NDOT Research Report

Advancing Durable Pavement Marking Materials in Nevada

Final Management Report

December 2005

A Report on Research Sponsored by

Nevada Department of Transportation
Carson City, Nevada

and

Federal Highway Administration

ADVANCING DURABLE PAVEMENT MARKING MATERIALS IN NEVADA

FINAL MANAGEMENT REPORT

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16. Abstract

The durability of pavement markings was identified as an operational issue in all of the Nevada Department of Transportation (NDOT) maintenance districts. Epoxy traffic paint, the primary material for striping high-volume roadways, was not performing as expected. An investigation into the cause of the poor serviceability resulted in the determination that the problem was systematic, and not due to any singular cause. Various environmental, installation, material, and miscellaneous complications occurred that reduced the expected service life.

A state survey was conducted to determine what experience other states were having with common pavement marking materials. Responses from twenty-three states indicated that no single factor appeared to stand out as the common determinate of superior product that correlates with the service life of pavement marking materials.

Thirty pavement marking products were applied and evaluated on five test sites in Nevada. The materials included waterborne, polyurea, epoxy, alkyd thermoplastic, and permanent tape products. Test sections consisted of edge and centerline application that varied in length from 0.15 to 3 miles long. The test sections were monitored for retroreflectivity, color, and durability data. Test site results show that the life expectancy of pavement markings varied greatly and were dependent upon placement procedures, snow removal activities, and ultraviolet degradation of the yellow colored materials. Assorted traffic bead gradations and waterborne paint application rates were compared.

The complete examination of all procedures involved with pavement marking application resulted in modification of established methods and provided an environment for obtaining higher quality pavement markings. Modifications included specification adjustments, qualified products list changes, constructability enhancements, and materials, sampling, and testing improvements.

A pavement marking matrix was developed for use on all NDOT contract and restriping work. The matrix includes material application guidelines for varying traffic and climatic conditions based upon the experience of in-house personnel. The matrix provides systematic and cost-effective guidelines for decision makers.

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NOMENCLATURE

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
ASTM	American Society for Testing and Materials International
C	Catalyst
CL	Centerline
CY	Cubic Yards
DOT	Department of Transportation
DUR	Durability
E	East
Ea	Each
EPI	Ennis Paint, Incorporated
EPO	Epoplex
FHWA	Federal Highway Administration
GAL	Gallon
LF	Lead Free
M	Million
MP	Milepost or Moisture Proof
MPH	Miles Per Hour
N	North
NCHRP	National Cooperative Highway Research Program
N/A	Not Applicable
N/AVAIL	Not Available
NDOT	Nevada Department of Transportation
NHS	National Highway System
NTPEP	National Transportation Product Evaluation Program
OGWC	Open-grade Wearing Course
PBS	Plantmix Bituminous Surface
PCCP	Portland Cement Concrete Pavement
PCI	Poly-Carb, Incorporated
PPC	Pervo Paint Company
QPL	Qualified Products List
R	Resin
RR	Retroreflectivity Readings
S	South
SR	State Route
Spec	Specification
SW	Sherwin Williams
TMT	TMT-Pathway LLC
TRB	Transportation Research Board
TRIS	Transportation Research Information Services
US	United States Route
VRB	Variable
W	West
YR	Year

EXECUTIVE SUMMARY

Problem Statement

The durability of pavement marking materials was identified as an operational issue in all Nevada Department of Transportation (NDOT) districts. Epoxy traffic paint, the primary material for striping high-volume roadways, was not performing as expected. A review of epoxy traffic paint striping costs revealed that NDOT spent over $9,000,000 for epoxy traffic paint between 1995 and 2000. Approximately 40% of the projects this money was spent on were deemed unacceptable. The numerous complaints from NDOT construction and maintenance personnel resulted in a collective effort by a specially formed Pavement Marking Task Force and this research effort to improve the longevity of pavement markings at minimum cost. Failure to act on this situation would have resulted in further economic loss.

Choosing effective pavement marking materials to be used in arduous climatic conditions with varying traffic volumes can be difficult for decision makers faced with budget constraints and a large roadway system to maintain. Decision makers must contend with many nonmaterial issues when choosing effective pavement markings. Proper installation methods are critical in order to obtain the expected service life of the material. Damage from snow removal activities will reduce the effectiveness and durability of pavement markings. Choices for extending service life in high snowplow areas are limited and very costly. As such, decision makers must weigh the benefits of expected service life, user delay cost, type of material, and placement procedures when selecting products to be used in different locations.

With so many pavement marking materials available, choosing and placing products that work best in specific conditions can be time consuming and confusing. The objective of this research was to develop a matrix listing recommended marking products to be used under differing environmental conditions and traffic volumes. The matrix is intended to be a guideline for decision makers tasked with creating a safe roadway environment for the traveling public. Use of the matrix will prevent product placement errors and provide consistency in the roadway network.

Findings

NDOT Construction Personnel Survey

Investigation into the cause for the poor durability of epoxy traffic paint was conducted. A survey of construction personnel revealed that numerous complications occurred during initial pavement marking operations that contributed to the lack of long-term durability. Installation problems such as poor surface preparation, equipment malfunction, thin material coating thickness, and improper mixing all contributed to poor placement procedures. Environmental issues such as low ambient temperature during product placement and insufficient curing of open-grade wearing surfaces had deleterious affect on product durability. Additionally, lack of experienced installation operators, deficient inspection procedures, and the inability to properly handle the workload of the striping season contributed to poor performance. Because of all these issues, it was determined that the poor durability of epoxy traffic paint was a systematic problem, and not due to any singular cause. Every pavement marking project deemed unacceptable was due to a unique problematic combination of occurrence that reduced the expected service life.

State Survey

A state department of transportation survey was conducted to determine what experience other states were having with common pavement marking materials. Responses from twenty-three states indicate that solvent-borne, epoxy, waterborne, and polyurea traffic paints as well as thermoplastics and tape are commonly used for long line pavement marking operations. Survey results reveal there is significant variation in the service life of these materials. For epoxy traffic paint, states were getting an average three-year service life. NDOT's experience with epoxy traffic paint service life varies from three months to four years. This was the most inconsistent life expectancy among reported data.

The survey contained fourteen questions regarding snowplow policy, specifications, retroreflectivity equipment, and restriping criteria used by the agencies. No single factor appeared to stand out as the common determinate of superior product that correlates with the service life of pavement marking materials.

Pavement Marking Test Sections

Thirty pavement marking products were applied and evaluated on five test sites in Nevada. The products included waterborne, polyurea, epoxy, alkyd thermoplastic, and permanent tape products. Test sections consisted of edge and centerline application that varied in length from 0.15 to 3 miles long. The test sections were objectively monitored for retroreflectivity and color data. The durability of the test sections was also examined.

Test site results show that the life expectancy of pavement markings varied greatly and were dependant upon placement procedures, snow removal activities, and ultraviolet degradation of the yellow colored paint products. Assorted traffic bead gradations and application rates were compared and evidence shows that NDOT's Type A bead used with waterborne paint exhibited better retroreflectivity performance over the Type B traffic bead. Moreover, the Type A traffic beads applied at nine pounds per gallon had higher retroreflectivity readings than Type A traffic beads applied at twelve pounds per gallon. Tabulated data and comparison graphs for all test sites were developed along with a summary of results for each test site.

Conclusions

The collaborative efforts of the Pavement Marking Task Force and this research project were the cornerstone of NDOT's attempt to improve pavement marking durability and provide cost-effective, quality striping to Nevada's traveling public. The research prompted the complete examination of all procedures involved with pavement marking material application. This examination included review of contract specification requirements as well as testing, sampling, inspection, and quality control procedures. Based on the examination, pavement marking system improvements were implemented subject to discussion and approval by qualified group consensus of the Pavement Marking Task Force members.

Constructing the pavement marking test sections contributed to improved striping operations by allowing contractors, manufacturers, and NDOT personnel to work together and share knowledge and experience about how better placement procedures can contribute to pavement marking longevity. This interaction caused NDOT to improve

established methods and provided an environment for obtaining higher quality pavement markings. The following modifications were enacted to improve NDOT's pavement marking operations.

Specification Improvements

- Allowed more lenient time frames for permanent paint application: Due to stringent pavement marking application time frames on new roadways and heavy workload before winter shut down, many contractors were overtaxed. This resulted in poorly maintained equipment and a hurried approach to pavement marking operations. The specifications now allow extended time frames for permanent paint application. Contractors have additional time to plan for work and keep equipment in properly working order. This improvement results in a more cooperative work environment between NDOT and contractors.
- Developed a polyurea traffic paint specification: Interest for polyurea traffic paint markings was prompted and several polyurea paint pavement marking projects were constructed in the Las Vegas area. Preliminary comments from engineers are encouraging.
- Developed minimum retroreflectivity requirements for temporary and permanent traffic paint contract acceptance: Retroreflectivity requirements have already improved the quality of several large striping contracts. Projects that do not meet minimum requirements are restriped or a reduced payment is negotiated based upon the severity of the infraction. Each situation is handled on a case-by-case basis.
- Improved waterborne paint specification: The compositional requirements for waterborne paint have been updated.
- Changed traffic bead specification for waterborne traffic paints: The traffic bead specification was changed to exclusive use of Type A bead for waterborne paints.

Qualified Products List (QPL) Changes

- Waterborne, polyurea, and epoxy traffic paints: The QPL was updated with new sections for Type I and Type II waterborne paints. Previously, there was only an approved resin list. An approved polyurea paint products list was developed. Previously, polyurea was not used on NDOT's roadways. Additionally, the number of qualified epoxy traffic paint products was increased.

Constructability Improvements

- Initiated yearly inspection training for construction crew personnel: Training includes videos, discussion, and use of retroreflectometers.
- Eliminated the use of rumble strip seal and improved logistics for striping staged construction: Temporary waterborne paint is allowed in lieu of temporary epoxy paint on certain projects. This reduces costs for long-term or staged construction work.

Materials, Sampling, and Testing Enhancements

- Requisitioned retroreflectometers for state maintenance and construction personnel: New test methods were created to enforce project retroreflectivity minimums.
- Reviewed material sampling procedures with paint companies: The information was circulated throughout the striping community.
- Worked with bead manufacturers to make bead bag labels more user friendly: Improved bead bag labels should reduce errors of placing incorrect bead types on liquid pavement marking materials.

Recommendations

The following actions are recommended to further improve pavement marking operations throughout the state:

1) Adopt the pavement marking guidelines matrix for use on all contract and restriping work. This matrix was developed for various traffic and climatic conditions based upon the experience of in-house personnel. This matrix will provide systematic and cost-effective guidelines for decision makers when selecting pavement marking materials (Table E-1).
2) Use the life cycle cost analysis examples to assist in selecting the most viable product and placement method for striping in rural and urban areas (Figure E-1).
3) Investigate better traffic bead technology, including use of direct melt glass.
4) Develop a systematic pavement marking management system and criteria for restriping operations.
5) Implement additional specification, constructability, materials, sampling, and testing procedure improvements as recommended by the research report.

