed deed was delivered to, accepted in writing by the SHA, and recorded in the land records office, the Division posts the recordation data in a log or similar record. The Division then establishes follow-up procedures to assure that post construction activities related to the transfer are implemented.

12.6.2.2 Plats and Legal Descriptions

Plats and legal descriptions used in developing an application for a land transfer should conform to the following standards unless written agreement between the parties state otherwise.

1. Maps and plats should be printed on paper of a size for attachment to the deed. If the size exceeds 8½ x 11 inches [216 mm x 279 mm], they should be folded and mounted on 8½ x 11 inch [216 mm x 279 mm] paper. Very large or bulky maps may be cut in sections for mounting, or reduced, provided the reduction is clear and legible. Plats that are illegible, too small, or not properly mounted should be returned to the SHA for correction. The map or plat should show a survey of the requested land or should otherwise be sufficient to enable an engineer or surveyor to locate the land.

2. Maps, plats, and legal and narrative descriptions should be reviewed concurrently to determine that all courses, distances and reference points in the legal description are shown on the plat, so that the documents may be used independently. A metes and bounds description should be reviewed to make certain that the description yields an enclosed parcel.

3. Land descriptions may be by metes and bounds, a public land survey, or a legal subdivision description. The above types are preferred, but a centerline or other description is acceptable when allowed by the Federal Land Management Agency or by the provisions of (4) below. The description should also include the tract number and total acreage of each parcel.

4. A road or trail in place is a sufficient boundary or monument for a right of way when there is agreement among the parties involved and such property description is not in conflict with State law. The use of a United States Geological Survey Map or an aerial photo is acceptable instead of a centerline survey plat, for an existing road or trail. This procedure may be used for low risk boundary situations, not involving significant project expenditures, or when there is no dispute over ownership or land rights. The map or photo should be attached to the deed and a “Certificate of Right-of-way Description Standard” (such as used by the Forest Service) may be included along with the title documents.

5. The plat or map shall, at a minimum, include the following information on all copies.

   a. Control of access lines, if applicable, identified by appropriate symbol and map legend. Permitted access points should be located by survey between station numbers.

   b. The area to be transferred outlined in red marker.

   c. The acreage or square footage contained in each tract, if feasible. The area of very small parcels should be shown in square feet [meters].

   d. Tract Number assigned to each parcel.

   e. Section lines and section numbers, if applicable.

   f. Name of State and County wherein land is located.

   g. Citation to Federal-aid project number and project name.

   h. Terminal and lateral limits of the project.

   i. The map or plat should identify the location of appurtenances which are significant to the project or of noteworthy value, i.e., buildings, bridges or roads.

6. Land transfers for one project, under the jurisdiction of more than one agency, shall be separately described, but processed and coordinated so that the transfers coincide.

12.6.3 TRANSFER PROCEDURES OF OTHER AGENCIES

In some situations the controlling agency may elect to utilize their own authority and procedures for effecting land transfers. These authorities are ancillary to or in lieu of the authority of Title 23, USC, and the procedures outlined above. When land transfers occur under the authority of the other Federal agency, the transfer is effected in a manner acceptable to the FHWA.

When authorities other than those under Title 23, USC, are used, the cooperating agency or FLH may receive a grant of a permit, license, and right of entry or similar document with conditions from the Federal land management agency in lieu of a land transfer. This procedure is acceptable for temporary uses and for material or maintenance sites.

The land transfer procedures of various controlling agencies are discussed below, with additional information available in Chapters 14 and 16 of the *PDG*.

12.6.3.1 Department of Agriculture, Forest Service

The Forest Service is responsible for protection and multiple use management of National Forest Lands and resources. Requests for transfer of property for which the Forest Service is the Federal Land Management Agency shall be consistent with the 1998 Memorandum of Understanding between the Forest Service and the FHWA, as amended.

The Forest Director having jurisdiction over the needed land should be contacted early in the project development process to discuss the transfer. The land transfer request is submitted to the Regional Forester, or other designated representative of the Forest Service for approval. The application can include a request for an interim right of entry, pending execution of the instrument of transfer. If approved, the Regional Forester, or other designated representative of the Forest Service, will negotiate agreement on any required stipulations. The Forest Service shall then send a letter of consent to FLH and the cooperating agency agreeing to an imminent appropriation and transfer, and granting an interim right of entry.

These transfers of interests in Forest Service lands are by Highway Easement Deed and agreed upon stipulations, terms and conditions, some of which have been previously agreed upon; others are permissible if concurred in by the FHWA and Forest Service.

12.6.3.2 Department of the Interior

12.6.3.2.1 Bureau of Indian Affairs

Applications for right of way or interests in land on Indian lands are submitted directly to the Bureau of Indian Affairs (BIA) by the SHA in accordance with 25 CFR 162 and 25 CFR 169. The transfer is effected by the BIA pursuant to its own statutory authority. For purposes other than those specified therein, transfers are made under the provisions of 23 USC 107(d) and 23 USC 317. More detailed information on working with the BIA and Tribal governments is included in Section 12.7

12.6.3.2.2 Bureau of Land Management

The Bureau of Land Management (BLM) has jurisdiction over certain Federal lands (e.g., non-military Federal lands that are not part of a National Park, Monument, Wildlife Refuge, Forest, or Western States water project). Applications can be submitted to BLM directly or via the FHWA Counsel. The transfer is effected pursuant to an Interagency Agreement between BLM and FHWA, and takes the form of a Highway Easement Deed between the cooperating agency and

FHWA. This procedure may not be appropriate for temporary use of land controlled by BLM. Temporary uses such as the use of a site for construction equipment, maintenance, or for gathering barrow materials may be more conducive to a permitting process, rather than with a recorded deed and land transfer.

The BLM, as the steward of certain public lands, must have a request that identifies land parcels and their uses. It cannot grant an overall request to use BLM lands for borrow material without identifying the location and quantity of material to be used. Under 30 U.S.C. 601, BLM may, in its discretion, transfer material without charge.

12.6.3.2.3 Bureau of Reclamation

The Bureau of Reclamation (BOR) has jurisdiction over certain other Federal lands associated with water resource projects in seventeen western States. In transfers involving these lands, the request is submitted to the BOR, which, in some instances, coordinates the transfer decision with the BLM. The BOR will effect the transfer unless it defers to BLM for a decision and subsequent transfer on behalf of BOR.

12.6.3.2.4 National Park Service

Application for rights-of-way or interests in lands controlled by the National Park Service (NPS), submitted pursuant to 23 USC 107(d) and 23 USC 317, are reviewed and processed in the normal manner as described above, except that the transfer is effected by the FHWA, and that the instrument of transfer document or deed must be approved and concurred in by the NPS Director, prior to issuance.

Submissions affecting NPS lands must be sent to the NPS Headquarters and conform to 36 CFR 14, including Subpart D, which addresses transfers under Title 23, United States Code. The NPS will determine if use of the lands for highway purposes is consistent with its management program and if the SHA agrees to measures necessary to maintain program values.

12.6.3.2.5 Fish and Wildlife Service

Applications for rights-of-way or interests in lands under the control and supervision of Fish and Wildlife Service are submitted by FHWA Counsel to the appropriate Regional Director of the Fish and Wildlife in accordance with the procedures set out in 50 CFR 29, Subpart B, Land Use Management.

Part 29 provides that where the land administered by the Secretary of the Interior, through the Fish and Wildlife Service, is owned in fee by the United States and the requested right of way is compatible with the objectives of the area, a permit or easement may be granted by the Regional Director. Generally, an easement or permit will be issued for a term of 50 years or for as long as it is used for the purpose granted.

Also, transfer agreements should recognize that unless otherwise stated, no interest granted shall give the grantee any right to use or remove any material, earth, or stone for construction or other purposes. However, stone or earth removed from the right of way in the construction of a project may be used elsewhere along that right of way in the construction of the same project.

12.6.3.3 Military Departments

The military departments have statutory authority for granting rights of way over lands under their jurisdiction (10 USC 2668). This law provides for the granting of easements instead of fee estates. These departments may prefer to transfer an easement under their own authority.

