

**Performance of Polymer Modified Hot Mix Asphalt Pavements
- An Extended Evaluation**

State Study No. 141

Prepared by:

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**Research Division
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16. Abstract In the summer of 1996, the Mississippi Department of Transportation (MDOT) initiated a field trial (MDOT State Study No. 111) and a laboratory study (MDOT State Study No. 123) to evaluate the use of polymer modified asphalts in hot mix asphalt pavements. In the field trial, nine experimental sections were compared. Eight of the sections contain different polymer modification, including four styrene-butadiene copolymers, one polyethylene, two crumb rubbers, and a gelled asphalt. A ninth section containing no modifiers serves as the control section for the experiment. This experiment was constructed on a section of Interstate 55 Northbound near Grenada, Ms. that is subjected to approximately one million Equivalent Single Axle Loadings (ESALs) per year. Each section is one half mile in length and is separated from the next section by a one half mile long non-modified section. Contained within this report is the summary of activities related to MS State Study No. 141, which examines the long-term performance of the nine sections. As part of State Study No. 141, an effort has been made to characterize the performance of each of the sections by utilizing MDOT's Pavement Condition Rating (PCR) which was developed in conjunction with MDOT's Pavement Management System.			
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During the period of this study, the Executive Director of MDOT was Mr. Hugh Long followed by Mr. Larry "Butch" Brown. The Deputy Executive Director / Chief Engineer was Mr. James Kopf, P.E. followed by Mr. Harry Lee James, P.E.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
Chapter 1 – Project Introduction	1
Chapter 2 – Project Layout	3
Chapter 3 – Rut Performance	5
Chapter 4 – Pavement Condition Ratings	7
Chapter 5 – Estimated Remaining Service Life	10
Chapter 6 – Skid Resistance	13
Chapter 7 – Macrotexture	16
Chapter 8 – Conclusions	18
Appendix A – Extrapolated PCR & Rut Data	

LIST OF FIGURES

<u>Figure or Table</u>	<u>Page</u>
1. Project Location	3
2. Modifiers Utilized for Field Trial	4
3. Field Collection of Rut Data	5
4. Rut Performance	6
5. PCR Performance	9
6. Kraton PCR Performance	10
7. Extrapolated Kraton PCR Performance	11
8. Kraton Rut Performance	11
9. Extrapolated Kraton Rut Performance	12
10. Remaining Service Life Results	12
11. MDOT Pavement Friction Tester	14
12. Friction Results	15
13. Spreading Glass Spheres into Circular Patch for Macrotexture Measurement	16
14. Macrotexture Results	17

PROJECT INTRODUCTION

In the summer of 1996, the Mississippi Department of Transportation (MDOT) initiated a field trial¹ (MDOT State Study No. 111) and a laboratory study² (MDOT State Study No. 123) to evaluate the use of polymer modified asphalts in hot mix asphalt pavements. In the field trial¹, nine experimental sections were compared. Eight of the sections contain different polymer modification, including four styrene-butadiene copolymers, one polyethylene, two crumb rubbers, and a gelled asphalt. A ninth section containing no modifiers serves as the control section for the experiment. This experiment was constructed on a section of Interstate 55 Northbound near Grenada, Ms. that is subjected to approximately one million Equivalent Single Axle Loadings (ESALs) per year. Each section is one half mile in length and is separated from the next section by a one half mile long non-modified section. During construction, more than 500 samples of asphalt cement, loose hot mix, and cores were taken for evaluation. Performance of these modified test sections has been monitored since construction by taking cores, rut measurements, conducting distress surveys and performing various non-destructive testing methods.

MS State Study No. 123², which was to test and study the asphalt samples, was conducted by The Mississippi Polymer Institute located at the University of Southern Mississippi (USM) and by Paragon Technical Development under contract to USM. The primary objective of this project was to study selected Superpave tests on asphalt binders to evaluate their applicability to polymer modified asphalts. Other tasks included the determination of experimental techniques to evaluate the concentration of polymer additives in polymer modified asphalts and

¹ "Polymer Modified Hot Mix Asphalt Field Trial", (State Study No. 111, FHWA/MS-DOT-RD-99-111), Mississippi Department of Transportation, Research Division, P.O. Box 1850, Jackson, MS, December 1999.

² "Evaluation of Polymer Modified Asphalts For Potential Application on Mississippi State Highways", (State Study No. 123, FHWA/MS-DOT-RD-99-123), Mississippi Polymer Institute, The University of Southern Mississippi and Mississippi Department of Transportation, Research Division, P.O. Box 1850, Jackson, MS, July 1999.

the evaluation of rutting potential of roadway cores and gyratory specimens in the Asphalt Pavement Analyzer (APA), a commercial version of the Georgia loaded wheel tester.

Contained within this report is the summary of activities related to MS State Study No. 141, which examines the long-term performance of the nine sections. As part of State Study No. 141, an effort has been made to characterize the performance of each of the sections by utilizing MDOT's Pavement Condition Rating (PCR) which was developed in conjunction with MDOT's Pavement Management System. By periodically examining the PCRs of each section over the course of approximately 7 years and 7 million Equivalent Single Axle Loads (ESALs), a comparison can be made between the modifiers with respect to overall pavement performance. Using this information, conclusions can be drawn as to the amount of remaining service life within each section.

All three of these projects (MS State Study No. 111, MS State Study No. 123 & MS State Study No. 141) have and will continue to provide the State of Mississippi, as well as the global research community with valuable information concerning SuperPave, accelerated rut testing, polymer modification and the performance of asphalt pavements in general.

PROJECT LAYOUT

The Mississippi Modified Field Trial was constructed in 1996 by the Lehman-Roberts Company on Interstate 55 Northbound in Grenada & Yalobusha Counties located in North Central Mississippi. For this section of pavement the Long-Term Pavement Performance Binder Selection Software (LTPP Bind V2.1) recommends a PG grade of 70-16 (98% reliability).

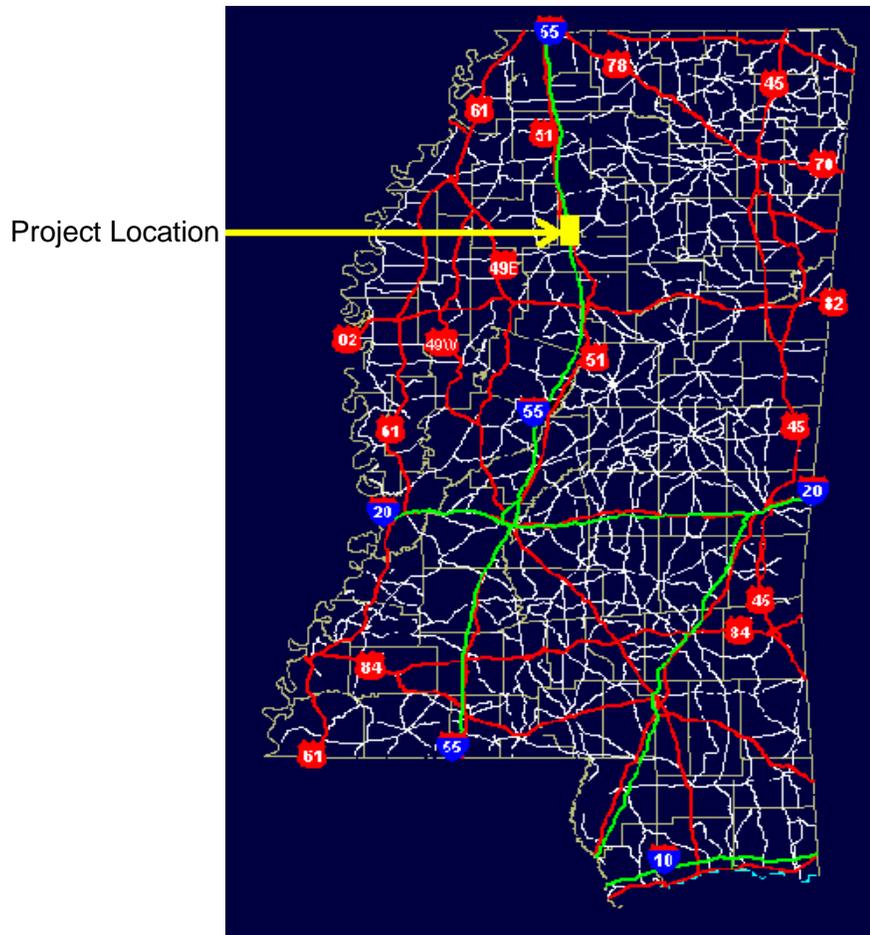


Figure 1 – Project Location

Eight (8) different modifiers were utilized for the research. An effort was made to select modifiers from the different chemical groups that are in widespread use for modifying HMA. The polymer loading was determined on the basis of the manufacturer's recommendation.

<u>Tradename</u>	<u>Manufacturer</u>	<u>Polymer Type</u>	<u>Polymer Loading</u>
Kraton	Shell Chemical Co.	SBS Block Copolymer	4.0%
Ultrapave	Textile Rubber & Chem.	SB Latex	3.0%
Novophalt	Advanced Asphalt Tech.	LDPE (recycled)	5.5%
Styrelf	Koch Materials	SB Block Copolymer	6.0%
GF-80 Rubber	Rouse Rubber Ind.	-80 Mesh Tire Rubber	10.0%
Seal-O-Flex	Ergon Inc.	SBS Block Copolymer	4.25%
Multi-grade	Asphalt Materials	Gelled Asphalt	2.0%
Cryo-80 Mesh	Cryopolymer	Cryogenic Ground Tire Rubber	10.0%

Table 2 – Modifiers Utilized for Field Trial

Each of the modifiers was blended with an AC-20 (PG 64-22) base cement. The control section was an unmodified AC-30 (PG 67-22).

For the purpose of this research, a 500' long (12' wide) analysis section was utilized in each of the modified sections for facilitating pavement evaluations.

RUT PERFORMANCE

One of the most desirable characteristics of a pavement is its ability to resist permanent wheel path deformation. Wheel path deformation or rutting as it is more commonly referred to can pose a significant hazard to the traveling public during periods of inclement weather. With that in mind, each of the sections were monitored for rut resistance over a seven (7) year period.