The team effort and cooperation of in-house staff including Maintenance, Traffic, Research, Construction, and Materials Divisions have resulted in customized changes to NDOT's pavement marking operations that will improve the longevity of pavement markings. However, there is still much work to be accomplished. By adopting project recommendations, NDOT will maintain a proactive stance in the pursuit of updating construction practices to realize benefits of new methods and technology.

Table E-1 Guidelines for Pavement Marking Application on NDOT's Roadway System

*NEW CONSTRUCTION PAVEMENT MARKING GUIDELINES

Elevation	ROAD CATEGORY 1 Controlled Access	ROAD CATEGORY 2 ESAL > 540 or ADT > 10,000	ROAD CATEGORY 3 540 >= ESAL > 405 or 1,600 < ADT <= 10,000 + NHS	ROAD CATEGORY 4 405 >= ESAL > 270 or 400 < ADT <= 1,600	ROAD CATEGORY 5 ADT <= 400
Elevation Over 5000 ft	Epoxy	Epoxy	Waterborne	Waterborne	Waterborne
Elevation Under 5000 ft	Epoxy or [4]Polyurea	Epoxy or [4]Polyurea	Waterborne	Waterborne	Waterborne

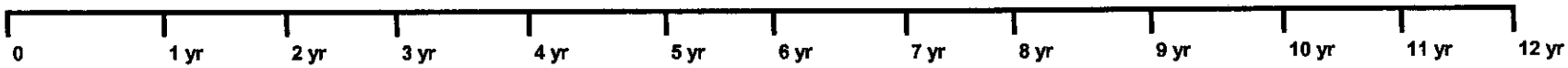
*RESTRIPING PAVEMENT MARKING GUIDELINES

Projected Pavement Life and Elevation	ROAD CATEGORY 1 Controlled Access	ROAD CATEGORY 2 ESAL > 540 or ADT > 10,000	ROAD CATEGORY 3 540 >= ESAL > 405 or 1,600 < ADT <= 10,000 + NHS	ROAD CATEGORY 4 405 >= ESAL > 270 or 400 < ADT <= 1,600	ROAD CATEGORY 5 ADT <= 400
Projected Pavement Life of 2-5 Years (Elevation Over 5000 ft)	Epoxy or Waterborne	Epoxy or Waterborne	Waterborne	Waterborne	Waterborne
Projected Pavement Life of 2-5 Years (Elevation Under 5000 ft)	Epoxy, [4]Polyurea, or Waterborne	Epoxy, [4]Polyurea, or Waterborne	Waterborne	Waterborne	Waterborne
Projected Pavement Life 2 years or Less (Elevation Over/Under 5000 ft)	Waterborne	Waterborne	Waterborne	Waterborne	Waterborne

***NOTES**

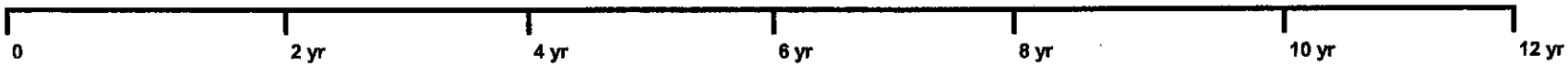
1. Transverse lines, symbols, and legends may be waterborne paint, thermoplastic, or pavement marking film/tape for all districts.
2. Nonreflective and reflective pavement markers for lane lines in District I when required.
3. ADT and ESALs are two directional traffic.
4. Polyurea traffic paint can be used in areas with less than 10 snowplow passes per year.

Scenario 1: **Waterborne paint service life of 1 year. Initial waterborne striping by contractor and waterborne restriping by NDOT maintenance forces every year.**
Costs for user delay, mobilization, traffic control, and eradication are not included.



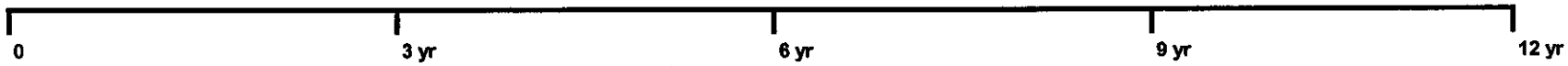
Present Worth Cost = $4,240 per mile

Scenario 2: **Waterborne paint service life of 2 years. Initial waterborne striping by contractor and waterborne restriping by NDOT maintenance forces every two years.**
Costs for user delay, mobilization, traffic control, and eradication are not included.



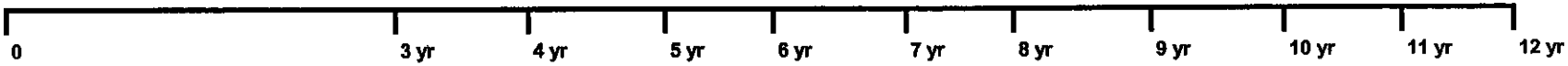
Present Worth Cost = $2,470 per mile

Scenario 3: **Epoxy paint service life of 3 years. Initial epoxy striping and epoxy restriping by contractor every three years.**
Includes costs for mobilization, traffic control, and eradication or recess grind for years 3, 6, and 9. User delay cost is not included.



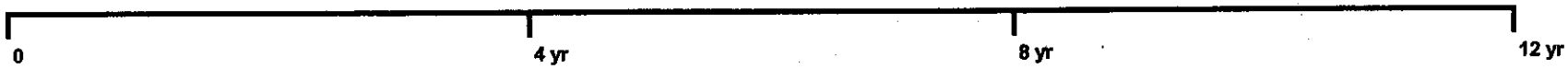
Present Worth Cost = $28,300 per mile

Scenario 4: **Epoxy paint service life of 3 years. Initial epoxy striping by contractor and waterborne restriping by NDOT maintenance forces every year.**
Costs for user delay, mobilization, and traffic control are not included.



Present Worth Cost = $5,345 per mile

Scenario 5: **Polyurea paint service life of 4 years. Initial polyurea striping and polyurea restriping by contractor every four years.**
Includes costs for mobilization, traffic control, and eradication or recess grind for years 4 and 8. User delay cost is not included.



Present Worth Cost = $24,160 per mile (NDOT does not have long-term experience with polyurea traffic paint and service life is based on other states' experience)

Figure E-1 12-Year Life Cycle Cost Analysis for One Linear Striping Mile (8-inch White)

ADVANCING DURABLE PAVEMENT MARKING MATERIALS IN NEVADA

CHAPTER 1 - INTRODUCTION

1.1 Background

The Nevada Department of Transportation (NDOT) is responsible for efficiently planning, designing, constructing, and maintaining a safe and effective seamless transportation system for Nevada's economic, environmental, and social needs. This mission is accomplished in part by updating construction standards and practices to improve operations and realize benefits of new technology. One challenge facing NDOT is to incorporate cost-effective and long lasting pavement markings that will bolster motorists' safety.

Several years ago, a concern over the poor performance of epoxy traffic paint became an operational issue. NDOT striping crews were restriping large portions of roadways long before the expected epoxy traffic paint service life of 3 to 4 years was obtained. Ineffective pavement markings became so commonplace that NDOT was motivated to evaluate its pavement marking operations and place a high priority on performing research to improve practices and extend pavement marking service life.

This report is a compilation of results for the Advancing Durable Pavement Marking Materials in Nevada research project. The purpose of the project was to pool NDOT's resources, avoid fragmentary attempts at field-testing, and gather information that would assist with improving the cost-effectiveness of pavement marking systems.

NDOT used the information contained in this report to compare the performance of similar materials, expand NDOT's Qualified Products List, improve specifications, and calculate cost-effectiveness. The primary result of this project is a matrix that lists the recommended pavement marking materials for use on NDOT roadways based on traffic and climate data.

1.2 Quantifying Lack of Durability for Epoxy Traffic Paint

Between 1995 and 2000, NDOT spent over $9,000,000 for epoxy traffic paint striping costs through 73 contract construction projects. The projects were reviewed to determine how long the original epoxy traffic paint lasted before NDOT maintenance forces were required to restripe the roadway. Approximately 40% of the projects required restriping within three years of the date of application.

Maintenance pavement marking records were scrutinized through use of the Maintenance Management System database for paint application rates on roadways with original epoxy traffic paint applied in construction contracts. Projects that required ten percent or more restriping within three years of original application were determined to have unacceptable performance. Table 1.1 shows that 1,571 striping miles were considered to have unacceptable epoxy traffic paint performance for the years 1995 through 2000.

TABLE 1.1
"Unacceptable Performance" of Epoxy Traffic Paint in Striping Miles*

	UNACCEPTABLE PERFORMANCE (IN STRIPING MILES)		
YEAR	DISTRICT II	DISTRICT III	DISTRICTS II & III
1995	254	268	522
1996	261	84	345
1997	113	64	177
1998	150	86	236
1999	64	134	198
2000	N/A	93	93
TOTAL	**842**	**729**	**1,571**

* District I is not included in the analysis because the use of permanent tapes and reflective pavement markers were more prevalent in the area.

1.3 Causes for Poor Performance of Epoxy Traffic Paint

A resident engineer survey was conducted in order to discover problems that occurred during initial contract striping operations that may have contributed to the poor durability of epoxy traffic paint. The survey revealed that the following issues contributed to poor long-term paint performance:

- Equipment breakdown and inexperienced striping personnel
- Temperature and weather conditions
- Inadequate cure time of roadway surfaces
- Material quality and off color products
- No quality control of the overall striping operations
- Application problems - variable stripe widths and inadequate coating thickness
- Inability to mix the epoxy paint properly resulting in black spots
- Snowplow damage
- Stringent time requirements for permanent pavement marking placement
- Large quantity of projects and short window of opportunity to complete the projects

The resident engineer survey identified several application issues. Issues included the difficulty of monitoring the material coating thickness test used by construction inspectors for quality assurance and placing certain pavement marking products where failure is likely (e.g., permanent tape in snow removal areas). The following summarizes the environmental, installation, and material reasons identified as plausible explanations for the reduction in epoxy traffic paint service life.

Environment:

Several complications contribute to the environmental problems associated with the premature failure of epoxy traffic paint. One problem is low ambient temperature during epoxy traffic paint placement. Much of the striping is done at the end of the construction season when the ambient temperature is near or below manufacturers' installation recommendations. Another problem is insufficient curing time of open-grade wearing

courses. Placing striping on insufficiently cured pavement will have an adverse effect on the bond between paint and roadway.