Applications for transfers affecting lands under the control of the Army or the Air Force are submitted directly to the installation commander and to the District Engineer - Corps of Engineers. For Navy lands, the application is sent to the Public Works Officer of the Naval District involved. Where a satisfactory approval from the Navy is not readily obtained, the application can be process pursuant to 23 USC 107(d) or 23 USC 317 described above.

12.6.3.4 Veterans Administration

Under 38 USC 8124, the Veterans Administration (VA) is authorized to grant to any State, or political subdivision thereof, easements in and rights of way over lands under the VA's supervision and control, with such terms and conditions as it deems advisable. The application is submitted directly to the VA when an easement is requested from the VA.

12.6.3.5 General Services Administration

Special conditions may apply as in 41 CFR 102-75, Real Property Disposal, in general, and specifically in Subpart B, Utilization of Excess Real Property and Subpart C, Surplus Real Property Disposal. The General Services Administration may require the FHWA and the granting agency to agree on certain transfer conditions, such as the following: “In the event of a reversion, the acquiring agency shall be responsible for the protection and maintenance of the subject premises from the date of notice of intent to revert title until such time as a quitclaim deed re-vesting title in the United States of America is recorded.”

12.6.4 FORMS OF TRANSFER

Transfers made under the provisions of 23 USC 107(d) and 23 USC 317, with the exception of Forest Service and BLM lands, need not be in any particular form as long as they comply with statutory conditions. 23 USC 107(d) provides for FHWA to make such arrangements as may be necessary “to give” the SHA or designee constructing the project adequate rights of way and control of access from adjoining lands. Section 317 (b) is equally broad, although it does not provide for control of access. It recites that the land and materials “may be appropriated and transferred to the State highway department, or its nominee, for such purposes and subject to the conditions so specified.”

The granting document must be certified by an attorney licensed within the State as being legally sufficient, as required by 23 CFR 710.601(f). The granting document(s) shall include the following information.

1. The statutory authority under which the transfer is authorized.
2. The identity of the Federal-aid or Interstate highway project involved.
3. A determination that the lands or interests in lands described therein are reasonably necessary for the project.
4. A statement that the head of the agency having jurisdiction over the land has authorized the Department of Transportation and FHWA to transfer the lands or interests in lands to the SHA.
5. An appropriate granting clause.

Except for grants affecting lands of the Forest Service and the BLM, the conveying instrument is a highway easement deed (See example in Exhibit 12.6–B) wherein the United States of America, acting through the FHWA, appropriates, remises, releases, quitclaims and transfers to the SHA, the lands or interests in land described therein, subject to any specified conditions. The deed concludes with an acceptance of the transfer and the SHA certifies that it accepts the right of way or other interest conveyed and agrees to abide by the conditions of the deed. Grants affecting Forest Service lands are affected by a highway easement deed agreed to by FHWA and the Forest Service.

Generally, the legal description, Exhibit “A”, and the plat, Exhibit “B”, will be attached to and made a part of the granting document. (See examples in Exhibit 12.6–B). In some jurisdictions, where the plat is not required, the instrument is legally sufficient and entitled to be recorded as a land record of the State, if a metes and bounds description, or other acceptable form of legal description is used. In other jurisdictions, a plat, citation to a recorded subdivision plat or other land map will suffice as the description, if the method used meets the requirements of State law.

Exhibit 12.6–B EASEMENT DEED

<< TO BE PROVIDED >>

12.6.5 CONDITIONS OF TRANSFER

Under the provisions of 23 USC 317(b), transfers of lands are subject to conditions which the Secretary of the Department having control of such lands “deems necessary for the adequate protection and utilization of the reserve.”

The policy of the FHWA is to concur in all reasonable conditions of transfer. For example, a requirement that the State convey to the United States comparable lands might be deemed reasonable if the substitute lands are essential to enable the agency presently occupying the land to carry out its functions. If substitute lands are not required, but are requested solely as compensation, the condition is not considered reasonable. Other conditions, as further described below, may involve providing payment of compensation or functional replacement of improvements. In such events, it is suggested that, where appropriate, the interest in the property described in the transfer request be a fee simple.

It has been the policy of FHWA that transfers generally be without the payment of compensation. This policy is supported by an opinion dated as far back as 1947, when the then Acting Attorney General stated: "I concur in the conclusion of the General Counsel of the War Assets Administration that transfer of the land without monetary consideration is authorized by Section 17 of the Federal Highway Act…"

Various Federal or quasi-Federal agencies, such as the Tennessee Valley or Bonneville Power Authorities, may be required to receive compensation because they have fiduciary responsibilities to bondholders or other creditors or because funding of operational costs may be dependent, in whole or in part, on revenues received from real estate assets. In these circumstances, compensation may be a proper condition of transfer, if no other arrangements or conditions can be negotiated.

A Federal agency is entitled to compensation for those appurtenances on its facilities that are to be removed or destroyed in connection with the transfer of its lands. Thus, a Federal agency could impose as a condition of transfer that the State provide substitute land and for the construction thereon, facilities comparable to those taken in conjunction with the transferred land. However, the substitute land and facilities must be essential for the continued operation of the remaining lands according to the agency purpose. The FHWA can concur in such a condition, provided the substitute land and facilities do not include an enhancement of the existing facilities. The transferor agency is to assume the cost of any enhancements.

In calculating the value of facilities that must be replaced, there should be a deduction for the accrued depreciation of the old facility. When a satisfactory arrangement cannot be achieved with the transferor agency, the matter should be referred to FHWA Counsel. A military department may request that the SHA pay the entire cost of replacing a facility (without enhancement), since the service may not be able to use funds for construction without specific Congressional approval. In this situation, the terms of the project agreement must be referenced to determine who will agree to pay the replacement cost when there is a great need for the highway construction project at that location.

A condition requiring review from the US Property Review Board is not necessary. By letter of March 10, 1983, the Assistant to the President for Policy Development advised FHWA that highway conveyances under 23 USC 107(d) and 23 USC 317 are exempt from review by the United States Property Review Board, and as such are not "public benefit discount conveyances" as described in Executive Order 12348 of February 25, 1982.

The Archaeological Resources Protection Act of 1979, 16 USC 470aa-mm, provides certain conditions and permits which may apply to projects when archaeological resources may exist in the project area.

12.6.6 SPECIAL USE PERMITS

There are limited applications of special use permits, which may be used for temporary staging areas, temporary field offices and laboratory trailers, temporary storage areas, material sources and waste sites. These permits should be used restrictively, and coordinated early in the project development process such that all necessary environmental analysis, engineering and decision-making is included in the overall project development and design process.

Follow the affected land management agency requirements for processing special use permits.

12.7 TRIBAL TRUST LANDS

This section pertains to the acquisition process when Indian lands may be required for non-IRR road projects.

FLH provides transportation planning and engineering support in conjunction with the Bureau of Indian Affairs (BIA) in developing the Indian Reservation Roads (IRR) program as indicated in Section 2.3.1.3. The support services provided do not involve oversight of right-of-way acquisition, as the BIA is responsible for that function. Operations of the IRR program can be found in 25 CFR 170.

The IRR program is advanced under terms in the May 24, 1983 MOA with the BIA and FAPG G6090.17. For projects that are part of the IRR system, the BIA is responsible for right-of-way acquisition.

Indian lands include any tract of land where interest in the surface estate is owned by a tribe or individual Indian in trust or restricted status.

The procedures used are similar to those outlined in the preceding section for public land transfers. The BIA is the Federal Land Management Agency with fiduciary responsibility on behalf of the Indian landowners and is authorized by Federal law to grant easements across Indian land for right of way when the tribe and individual Indian owners consent.

The difference between a public land transfer and one dealing with lands administered by the BIA is that a tribal government, and in certain instances, individual owners must be contacted to obtain their consent before any transfer is approved. State governments may also have to be consulted to coordinate the future maintenance requirements for the proposed highway improvement.

12.7.1 REGULATIONS AND GUIDANCE

During project development, there are a number of Federal laws that may require consultation with Indian tribes or individuals. The Native American Graves Protection and Repatriation Act of 1999, P.L. 101-601; 25 USC 32 (NAGPRA) provides that Federal Agencies must consult with Indian tribes or individuals prior to authorizing the intentional removal of Native American human remains, funerary objects, sacred objects, and objects of cultural heritage. Federal agencies and the affected tribes or individuals must agree as to the handling and disposition of "cultural items" as defined by the act. NEPA and NHPA provisions may also come into play during project development and have an impact on right of way considerations with respect to the protection of Indian cultural and historic resources.