Figure 3 – Field Collection of Rut Data

Rut measurements were taken at 50 foot intervals throughout each 500 foot analysis section approximately every six (6) months.

FIELD RUT PERFORMANCE

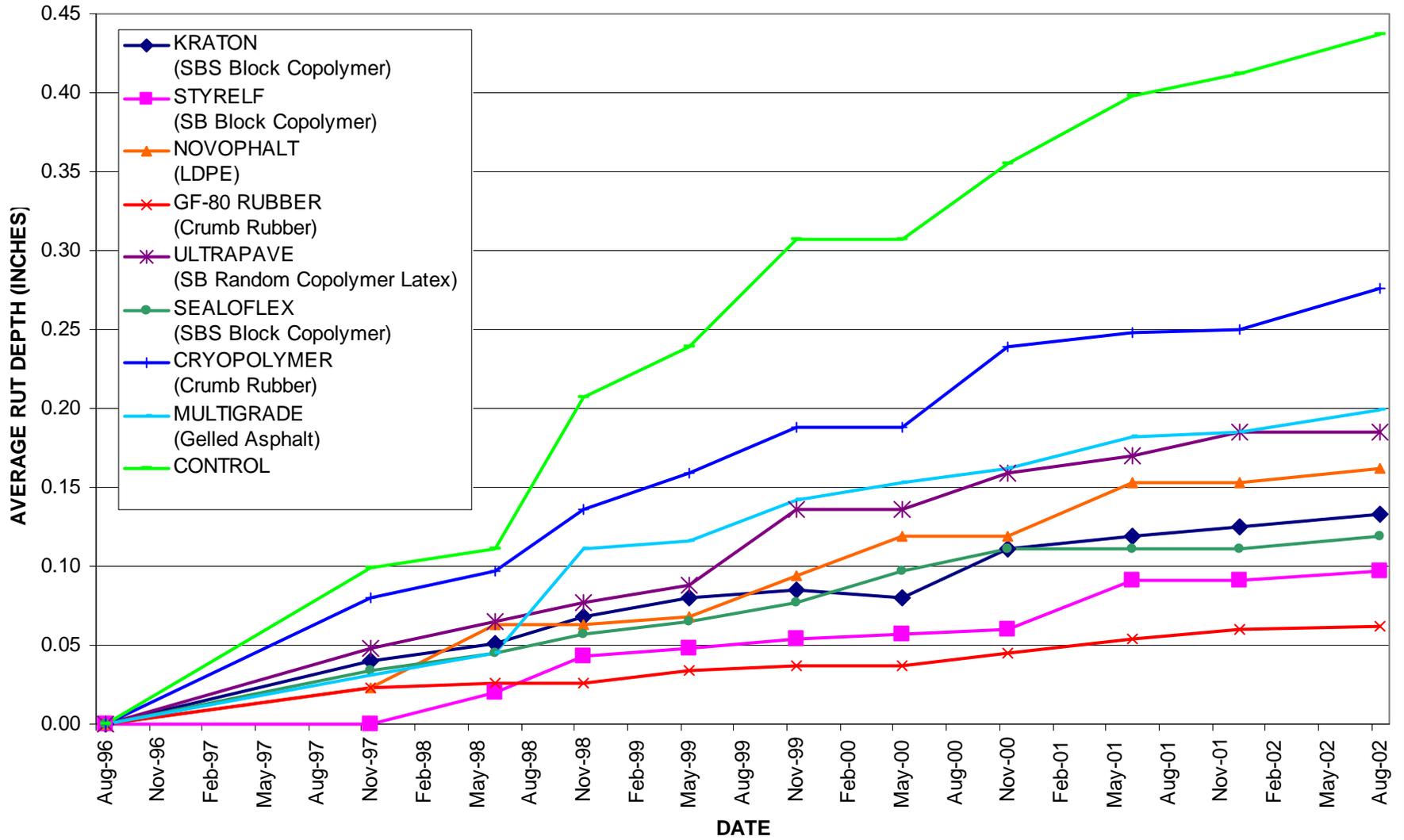


Figure 4 – Rut Performance

PAVEMENT CONDITION RATINGS

Rut resistance is only one desirable quality of a flexible pavement. A pavement can be so stiff that it fails to deform in the wheel paths but due to its stiffness it exhibits many other forms of distress such as cracking and raveling. These forms of distress are detrimental to the structure of a pavement primarily because they allow moisture to infiltrate the pavement system.

MDOT utilizes a Pavement Condition Rating (PCR) to characterize the health of its network of pavements. The PCR is on a scale of 0 – 100 with 100 characterizing a pavement in perfect condition. MDOT calculates PCR's based on the formula below:

$$\text{PCR} = 100 \left(\frac{12 - \text{IRI}}{12} \right)^{.9567} \left(\frac{205 - \text{DP}}{205} \right)^{1.4857}$$

where,

PCR = Pavement Condition Rating
IRI = International Roughness Index (mm/m)
DP = Distress Deduct Points

IRI is collected using the Departmental high speed inertial profiler which utilizes a three point laser for smoothness data collection. Distress Deduct Points (DP) was developed by Dr. K.P. George at the University of Mississippi as part of MS State Study No. 119.³ The DP is based upon the distresses identified in the *Distress Identification Manual for the Long-Term Pavement Performance Project SHRP-P-338*⁴ developed by the Strategic Highway Research Program (SHRP) and quantifies the amount of distress that is identified in a 500' long x 12' wide (one lane width) section of pavement.

³ "Pavement Management Information System – Phase II" (State Study No. 119, FHWA/MS-DOT-RD-93-119), Department of Civil Engineering, The University of Mississippi, February 1993.

⁴ "Distress Identification Manual for the Long-Term Pavement Performance Project" (FHWA-RD-03-031), Office of Infrastructure Research and Development, Federal Highway Administration, June 2003.

Over the project life the PCR was determined for each section on two occasions. Additionally the initial PCR for each section immediately upon completion of construction has been assumed to be 97. Using these three PCR data points, conclusions as to the degradation of each modified section can be made.

PCR Performance

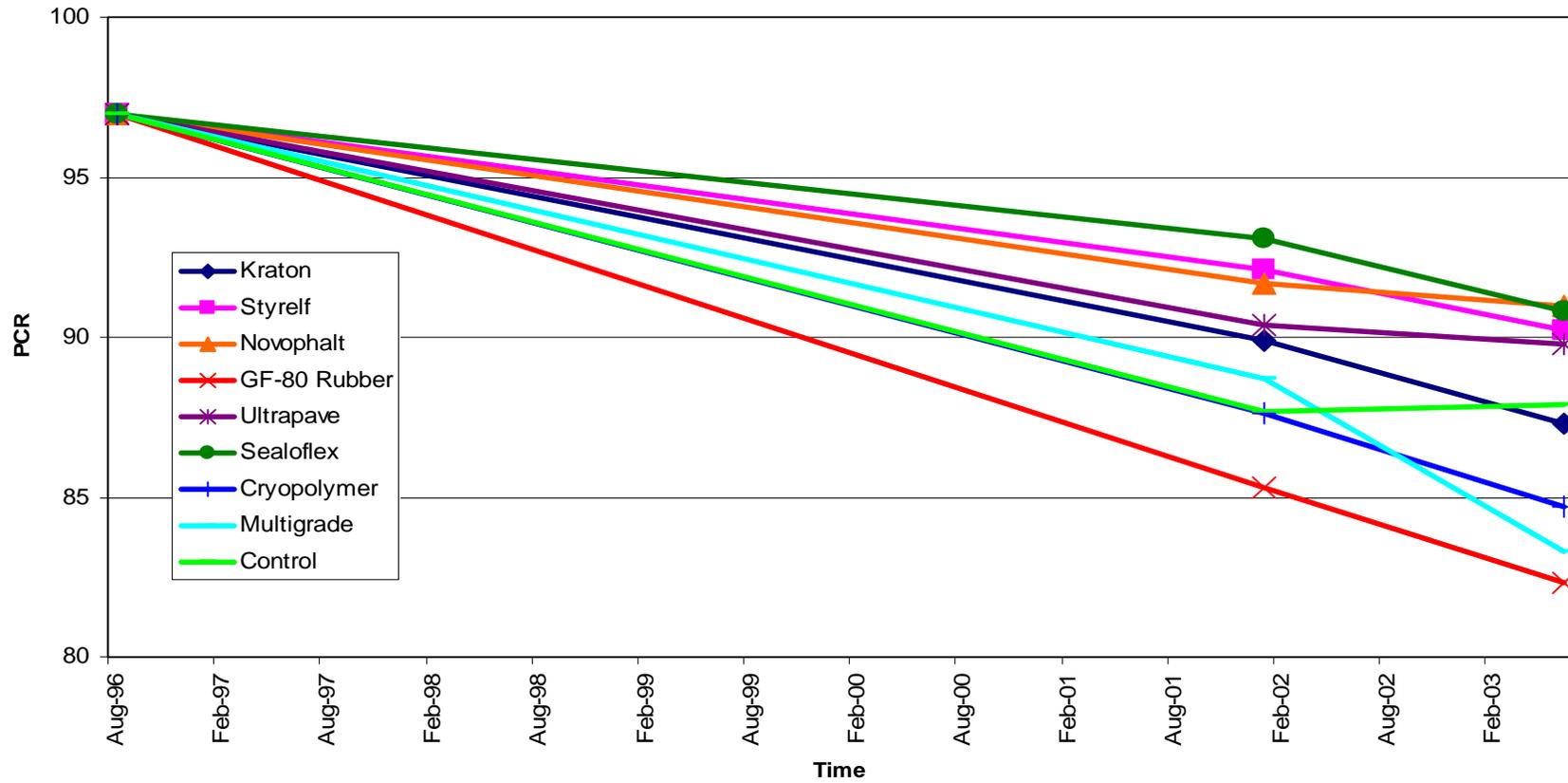


Figure 5 – PCR Performance

ESTIMATED REMAINING SERVICE LIFE

MDOT's criteria for rehabilitating existing flexible pavements on its Interstate system is to address those pavements that have a PCR of less than 72 or an average rut depth of greater than 0.25 inches. Therefore it is at these thresholds that MDOT considers an Interstate pavement to have extinguished its remaining service life.