Installation:

Common installation problems include poor surface preparation, equipment malfunction, thin material coating thickness, and improper mixing. Good surface preparation is critical for optimal pavement marking operations. The curing compound must be removed from new concrete and the surface should be clean. Dust, dirt, and debris can build up on curing bituminous pavement within a short time. The striping equipment is reported to be in various stages of malfunction and breaks down often. It is essential the equipment be calibrated and in good working order. Thin material coating thickness is often reported as a concern. The thin coating thickness on open-grade pavement surfaces does not fill the voids to provide sufficient coverage. Visible black spots are a result of improper mix ratios between the resin and hardener. Improperly mixed paint will not cure and this phenomenon has been observed frequently on roadways. Improper mixing happens because of poor equipment maintenance and operator error.

Material:

An investigation by an epoxy traffic paint manufacturer attributes some of the poor performance to the repeated use of inferior epoxy traffic paint product (20). There has been many difficulties connected with the use of the inferior product, and this product has been reformulated.

Miscellaneous:

Other factors contributed to the reduction in epoxy traffic paint service life. Inadequate training, lack of experienced installation operators, and poor inspection procedures were considerations. In addition, the inability to handle the workload of the striping season was a determining influence. Without properly maintained equipment, problems such as worn tips, improper pressures, and frequent breakdowns occurred that caused inferior line quality. Moreover, stringent time requirements for permanent pavement marking placement caused distress for contractors burdened with heavy workloads. Additionally, the damage caused by snow removal activities significantly reduced service life in high mountain areas.

1.4 Pavement Marking Task Force

The desire to improve pavement marking operations and obtain better life expectancies for traffic paint led to the establishment of a Pavement Marking Task Force. The Task Force is comprised of representatives from various divisions within NDOT. The benefit of the Task Force working in cooperation with this research effort included implementing procedures to obtain higher quality pavement marking operations. Improved standard specifications and a reduction of material failures were by-products of the effort.

Initial improvements were updating the contract waterborne paint specification and initiating pavement marking inspection training for NDOT personnel. The Task Force organized an industry meeting in June 2001 to promote communication between epoxy traffic paint manufacturers and striping contractors. The meeting was sponsored to identify possible causes of premature failure and make recommendations to improve

overall pavement marking effectiveness. The Task Force was also instrumental in developing the Advancing Durable Pavement Marking Materials in Nevada research project. This project helped focus NDOT's attention on working together for the common goal of improving pavement marking operations throughout the state.

1.5 Advancing Durable Pavement Marking Materials in Nevada

NDOT is committed to improving transportation technology through its Annual Research, Development, and Technology Transfer Work Program (Annual RD&T). One goal of the research program is to develop and implement new technical knowledge for practical use throughout the agency. Management realized that a durable pavement marking research project would be an ideal candidate for inclusion into the Annual RD&T. The success of the project would benefit NDOT's mission of providing a safe environment for the traveling public.

A pavement marking research proposal was introduced to NDOT's Research Management Committee and accepted for inclusion in the Annual RD&T on October 1, 2001. The expected project duration was three years and entitled Advancing Durable Pavement Marking Materials in Nevada. The primary objective of the research project was to develop a matrix listing recommended pavement marking products to be used under differing environmental conditions and traffic volumes. Other expected benefits of the research were new or improved standard specifications and an expanded pavement marking product base listed in the Qualified Products List. The research included the construction of pavement marking test sections. Thirty pavement marking products were monitored at five different locations throughout the state. Durability, retroreflectivity, and color measurements were recorded and provided in the report. Moreover, this research project focused attention on the importance of quality pavement markings and created a momentum of higher expectations that continues today.

The Advancing Durable Pavement Marking Materials in Nevada research project included a review of national pavement marking research and other states' specifications and qualified or approved products lists. Appendix A lists information resources and references used in the context of this research. The information search included a NDOT pavement marking survey resulting in responses from twenty-three states.

1.6 State Survey

NDOT surveyed other states to determine what experiences the states were having with common pavement marking materials. The survey contained questions regarding types of markings used by the agency, service life, specifications, and materials. In addition, data regarding pavement marking management systems and restriping criteria were requested. Table 1.2 contains the types of pavement markings materials used by the responding states' department of transportation.

Table 1.2 Types of Pavement Marking Materials Used by State DOTs

State DOT	Solvent-borne Paint	Methacrylate-Based Paint	Hot Applied Thermoplastic	Epoxy Paint	Waterborne Paint	Permanent Tape	Spray Thermoplastic	Polyurea Paint	Modified Urethane	Preformed Thermoplastic
AK	X	X	X							
CT				X	X	X				
GA					X	X	X	X		
IL	X		X	X	X	X	X	X		
IN			X	X		X				
IA	X		X	X	X	X		X	X	
KY			X	X	X	X	X	X		
MI	X		X	X	X	X	X	X		
NE	X		X	X	X	X				
NH					X					
NM					X			X		
NV	X			X	X	X				
OH	X		X	X	X	X				X
OR		X	X		X	X	X			
PA			X	X	X					
RI	X			X		X				
SC			X	X	X	X	X			
TN			X		X	X	X			
TX					X	X	X			
UT	X		X	X	X	X				
VT			X	X	X	X				
WI				X	X	X				
WY		X		X	X	X				
Total	9	3	14	16	20	19	8	6	1	1

Figure 1.1 displays the expected service life for epoxy, waterborne, permanent tape, and spray thermoplastic pavement marking materials from several agencies. There is a large variation in service life for each material.

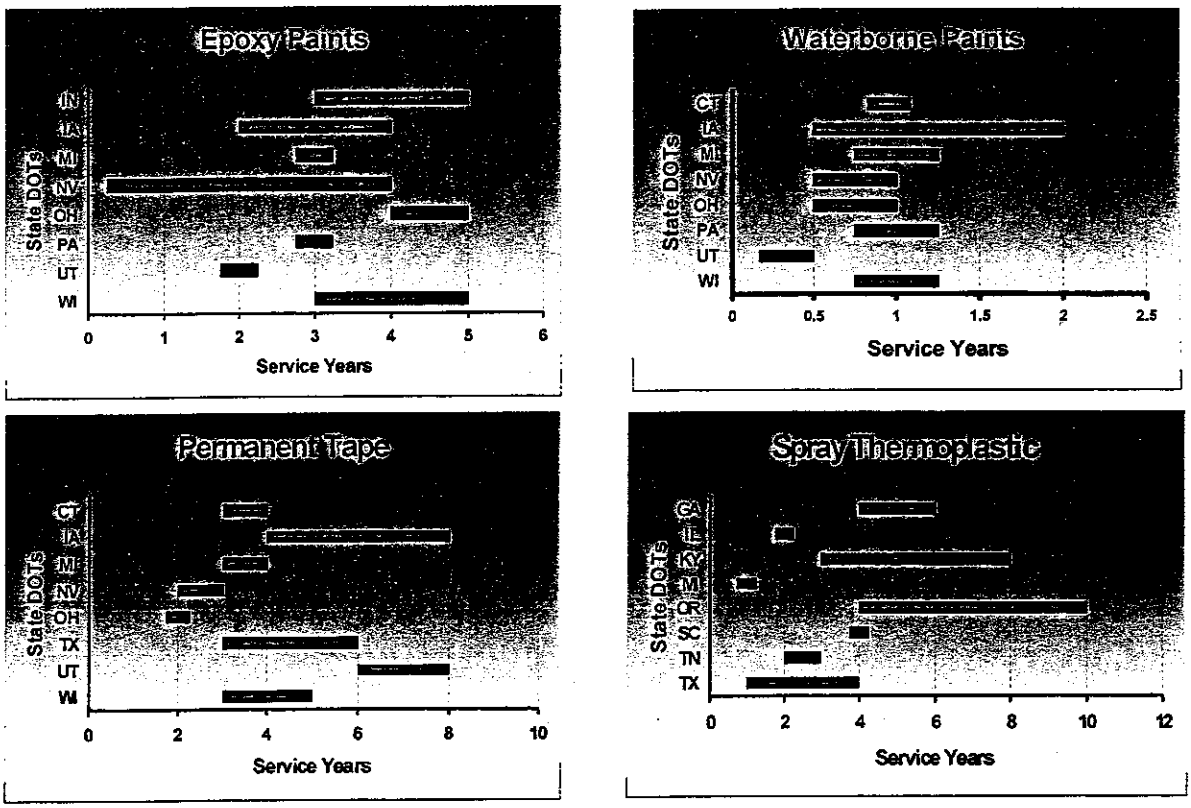


Figure 1.1 Expected Service Life for Pavement Marking Products

Selected responses from the fourteen-question survey include the following:

Does agency have a pavement marking management system in place?

- 7 state DOTs responded "Yes" – IN, MI, NH, OR, RI, TN, and WY
- Examples include statewide goals, application databases, 10-year plans, regular schedules, tracking costs, and QA/QC program

Is striping replaced on an as-needed basis or predetermined schedule?

- 6 states responded that striping is replaced on an "as-needed" basis
- 8 states responded that striping is replaced on a "schedule"
- 9 states replied that striping is replaced both "as-needed" and on a "schedule"
- Overall, striping schedules are based on type of road and type of marking material applied

What criteria are used for restriping?
(Choices: Observation, Retroreflectivity Readings, or Other)

- 9 states restripe based on observation only
- 3 states restripe on a schedule only
- 5 states restripe based on observation and retroreflectivity readings
- 5 states restripe based on observation and some type of schedule
- 1 state restripes based on observation, retroreflectivity readings, and schedule

What primary type of specification does agency use for pavement markings?

- 10 states use compositional specifications
- 5 states use performance specifications
- 8 states use various combinations of compositional, performance, and warranty specifications

The survey information illustrates the diversity of materials used on state highways, the large variation in service life of the materials, and different restriping criteria used by the agencies. No single factor appears to stand out as the common determinate of superior product that correlates with the service life of pavement marking materials. Appendix B contains the fourteen-question survey and state response.

1.7 Report Outline

NDOT invited paint manufacturers to participate in the field-testing of their products. The outcome was the submission of over forty products for review. The thirty products chosen for evaluation were placed on five test site locations with advice from the Pavement Marking Task Force. The research study design is located in Chapter 2, field application data is organized in tabular format in Chapter 3, and test site measurements and observations are contained in Chapters 4 through 9. Laboratory evaluations, estimated service life for the test sites, cost analysis, project matrix, and summary and recommendations are located in Chapters 10, 11, and 12 respectively.

CHAPTER 2 – RESEARCH STUDY DESIGN

2.1 Test Sites

The field test sites consisted of four plantmix bituminous surfaces (PBS) with open-grade wearing courses (OGWC) and one Portland cement concrete pavement (PCCP) surface. Test sites were selected based on elevation, average daily traffic (ADT), and environmental conditions. The areas selected were representative of the pavements upon which the traffic marking material will be used and the extreme climatic conditions prevalent in Nevada. These conditions include mountainous regions with rigorous snow removal activities to arid desert terrain. Table 2.1 lists relevant information for each test site.