When right of way is required from Indian lands, the conveyance of property rights will be under provisions in 25 USC 8. Sections 323-328 of that chapter provide the statutory language, and the related regulations issued by the BIA are in 25 CFR 169. The regulations provide that right of way grants for easements across Indian lands must have the consent of the Indian owners, with consent potentially required from both individual and tribal owners. The legal title to trusts or restricted lands are held by the United States of America for the benefit of a tribe(s) or an individual Indian(s). The BIA Land Titles and Records Office (LTRO) records the official documents with the legal description, owners, and existing encumbrances of Indian lands.

The Tribal Leaders Directory provides contact information for all federally recognized tribal government officials and the BIA Regional and Agency offices.

Tribes are sovereign governments under Federal law and regulations. They need to be recognized as such and included in all project activities that might affect their lands. Procedures used when dealing with local public agencies and the general public need to be carefully evaluated to see if they are appropriate for use with tribal governments and the residents of the reservation.

There are about 280 land areas currently administered as Federal Indian reservations in 33 States. Reservation lands are those held in trust by the Federal government for the common benefit of the tribe. Allotted lands are reservation "trust" lands conveyed by the government to individual Native Americans.

Many States and some State departments of transportation have established government-to-government agreements with the tribes that have land holdings located within their borders. A good example of State liaison efforts is the *Minnesota Tribes and Transportation E-Handbook* where agreements, policies, and programs affecting the tribes are enumerated. Washington DOT Tribal Liaison office is another State site that provides a comprehensive coverage of the efforts being made to establish effective government-to-government relationship with the tribes.

Federal agencies also have developed liaison efforts to engage tribal governments. The FHWA Tribal Transportation Planning site provides background information and links to information regarding developing transportation planning capabilities including the IRR program. Other Federal agencies directly related to the FLH program, namely the U.S. Forest Service, US Fish and Wildlife Service, and the National Park Service have developed government-to-government programs for working with the tribes. All agencies under executive order must establish a government-to-government consultation process with the native tribes when implementing programs affecting tribal interests.

12.7.2 TRIBAL SOVEREIGNTY AND CONSULTATION

Indian tribes are recognized as domestic dependent nations with sovereign powers, except as divested by the United States. Any action that will involve lands held in trust by the United States for the benefit of a tribe or a member of a tribe will require early and ongoing consultation with the tribe.

Executive Order 13175, entitled Consultation and Coordination with Indian Tribal Governments, establishes regular and meaningful consultation and collaboration with tribal officials in the development of Federal policies that have tribal implications. Indian tribes are recognized as domestic dependent nations with sovereign powers, except as divested by the United States.

The following four essential elements must be met in developing effective consultation with the tribes.

- Identifying appropriate tribal governing bodies and individuals from whom to seek input;
- Conferring with appropriate tribal officials and/or individuals to obtain their views regarding project activities, right of way requests, and how particular locations may affect traditional tribal activities, practices, or beliefs;
- Treating tribal information as a necessary factor in defining the alternatives for acceptable project locations and right of way requirements;
- Creating and maintaining a permanent record showing how tribal information was obtained and used during the project development and right of way application process.

Effective consultation demands more effort than routine public participation. Tribal consultation means a dialogue between FLH and a tribal government regarding proposed project activities, with the intention of securing meaningful tribal input and involvement in the decision making process. Since the first step to obtain any right of way across Indian lands is the consent of the tribe, the consultative process must be started early and be an ongoing part of project development. This will require visits with tribal councils and appropriate tribal leaders on a recurring basis. Such face-to-face meetings, without regard to specific issues or proposed actions, help in developing relationships that can reduce the time and effort spent in consultation devoted to obtaining approvals on individual projects or actions. These early meetings should be used to discuss how, when, and with whom follow-on consultation would occur with those affected tribes and/or their designated representatives. It is very important to remember that this is government-to-government consultation and should be treated with appropriate respect and dignity of position.

When publishing notices and/or open letters to the public, it is good practice to send individual letters to tribes requesting their input on actions being considered, with individualized follow up to assure that tribal officials understand the issue at hand and that the consultation is being made in good faith.

It is important to note that a lack of response might be related to the sensitivity of the information involved. The tribes may be reluctant to provide specific information particularly when places of religious important are involved. This could be because of the fact that it is culturally impermissible to share such information outside the tribe, or because the relationship with the tribe has not been sufficiently developed.

Consultation requirements and procedures, including the identification of the appropriate consultation partner vary according to the legal basis for consultation and any MOU or MOA that may apply with the Tribe, the BIA, or the State. Specific consultation should focus on groups known to have concerns about the geographic area under consideration.

To identify contacts within tribes, the BIA publishes an annual list of federally recognized tribes in the *Federal Register*. This list is the best starting point for identifying recognized tribes with which the United States has a government-to-government relationship. This list is not exhaustive, however, and must be augmented by other sources such as the State Office of

Indian Affairs. Tribes and groups with historic ties to the lands in question, including those that are no longer locally resident, should be given the same opportunity as resident tribes and groups to identify their selected contact persons, issues, and concerns regarding the proposed improvement.

Initial inquiries should be addressed to the presiding government official of the Indian tribe, e.g., the Tribal Chairman. Initial discussions should attempt to determine which individual(s) will be officially authorized to serve as the point of contact and representative/spokesperson for highway and right of way matters that may come up during project development.

In preparing for consultation, the first step is to identify a clear purpose for meeting with the tribe and to identify with whom the consultation should take place. The second step is to review past history and any known tribal concerns regarding State or Federal project actions that might remain unresolved. Recorded sources that could be reviewed include:

- Previous correspondence with tribes;
- Records of previous consultation;
- Public participation records for land use plans;
- Plan protest records;
- Transcripts of public hearings; and
- Minutes of public meetings.

After establishing the need and a purpose for consulting and determining with whom to consult, an initial contact should be made with the tribal appointee by letter and telephone, explaining the reason for the contact. During that contact, request their direct participation and input and ask them to identify any other tribal officials who they think should be contacted. Tribal government officials are the appropriate spokespersons where proposed actions might affect tribal issues and concerns. The tribal government officials are responsible for any tribal members that may have pertinent information concerning cultural and religious values/concerns.

Correspondence with the tribe can serve as notification or just be a written precursor or supplement to direct, person-to-person consultation. All correspondence including notification and consultation documents shall be retained as part of the project record. If a letter is returned as undeliverable, retain the canceled, unopened letter in the project file and, if appropriate, begin more direct (and documented) attempts to gather the needed input from the tribe. The project records must show that an effort was made in good faith to obtain and weigh tribal input in the decision making process. If a project decision does not conform to the tribe's requests, the ability to apply for and obtain necessary highway easements for the project may be jeopardized.

Just as for written communication with the tribe, document all attempts to establish telephone communication, including a record of all conversations conducted by telephone through a signed and dated note to the files. All the aforementioned information, as well as copies of any relevant emails need to be included in the permanent project record.

The amount of consultation required to advance a project will be based on the involved tribes, scope of the project, and the following considerations.

- Potential harm or disruption that a proposed action could cause;
- Alternatives available to reduce or eliminate potential harm or disruption;
- Completeness and appropriateness of the list of Native American groups and individuals consulted;
- Nature of the issues raised;
- Intensity of concern expressed;
- Legal requirements posed by treaties (if any);
- Ability to resolve issues through further discussions;
- Need for further consultation.

It is important to keep in mind that many, perhaps most, specific issues of Native American concern will not be issues associated with cultural resources such as archaeological sites. Rather, Native American cultural concerns are likely to center on issues of access, collection and use of plants and animals, protection of religious places, and incompatible land and resource uses. Information that is related to cultural resources or areas identified as having ongoing traditional religious significance and use should be considered extremely sensitive. Any maps or other project information should be treated as confidential working files, and kept private unless specifically authorized for release by the tribe.

At the end of a consultation process, the preferred alternative and the right of way needs that were identified for the project must address the tribal concerns. Tribal consent to the project is the first step in the application process to the BIA for granting easements for project right of way as outlined below.