Using the PCR & rut data for each of the modified sections a linear extrapolation based on performance to date can be calculated and an estimated time to a PCR of 72 and a rut depth of 0.25 inches can be obtained. For example, for the Kraton modifier section:

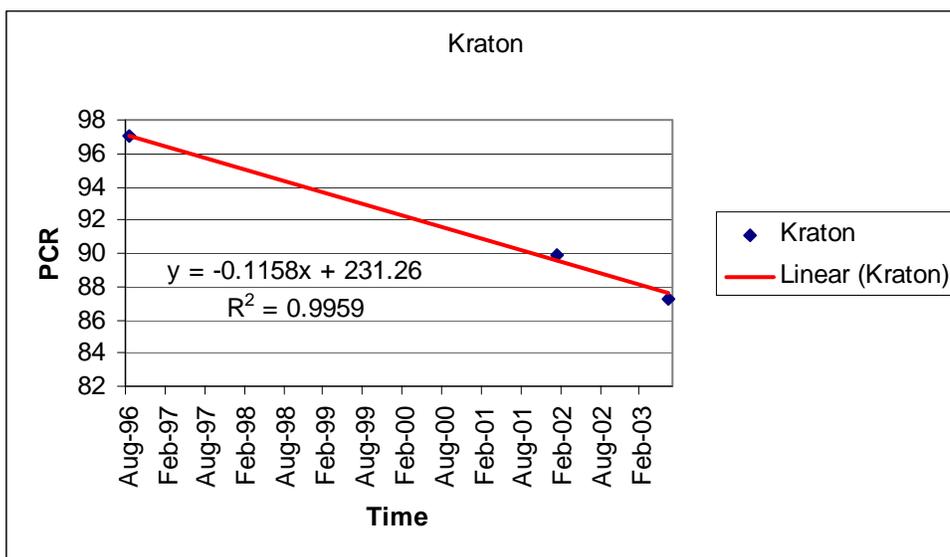


Figure 6 – Kraton PCR Performance

Based on the PCR performance to date, the following equation for PCR related to time for the Kraton section can be calculated:

$$y = -0.1158x + 231.26$$

where,

$$\begin{aligned} y &= \text{PCR} \\ x &= \text{time} \end{aligned}$$

Using this equation it can be calculated that the Kraton modified section will reach a PCR of 72 in the year 2014.

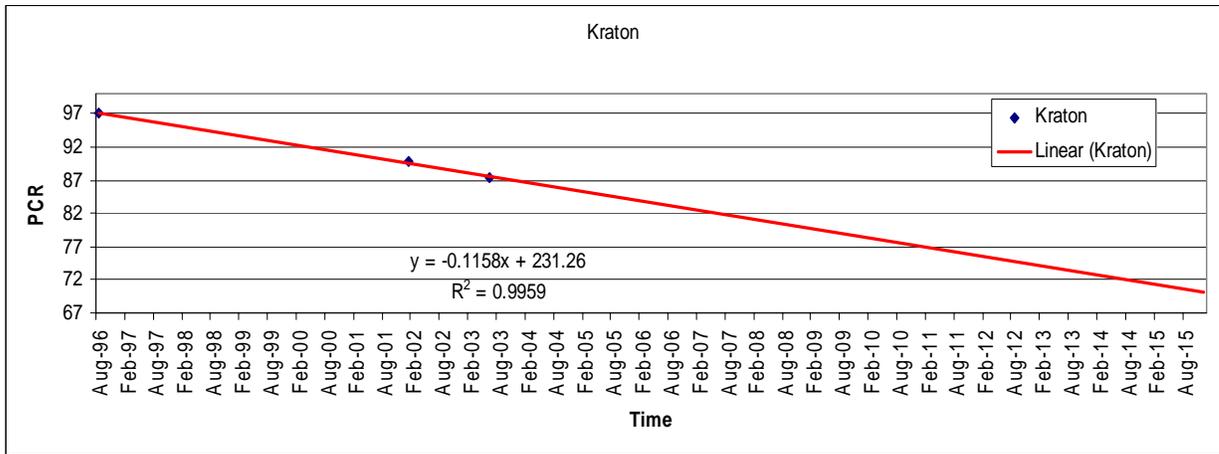


Figure 7 – Extrapolated Kraton PCR Performance

Similarly this calculation can be made with respect to the rut performance of each section. For example, the rut measurements for the Kraton section can be plotted and an equation calculated that relates rut depth to time.

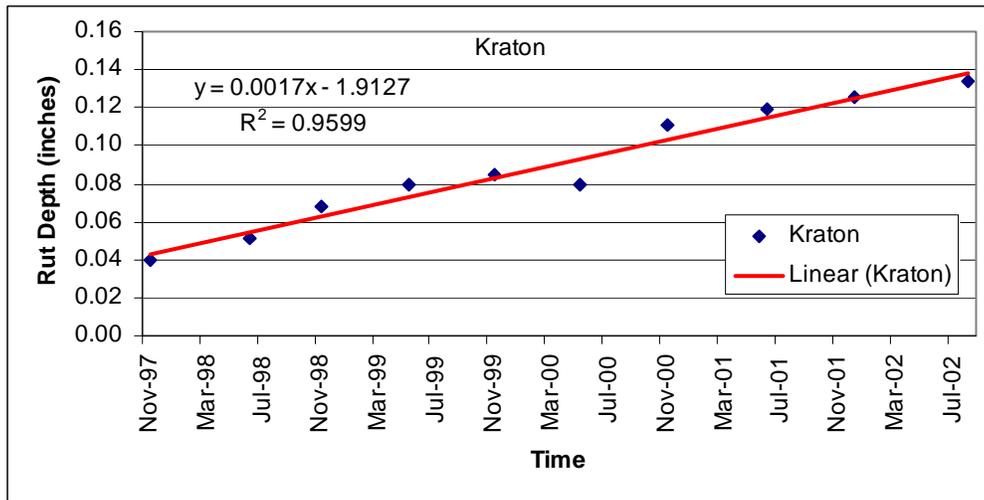


Figure 8 – Kraton Rut Performance

Based on the rut resistance to date, the following equation for rut depth related to time for the Kraton section can be calculated as:

$$y = 0.0017x - 1.9127$$

where,

y = rut depth (in.)

x = time

Using this equation it can be calculated that the Kraton modified section will reach a rut depth of 0.25" in the year 2008.

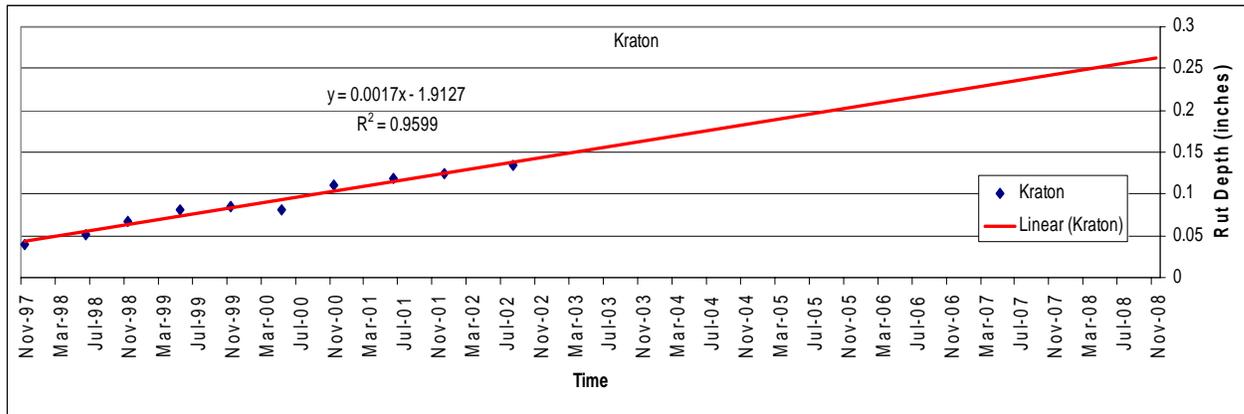


Figure 9 – Extrapolated Kraton Rut Performance

By performing this exercise for each of the sections a remaining service life with respect to both PCR & rut depth can be calculated for each section. Since MDOT considers the service life to be exhausted when either one of the thresholds has been met, the earlier date that the PCR or rut depth has been achieved for each modifier can be considered the point at which the pavement has no remaining service life.

<u>Modifier</u>	<u>.25" Threshold Date</u>	<u>PCR 72 Threshold Date</u>
Kraton	2008	2014
Styrelf	2010	2023
Novophalt	2005	2024
GF-80 Rubber	2023	2008 (see note below)
Ultrapave	2004	2019
Sealoflex	2009	2026
Cyropolymer	2001	2010
Multigrade	2003	2010
Control	1999	2014

Table 10 - Remaining Service Life Results (bold indicates critical date)

It should be pointed out that previous research has demonstrated that the degradation of pavement condition is best characterized by a parabolic curve rather than a linear relationship. This is to say that as a pavement deteriorates the rate of degradation begins to increase with time. Therefore the pavement sections would reach the MDOT PCR threshold of 72 much

quicker than a linear relationship would produce. Unfortunately this research provided only three values for PCR throughout the life of the pavement sections and was therefore impossible to accurately characterize the actual distress rate in terms of a parabolic curve. Fortunately the controlling critical MDOT rehabilitation threshold date for all but one section was a function of the rut performance. The author would caution the reader in placing too much emphasis on the year 2008 PCR threshold for the GF-80 rubber. Undoubtedly this section will reach its PCR threshold much sooner than a linear relationship is capable of producing.

For a complete listing of extrapolated linear PCR & rut depth values for each modified section see Appendix A.

SKID RESISTANCE

The Mississippi Department of Transportation utilizes a full-scale ribbed automotive tire pavement friction tester in accordance with ASTM E 274-90 to monitor the skid resistance on its network of pavements. During the course of the polymer field trial project, each test section was periodically tested in accordance with the standard departmental operating procedure for skid resistance data collection. Measurements are taken using a ribbed tire conforming to ASTM E501 at a traveling speed of 40 mph.



Figure 11 -MDOT Pavement Friction Tester

As evidenced by the friction data shown for all of the sections, no discernable difference in friction was exhibited with respect to polymer modification. Each section began the project with a friction number in the upper 40's to low 50's and as the sections aged the friction decreased and to and stabilized in the lower 40's to upper 30's range.