Table 2.1 Test Sites and Relevant Information*

LOCATION	PAVEMENT TYPE AND AGE	AVERAGE ELEVATION (FEET)	ADT	ANNUAL TEMP AVE HIGH / LOW (°F)	AVERAGE PRECIPITATION (INCHES/YEAR)
SR028 Washoe County MP 0.00- 8.00	PBS w/OGWC 8 years old	6,250	7,300	58 / 30	15.90
SR431 Washoe County MP 4.00- 5.50	PBS w/OGWC 4 years old	7,250	5,600	53 / 30	22.95
US050 Churchill County MP 31.42- 43.76	PBS w/OGWC 3 weeks old	3,750	1,200	68 / 38	5.55
US093 Clark County MP 59.00- 70.00	PBS w/OGWC 5 years old	2,250	1,700	80 / 50	5.17
US095 Clark County MP 63.50- 66.50	PCCP 11 years old	2,250	84,500	80 / 50	5.17

***NDOT Source - Pavement Analysis Database**

2.2 Materials Tested

There were thirty pavement marking products applied and evaluated on five test sites located throughout Nevada. The products included ten waterborne paints, six polyurea paints, six epoxy paints, four alkyd thermoplastic products, and four permanent tape products. Waterborne paints were installed on SR028, US050, and US093 from August through October 2002. Polyurea, alkyd thermoplastic, waterborne, and epoxy pavement marking products were placed on US095 in September 2002. Polyurea, alkyd thermoplastic, and epoxy pavement marking products were placed on SR431 in September 2002. In addition, permanent tape and single and double applications of waterborne paint were installed on SR431, as a separate site evaluation, in September 2003. Table 3.1 lists the pavement marking materials placed and evaluated.

2.3 Installation

The product manufacturers supplied and placed the polyurea, epoxy, alkyd thermoplastic, and permanent tape pavement marking materials. NDOT striping crews placed all waterborne paints. Both the manufacturers and NDOT personnel supervised installation of the products and NDOT provided traffic control. The polyurea, epoxy, waterborne, alkyd thermoplastic, and traffic bead materials were applied in a single operation using approved equipment as specified in 632.03.02 of NDOT's Standard Specifications (34).

All materials placed were representative of manufacturers' working batch supplies and were sampled in accordance with NDOT procedures.

Each manufacturer supplied enough material to longitudinally stripe roadway sections that varied in length from 0.15 to 3 miles. The test sections consisted of both 4-inch yellow centerlines and 4-inch white edge lines for all locations, with the exception of US095. The US095 test site consisted of an 8-inch white edge line and an 8-inch yellow median line in the northbound lane.

Striping contractors calibrated equipment for proper bead loading and material coating thickness. Product manufacturers and NDOT personnel verified the calibration. In addition, check stripes were placed at nearby locations before actual test stripes were applied on the roadway. Sample plates were taken for all check and roadway striping for liquid pavement marking products to verify material coating thickness.

The materials were applied to dry surfaces. Table 2.2 is a summary of the surface preparation for each test site. The test sections placed on SR431 in 2002 and 2003 were recessed to protect the pavement markings from snowplow damage. Table 2.3 lists the recess depths for the SR431 2002 test site. The materials placed on the SR431 2003 test site were recessed approximately 300 mils.

Table 2.2 Summary of Surface Preparation

LOCATION	SURFACE PREPARATION	PLACEMENT
SR028 Test Site	Sweeping by vacuum broom and compressed air by striping truck.	Products were placed over worn out paint typical of field restriping conditions.
SR431 Test Site (2002)	Grinding to depth, sweeping by vacuum broom, and application of compressed air by generator.	Products were recessed from 60 mils to 100 mils according to manufacturers' directions. See Table 2.3 for specific depths of grind.
SR431 Test Site (2003)	Grinding to depth, sweeping by vacuum broom, and application of compressed air by generator.	Products were recessed approximately 300 mils.
US050 Test Site	Compressed air by striping truck.	Products were placed on a newly paved roadway surface.
US093 Test Site	Compressed air by striping truck.	Products were placed over worn out paint typical of field restriping conditions.
US095 Test Site	100% removal of old product, sweeping by vacuum broom, and compressed air by striping truck.	Products were placed on PCCP surface.

Table 2.3 Recess Depths for SR431 2002 Test Site

SR431 2002 TEST SITE			
Material Type	**Product Trade Name**	**Color**	**Recess Depth (Mils)**
Alkyd Thermoplastic	885555/W5E-5GS-1A 885315/Y2E-5GS-1A	White and Yellow	100
Epoxy	LS52	White and LF Yellow	100
Polyurea	LS90	White and LF Yellow	80
Polyurea	LPM 1200	White and LF Yellow	60
Polyurea	LPM 1000	White and LF Yellow	60
Epoxy	Mark-55.3	White and Yellow	60

Chapter 3 contains all compiled pavement marking application data, bead application data, and weather data during placement in tabular format.

2.4 Field Data Collection Methodology

The field data collection procedures are based on information provided in the National Transportation Product Evaluation Program Project Work Plan for the Field and Laboratory Evaluation of Pavement Marking Materials (9). ASTM D 713, "Standard Practice for Conducting Road Service Tests on Fluid Traffic Marking Materials," ASTM International was also used as reference (11). The installed test site striping was placed longitudinally for centerlines, median lines, and edge lines in order to evaluate the products under "real world" conditions. Monitoring was based on the number of observations that investigators thought

would be effective and logistically reasonable. The striping was reviewed in the exact condition perceived by the traveling public. Efforts were made to monitor materials in uniform conditions away from noticeable striping wear due to approaches, curves, intersections, areas near turning movements, and dirt or grime. However, no effort was made to "clean" the striping by washing or other means before taking measurements.

Retroreflectivity, color, and durability data were initially collected within 7 to 14 days of installation and at periodic intervals thereafter. Winter weather conditions in central western Nevada prevented data collection on SR028, SR431, and US050 during the winter months. However, spring evaluations were conducted at these locations despite leftover deicing or salt residue.

Data collected for each pavement marking product included a subjective rating of the durability of the material based on information provided in ASTM D 913, "Standard Test Method for Evaluating Degree of Resistance to Wear of Traffic Paint" and ASTM D 2205, "Standard Guide for Selection of Tests for Traffic Paints," ASTM International (12, 13). Tables 4.1, 5.1, 6.1, 7.1, 8.1, and 9.1 contain reported durability observations.

Retroreflectivity measurements were based on guidelines presented in ASTM D 6359, "Standard Specification for Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments," and ASTM E 1710, Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer," ASTM International (14, 17). The equipment used was a portable LTL–X retrometer with 30-meter geometry. The illumination angle for this equipment is 1.24° and the observation angle is 2.29°. Measurements are reported in units of millicandelas per square meter per lux ($mcd/m^2/lux$). Tables 4.1, 5.1, 6.1, 7.1, 8.1, and 9.1 contain reported retroreflectivity measurements.

A BYK Gardner Color-guide 45/0 Spectrophotometer was used to measure daytime chromaticity (color) coordinates of the pavement marking materials. Measurements were taken in Y, x, y CIE coordinates with a 2-degree observer using a D65 type illuminant. Daytime chromaticity requirements from ASTM D 6628, "Standard Specification for Color of Pavement Marking Materials," ASTM International were used to evaluate the acceptability of reported color results (15). All chapter results reported in black print plot within the acceptable daytime color boundaries as described in ASTM D 6628. All chapter results listed in red print and underlined are outside the acceptable daytime color boundaries as described by ASTM D 6628. Tables 4.2, 5.2, 6.2, 7.2, 8.2, and 9.2 contain reported color coordinates.

Winter maintenance activities and snow removal data were collected for each test site. The data is detailed in the chapter results for various locations.

2.5 Laboratory Evaluation Methodology

NDOT's Materials Division tested the pavement marking products and traffic beads placed on the test sites. The products were evaluated for compliance to NDOT's Standard Specifications for Road and Bridge Construction, Sections 729 – Traffic Paint, and 730 – Traffic Beads (34). Chapter 10 gives an account of the tests, acceptance criteria, and laboratory evaluations for the materials.

CHAPTER 3 – PAVEMENT MARKING MATERIALS

Field Application Data

Table 3.1 is a list of the pavement marking materials placed and evaluated on the test sites. The materials include polyurea, epoxy, alkyd thermoplastic, waterborne and permanent tape products. The companies that participated in the project were 3M Traffic Control (3M), Ennis Paint, Inc. (EPI), Epoplex (EPO), Pervo Paint Company (PPC), Poly-Carb, Inc. (PCI), Sherwin Williams (SW), and TMT-Pathway, LLC (TMT).

Table 3.2 contains pavement marking application data. The data consists of the date and time of placement as well as temperature and applied thickness of materials. The use of primer for alkyd thermoplastic and tape products is also mentioned.

Table 3.3 is comprised of traffic bead application data. Bead application data includes the bead type used for each material, application rate in pounds per gallon, and type of bead coating.

Proper weather conditions during pavement marking placement play an important role in obtaining long-lasting performance. Tables 3.4 through 3.8 consist of the local weather data during pavement marking application. The data includes atmospheric temperature, relative humidity, dew point, wind speed, and wind direction. The pavement temperature is also recorded.