12.7.3 APPLICATION PROCEDURES

Applications for right of way or interest in land that is on Native American lands are submitted directly to in the BIA in accordance with 25 CFR 162 and 25 CFR 169. BIA conducts the transfer of land pursuant to its own statutory authority. For purposes other than those specified therein, transfers are made under the provisions of 23 USC 107(d) and 23 USC 317.

25 CFR 162.601 provides, in part, that the Secretary of the Interior may grant leases on government land and on individually owned Indian land when the Secretary has written authority to execute leases on the Indian's behalf; and on an Indian's land whose whereabouts are unknown. Applications for right of way across such lands should be submitted to the BIA for transfer. *BIA represents individuals on all land leases.*

25 CFR 169 has procedures under which rights of way over government, tribal, and individually owned land may be granted. Consent of the tribe or individual Indian owner may be required and 43 CFR 7 (Protection of Archaeological Resources) may apply. If such resources are present, the BIA must issue a permit and obtain the consent of the Indian landholders.

When a Federal, State, or local agency is applying for a grant of an easement from Indian lands, the following general steps apply (except where State specific agreements are in place with the tribe or the BIA).

- Application for permission to survey.
- Consent of landowner.
- Title Status Report (TSR).
- Right of way application (in DUPLICATE).
- Survey plat (in DUPLICATE).
- Field notes.
- Applicant's certificate.
- Engineer's affidavit.
- Landowner's consent to grant ROW.
- Field inspection.
- Appraisal.
- NEPA document.
- Payment (Receipt).
- Grant of easement for right of way.

The process to obtain a grant of easement for right of way is initiated through the BIA Agency Office. The initial step is filing an Application for Permission to Survey for Right of Way. The application will initiate the BIA agency office to file a Request for Title Status Report (TSR) with the BIA Land Titles and Records Office (LTRO). The LTRO prepares the TSR, which provides the land ownership information along the proposed right of way necessary to complete the right of way/cadastral surveys activities outlined in Section 5.4.5.

Based on the TSR information, the cooperating agency or the agency responsible for right of way acquisition will prepare appraisals and obtain consent forms from all Indian tribes or individuals holding an ownership interest in the property affected by the project.

For tribal lands, a tribal resolution passed by the tribe's federally recognized governing body and signed by duly authorized tribal officers is required. The resolution should include the following information:

- Name of tribe.
- A statement specifically addressing what the tribe is requesting the Secretary to approve.
- Land description.
- Tract (allotment) number, if applicable.
- Tribal organizational authority.
- Authority for the signatories.
- Date the resolution was signed.
- Date the tribe met on the resolution, if different from the date the resolution was signed.

When seeking a consent resolution from the tribal government, requesting both permission to conduct survey as well as to grant right of way can save time. If both consents are requested simultaneously, a minimum consideration must be specified, with the actual amount fully dependent on an appraisal.

For land that is held in trust on behalf of individual Indians, a consent form will have to be obtained from each owner or group of owners as part of the process for being granted an easement for right of way. Prior to seeking owners consent, the property must be appraised.

Property appraisals are usually prepared by the requesting agency. The appraiser must attach to his report a Certificate of Appraisal and the BIA Office of Appraisal Services must review all reports. A Review of Land Appraisals report will be issued to set the minimum consideration on all parcels for which a grant of easement is being requested.

Negotiating for consent based on approved appraisals for tracts held in trust by individual Indians can sometimes create problems since in many cases the TSR may indicate multiple ownership interests on a single tract. Prevailing statutory authority from the 1948 Indian Land Consolidation Act (ILCA) provides a general framework that requires obtaining consent from a simple majority of owners. Under terms of the American Indian Probate Reform Act of 2004, the minimum consent requirements for land transactions are indicated to be:

1. Ninety percent (90%) if five or fewer owners.
2. Eighty percent (80%) if between 6 and 10 owners.
3. Sixty percent (60%) if between 11 and 19 owners.
4. A simple majority, if more than 20 owners.

The process to track down and secure consent can involve a lot of effort and be a very lengthy process even with these stated percentages. The agency responsible for land acquisition should confirm the number of partial owner consent forms that will be acceptable in support of a grant of easement request through the BIA agency office. This confirmation should be obtained prior to seeking out consent from the list of owners reported in the TSR.

12.8 PRIVATE LAND ACQUISITION

This section outlines the key Federal acquisition policies and standards that are minimal requirements for acquiring privately owned property for federally funded projects, and indicates the extent of stewardship and quality control desirable to assure that the acquisition by the cooperating agency complies with Federal and State policies.

12.8.1 OVERVIEW OF THE PRIVATE LAND ACQUISITION PROCESS

The following sections summarize the overall process for acquiring privately owned property for federally funded projects.

12.8.1.1 Project Scoping

Whenever project needs identify that acquisition from privately owned property may be required, interagency agreements are used to establish the funding and acquisition responsibilities for needed right of way. Refer to Section 2.4 for a description of interagency agreements. These agreements typically establish either a State or a County as the cooperating agency to assume responsibility for obtaining needed right-of-way including utility relocation. Assess carefully the type of land acquisition required for each project before selecting the cooperating agency. This is especially important for new location routes where displacements of residential or commercial properties may be required. In those situations, using the State DOT may be the more prudent choice because their staffing and experience with Federal and State acquisition and relocation policies.

The following activities should be performed for the project scoping stage:

- Identification of cooperating/acquiring agency
- Identification of potentially impacted property owners and complexities
- Analyze right of way impacts and provide input for NEPA process
- Participate in SEE team activities
- Participate in Public meetings and hearings
- Identify unique right of way acquisition issues and potential conflicts
- Meeting with cooperating agency to assess acquisition capability
- Develop cooperating agency acquisition plan

Coordinate the project scoping activities with the other interdisciplinary scoping activities performed during the preliminary engineering investigation and development of the Project Scoping Report. See Section 4.5.2.12.4.

12.8.1.2 Preliminary Design

Develop the preliminary right of way information in conjunction with the preliminary design and alternatives analysis described in Section 4.7 and Section 4.8.

The following activities should be performed in conjunction with the preliminary design:

- Determine right of way impact assessment for various design options
- Prepare right of way cost estimate
- Perform Design/Right of way plan review
- Perform right of way field review with property owner meetings
- Coordinate design accommodations to reduce right of way
- Determine acquisition service options
    - ◊ In house or state certified cooperating agency
    - ◊ Contract with SDOT
    - ◊ Acquisition services contract
    - ◊ Design/Build options for right of way acquisition
- Assess advancing right of way acquisition options
    - ◊ Allowable acquisition activities prior to NEPA decision document
    - ◊ Hardship acquisition
    - ◊ Protective buying (corridor protection)

12.8.1.3 Final Design

Develop the final right of way information in close coordination with the development of the final design described in Chapter 9.

The following activities should be performed in conjunction with the final design:

- Prepare right of way acquisition documents
- Right of Way acquisition process activities, including:
    - ◊ Acquisition of State owned land
    - ◊ Functional replacement
    - ◊ Appraisal waivers
    - ◊ Donations
    - ◊ Real estate appraisals/valuation
    - ◊ Appraisal review
    - ◊ Temporary easements
    - ◊ Closing and payment
    - ◊ Mortgage releases
    - ◊ Relocations
    - ◊ Environmental mitigation
    - ◊ Right of entry
    - ◊ Administrative settlements
    - ◊ Resolution of necessity
    - ◊ Order for possession
    - ◊ Legal settlements
    - ◊ Final order of Condemnation
    - ◊ Project property management
    - ◊ Disposal of excess right of way

- Initiate property negotiations
- Maintenance of acquiring agent parcel negotiation record
- Real estate oversight and guidance of acquisition process

12.8.1.4 PS&E Development and Finalization

Develop the final right of way information in coordination with the PS&E development described in Chapter 9.

The following activities should be performed in conjunction with the PS&E development and finalization:

- Finalize right of way acquisition documents
- Tabulation of right of way acquisition commitments to PS&E package
- Quality Assurance Checklist, including
    - ◊ Utility certification in accordance with 23 CFR 635.309(b)
    - ◊ Right of way certification in accordance with 23 CFR 635.309(c)(1), (2), or (3)
    - ◊ Letter of Consent for federal land transfer

12.8.1.5 Construction

The following activities should be performed in conjunction with the project construction:

- Follow-up on right of way commitments, and
- Subsequent acquisitions related to construction activities, if necessary.