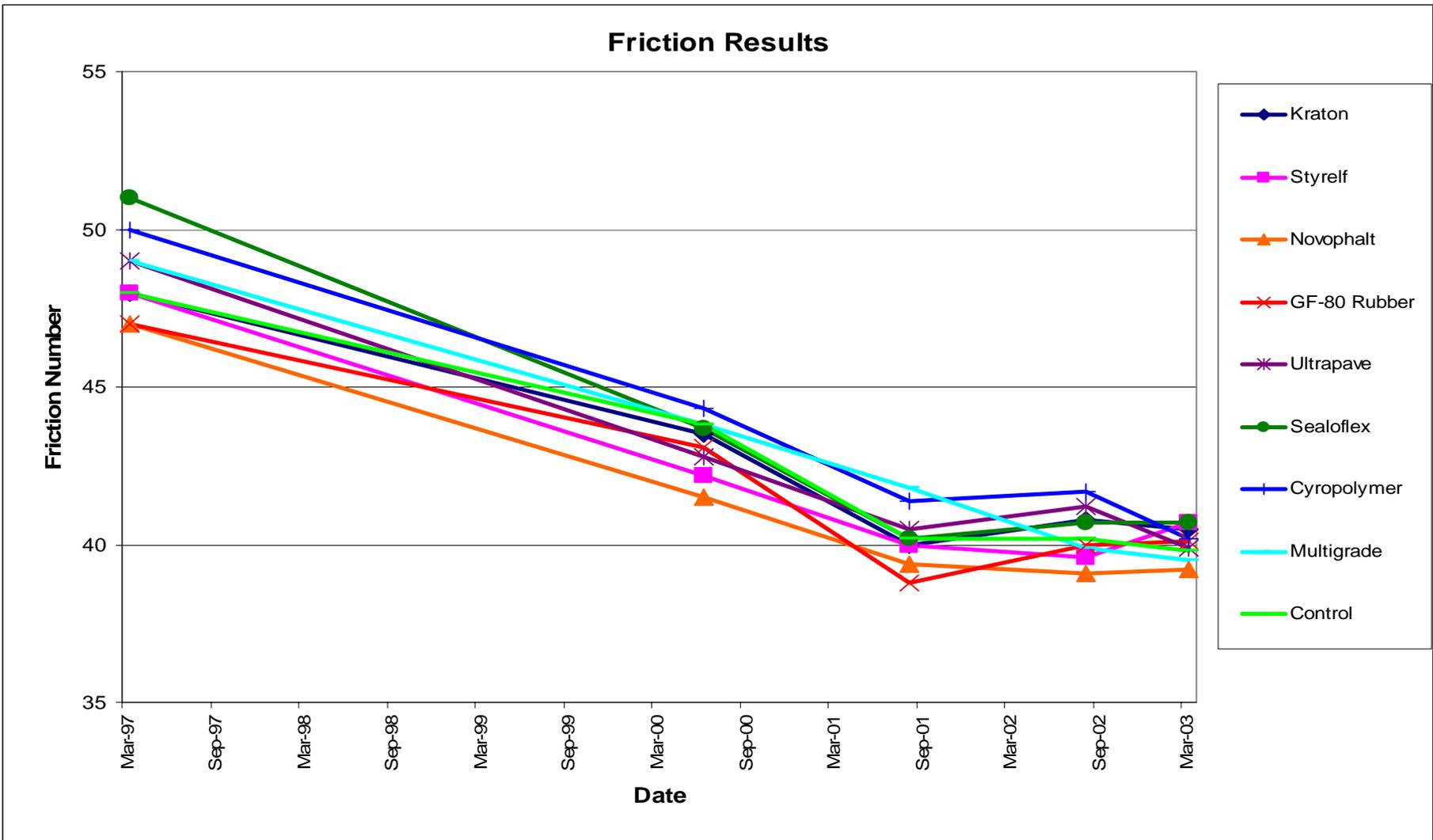


Figure 12 – Friction Results

MACROTEXTURE

For the purpose of measuring surface macrotexture depth for each modified pavement analysis section, MDOT utilized the method set forth in ASTM Standard E 965-87. This method utilizes solid glass spheres having 90% roundness in accordance with ASTM Test Method D 1155. The glass spheres must be graded to have a minimum of 90% by weight passing a No. 60 sieve and retained on a No. 80 sieve.



Figure 13 – Spreading glass spheres into circular patch for Macrotexture measurement

Macrotexture data was collected on three separate occasions for each analysis section during the life of the project. The macrotexture results are useful in determining how much “fine” material has been lost from the surface of the asphalt pavement. Based on this loss of fine material a generalization can be made regarding the propensity of the pavement surface to allow moisture infiltration into the system.

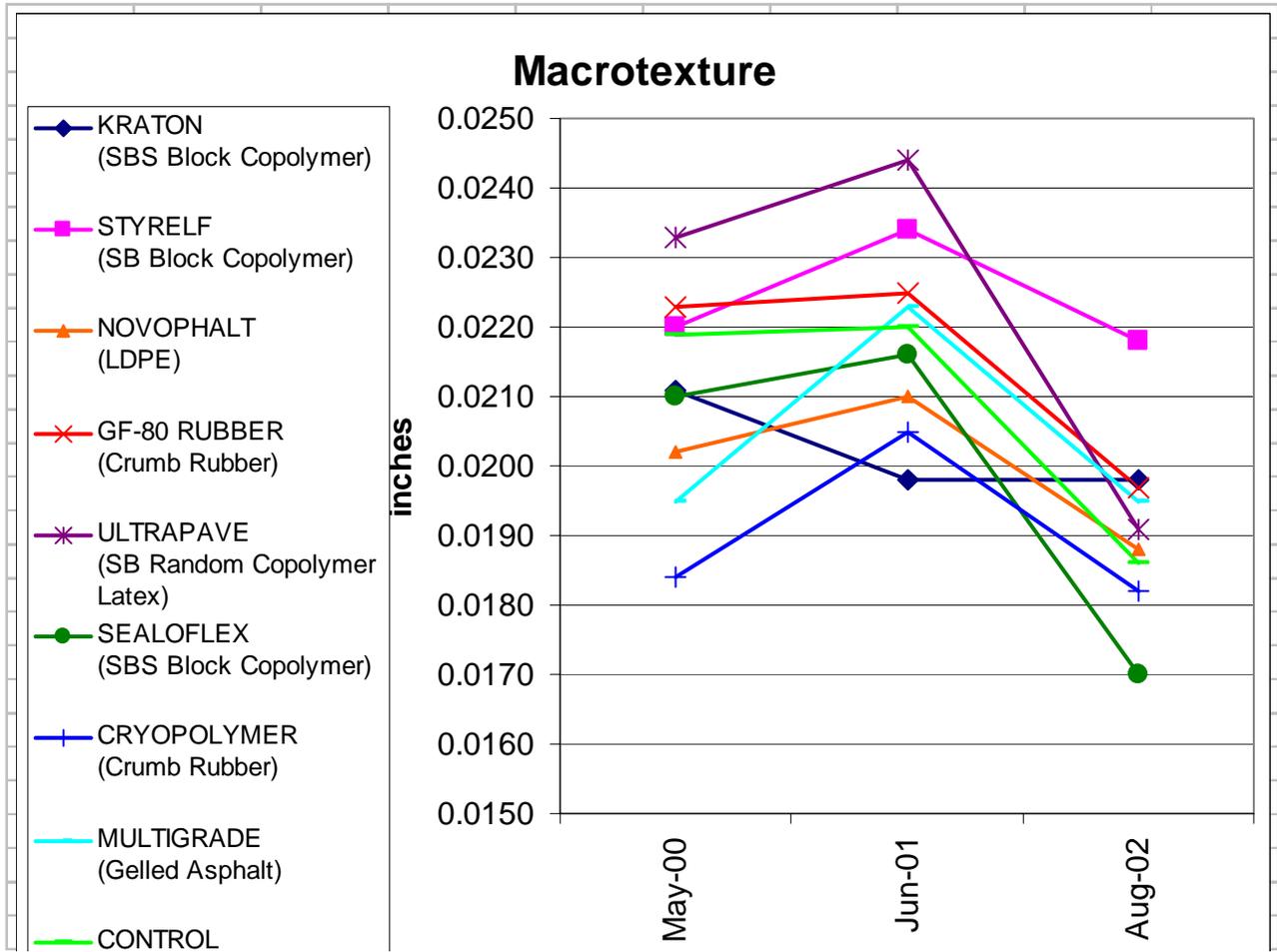


Figure 14 – Macrotexture Results

CONCLUSIONS

The preliminary findings of this research led MDOT in February 1998 to adopt Special Provision No. 907-702-10 "Petroleum Asphalt Cement and Polymer Modified Petroleum Asphalt Cement". As related to polymers, the requirements of this special provision were the following:

1. Unless otherwise specified, polymer modified asphalt cement for use in plant mix bituminous base and pavements shall conform to AASHTO Designation: MP-1, Grade PG 76-22.
2. Asphalt cement Grade PG 76-22 shall be the product resulting from the addition of a polymer modifier to a PG 64-22 or lower grade asphalt cement and not by some other refining technique.
3. The polymer shall be a Styrene Butadiene Styrene, a Styrene Butadiene Rubber or an equal approved by the Engineer. The polymer shall be thoroughly blended with the asphalt cement at the refinery or terminal prior to shipment to the hot mix plant.
4. Crumb rubber shall be produced by ambient grinding methods.