Table 3.1 Pavement Marking Materials Tested

Vendor Name	Vendor ID	Project Code	Material Type	Product Trade Name	Color
3M Traffic Control	3M	PMRP-02-NV-01	Polyurea	LPM 1000	White
		PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow
		PMRP-02-NV-03	Polyurea	LPM 1200	White
		PMRP-02-NV-04	Polyurea	LPM 1200	LF Yellow
		PMRP-02-NV-27	Tape (High Performance)	A380IES	White
		PMRP-02-NV-28	Tape (High Performance)	A381IES	Yellow
		PMRP-02-NV-29	Tape (Wet Reflective)	A820	White
		PMRP-02-NV-30	Tape (Wet Reflective)	A821	Yellow
Ennis Paint, Inc.	EPI	PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	White
		PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow
		PMRP-02-NV-07	Waterborne Paint	NVW-40-M-2	White
		PMRP-02-NV-08	Waterborne Paint	NVY-40-M-2	LF Yellow
Epoplex	EPO	PMRP-02-NV-09	Epoxy	LS52	White
		PMRP-02-NV-10	Epoxy	LS52	LF Yellow
		PMRP-02-NV-11	Epoxy	LS50	White
		PMRP-02-NV-12	Epoxy	LS50	Yellow
		PMRP-02-NV-13	Polyurea	LS90	White
		PMRP-02-NV-14	Polyurea	LS90	LF Yellow
Pervo Paint Company	PPC	PMRP-02-NV-15	Waterborne Paint	6050	White
		PMRP-02-NV-16	Waterborne Paint	6053	LF Yellow
		PMRP-02-NV-17	Waterborne Paint	7950	White
		PMRP-02-NV-18	Waterborne Paint	7953	LF Yellow
		PMRP-02-NV-19	Alkyd Thermoplastic	T-1001AASHTO	White
		PMRP-02-NV-20	Alkyd Thermoplastic	T-1003AASHTO	LF Yellow
Poly-Carb, Inc.	PCI	PMRP-02-NV-21	Epoxy	Mark-55.3	White
		PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow
Sherwin Williams	SW	PMRP-02-NV-23	Waterborne Paint	BP19421	White
		PMRP-02-NV-24	Waterborne Paint	BP19422	LF Yellow
TMT-Pathway LLC	TMT	PMRP-02-NV-25	Waterborne Paint	2771A9	White
		PMRP-02-NV-26	Waterborne Paint	2772A9	LF Yellow

Table 3.2 Application Data for SR028 and SR431 - 2002 Test Site (Page 1 of 4)

Project Code	Location	Material Type	Product Trade Name	Color	Vendor ID	Date Applied	Time Applied	Applied Material Temperature (°F)	Applied Thickness (Wet Mil)	Primer
SR028 (PBS w/OGWC)										
PMRP-02-NV-15	SR028-WA MP 0.00 - 1.00	Waterborne Paint	6050	White	PPC	9/12/2002	10:00 AM	Ambient	25	N/A
PMRP-02-NV-16	SR028-WA MP 0.00 - 1.00	Waterborne Paint	6053	LF Yellow	PPC	9/12/2002	10:00 AM	Ambient	25	N/A
PMRP-02-NV-07	SR028-WA MP 1.00 - 2.00	Waterborne Paint	NVW-40-M-2	White	EPI	9/12/2002	12:30 PM	Ambient	25	N/A
PMRP-02-NV-08	SR028-WA MP 1.00 - 2.00	Waterborne Paint	NVY-40-M-2	LF Yellow	EPI	9/12/2002	12:30 PM	Ambient	25	N/A
PMRP-02-NV-25	SR028-WA MP 4.00 - 5.00	Waterborne Paint	2771A9	White	TMT	9/11/2002	2:00 PM	Ambient	25	N/A
PMRP-02-NV-26	SR028-WA MP 4.00 - 5.00	Waterborne Paint	2772A9	LF Yellow	TMT	9/11/2002	2:00 PM	Ambient	25	N/A
PMRP-02-NV-23	SR028-WA MP 5.00 - 6.30	Waterborne Paint	BP19421	White	SW	9/11/2002	11:15 AM	Ambient	25	N/A
PMRP-02-NV-24	SR028-WA MP 5.00 - 6.30	Waterborne Paint	BP19422	LF Yellow	SW	9/11/2002	11:15 AM	Ambient	25	N/A
PMRP-02-NV-17	SR028-WA MP 6.30 - 8.00	Waterborne Paint	7950	White	PPC	9/10/2002	2:30 PM	Ambient	25	N/A
PMRP-02-NV-18	SR028-WA MP 6.30 - 8.00	Waterborne Paint	7953	LF Yellow	PPC	9/10/2002	2:30 PM	Ambient	25	N/A
SR431 2002 Test Site (PBS w/OGWC)										
PMRP-02-NV-05	SR431-WA MP 4.00 - 4.30	Alkyd Thermoplastic	885555/W5E-5GS-1A	White	EPI	9/12/2002	12:45 PM	410	80	Thermo Adhesive
PMRP-02-NV-06	SR431-WA MP 4.00 - 4.30	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	9/12/2002	12:45 PM	410	80	Thermo Adhesive
PMRP-02-NV-09	SR431-WA MP 4.30 - 4.60	Epoxy	LS52	White	EPO	9/12/2002	3:00 PM	125	25	N/A
PMRP-02-NV-10	SR431-WA MP 4.30 - 4.60	Epoxy	LS52	LF Yellow	EPO	9/12/2002	3:00 PM	125	25	N/A
PMRP-02-NV-13	SR431-WA MP 4.60 - 4.90	Polyurea	LS90	White	EPO	9/12/2002	9:30 AM	140	20	N/A
PMRP-02-NV-14	SR431-WA MP 4.60 - 4.90	Polyurea	LS90	LF Yellow	EPO	9/12/2002	9:30 AM	140	20	N/A
PMRP-02-NV-03	SR431-WA MP 4.90 - 5.05	Polyurea	LPM 1200	White	3M	9/13/2002	1:45 PM	160 R / 135 C	22	N/A
PMRP-02-NV-04	SR431-WA MP 4.90 - 5.05	Polyurea	LPM 1200	LF Yellow	3M	9/13/2002	1:45 PM	165 R / 135 C	22	N/A
PMRP-02-NV-01	SR431-WA MP 5.05 - 5.20	Polyurea	LPM 1000	White	3M	9/13/2002	1:45 PM	160 R / 135 C	22	N/A
PMRP-02-NV-02	SR431-WA MP 5.05 - 5.20	Polyurea	LPM 1000	LF Yellow	3M	9/13/2002	1:45 PM	165 R / 135 C	22	N/A
PMRP-02-NV-21	SR431-WA MP 5.20 - 5.50	Epoxy	Mark-55.3	White	PCI	9/13/2002	10:30 AM	130	25	N/A
PMRP-02-NV-22	SR431-WA MP 5.20 - 5.50	Epoxy	Mark-55.3	Yellow	PCI	9/13/2002	12:30 PM	130	25	N/A

Table 3.2 Application Data for SR431 - 2003 Test Site (Page 2 of 4)

Project Code	Location	Material Type	Product Trade Name	Color	Vendor ID	Date Applied	Time Applied	Applied Material Temperature (°F)	Applied Thickness	Primer
SR431 2003 Test Site (PBS w/OGWC)										
PMRP-02-NV-15	SR431-WA MP 4.90 - 5.20 (Single Application)	Waterborne Paint	6050	White	PPC	9/25/2003	1:00 PM	Ambient	25 wet mils	N/A
PMRP-02-NV-16	SR431-WA MP 4.90 - 5.20 (Single Application)	Waterborne Paint	6053	LF Yellow	PPC	9/25/2003	1:00 PM	Ambient	25 wet mils	N/A
PMRP-02-NV-15	SR431-WA MP 4.90 - 5.20 (Double Application)	Waterborne Paint	6050	White	PPC	9/25/2003	3:00 PM	Ambient	25 wet mils per application	N/A
PMRP-02-NV-16	SR431-WA MP 4.90 - 5.20 (Double Application)	Waterborne Paint	6053	LF Yellow	PPC	9/25/2003	3:00 PM	Ambient	25 wet mils per application	N/A
PMRP-02-NV-27	SR431-WA MP 4.90	Tape High Performance	A380IES	White	3M	9/25/2003	1:45 PM	Ambient	60 mils	N/A
PMRP-02-NV-28	SR431-WA MP 5.20	Tape High Performance	A381IES	Yellow	3M	9/25/2003	1:45 PM	Ambient	60 mils	N/A
PMRP-02-NV-29	SR431-WA MP 4.90	Tape Wet Reflective	A820	White	3M	9/25/2003	2:30 PM	Ambient	30 mils	P-50 Primer
PMRP-02-NV-30	SR431-WA MP 5.20	Tape Wet Reflective	A821	Yellow	3M	9/25/2003	2:30 PM	Ambient	30 mils	P-50 Primer

Table 3.2 Application Data for US050 (Page 3 of 4)

Project Code	Location	Material Type	Product Trade Name	Color	Vendor ID	Date Applied	Time Applied	Applied Material Temperature (°F)	Applied Thickness (Wet Mil)	Primer
US050 (PBS w/OGWC)										
PMRP-02-NV-07	US050-CH MP 31.42 - 33.00	Waterborne Paint	NVW-40-M-2	White	EPI	8/22/2002	4:30 PM	Ambient	25	N/A
PMRP-02-NV-08	US050-CH MP 31.42 - 33.00	Waterborne Paint	NVY-40-M-2	LF Yellow	EPI	8/22/2002	4:30 PM	Ambient	25	N/A
PMRP-02-NV-23	US050-CH MP 33.00 - 34.50	Waterborne Paint	BP19421	White	SW	8/21/2002	4:00 PM	Ambient	25	N/A
PMRP-02-NV-24	US050-CH MP 33.00 - 34.50	Waterborne Paint	BP19422	LF Yellow	SW	8/21/2002	4:00 PM	Ambient	25	N/A
PMRP-02-NV-25	US050-CH MP 34.50 - 36.00	Waterborne Paint	2771A9	White	TMT	8/21/2002	11:00 AM	Ambient	25	N/A
PMRP-02-NV-26	US050-CH MP 34.50 - 36.00	Waterborne Paint	2772A9	LF Yellow	TMT	8/21/2002	11:00 AM	Ambient	25	N/A
PMRP-02-NV-17	US050-CH MP 36.00 - 37.50	Waterborne Paint	7950	White	PPC	8/21/2002	1:30 PM	Ambient	25	N/A
PMRP-02-NV-18	US050-CH MP 36.00 - 37.50	Waterborne Paint	7953	LF Yellow	PPC	8/21/2002	1:30 PM	Ambient	25	N/A
PMRP-02-NV-15	US050-CH MP 37.50 - 39.00	Waterborne Paint	6050	White	PPC	8/20/2002	1:50 PM	Ambient	25	N/A
PMRP-02-NV-16	US050-CH MP 37.50 - 39.00	Waterborne Paint	6053	LF Yellow	PPC	8/20/2002	1:50 PM	Ambient	25	N/A
PMRP-02-NV-15	US050-CH MP 39.00 - 41.00 (N Edge)	Waterborne Paint	6050	White	PPC	8/20/2002	2:45 PM	Ambient	25	N/A
PMRP-02-NV-16	US050-CH MP 39.00 - 41.00 (CL)	Waterborne Paint	6053	LF Yellow	PPC	8/22/2002	2:00 PM	Ambient	25	N/A
PMRP-02-NV-15	US050-CH MP 39.00 - 41.00 (S Edge)	Waterborne Paint	6050	White	PPC	8/22/2002	2:00 PM	Ambient	25	N/A
PMRP-02-NV-15	US050-CH MP 41.00 - 42.00 (N Edge)	Waterborne Paint	6050	White	PPC	8/22/2002	10:00 AM	Ambient	25	N/A
PMRP-02-NV-16	US050-CH MP 41.00 - 42.00 (CL)	Waterborne Paint	6053	LF Yellow	PPC	8/22/2002	10:00 AM	Ambient	25	N/A
PMRP-02-NV-15	US050-CH MP 41.00 - 43.76 (S Edge)	Waterborne Paint	6050	White	PPC	8/30/2002	11:15 AM	Ambient	25	N/A
PMRP-02-NV-15	US050-CH MP 42.00 - 43.00 (N Edge)	Waterborne Paint	6050	White	PPC	8/22/2002	11:45 AM	Ambient	18	N/A
PMRP-02-NV-16	US050-CH MP 42.00 - 43.00 (CL)	Waterborne Paint	6053	LF Yellow	PPC	8/22/2002	11:45 AM	Ambient	18	N/A
PMRP-02-NV-15	US050-CH MP 43.00 - 43.76 (N Edge)	Waterborne Paint	6050	White	PPC	8/22/2002	11:15 AM	Ambient	18	N/A
PMRP-02-NV-16	US050-CH MP 43.00 - 43.76 (CL)	Waterborne Paint	6053	LF Yellow	PPC	8/22/2002	11:15 AM	Ambient	18	N/A