12.8.2 GUIDANCE AND REFERENCE MATERIAL

The acquisition of private property for a public improvement is based on Federal and State eminent domain laws. The action of taking property under eminent domain law is normally termed condemnation, although some State laws may use other terms. Both Federal and State laws relating to eminent domain require payment of just compensation. Although eminent domain and condemnation of private property to advance public projects is well established, it is not used in all situations. Since the use of eminent domain requires court action, procedural policies have been enacted to promote amicable settlements with owners.

The following reference materials should be used, as applicable:

1. Uniform Act
2. FHWA Right-of-Way Project Development Guide (*PDG*)
3. FHWA *Real Estate Acquisition Guide*
4. State Code or State DOT Right of Way Manuals

The FHWA Realty pages also contain several helpful resources regarding Federal guidance and interpretation of how laws are applied.

12.8.3 STEWARDSHIP AND QUALITY CONTROL

For FLH projects the cooperating agency is responsible for providing the right of way necessary for the project. In some instances, Federal funding may be available for use by the cooperating agency to acquire project right of way. The agreements required to make provisions for acquisition of right of way are discussed in Section 2.4. At the time that project-specific agreements are being negotiated, especially if extensive right of way or relocations of families or businesses are possible, the familiarity with Federal and State right of way acquisition policies and the capabilities of the cooperating agencies staff need to be assessed.

Since project funding is dependent on having any needed property acquired in accordance with the provisions in the Uniform Act and related State law, the cooperating agency should be evaluated to assure they are sufficiently conversant with the Act and have procedures, either actual or contractual, that can accomplish the acquisitions anticipated to be needed for the project. Early coordination with the cooperating agency on right-of-way acquisition requirements should identify where supplemental assistance may be required, if necessary, to provide the proper level of project oversight.

Where the State DOT is designated as the cooperating agency, there is a high degree of assurance that it will comply with the provisions in the Uniform Act. In instances where local county and municipal governments will be the cooperating agency, the State DOT right-of-way staff that are responsible for advancing local projects are a primary source of information on the capabilities of such governments. Many states have some form of local public agency (LPA) program to advance their own stewardship responsibilities. The FHWA Division Office can assist in determining the appropriate contact and providing insight into how effective the State program may be in providing training and other support services to the local governments that may be involved in project related right-of-way acquisition.

The results of the early coordination efforts will provide an indicator of the scope and extent of oversight responsibilities FLH may have to provide during the active acquisition period. Where a cooperating agency has limited or no State supported prior training regarding implementation of the Uniform Act, an intensive effort may be required. Developing an appropriate oversight plan for each project to ensure the right-of-way program is administered in an effective and efficient manner and in compliance with Federal and State guidelines is an essential component of project activity. Oversight may include: (1) all required review and approval actions, and (2) quality assurance reviews, process reviews, and project reviews necessary to validate compliance with the Uniform Act and State right of way procedures.

The importance of ongoing review and oversight is essential so that the certification process, outlined in Section 12.9 can be accepted.

12.8.4 ACQUISITION PROCESS

Each State DOT is required to have available a written description of their acquisition process. This document is primarily required as an informational document to provide to landowners whose land is needed for State projects. Many States use a modified version of the Federal Acquisition Brochure. This brochure identifies the policies that are required by the Uniform Act when acquiring real property interests for a federally funded project. In general, the Uniform Act requires that the acquiring agency make a prompt written offer to the property owner. This offer should be based on the agency's current estimate of just compensation, including the amount and a summary of the basis for the offer.

The Uniform Act requires the following actions be taken when acquiring real property:

1. Appraise the property before initiating negotiations, and provide the owner or his designated representative an opportunity to accompany the appraiser during his inspection of the property.
2. Before initiating negotiations, establish an amount believed to represent just compensation. In no event shall such amount be less than the agency's approved appraisal of the fair market value of such property.
3. Make a prompt offer to acquire the property for the full amount established as just compensation. Provide the owner with a written statement of, and summary of the basis for the offer and where appropriate, a breakdown of the amount of the offer that applies to the real property acquired and any damages to the remaining real property.
4. Make every reasonable effort to acquire expeditiously the real property by negotiation.
5. Do not defer negotiations or advance the time of condemnation or delay the deposit of funds in court for the use of the owner, or take any other action coercive in nature, in order to compel an agreement on the price to be paid for the property.
6. Make no attempt to require an owner to surrender possession of real property before full payment of the agreed purchase price, or a full deposit is made with the court for the benefit of the owner. The agreed purchase price/full deposit should not be less than the agency's approved appraisal of the fair market value of such property, or the amount of the award of compensation in the condemnation process for such property.
7. If the acquisition of only a portion of a property would leave the owner with an uneconomic remnant, make an offer to acquire that remnant. The acquiring agency determines when the real property remaining with the owner after a partial acquisition creates an uneconomic remnant with little or no value or utility to the owner.

The State right-of-way manual will outline the procedures available within the State for meeting the acquisition requirements of the Uniform Act and will also provide the options and alternatives that the State has adopted for property acquisition.

For cooperating agencies that do not have staff sufficient to appraise, negotiate or provide relocation services, the use of State DOT personnel or consultants may be necessary. Guidance on right-of-way contracting is available on the *Realty Program Administration* page, the *PDG*, *Real Estate Acquisition Guide*, and through consultation with SDOT staff.

12.8.4.1 Donations

Right of way acquisition is generally based on the owner being paid for the property needed for the project. There are situations however when an owner may desire to donate his property, in whole or in part. The Uniform Act acknowledges that a donation can be accepted. However, it requires that each owner must be fully informed of his right to receive just compensation for such property. Each owner must be provided an explanation of the acquisition process, including the right of having the property appraised and being made an offer of just compensation before the property owner waives his rights and the agency accepts the donation.

Sometimes an owner's offer to donate a whole or part of a property involves a request for construction features that will benefit the owners remaining property. Agreements to donate based on providing a new driveway, entrance, or other features in lieu of cash compensation are possible provided a comparison is made of the donated property's value and the cost of the additional construction features to ensure that the costs are equivalent.

As with any land purchase, the cooperating agency should be cautious and ensure that no environmental concerns such as the presence of hazardous waste are associated with the property being offered before accepting a donation.

12.8.4.2 Valuation

The Uniform Act and the implementing regulations require that the acquiring agency must estimate an amount believed to be just compensation except when the landowner proposes a donation. Under eminent domain law, this amount is usually equivalent to fair market value as determined by an appraisal.

An appraisal is an independent and impartial written statement prepared by a qualified appraiser setting forth an opinion of defined value of an adequately described property as of a specific date. This statement is supported by the presentation and analysis of relevant market information.

The method of valuation used on any particular property is dependent on the type of property, its expected value and the complexity of the appraisal problem. In addition, the Uniform Act regulations require each SDOT to have criteria for determining the minimum qualifications of appraisers, consistent with the complexity of the appraisal assignment. If a contract appraiser is used to do a detailed appraisal, the appraiser must be State-certified in accordance with Title XI of the Financial Institutions Reform, Recovery, and Enforcement Act of 1989. Refer to the State Regulatory Board within each State for information on State-certified real estate appraisers.

12.8.4.3 Appraisal Waiver Procedure

In certain situations, when the property required for a project is determined to have a low value and the valuation process is complicated, the requirement for preparing an appraisal can be waived. A waiver valuation (See 49 CFR 24.102(c)) is not an appraisal, so appraisal-related requirements, such as owner accompaniment and appraisal review, are not Federal requirements when waiver procedures are used.

The State Right-of-Way Manual will indicate what is considered a low value acquisition and provide necessary guidance for determining the type of property acquisitions and whether local agencies may use the waiver valuation procedure.

The Federal rule provides agencies the authority to define the low value criteria used to determine when a waiver of appraisals can be used. The agency can select any amount up to $10,000 as the value limit beyond which an appraisal would have to be prepared. Agencies can also request approval from the funding agency to use a higher amount up to $25,000 for defining a low value acquisition. Whatever low value amount is in use and available to the cooperating agency, the property acquisition must also be uncomplicated in order to waive the appraisal requirements of the Uniform Act.