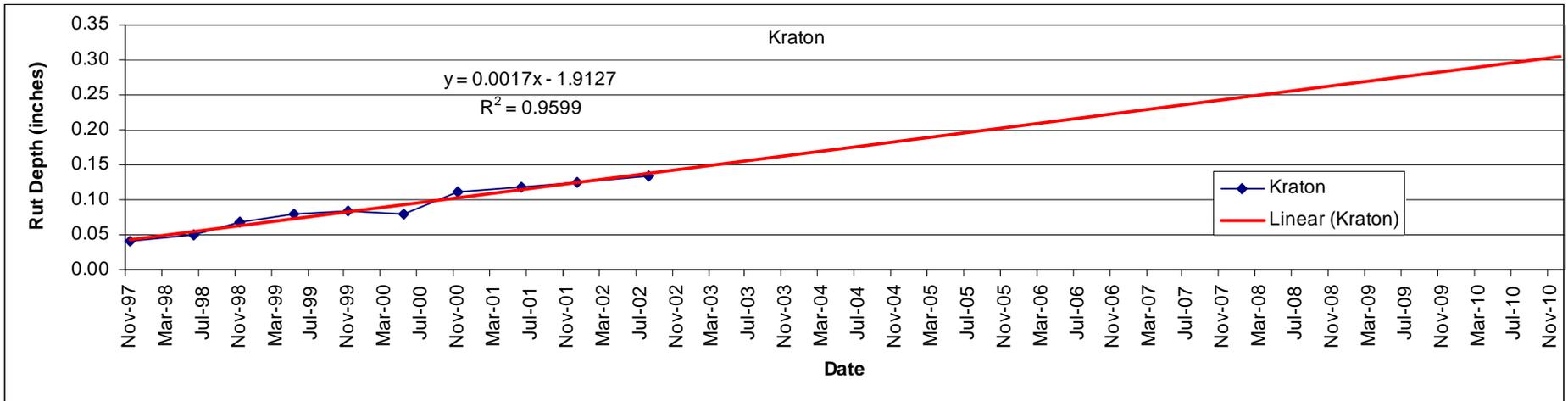
Currently MDOT is paying less than 10% more per ton for polymer modified hot mix asphalt as opposed to hot mix asphalt containing no polymer modification. The results of this research show that the types of polymers most commonly utilized by MDOT (i.e. Kraton, Styrelf and Sealoflex) are exhibiting a service life in excess of 400% of that which the control section (neat asphalt) is providing. Therefore for less than a 10% increase in the cost of the material, MDOT is achieving a service life increase of over 400%.

MDOT is certainly realizing substantial benefit from the utilization of polymer modification of asphalt binders. It will however take time to implement polymer modification throughout the network. With each polymer modified asphalt pavement that is constructed in Mississippi, the

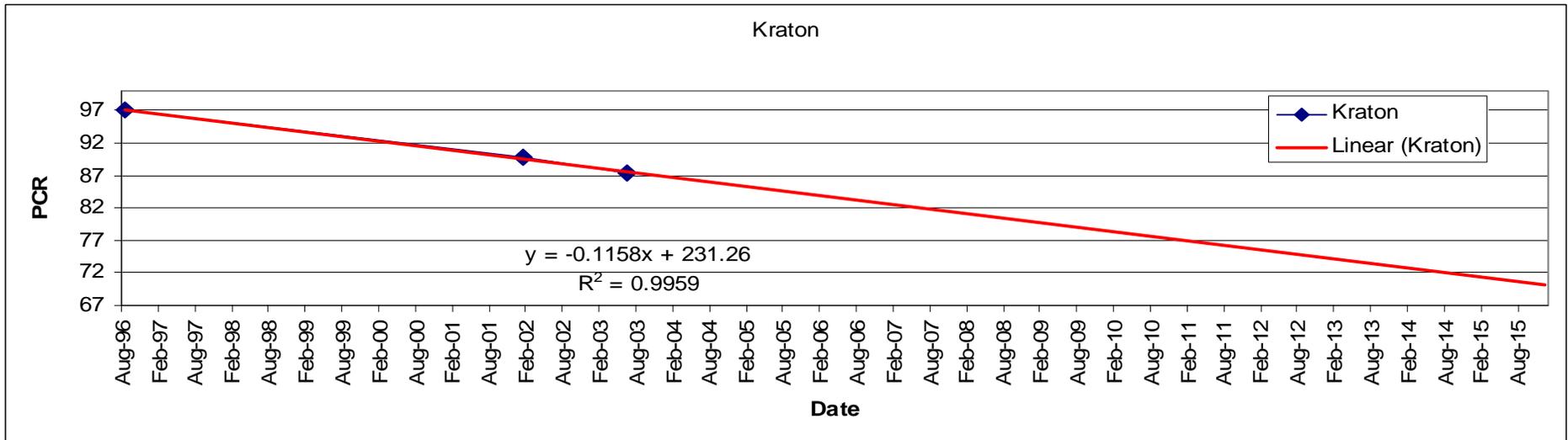
service life of the system is being extended, thus providing a more economical network of pavements. More importantly, by reducing a pavements propensity to rut, MDOT is creating a safer system of highways, thereby protecting Mississippi's most precious resource....her people.

Appendix A

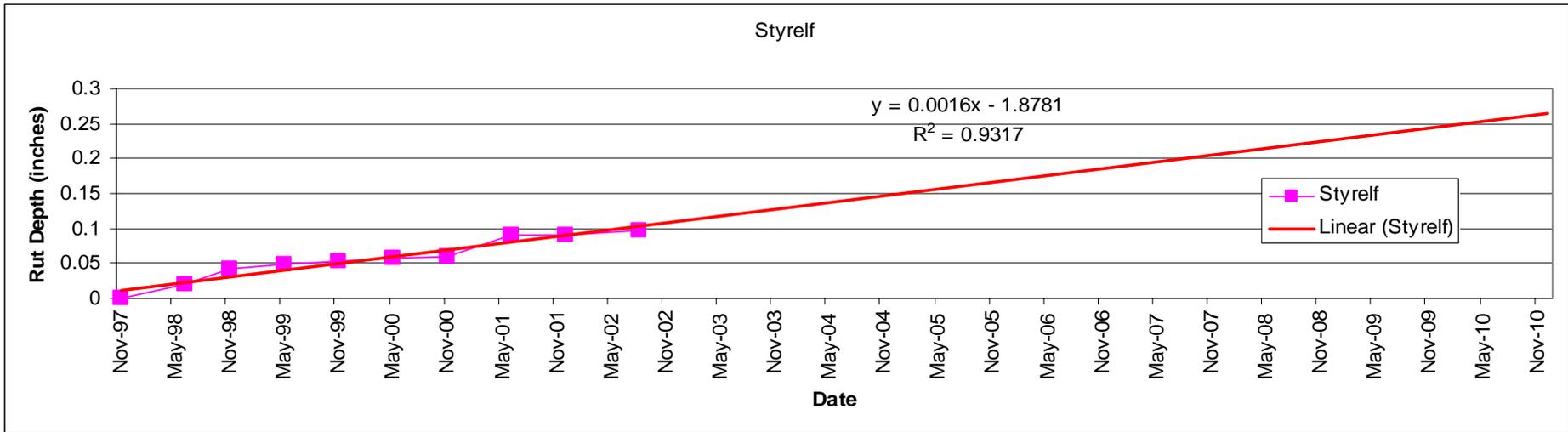
PCR & Rut Performance Extrapolation Data