Table 3.2 Application Data for US093 and US095 (Page 4 of 4)

Project Code	Location	Material Type	Product Trade Name	Color	Vendor ID	Date Applied	Time Applied	Applied Material Temperature (°F)	Applied Thickness (Wet Mil)	Primer
US093 (PBS w/OGWC)										
PMRP-02-NV-15	US093-CL MP 59.00 - 61.00	Waterborne Paint	6050	White	PPC	10/14/2002	12:15 PM	Ambient	25	N/A
PMRP-02-NV-16	US093-CL MP 59.00 - 61.00	Waterborne Paint	6053	LF Yellow	PPC	10/14/2002	12:15 PM	Ambient	25	N/A
PMRP-02-NV-23	US093-CL MP 61.00 - 63.00	Waterborne Paint	BP19421	White	SW	10/15/2002	10:00 AM	Ambient	25	N/A
PMRP-02-NV-24	US093-CL MP 61.00 - 63.00	Waterborne Paint	BP19422	LF Yellow	SW	10/15/2002	10:00 AM	Ambient	25	N/A
PMRP-02-NV-17	US093-CL MP 63.00 - 65.00	Waterborne Paint	7950	White	PPC	10/15/2002	12:30 PM	Ambient	25	N/A
PMRP-02-NV-18	US093-CL MP 63.00 - 65.00	Waterborne Paint	7953	LF Yellow	PPC	10/15/2002	12:30 PM	Ambient	25	N/A
PMRP-02-NV-25	US093-CL MP 65.00 - 67.00	Waterborne Paint	2771A9	White	TMT	10/16/2002	11:00 AM	Ambient	25	N/A
PMRP-02-NV-26	US093-CL MP 65.00 - 67.00	Waterborne Paint	2772A9	LF Yellow	TMT	10/16/2002	11:00 AM	Ambient	25	N/A
PMRP-02-NV-07	US093-CL MP 67.00 - 70.00	Waterborne Paint	NVW-40-M-2	White	EPI	10/16/2002	1:00 PM	Ambient	25	N/A
PMRP-02-NV-08	US093-CL MP 67.00 - 70.00	Waterborne Paint	NVY-40-M-2	LF Yellow	EPI	10/16/2002	1:00 PM	Ambient	25	N/A
US095 (PCCP)										
PMRP-02-NV-11	US095-CL MP 63.50 - 64.00	Epoxy	LS50	White	EPO	9/25/2002	11:00 PM	125	15	N/A
PMRP-02-NV-12	US095-CL MP 63.50 - 64.00	Epoxy	LS50	Yellow	EPO	9/24/2002	11:30 PM	125	15	N/A
PMRP-02-NV-01	US095-CL MP 64.00 - 64.50	Polyurea	LPM 1000	White	3M	9/25/2002	11:30 PM	160 R / 135 C	20	N/A
PMRP-02-NV-02	US095-CL MP 64.00 - 64.50	Polyurea	LPM 1000	LF Yellow	3M	9/25/2002	12:00 AM	165 R / 135 C	20	N/A
PMRP-02-NV-21	US095-CL MP 64.50 - 65.00	Epoxy	Mark-55.3	White	PCI	9/26/2002	12:00 AM	130	20	N/A
PMRP-02-NV-22	US095-CL MP 64.50 - 65.00	Epoxy	Mark-55.3	Yellow	PCI	9/25/2002	1:00 AM	130	25	N/A
PMRP-02-NV-19	US095-CL MP 65.00 - 65.50	Alkyd Thermoplastic	T-1001AASHTO	White	PPC	9/26/2002	2:00 AM	400	60	Thermo Adhesive
PMRP-02-NV-20	US095-CL MP 65.00 - 65.50	Alkyd Thermoplastic	T-1003AASHTO	LF Yellow	PPC	9/25/2002	2:30 AM	400	60	Thermo Adhesive
PMRP-02-NV-05	US095-CL MP 65.50 - 66.00	Alkyd Thermoplastic	885555/W5E-5GS-1A	White	EPI	9/26/2002	1:30 AM	410	80	Thermo Adhesive
PMRP-02-NV-06	US095-CL MP 65.50 - 66.00	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	9/25/2002	2:00 AM	410	80	Thermo Adhesive
PMRP-02-NV-15	US095-CL MP 66.00 - 66.50	Waterborne Paint	6050	White	PPC	10/31/2002	N/AVAIL	Ambient	22	N/A
PMRP-02-NV-16	US095-CL MP 66.00 - 66.50	Waterborne Paint	6053	LF Yellow	PPC	9/25/2002	3:00 AM	Ambient	22	N/A

Table 3.3 Bead Application Data for SR028 and SR431 - 2002 Test Site (Page 1 of 4)

Project Code	Location	Material Type	Product Trade Name	Color	Vendor ID	Bead Type	Beads Pounds/Gal	Bead Coating
SR028 (PBS w/OGWC)								
PMRP-02-NV-15	SR028-WA MP 0.00 - 1.00	Waterborne Paint	6050	White	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-16	SR028-WA MP 0.00 - 1.00	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-07	SR028-WA MP 1.00 - 2.00	Waterborne Paint	NVW-40-M-2	White	EPI	NV Spec Type A	9	Embedment
PMRP-02-NV-08	SR028-WA MP 1.00 - 2.00	Waterborne Paint	NVY-40-M-2	LF Yellow	EPI	NV Spec Type A	9	Embedment
PMRP-02-NV-25	SR028-WA MP 4.00 - 5.00	Waterborne Paint	2771A9	White	TMT	NV Spec Type A	9	Embedment
PMRP-02-NV-26	SR028-WA MP 4.00 - 5.00	Waterborne Paint	2772A9	Yellow	TMT	NV Spec Type A	9	Embedment
PMRP-02-NV-23	SR028-WA MP 5.00 - 6.30	Waterborne Paint	BP19421	White	SW	NV Spec Type A	9	Embedment
PMRP-02-NV-24	SR028-WA MP 5.00 - 6.30	Waterborne Paint	BP19422	LF Yellow	SW	NV Spec Type A	9	Embedment
PMRP-02-NV-17	SR028-WA MP 6.30 - 8.00	Waterborne Paint	7950	White	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-18	SR028-WA MP 6.30 - 8.00	Waterborne Paint	7953	LF Yellow	PPC	NV Spec Type A	9	Embedment
SR431 2002 Test Site (PBS w/OGWC)								
PMRP-02-NV-05	SR431-WA MP 4.00 - 4.30	Alkyd Thermoplastic	885555/W5E-5GS-1A	White	EPI	AASHTO M-247-I	10 lbs/100 sq. ft.	N/AVAIL
PMRP-02-NV-06	SR431-WA MP 4.00 - 4.30	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	AASHTO M-247-I	10 lbs/100 sq. ft.	N/AVAIL
PMRP-02-NV-09	SR431-WA MP 4.30 - 4.60	Epoxy	LS52	White	EPO	NV Spec Types I and II	9 ea (18 total)	Type 1 - Silane-type Type II - MP
PMRP-02-NV-10	SR431-WA MP 4.30 - 4.60	Epoxy	LS52	LF Yellow	EPO	NV Spec Types I and II	9 each (18 total)	Type 1 - Silane-type Type II - MP
PMRP-02-NV-13	SR431-WA MP 4.60 - 4.90	Polyurea	LS90	White	EPO	NV Spec Types I and II	9 each (18 total)	Type 1 - Silane-type Type II - MP
PMRP-02-NV-14	SR431-WA MP 4.60 - 4.90	Polyurea	LS90	LF Yellow	EPO	NV Spec Types I and II	9 each (18 total)	Type 1 - Silane-type Type II - MP
PMRP-02-NV-03	SR431-WA MP 4.90 - 5.05	Polyurea	LPM 1200	White	3M	Reflective Elements & NV Spec Type III	3 8	N/A MP
PMRP-02-NV-04	SR431-WA MP 4.90 - 5.05	Polyurea	LPM 1200	LF Yellow	3M	Reflective Elements & NV Spec Type III	3 8	N/A MP
PMRP-02-NV-01	SR431-WA MP 5.05 - 5.20	Polyurea	LPM 1000	White	3M	NV Spec Type III	8	MP
PMRP-02-NV-02	SR431-WA MP 5.05 - 5.20	Polyurea	LPM 1000	LF Yellow	3M	NV Spec Type III	8	MP
PMRP-02-NV-21	SR431-WA MP 5.20 - 5.50	Epoxy	Mark-55.3	White	PCI	Megalux FP-96 Type 3 & AASHTO M-247-81 Type 1	9 each (18 total)	Type 3 - T-20 Type 1 - MR T-01
PMRP-02-NV-22	SR431-WA MP 5.20 - 5.50	Epoxy	Mark-55.3	Yellow	PCI	Megalux FP-96 Type 3 & AASHTO M-247-81 Type 1	9 each (18 total)	Type 3 - T-20 Type 1 - MR T-01

Table 3.3 Bead Application Data for SR431 - 2003 Test Site (Page 2 of 4)

Project Code	Location	Material Type	Product Trade Name	Color	Vendor ID	Bead Type	Beads Pounds/Gal	Bead Coating
SR431 2003 Test Site (PBS w/OGWC)								
PMRP-02-NV-15	SR431-WA MP 4.90 - 5.20 (Single Application)	Waterborne Paint	6050	White	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-16	SR431-WA MP 4.90 - 5.20 (Single Application)	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-15	SR431-WA MP 4.90 - 5.20 (Double Application)	Waterborne Paint	6050	White	PPC	NV Spec Type A	9 each application	Embedment
PMRP-02-NV-16	SR431-WA MP 4.90 - 5.20 (Double Application)	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type A	9 each application	Embedment
PMRP-02-NV-27	SR431-WA MP 4.90	Tape High Performance	A380IES	White	3M	N/A	N/A	N/A
PMRP-02-NV-28	SR431-WA MP 5.20	Tape High Performance	A381IES	Yellow	3M	N/A	N/A	N/A
PMRP-02-NV-29	SR431-WA MP 4.90	Tape Wet Reflective	A820	White	3M	N/A	N/A	N/A
PMRP-02-NV-30	SR431-WA MP 5.20	Tape Wet Reflective	A821	Yellow	3M	N/A	N/A	N/A