12.8.4.4 Appraisal Standards

The Department of Justice *Uniform Appraisal Standards for Federal Land Acquisitions* is the primary Federal guide dealing with appraisal standards and documentation standards for detailed reports. The Department of Justice Guide includes as Appendix A an Appraisal Report Documentation Checklist indicating the scope of reporting appropriate for a detailed appraisal.

Appraisal standards, forms and procedures that apply to acquisitions in each State are included in the State's Right-of-Way Manual or may be contained in a separate Appraisal Manual. The appraisal format(s) that may apply to any given project location and be appropriate for each property to be appraised will be determined by State DOT procedures and the appraisal standards adopted by the State Appraisal regulatory board.

All appraisals must include a certification by the appraiser based on the State requirements.

12.8.4.5 Determining the Amount of the Initial Offer

All appraisals must be reviewed by a qualified review appraiser. The review provides both a technical check regarding the data contained in each report and how it was analyzed to arrive at the fair market value conclusion. Depending on State procedures, the review appraiser can either establish the amount believed to be just compensation or provide a recommendation regarding the appraised values to the acquiring agency for use in establishing just compensation. Appendix A of 49 CFR 24, Section 24.104, *Review of appraisals*, contains a broad description of the role a qualified review appraiser has in providing quality control over the amount an agency establishes as just compensation.

12.8.4.6 Making the Offer and Negotiating

The full amount estimated to be just compensation must be offered to the owner in writing. The amount established as just compensation is date sensitive and therefore the offer must not be delayed. While personal contact with the owner is preferred, offers can be made via the mail provided such a practice is provided for in State procedures.

Owners are to be afforded sufficient time to consider the offer and to assemble any information they deem necessary to judge its adequacy. The acquiring agency must record and maintain a written record of all contacts with the owner including offers made, counter offers received, and discussions relating to the purchase.

When justified through the negotiation process and the exchange of information with the owner, settlements above the original estimate of just compensation are acceptable. The negotiation record should support how the settlement amount and agreement were reached.

Any additional or revised construction features that are discussed during the negotiation process need to be carefully considered and approved before a settlement agreement is accepted. Construction features included in a settlement agreement need to be incorporated into the final design plans.

Other settlement considerations such as allowing existing buildings to remain in the designated right-of-way can also be considered during the negotiation process. Granting a permit for encroachments can be part of a settlement agreement when such an action will not pose any safety or maintenance problem.

When an agreed settlement is reached and immediate possession is needed to advance construction, the owner can be asked if he would grant an immediate right of entry prior to making full payment for the acquired property.

12.8.4.7 Settlements and Payments

Settlements reached through the negotiation process need to be processed and payment made to the owner using closing procedures established by the State. Closing procedures must provide for any applicable mortgage releases and address any other title issues before payment is made and the deed recorded to conclude the property purchase.

In addition, the agency should arrange to pay or reimburse the owner for any incidental costs associated with the property transfer. The property owner should be informed early in the acquisition process of the Agency’s policies regarding incidental costs and identify those reasonable and necessary expenses that are covered.

12.8.4.8 Requesting Condemnation

When an agreed settlement is not achieved, or condemnation action is required to clear title issues, the practices of each State regarding the use of eminent domain and condemnation apply. Property that cannot be acquired through agreement must be turned over to the State office holding authority for filing condemnation actions either with the courts or intermediate boards that may be established by State law.

A deposit of the full amount of the last written offer to the owner must be made on the owners behalf. No order of possession by the court should be accepted unless the owner has access to the full amount of the deposit.

12.8.5 RELOCATION ISSUES

The Uniform Act provides a number of benefits to reimburse out of pocket expenditures that owners and tenants face when displaced from property acquired for a public improvement. For the type of projects advanced under the FLH programs there are limited situations where occupied improvements are acquired and residential or business displacement occur. Because the relocation program has an array of benefits available to persons displaced from residential and non-residential properties, it is highly desirable that the State DOT be engaged to provide the notices, assistance and payment benefits that apply.

When dealing with relocation situations, the Uniform Act provides that no person lawfully occupying real property shall be required to move from a dwelling or to move a business or farm operation without at least a 90-day written notice. The full range of benefit options available to displaced persons under the Federal law are outlined in the FHWA *Relocation Brochure*.

Although displacements from occupied residential or commercial buildings are rare on FLH projects, there are relocation benefits that apply to personal property that may be stored on acquired lands requiring an owner or tenant to incur an expense to move them off the acquired right of way. Refer to Chapter 10 of the *PDG* for eligible costs that may be reimbursed when personal property is required to be removed from acquired property.

The provisions of the Uniform Act concerning relocation are found in Title II. As stated in the law, the purpose of Title II is to assure fair and equitable treatment of displaced persons so that such persons do not suffer disproportionate injury from projects designed to benefit the public as a whole. It is important to keep this purpose in mind, as it can serve as a valuable guide when making decisions on difficult questions.

For roads designed by FLH, the impact of the project on occupied improvements can often be adjusted to avoid the adverse impacts created on owners and tenants by being displaced from their residence, business or farm. Coordination with the acquisition agency and affected owners through the design process may avoid the costly relocation of wells or the demolition of improvements and resulting move of stored property.

12.8.6 STATE OWNED LANDS

State land management agencies whose lands are needed for highway purposes may operate under State laws that include provisions similar to the ones found in the U.S.C. dealing with the transfer of federal lands. When State owned lands are needed for a FLH project, the State rules and regulations must be reviewed to determine the requirements of the State application and approval process.

For state lands compensation is usually required although transaction may be arranged using land swaps, or other types of negotiated solutions. Functional replacement of acquired property is often preferred.

12.9 RIGHT OF WAY AND UTILITY RECORDS

The acquisition of right of way, relocation and accommodation of utilities are expected to be complete with all agreements in place prior to completing the contract assembly or acquisition package discussed in Chapter 9. This section discusses the documents that are required to be included in that package.

Acquisition records, plans and property plats related to project right-of-way need to be documented to conform to Federal and State laws and regulations. The general rule related to real estate transactions requires written documentation and full disclosure. This section addresses those project level and parcel level records that are essential to support right-of-way activities and funding.

12.9.1 RIGHT OF WAY CERTIFICATION

During the development of the final PS&E package as described in Chapter 9, it is essential to confirm the acquisition status of required right of way before soliciting bids for project construction. The status of any utility or railroad work required by the project must also be confirmed.

For projects where all right-of-way is being obtained through a land transfer from another federal agency, the approved agreements and the right of entries for all needed property should be available.

For projects where right of way is being acquired from private parties, the acquiring agency must prepare a right of way certification and submit it to FLH. The certification is prepared to indicate that the property interests needed for construction have been fully acquired, and are available for construction. If any occupied structures were acquired, the certification must indicate that all persons have been relocated and that the benefits required were provided as required by the Uniform Act and in accordance with State law.

In certain situations, where all property interests are not yet acquired, the certification statement must include a detailed availability report on parcels or properties that are still to be acquired clearly indicating the dates such property will become available for project construction. This statement should also indicate any acquired and vacant improvements remaining in the right of way that are to be included as a demolition work item in the construction contract.

Where it is determined that the completion of such work in advance of the highway construction is not feasible or practical due to economy, special operational problems and the like, the acquisition package shall contain appropriate notification in the bid proposals identifying the right of way clearance, utility, and railroad work which will be underway concurrently with the highway construction.

Any incomplete acquisition or relocation situations or utility/railroad work that may impact a contractor in developing his work schedule needs to be clearly identified in the acquisition package. The regulations related to the necessary certification and availability statements can be found in 23 CFR 635.309. The procedure, as applied to FLH projects, requires the cooperating agency to provide the right of way certification and availability statement to the FHWA FLH office coordinating the project. The form of the certification can follow that employed by the State for LPA projects, or a letterform similar to the example shown in Exhibit 12.9–A.