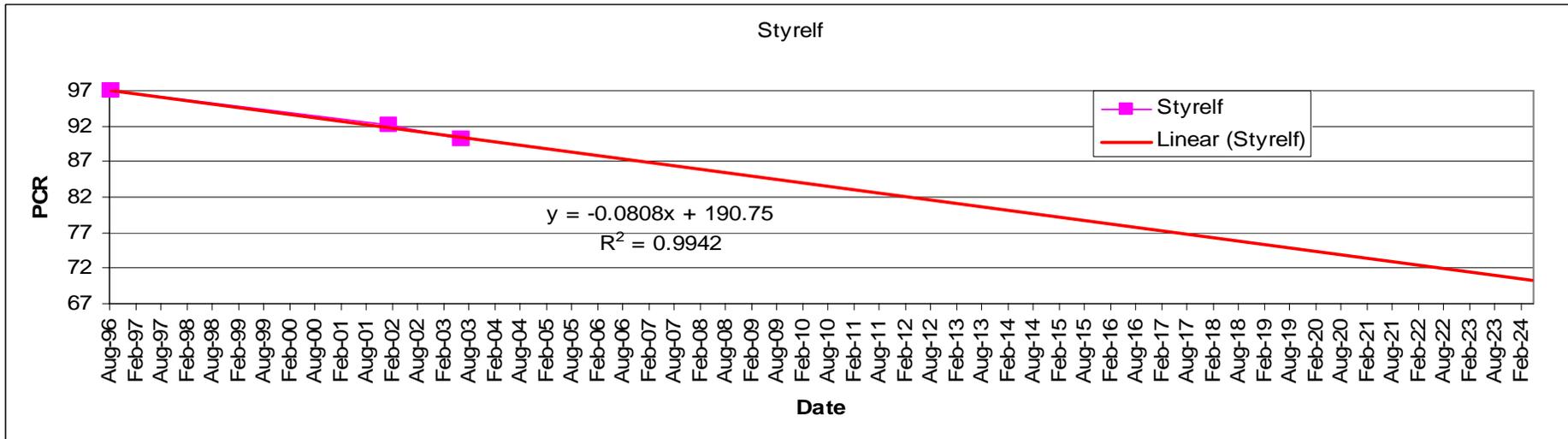
Kraton Extrapolated Rut Performance



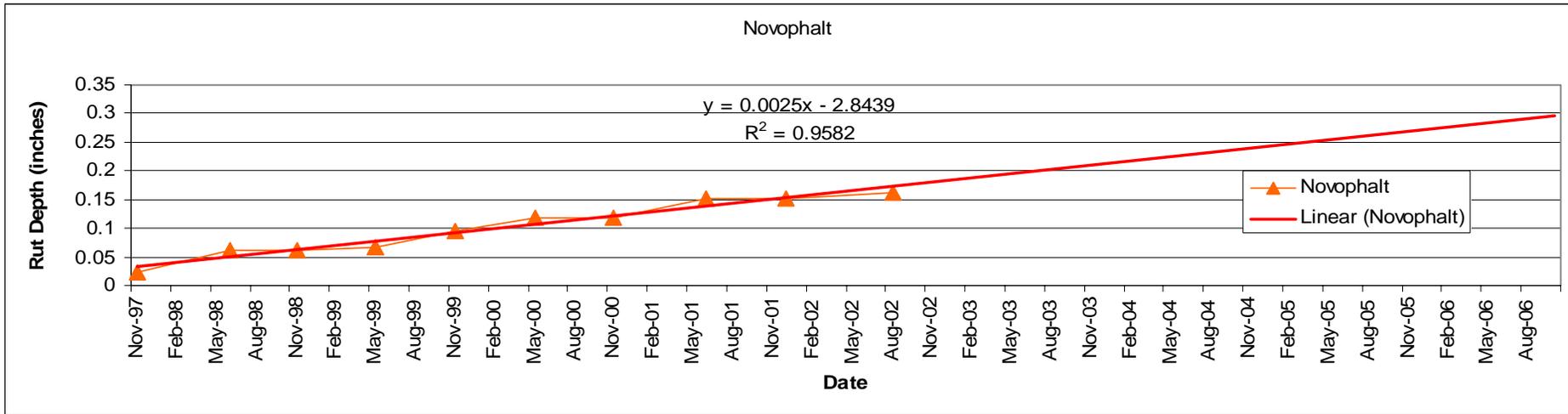
Kraton Extrapolated PCR Performance



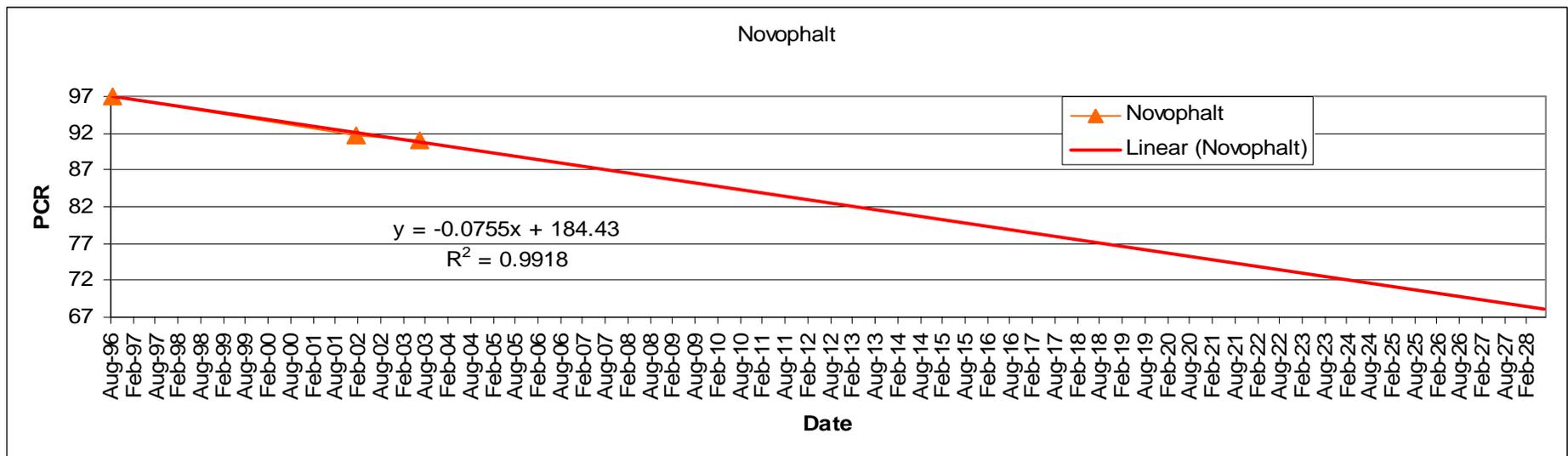
Styrelf Extrapolated Rut Performance



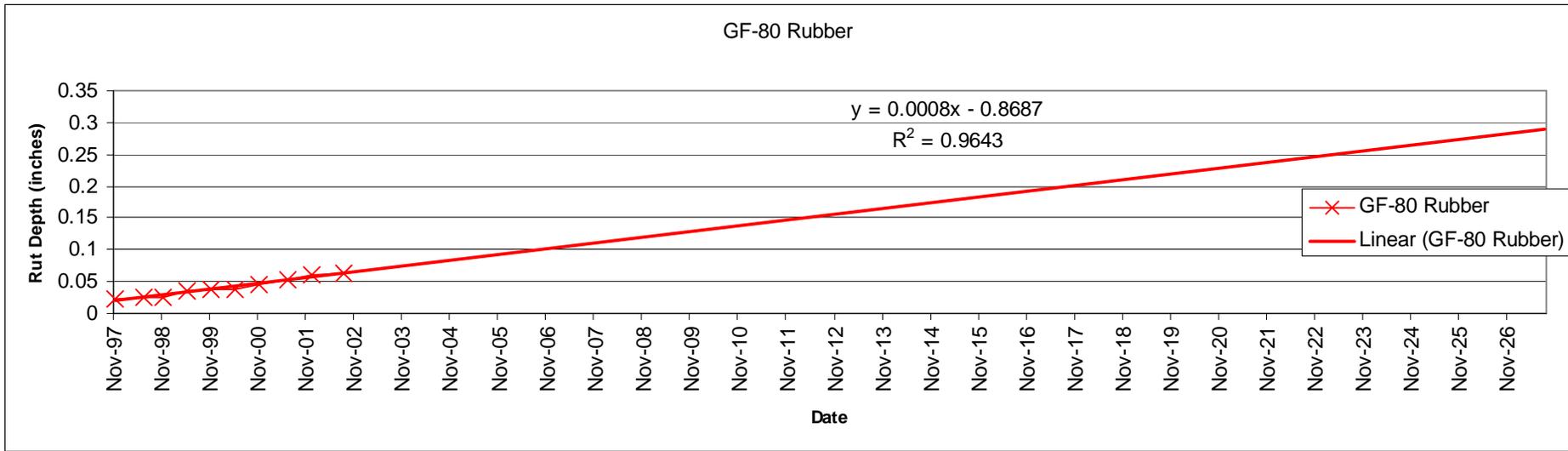
Styrelf Extrapolated PCR Performance