Table 3.3 Bead Application Data for US050 (Page 3 of 4)

Project Code	Location	Material Type	Product Trade Name	Color	Vendor ID	Bead Type	Beads Pounds/Gal	Bead Coating
US050 (PBS w/OGWC)								
PMRP-02-NV-07	US050-CH MP 31.42 - 33.00	Waterborne Paint	NVW-40-M-2	White	EPI	NV Spec Type B	9	Embedment
PMRP-02-NV-08	US050-CH MP 31.42 - 33.00	Waterborne Paint	NVY-40-M-2	LF Yellow	EPI	NV Spec Type B	9	Embedment
PMRP-02-NV-23	US050-CH MP 33.00 - 34.50	Waterborne Paint	BP19421	White	SW	NV Spec Type B	9	Embedment
PMRP-02-NV-24	US050-CH MP 33.00 - 34.50	Waterborne Paint	BP19422	LF Yellow	SW	NV Spec Type B	9	Embedment
PMRP-02-NV-25	US050-CH MP 34.50 - 36.00	Waterborne Paint	2771A9	White	TMT	NV Spec Type B	9	Embedment
PMRP-02-NV-26	US050-CH MP 34.50 - 36.00	Waterborne Paint	2772A9	Yellow	TMT	NV Spec Type B	9	Embedment
PMRP-02-NV-17	US050-CH MP 36.00 - 37.50	Waterborne Paint	7950	White	PPC	NV Spec Type B	9	Embedment
PMRP-02-NV-18	US050-CH MP 36.00 - 37.50	Waterborne Paint	7953	LF Yellow	PPC	NV Spec Type B	9	Embedment
PMRP-02-NV-15	US050-CH MP 37.50 - 39.00	Waterborne Paint	6050	White	PPC	NV Spec Type B	9	Embedment
PMRP-02-NV-16	US050-CH MP 37.50 - 39.00	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type B	9	Embedment
PMRP-02-NV-15	US050-CH MP 39.00 - 41.00 (N Edge)	Waterborne Paint	6050	White	PPC	NV Spec Type B	9	Embedment
PMRP-02-NV-16	US050-CH MP 39.00 - 41.00 (CL)	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-15	US050-CH MP 39.00 - 41.00 (S Edge)	Waterborne Paint	6050	White	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-15	US050-CH MP 41.00 - 42.00 (N Edge)	Waterborne Paint	6050	White	PPC	NV Spec Type B	12	Embedment
PMRP-02-NV-16	US050-CH MP 41.00 - 42.00 (CL)	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type B	12	Embedment
PMRP-02-NV-15	US050-CH MP 41.00 - 43.76 (S Edge)	Waterborne Paint	6050	White	PPC	NV Spec Type A	12	Embedment
PMRP-02-NV-15	US050-CH MP 42.00 - 43.00 (N Edge)	Waterborne Paint	6050	White	PPC	NV Spec Type B	9	Embedment
PMRP-02-NV-16	US050-CH MP 42.00 - 43.00 (CL)	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type B	9	Embedment
PMRP-02-NV-15	US050-CH MP 43.00 - 43.76 (N Edge)	Waterborne Paint	6050	White	PPC	NV Spec Type B	12	Embedment
PMRP-02-NV-16	US050-CH MP 43.00 - 43.76 (CL)	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type B	12	Embedment

Table 3.3 Bead Application Data for US093 and US095 (Page 4 of 4)

Project Code	Location	Material Type	Product Trade Name	Color	Vendor ID	Bead Type	Beads Pounds/Gal	Bead Coating
US093 (PBS w/OGWC)								
PMRP-02-NV-15	US093-CL MP 59.00 - 61.00	Waterborne Paint	6050	White	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-16	US093-CL MP 59.00 - 61.00	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-23	US093-CL MP 61.00 - 63.00	Waterborne Paint	BP19421	White	SW	NV Spec Type A	9	Embedment
PMRP-02-NV-24	US093-CL MP 61.00 - 63.00	Waterborne Paint	BP19422	LF Yellow	SW	NV Spec Type A	9	Embedment
PMRP-02-NV-17	US093-CL MP 63.00 - 65.00	Waterborne Paint	7950	White	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-18	US093-CL MP 63.00 - 65.00	Waterborne Paint	7953	LF Yellow	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-25	US093-CL MP 65.00 - 67.00	Waterborne Paint	2771A9	White	TMT	NV Spec Type A	9	Embedment
PMRP-02-NV-26	US093-CL MP 65.00 - 67.00	Waterborne Paint	2772A9	LF Yellow	TMT	NV Spec Type A	9	Embedment
PMRP-02-NV-07	US093-CL MP 67.00 - 70.00	Waterborne Paint	NVW-40-M-2	White	EPI	NV Spec Type A	9	Embedment
PMRP-02-NV-08	US093-CL MP 67.00 - 70.00	Waterborne Paint	NVY-40-M-2	LF Yellow	EPI	NV Spec Type A	9	Embedment
US095 (PCCP)								
PMRP-02-NV-11	US095-CL MP 63.50 - 64.00	Epoxy	LS50	White	EPO	NV Spec Types I and II	9 each (18 total)	Type 1 - Silane-type Type II - MP
PMRP-02-NV-12	US095-CL MP 63.50 - 64.00	Epoxy	LS50	Yellow	EPO	NV Spec Types I and II	9 each (18 total)	Type 1 - Silane-type Type II - MP
PMRP-02-NV-01	US095-CL MP 64.00 - 64.50	Polyurea	LPM 1000	White	3M	NV Spec Type III	8	MP
PMRP-02-NV-02	US095-CL MP 64.00 - 64.50	Polyurea	LPM 1000	LF Yellow	3M	NV Spec Type III	8	MP
PMRP-02-NV-21	US095-CL MP 64.50 - 65.00	Epoxy	Mark-55.3	White	PCI	Megalux FP-96 Type 3 & AASHTO M-247-81 Type 1	9 each (18 total)	Type 3 - T-20 Type 1 - MR T-01
PMRP-02-NV-22	US095-CL MP 64.50 - 65.00	Epoxy	Mark-55.3	Yellow	PCI	Megalux FP-96 Type 3 & AASHTO M-247-81 Type 1	9 each (18 total)	Type 3 - T-20 Type 1 - MR T-01
PMRP-02-NV-19	US095-CL MP 65.00 - 65.50	Alkyd Thermoplastic	T-1001AASHTO	White	PPC	CA Spec Types I and II	10 lbs/100 sq. ft.	N/AVAIL
PMRP-02-NV-20	US095-CL MP 65.00 - 65.50	Alkyd Thermoplastic	T-1003AASHTO	LF Yellow	PPC	CA Spec Types I and II	10 lbs/100 sq. ft.	N/AVAIL
PMRP-02-NV-05	US095-CL MP 65.50 - 66.00	Alkyd Thermoplastic	885555/W5E-5GS-1A	White	EPI	AASHTO M-247-I	10 lbs/100 sq. ft.	N/AVAIL
PMRP-02-NV-06	US095-CL MP 65.50 - 66.00	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	AASHTO M-247-I	10 lbs/100 sq. ft.	N/AVAIL
PMRP-02-NV-15	US095-CL MP 66.00 - 66.50	Waterborne Paint	6050	White	PPC	NV Spec Type A	9	Embedment
PMRP-02-NV-16	US095-CL MP 66.00 - 66.50	Waterborne Paint	6053	LF Yellow	PPC	NV Spec Type A	9	Embedment

Table 3.4 Weather Conditions During Application of Materials on SR028 and SR431 - 2002 Test Site (Page 1 of 2)

Date	Time	Pavement Temperature (°F)	Atmospheric Temperature (°F)	Relative Humidity (%)	Dew Point (°F)	Wind Speed (MPH)	Wind Direction (True)
9/10/2002	2:00 PM	115	73	14	21	5	30
9/10/2002	2:30 PM	114	75	15	25	5	30
9/10/2002	3:00 PM	112	75	15	25	4	20
9/10/2002	3:30 PM	107	75	15	25	2	VRB
9/10/2002	4:00 PM	103	75	15	25	2	VRB
9/11/2002	9:00 AM	70	63	29	30	2	VRB
9/11/2002	9:30 AM	78	64	28	30	2	VRB
9/11/2002	10:00 AM	90	66	27	31	5	40
9/11/2002	10:30 AM	93	70	24	31	5	40
9/11/2002	11:00 AM	93	72	22	31	5	40
9/11/2002	11:30 AM	96	72	21	30	4	20
9/11/2002	12:00 PM	104	73	20	29	4	20
9/11/2002	12:30 PM	106	73	15	23	4	20
9/11/2002	1:00 PM	113	75	13	21	2	VRB
9/11/2002	1:30 PM	121	75	13	21	4	20
9/11/2002	2:00 PM	110	75	13	21	7	30
9/11/2002	2:30 PM	105	75	13	21	6	VRB
9/11/2002	3:00 PM	101	75	13	21	3	VRB
9/11/2002	3:30 PM	98	75	14	22	3	VRB
9/11/2002	4:00 PM	98	75	14	23	3	VRB
9/12/2002	9:00 AM	70	64	27	29	0	N/A
9/12/2002	9:30 AM	78	66	25	29	0	N/A
9/12/2002	10:00 AM	83	70	22	29	5	40
9/12/2002	10:30 AM	85	72	18	26	3	40
9/12/2002	11:00 AM	86	72	18	26	3	40
9/12/2002	11:30 AM	92	74	17	27	3	VRB
9/12/2002	12:00 PM	101	75	19	30	3	VRB
9/12/2002	12:30 PM	111	77	14	25	3	VRB
9/12/2002	1:00 PM	103	77	11	18	3	VRB
9/12/2002	1:30 PM	113	77	12	20	3	VRB
9/12/2002	2:00 PM	113	77	12	20	3	VRB
9/12/2002	2:30 PM	111	77	12	20	3	VRB
9/12/2002	3:00 PM	111	77	11	19	4	20
9/12/2002	3:30 PM	111	77	11	19	0	N/A
9/12/2002	4:00 PM	104	77	12	20	0	N/A

Table 3.4 Weather Conditions During Application of Materials on SR028 and SR431 - 2002 Test Site (Page 2 of 2)