Exhibit 12.9–A SAMPLE RIGHT-OF-WAY CERTIFICATION FORM

RIGHT-OF-WAY CERTIFICATION

This is to certify that all necessary rights of way have been acquired, including legal and physical possession. Said rights of way have been acquired in accordance with Federal Highway Administration directives governing the acquisition of real property including CFR 49 Part 24.

This is to certify that there are no relocatees (families, businesses, or tenants) involved in this project.

All improvements (buildings, fences, signs, etc.) have been removed from the proposed right of way.

The status of utilities is as follows:

>> List each utility company and include status.

e.g., Power and Light Company – Adjustments to begin when contract is awarded and adjustments to be made concurrent with construction.

This is to certify that arrangements have been made as indicated above for the adjustment of all utility facilities as required for coordination with the physical construction schedules. As noted, the Contractor's operations should not be adversely affected.

Sincerely,

____

Agency Head/Mayor/President of the Board

____

Attorney for the Agency/City/County

The federal regulations allow three levels of certification. Each level relates to the degree of risk that exists for property being available to the contractor for use during construction. The levels are outlined in the regulation in sub section (c)(1) through (3). The level 1 certification is preferred as it provides that at the time of advertising full legal possession of all property rights necessary to construct the project have been secured. This means that payments have been made available to all owners. The level 2 certification is similar in that all properties are available for construction but some may be based on right of entry with payments or other actions still remaining to obtain full legal possession. The level 3 certification indicates that some properties are not available for use and must provide support for dates when physical occupancy will be provided to the contractor for construction activities. Examples of the wording for each level of available certification are indicated below.

1. **Certification Level 1.** I hereby certify the right of way on this project as conforming to 23 CFR 635.309(c)(1). All necessary right of way has been acquired. Trial or appeal of cases may be pending in court, but legal possession has been obtained for each parcel. There may be some improvements remaining on the right of way, but all occupants have vacated the lands and improvements. The County has physical possession of the right of way and has the right to remove, salvage, or demolish these improvements and enter on all land.

2. **Certification Level 2.** I hereby certify the right of way on this project as conforming to 23 CFR 635.309(c)(2). All necessary right of way has NOT been fully acquired, but the right to occupy and to use all rights of way required for the proper execution of the project has been acquired. Trial or appeal of some parcels may be pending in court and on other parcels full legal possession has not been obtained but right of entry has been obtained. All occupants have vacated the lands and improvements. The County has the right to enter on all land and has physical possession of the right of way and the right to remove, salvage, or demolish these improvements.

3. **Certification Level 3.** I hereby certify the right of way on this project as conforming to 23 CFR 635.309(c)(3). The acquisition or right of possession and use of a few remaining parcels is not complete, but physical construction may proceed. Occupants of residences, businesses, farms, or non-profit organizations have not yet moved from the right of way, but all occupants on such parcels have had replacement facilities or assistance made available to them. Physical occupancy and right to enter all parcels (Certification Level 1or 2) is anticipated by __________ *(enter date)*

   The FHWA has received appropriate notification identifying all locations where right of occupancy and use has not been obtained.

12.9.2 RIGHT-OF-WAY ACQUISITION RECORDS

Real property acquisition procedures place an emphasis on fully documenting decisions related to title, valuation, negotiations, settlement agreements, and conveyance documents. Any agency acquiring right of way for a federally funded project is expected to maintain parcel files that document each required action under the Uniform Act, including the appraisal or waiver valuation, the offers made, and a written contact log of the negotiations with the property owner. When relocation activity is required on a parcel, a separate relocation record should be created and provide the same type of information to document the offers, assistance and payments provided to comply with the Uniform Act.

The parcel records developed by the acquiring agency as part of the acquisition process are required to be available for review by State and FLH personnel. If the acquisition is federally funded, the agency is required to retain the records and have them available for review for three years from the date of acceptance of the final voucher for the project. State practices may also include record keeping requirements for property acquisition even if Federal funding was not used for project acquisition.

12.9.3 ACQUISITION STATISTICS

Acquisition activity subject to the provisions of the Uniform Act is subject to reporting requirements in §24.9(c).of 49 CFR 24. For FLH projects, the appropriate time to collect the required information is at the time the right of way certification is submitted. The reporting data to be obtained is summarized in Appendix B of 49 CFR 24. A project level report is prepared based on the right of way plans for the project and the above mentioned certification.

12.9.4 RECORDING RIGHT-OF-WAY PROJECT RECORDS

At the conclusion of the right of way acquisition process, a deed or easement is executed to complete the transfer of rights needed for the highway improvement.

Deeds and easements are the records of land ownership and transactions. Deeds are recorded in a central place, according to state law. The location differs from State to State. Some registries of deeds have posted information, indexes, and all or part of their holdings on their Web sites, available through the internet. Acquisition agencies at the municipal, county or State level should have full knowledge of existing procedures covering their recording policies.

The executed documents are usually permanent in nature, although some easements could have a very limited duration, and apply only during project construction. For long-term transfers, the deed or easement should be recorded to protect the public investment in right of way and maintain the chain of title available in public records.

Property transfers between governmental agencies also need to be recorded in the registry of deeds of the municipality or county in which the property is located. This protects the investment made in the highway by serving a public notice regarding the location and rights and interests held by the agency responsible for maintaining the facility. Refer to the local register of deeds to determine how individual property plat and project right of way transactions should be placed in the public record.

Upon completion of construction in National Forests, set survey monuments based on “as built” right of way if requested, in conformance with the Memorandum of Understanding between the State and Forest Service. Setting survey monuments for all projects is good policy and may be required by State law. The “as built” right of way plans should be filed or recorded based on State practices to complete the public record.

Chapter 13 – DESIGN FEEDBACK

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LIST OF EXHIBITS

CHAPTER 13

DESIGN FEEDBACK

13.1 GENERAL

This chapter provides policies, standards, practices, guidance, and references for identifying and documenting design feedback for continuous improvement of the project development and design process, during the review of designs, plans, specifications, and estimates (PS&E), and post design reviews.

The purpose of design feedback is to determine if the design process is accomplishing its intended objectives and to provide an input process for improving project development and design standards and practices. The process can be described as a means of obtaining feedback for the purpose of evaluating the effectiveness of the project development and design processes through the following:

- PS&E reviews,
- Analysis of construction changes,
- Post construction reviews,
- PS&E improvement meetings, and
- Periodic program reviews.

Although an effective and efficient design is sought for each project, the proposed design may not always be the ideal solution. The design and PS&E process may always be improved. Conducting reviews and analyzing feedback data are methods that will be useful in substantiating that current processes are adequate and assist in determining if changes are necessary. The feedback systems may range from informal communications to formal review and reporting procedures.

Refer to [EFLHD – CFLHD – WFLHD] Division Supplements for more information.

13.2 GUIDANCE AND REFERENCES

Most of the available guidance is concerned with reviews to be undertaken and the types of reporting formats. The following sections provide brief descriptions of manuals that are available in each Division Office and are to be reviewed for specific guidance.

13.2.1 FEDERAL-AID POLICY GUIDE (FAPG)

Although developed mainly for the Federal-aid Program, the *FAPG* contains many regulatory and non -regulatory applications to the FLH Program.

1. Order 1311.1A — *FHWA Order 1311.1A, Value Engineering*. This section discusses policy relating to value engineering in design and construction and the review of designs and standards.

2. FAPG 23 CFR 630B — *Federal-Aid Policy Guide 23 CFR 630B, Plans, Specifications and Estimates*. Paragraph 5C in the non-regulatory attachment, NS 23 CFR 630B, discusses the transformation of developmental specifications to Standard Specifications after gaining adequate and satisfactory experience from active contracts.

3. FAPG G6042.4 — *Federal-Aid Policy Guide G6042.4, Construction Projects Incorporating Experimental Features*. This section provides guidelines relating to inspection, reporting and evaluating experimental features included in construction projects.

13.2.2 FEDERAL LANDS HIGHWAY MANUAL (FLHM)

The *FLHM* contains the policies and procedures applicable to the FLH Program.

1. FLHM 1-C-2 — *Federal Lands Highway Manual 1-C-2, Work Method Improvements-Alternate Work Methods*. This section establishes policy for the Divisions to continuously search for methods to improve the effectiveness of performing the work by analyzing and scrutinizing existing methods, policies and procedures.