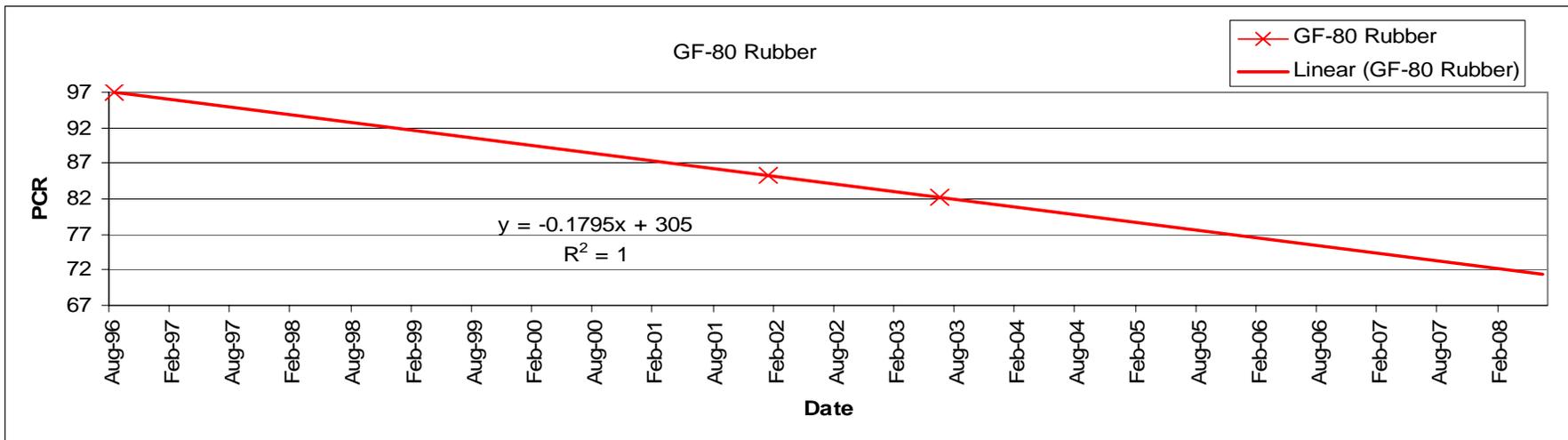
Novophalt Extrapolated Rut Performance



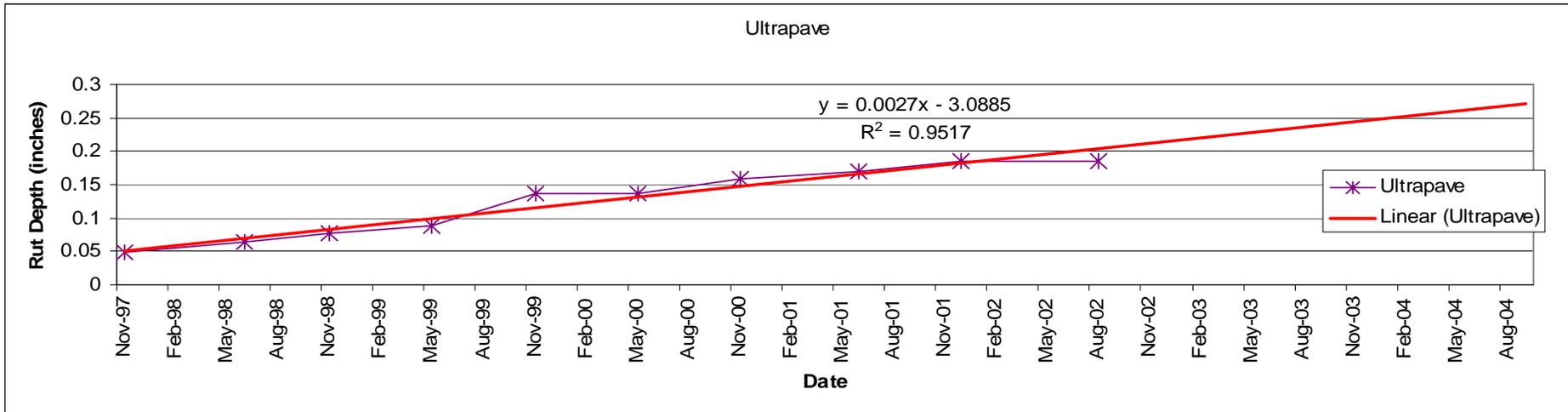
Novophalt Extrapolated PCR Performance



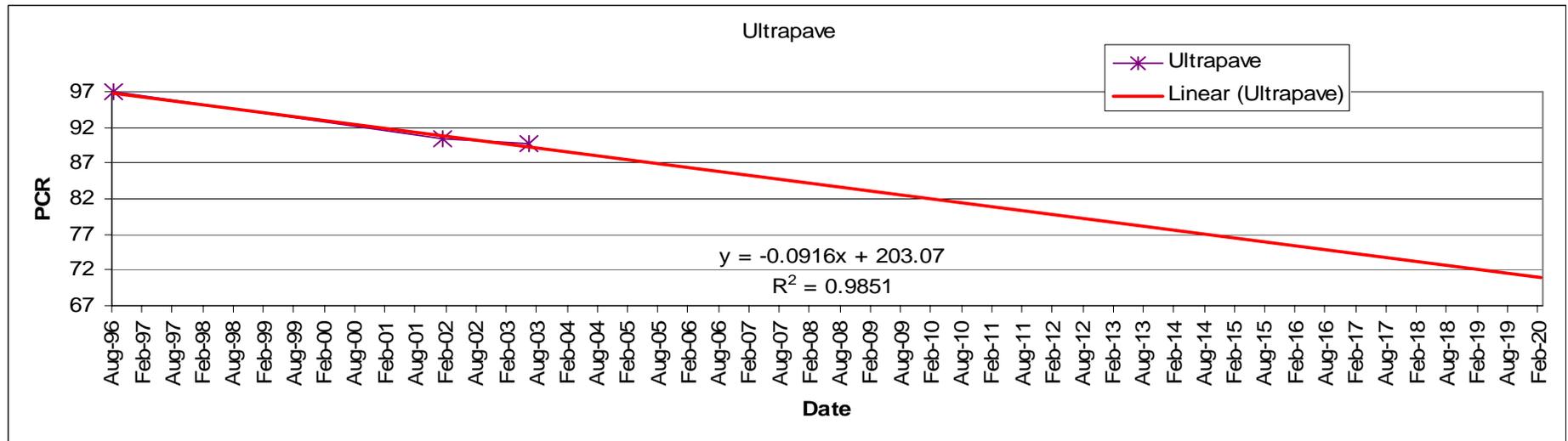
GF-80 Rubber Extrapolated Rut Performance



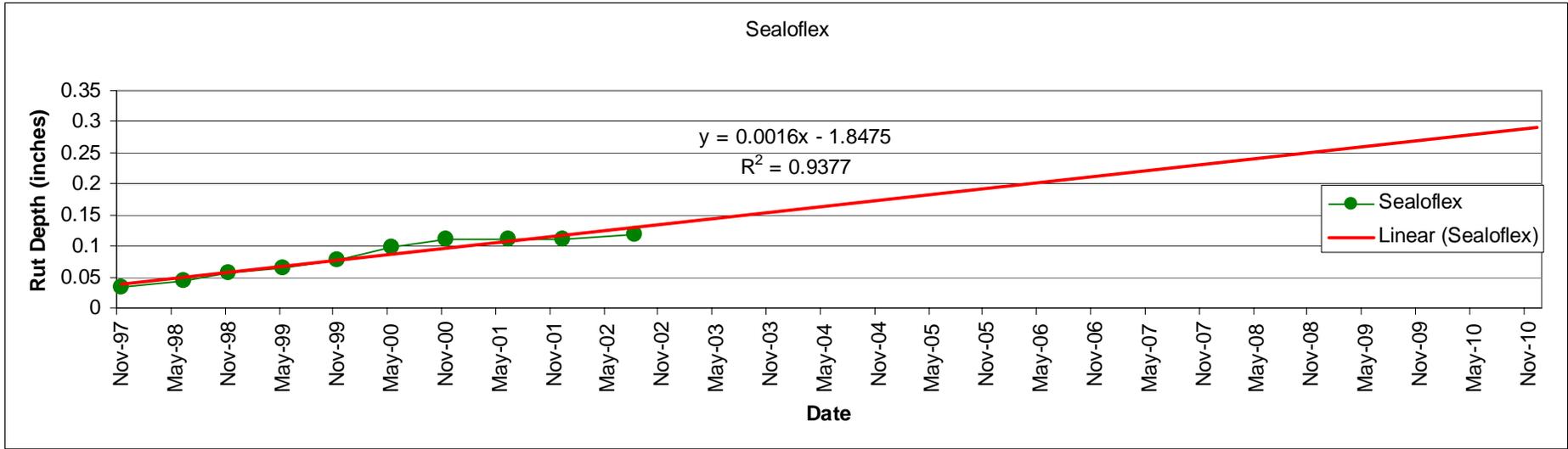
GF-80 Rubber Extrapolated PCR Performance



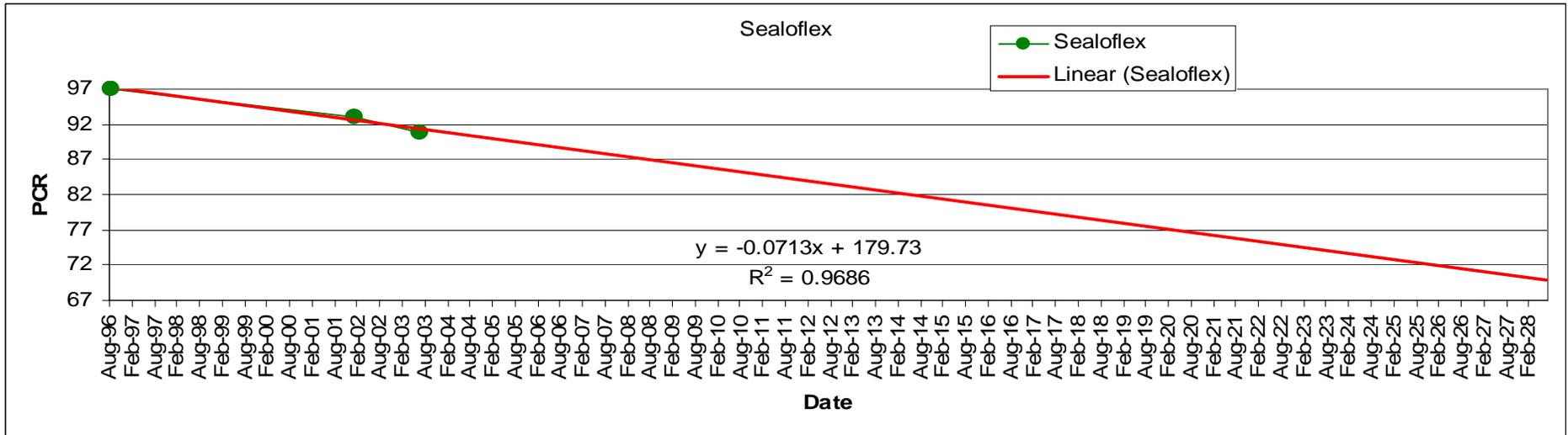
Ultrapave Extrapolated Rut Performance



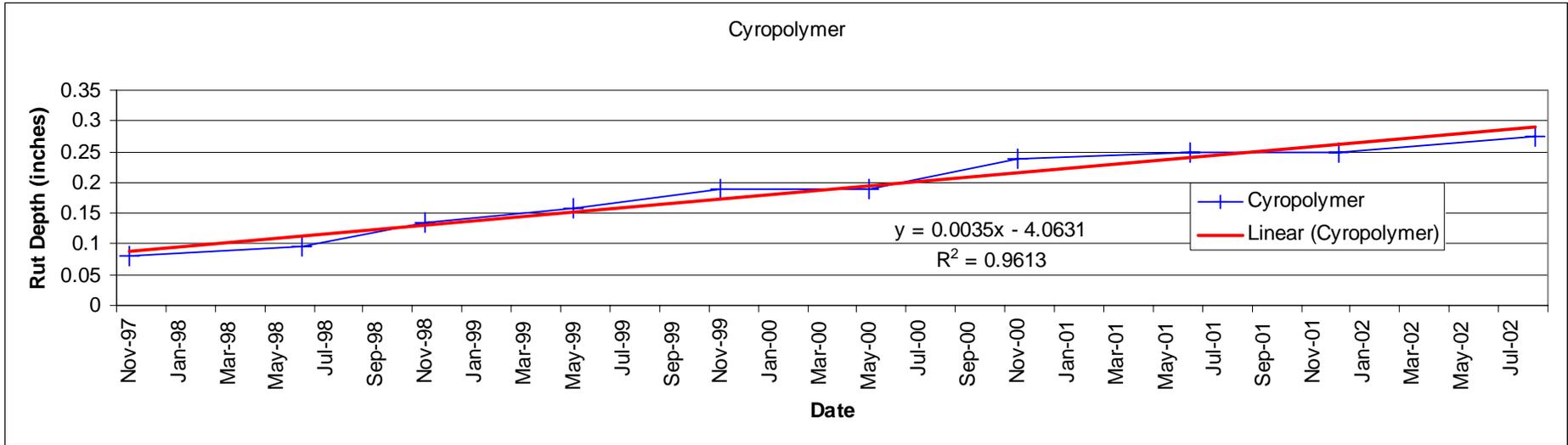
Ultrapave Extrapolated PCR Performance



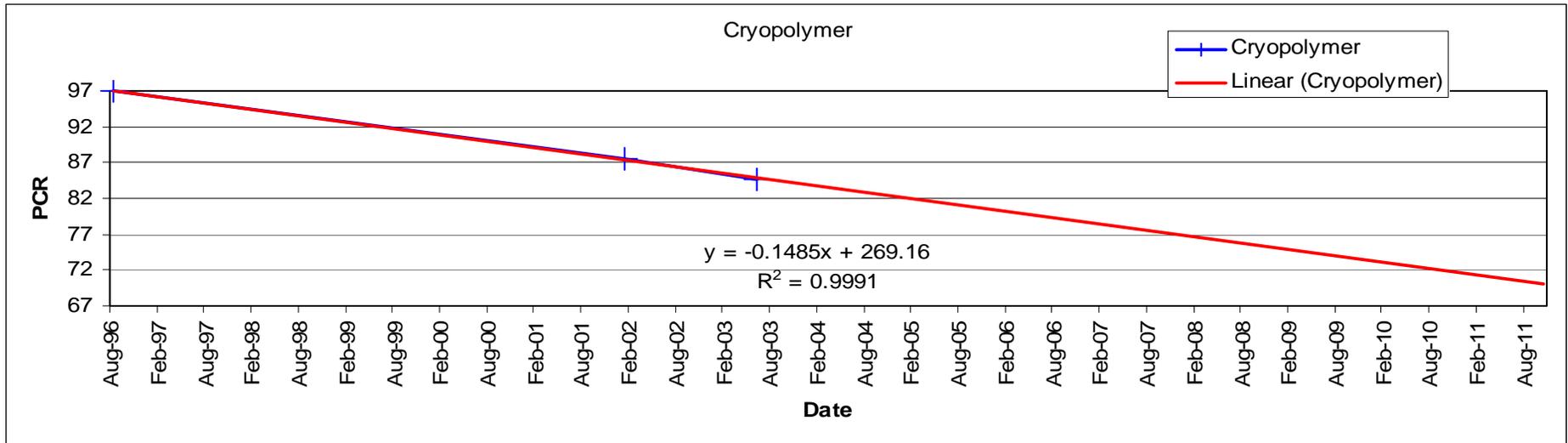
Sealoflex Extrapolated Rut Performance



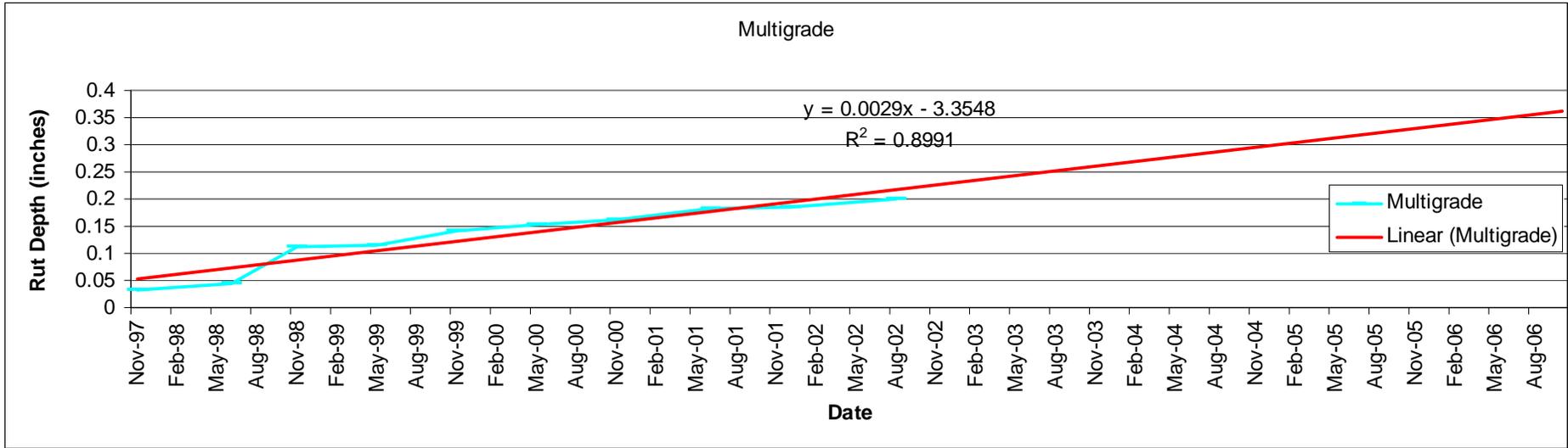
Sealoflex Extrapolated PCR Performance



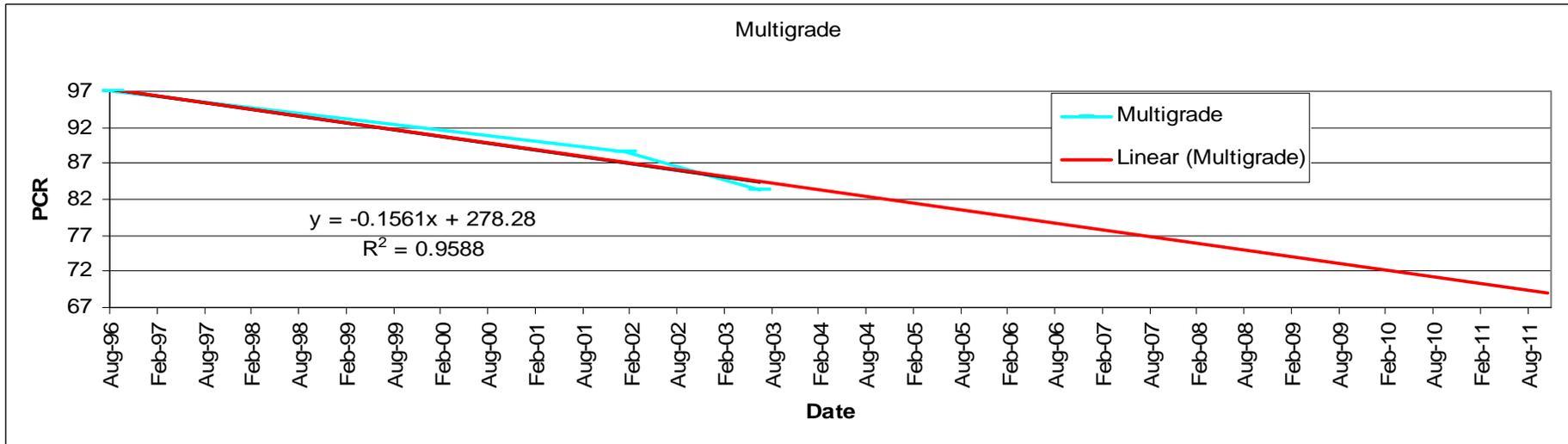
Cyropolymer Extrapolated Rut Performance



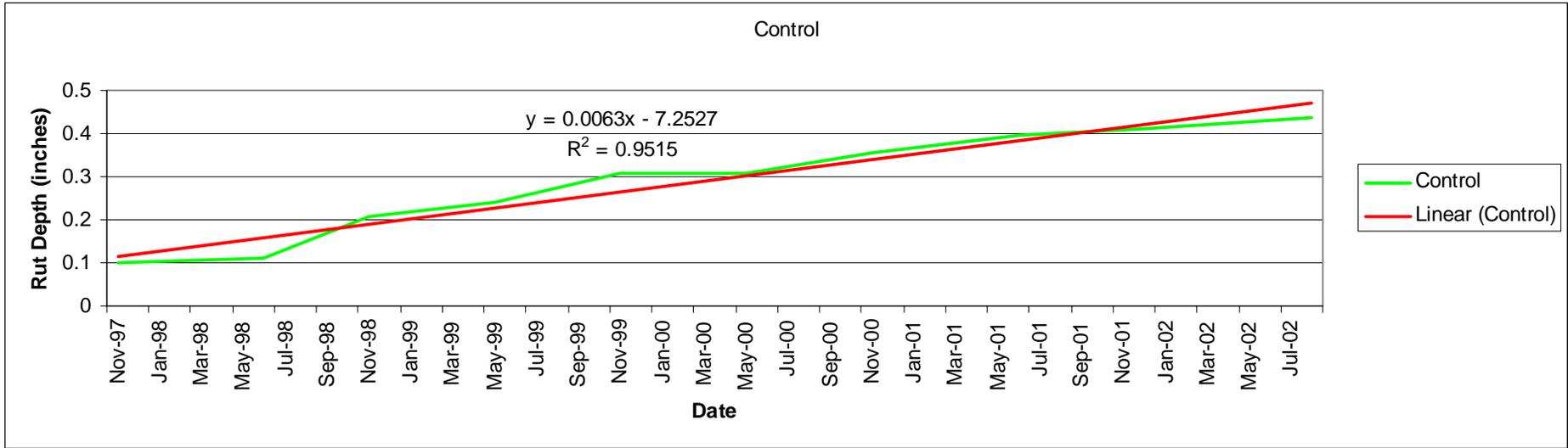
Cyropolymer Extrapolated PCR Performance



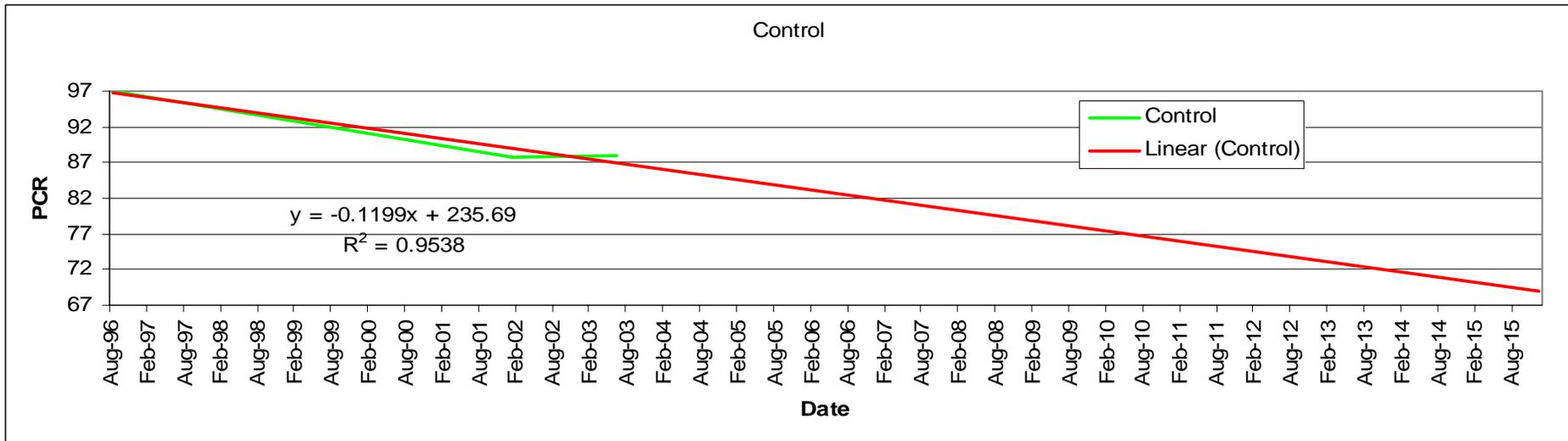
Multigrade Extrapolated Rut Performance



Multigrade Extrapolated PCR Performance



Control Extrapolated Rut Performance



Control Extrapolated PCR Performance