2. FLHM 3-C-2 — *Federal Lands Highway Manual 3-C-2, Exceptions to Minimum Engineering Standards - Risk Factors*. This section sets forth policy for adequate review, evaluation and documentation of engineering standards and exceptions to standards.

3. FLHM 4-A-3 *Federal Lands Highway Manual 4-A-3*, *Construction Claims and Disputes*. This section sets forth policy aimed at reducing claims by requiring a routine analysis of claims as they are settled. It also provides emphasis and direction toward improving operational procedures that deal with construction claims.

13.2.3 FLH CONSTRUCTION MANUAL

The *FLH Construction Manual* includes procedures for processing plan and specification changes and the requirements for final construction reports and as-constructed plans. These reports and plans are important sources of design feedback information.

13.3 OBTAINING AND EVALUATING FEEDBACK

This section provides general guidance and suggested practices for obtaining and evaluating design feedback, which can identify systematic improvements of the project development, design and PS&E processes. In addition to some of the more formalized procedures, a great deal of information is gained through documenting informal contacts and communications. This is true both within FHWA and with the client and cooperating agencies. Principal sources for this information are PS&E reviews and data obtained from tracking construction projects.

13.3.1 PS&E REVIEW AND IMPROVEMENT PROCESSES

FLH policy established in FLHM 1-C-2 requires that methods be established to continuously improve existing work methods, policies and procedures. The following activities should be conducted to continuously improve the design and PS&E process:

1. **PS&E Improvement Meetings**. These should be held periodically to evaluate design and PS&E practices, features, policies, specifications or other items relating to design and PS&E development. Evaluate design feedback obtained from all available sources. Document the evaluations and designate applicable items for systematic process improvement.
2. **Project PS&E Reviews**. These may involve both written comments and meetings held to resolve comments received in the project PS&E review process. Refer to Section 9.6.4 for the typical project reviews. Obtain feedback on the design and PS&E during project PS&E reviews. Items pertinent to the general design and PS&E processes, or applicable to other projects should also be documented separately from the project-specific comments, and compiled for systematic evaluation and process improvement.

13.3.2 ACTIVE CONSTRUCTION PROJECTS

As practical, obtain feedback on the design and PS&E during construction. There are a number of methods used to provide feedback information during construction. These involve a great deal of informal communications as well as specific reviews and reports. The following list identifies some of the more common sources of this information:

- Partnering meetings;
- Contract modifications;
- Value Engineering proposals;
- Trip reports from construction staff reviews;
- Field reviews of proposed design changes for problems (e.g., slides, drainage, materials sources);

- Environmental compliance reviews (see Chapter 3);
- Formal program management reviews; these may be general in nature or cover specific emphasis areas (e.g., hydraulics, safety);
- Informal contacts or field reviews with project personnel; designers should be encouraged to visit the site of active construction projects when they are in the vicinity;
- Construction feedback report (see Exhibit 13.3-A for sample report format);
- Videotapes, photographs, etc.;
- Contacts with owner/maintaining agencies;
- Final inspections;
- Contractor interviews; and
- Work-zone traffic control reviews.

The design feedback information obtained from the above sources may consist of project-specific information, as well as items pertinent to the general design and PS&E process or applicable to other projects. Document any process-related findings and recommendations identified during the above activities separately from the project-specific comments, and compile for systematic evaluation and process improvement.

Refer to [EFLHD – CFLHD – WFLHD] Division supplements for more information.

13.3.3 POST CONSTRUCTION

As practical, obtain feedback on the design and PS&E after completion of construction. The following are some of the sources of information available for after the completion of construction projects that will be of value in evaluating the effectiveness and adequacy of design features:

- Evaluation of contractor claims;
- Feedback from owner/maintaining agency; this information may be gained from informal contacts or specific reviews of problems or deficiencies;
- Formal post-construction reviews; these reviews provide an excellent means for evaluating the effectiveness of various design features; reviews should encompass maintenance, traffic operations, safety, drainage, erosion control and roadway performance;
- Skid testing;
- As-constructed plans;
- Final construction reports;
- Closeout meetings with the construction project engineer; these meetings can be an excellent means for obtaining suggestions and recommendations for improvement of future designs; and
- Bridge Inspection Reports and Roadway Inventory Reports.

Exhibit 13.3-A SAMPLE FEEDBACK REPORT

FEEDBACK REPORT

To: ____________________

From: ____________________

Date: ____________________

Instructions:

1. One problem per report.
2. May be completed in pencil or ink.
3. Forward original and 1 copy to Division office.
4. Retain a copy for your records.

Project Name: ____________________

Type of Contract: ____________________
(Grading, Base, Paving, Bridge, etc.)

List any problems encountered in the plans, specifications or administration of your contract, any problem associated with Division support services or any deficiencies where correction action or improvements can be incorporated into upcoming projects. Timely submission is essential for implementation of corrective actions.

Problem: ____________________

(attach additional pages if more space is needed)

Corrective Action Taken and Improvements Recommended for Future Projects: ____________________

Division Staff Comments: ____________________

Action Recommended and by Whom: ____________________

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The design feedback information obtained from the above sources may consist of project-specific information, as well as items pertinent to the general design and PS&E process or applicable to other projects. Document any process-related findings and recommendations identified during the above activities separately from the project-specific comments, and compile for systematic evaluation and process improvement.

13.4 MONITORING

Each FLH Division Office must have procedures to monitor their project development processes, including integrated feedback systems. The purposes of this monitoring are to:

- Assure management that the processes being used are in compliance with applicable regulations;
- Identify areas for needed improvements (i.e., technical and procedural); and
- Sustain efficient, safe and cost-effective designs.

Monitoring will provide appropriate and timely input for revisions and/or modifications to the following:

- Federal Lands Highway Manual,
- Project Development and Design Manual,
- Division Supplements,
- Standard Specifications,
- Division Library of Supplemental Specifications,
- Standard Plans,
- Division Details, and
- Division Standard Operating Procedures.

FLHO is responsible for modifying or revising the FLH-wide items. Refer to Section 1.1.5 for revising and updating the PDDM. Although accountable to FLHO, each Division Office is responsible for monitoring its own Division-specific items and standard operating procedures. As part of the project development and design process, each practitioner should also monitor application of the above items in developing their products and services, and contribute feedback for input to process improvement activities. Significant items identified through design feedback will be considered for nationwide use.

Federal Lands Highway

Project Development and Design Manual

U.S. Department of Transportation

Federal Highway Administration

PREFACE

Federal Lands Highway (FLH) has developed the *Project Development and Design Manual (PDDM)* to provide current policies and guidance for the interdisciplinary project development and design related activities performed by FLH Divisions and their consultants. It also serves as a guide for administrators, public officials and others, both within and outside FLH, who are responsible for advancing projects through the project development process.

The purpose of the *PDDM* is to:

- Provide current policies, standards, criteria and guidance for development and design of FLH projects;
- Be easily accessed by internal and external participants in the project development process;
- Be user-friendly with useful navigation and search tools;
- Provide immediate access to approved external references; and
- Be frequently updated to maintain credibility.

A primary goal of the *PDDM* is clarifying what is expected for FLH projects and delivering an end product that meets these expectations. The previous edition of the manual has been converted from a policy/procedures hard copy format manual to a policy/best practices, interactive web-based document with electronic links. Most theory-specific procedures or recommended methods, including computer software, are included in the updated *PDDM* by reference only. This manual is not intended to be a technical "how to" instructional guide.

The *PDDM* is a complete PDF web-based document allowing faster downloading, clearer formatting, word searches through Adobe Acrobat and hypertext links to reference documents and technical information. The manual defines FLH policies, standards and standard practices, criteria, guidance and discretionary expectations for project development.

The FLH Discipline Champions and their respective teams prepared this edition of the *PDDM*, with assistance from engineering consultants. The FLH Discipline Champions wish to express their appreciation to all contributors who assisted in the development of this manual, specifically the contributions of the following:

- FLH Division Engineers and Directors,
- FLH Branch Chiefs,
- FLH Staff,
- Materials furnished by other State and Federal agencies,
- Research publications and materials furnished by the private sector,
- Consultants who contributed to the preparation, and
- Federal land management agency partners and other reviewers.