Date	Time	Pavement Temperature (°F)	Atmospheric Temperature (°F)	Relative Humidity (%)	Dew Point (°F)	Wind Speed (MPH)	Wind Direction (True)
9/13/2002	9:30 AM	81	53	45	32	0	N/A
9/13/2002	10:00 AM	83	64	30	32	3	VRB
9/13/2002	10:30 AM	74	68	26	32	3	VRB
9/13/2002	11:00 AM	78	70	24	32	6	30
9/13/2002	11:30 AM	92	72	23	32	4	VRB
9/13/2002	12:00 PM	113	72	23	32	4	VRB
9/13/2002	12:30 PM	120	74	21	32	4	VRB
9/13/2002	1:00 PM	121	74	21	32	6	20
9/13/2002	1:30 PM	122	76	20	32	3	VRB
9/13/2002	2:00 PM	112	76	20	32	3	VRB
9/13/2002	2:30 PM	112	76	20	32	3	VRB
9/13/2002	3:00 PM	106	76	18	29	5	VRB
9/13/2002	3:30 PM	102	78	16	29	3	VRB

Table 3.5 Weather Conditions During Application of Materials on SR431 - 2003 Test Site

Date	Time	Pavement Temperature (°F)	Atmospheric Temperature (°F)	Relative Humidity (%)	Dew Point (°F)	Wind Speed (MPH)	Wind Direction (True)
9/25/2003	9:00 AM	N/AVAIL	66	29	33	0	N/A
9/25/2003	10:00 AM	N/AVAIL	72	22	31	4.5	VRB
9/25/2003	11:00 AM	N/AVAIL	74	21	32	0	N/A
9/25/2003	12:00 PM	N/AVAIL	78	16	29	5.5	VRB
9/25/2003	1:00 PM	109	79	12	22	10	80
9/25/2003	2:00 PM	112	79	12	22	6	130
9/25/2003	3:00 PM	104	80	12	23	6	130
9/25/2003	4:00 PM	107	80	12	23	0	N/A
9/25/2003	5:00 PM	N/AVAIL	72	18	26	9	330

Table 3.6 Weather Conditions During Application of Materials on US050

Date	Time	Pavement Temperature (°F)	Atmospheric Temperature (°F)	Relative Humidity (%)	Dew Point (°F)	Wind Speed (MPH)	Wind Direction (True)
8/20/2002	1:30 PM	132	84	22	41	8	230
8/20/2002	2:00 PM	134	86	18	38	8	290
8/20/2002	2:30 PM	137	86	18	38	8	290
8/20/2002	3:00 PM	126	84	17	34	10	300
8/21/2002	9:00 AM	79	64	37	37	0	N/A
8/21/2002	9:30 AM	91	67	35	38	3	VRB
8/21/2002	10:00 AM	98	68	37	41	4	VRB
8/21/2002	10:30 AM	107	70	38	43	4	VRB
8/21/2002	11:00 AM	110	70	38	43	3	VRB
8/21/2002	11:30 AM	115	71	30	38	3	VRB
8/21/2002	12:00 PM	119	73	26	36	4	VRB
8/21/2002	12:30 PM	123	75	26	38	5	330
8/21/2002	1:00 PM	128	75	26	38	5	330
8/21/2002	1:30 PM	132	76	23	36	4	VRB
8/21/2002	2:00 PM	134	77	23	36	4	VRB
8/21/2002	2:30 PM	132	79	21	36	8	320
8/21/2002	3:00 PM	134	79	21	36	8	320
8/21/2002	3:30 PM	134	79	21	36	6	VRB
8/21/2002	4:00 PM	130	79	21	36	4	VRB
8/21/2002	4:30 PM	122	79	21	36	7	10
8/22/2002	7:30 AM	64	60	38	34	5	330
8/22/2002	8:00 AM	68	64	33	34	5	330
8/22/2002	8:30 AM	75	66	31	34	5	350
8/22/2002	9:00 AM	88	70	29	36	5	360
8/22/2002	9:30 AM	88	71	28	36	4	VRB
8/22/2002	10:00 AM	102	74	25	36	3	VRB
8/22/2002	10:30 AM	107	75	24	36	3	VRB
8/22/2002	11:00 AM	114	75	29	41	5	360
8/22/2002	11:30 AM	117	77	25	38	5	360
8/22/2002	12:00 PM	128	79	20	34	3	VRB
8/22/2002	12:30 PM	131	80	19	34	3	VRB
8/22/2002	1:00 PM	137	81	20	36	2	VRB
8/22/2002	1:30 PM	136	82	18	34	3	VRB
8/22/2002	2:00 PM	139	82	16	32	3	VRB
8/22/2002	2:30 PM	137	82	18	34	5	320
8/22/2002	3:00 PM	134	82	18	34	6	320
8/22/2002	3:30 PM	136	84	17	34	6	320
8/22/2002	4:00 PM	130	84	17	34	6	320
8/22/2002	4:30 PM	118	84	17	34	7	320
8/22/2002	5:00 PM	118	84	17	34	5	10
8/30/2002	10:30 AM	112	78	24	38	2	170
8/30/2002	11:00 AM	118	81	20	36	3	170
8/30/2002	11:30 AM	122	83	20	38	6	300
8/30/2002	12:00 PM	127	84	19	38	7	300

Table 3.7 Weather Conditions During Application of Materials on US093

Date	Time	Pavement Temperature (°F)	Atmospheric Temperature (°F)	Relative Humidity (%)	Dew Point (°F)	Wind Speed (MPH)	Wind Direction (True)
10/14/2002	10:00 AM	77	71	20	28	0	N/A
10/14/2002	10:30 AM	81	72	19	28	0	N/A
10/14/2002	11:00 AM	88	73	20	30	0	N/A
10/14/2002	11:30 AM	90	73	19	28	0	N/A
10/14/2002	12:00 PM	90	77	16	28	4	70
10/14/2002	12:30 PM	96	79	18	32	4	60
10/14/2002	1:00 PM	98	79	18	32	4	50
10/15/2002	9:30 AM	78	70	18	24	0	N/A
10/15/2002	10:00 AM	79	70	18	25	3	200
10/15/2002	10:30 AM	81	74	16	25	3	200
10/15/2002	11:00 AM	84	76	15	25	0	N/A
10/15/2002	11:30 AM	88	76	15	25	0	N/A
10/15/2002	12:00 PM	91	77	14	25	4	260
10/15/2002	12:30 PM	95	80	14	27	4	260
10/15/2002	1:00 PM	99	81	14	27	4	260
10/16/2002	9:00 AM	N/AVAIL	67	20	24	0	N/A
10/16/2002	9:30 AM	N/AVAIL	70	18	24	0	N/A
10/16/2002	10:00 AM	N/AVAIL	72	19	27	0	N/A
10/16/2002	10:30 AM	N/AVAIL	73	17	26	0	N/A
10/16/2002	11:00 AM	N/AVAIL	76	15	25	0	N/A
10/16/2002	11:30 AM	N/AVAIL	78	14	25	0	N/A
10/16/2002	12:00 PM	N/AVAIL	79	15	27	5	60
10/16/2002	12:30 PM	N/AVAIL	80	14	27	5	60
10/16/2002	1:00 PM	N/AVAIL	81	14	28	6	60

Table 3.8 Weather Conditions During Application of Materials on US095

Date	Time	Pavement Temperature (°F)	Atmospheric Temperature (°F)	Relative Humidity (%)	Dew Point (°F)	Wind Speed (MPH)	Wind Direction (True)
9/24/2002	10:30 PM	81	85	18	35	5	240
9/24/2002	11:00 PM	84	83	18	35	6	240
9/24/2002	11:30 PM	84	83	18	35	6	240
9/25/2002	12:00 AM	84	84	17	34	8	200
9/25/2002	12:30 AM	83	83	17	34	6	190
9/25/2002	1:00 AM	83	83	17	34	6	190
9/25/2002	1:30 AM	83	85	16	35	6	190
9/25/2002	2:00 AM	82	87	16	35	5	200
9/25/2002	2:30 AM	82	83	18	35	5	200
9/25/2002	10:30 PM	88	90	19	43	6	230
9/25/2002	11:00 PM	88	86	20	41	8	200
9/25/2002	11:30 PM	88	87	20	41	8	200
9/26/2002	12:00 AM	88	90	17	40	8	40
9/26/2002	12:30 AM	88	88	18	40	8	40
9/26/2002	1:00 AM	86	88	18	39	3	180
9/26/2002	1:30 AM	86	86	18	37	5	180
9/26/2002	2:00 AM	86	85	18	37	8	40

CHAPTER 4 – RESULTS FOR SR028 TEST SITE

Background

The SR028 test site is located on a two-lane plantmix bituminous with open-grade wearing course roadway in Washoe County, Nevada from mileposts 0.00 to 8.00 (Figure 4.1 near Incline Village).

Waterborne pavement marking materials were longitudinally placed as center and edge lines over worn out paint in the same manner that occurs for typical NDOT maintenance restriping operations. Figure 4.2 shows a diagram of the test site layout. Materials were installed in September 2002 and monitored until February 2003.

Evaluation Based on Durability, Retroreflectivity, and Color

Durability

Table 4.1 presents the durability observations for the pavement marking materials placed on the SR028 test site. Good durability for both yellow and white markings lasted a minimum of 2.5 months. There was an average of 40% of the products left on the roadway within five months of application. Figures 4.6 and 4.7 illustrate the amount of wear that occurs on pavement markings due to snow removal activities.

Retroreflectivity

Table 4.1 lists the recorded retroreflectivity measurements. Figures 4.3 through 4.5 show retroreflectivity comparisons for the east edge, center, and west edge lines. Retroreflectivity measurements indicate that all yellow pavement markings were below 100 mcd/m^2/lux within 2.5 months. Only three of the ten white colored stripes retained readings over 125 mcd/m^2/lux throughout the monitoring process, despite a loss of durability.

Color

Table 4.2 contains the color measurement results for the pavement marking materials. Most yellow colored marking materials were noncompliant with ASTM D 6628, "Standard Specification for Color of Pavement Marking Materials," within 2.5 months of application (15). All white colored pavement markings were compliant with specified chromaticity coordinates after 5 months of application. However, the daytime luminance factor minimums were not achieved. The color measurements displayed with red font and underlined are measurements that do not meet daytime chromaticity coordinate or luminance factor color requirements according to ASTM D 6628.

Winter Maintenance Activities

This location is known for rugged winter conditions. Previous attempts at striping maintenance have included the application of solvent-borne traffic paint a minimum of three to four times per year.

Pavement markings were subjected to the winter maintenance activities listed in Tables 4.3 and 4.4. Activities included snow removal and application of salt and sand, salt and chlorides, and salt brine solution. The location was snowplowed an estimated 327 times

from November 2002 until February 2003. In addition, 43 cubic yards of salt and sand, 3.5 cubic yards of salt and chlorides, and 1225 gallons of salt brine solution were placed on the location from November 2002 until February 2003.

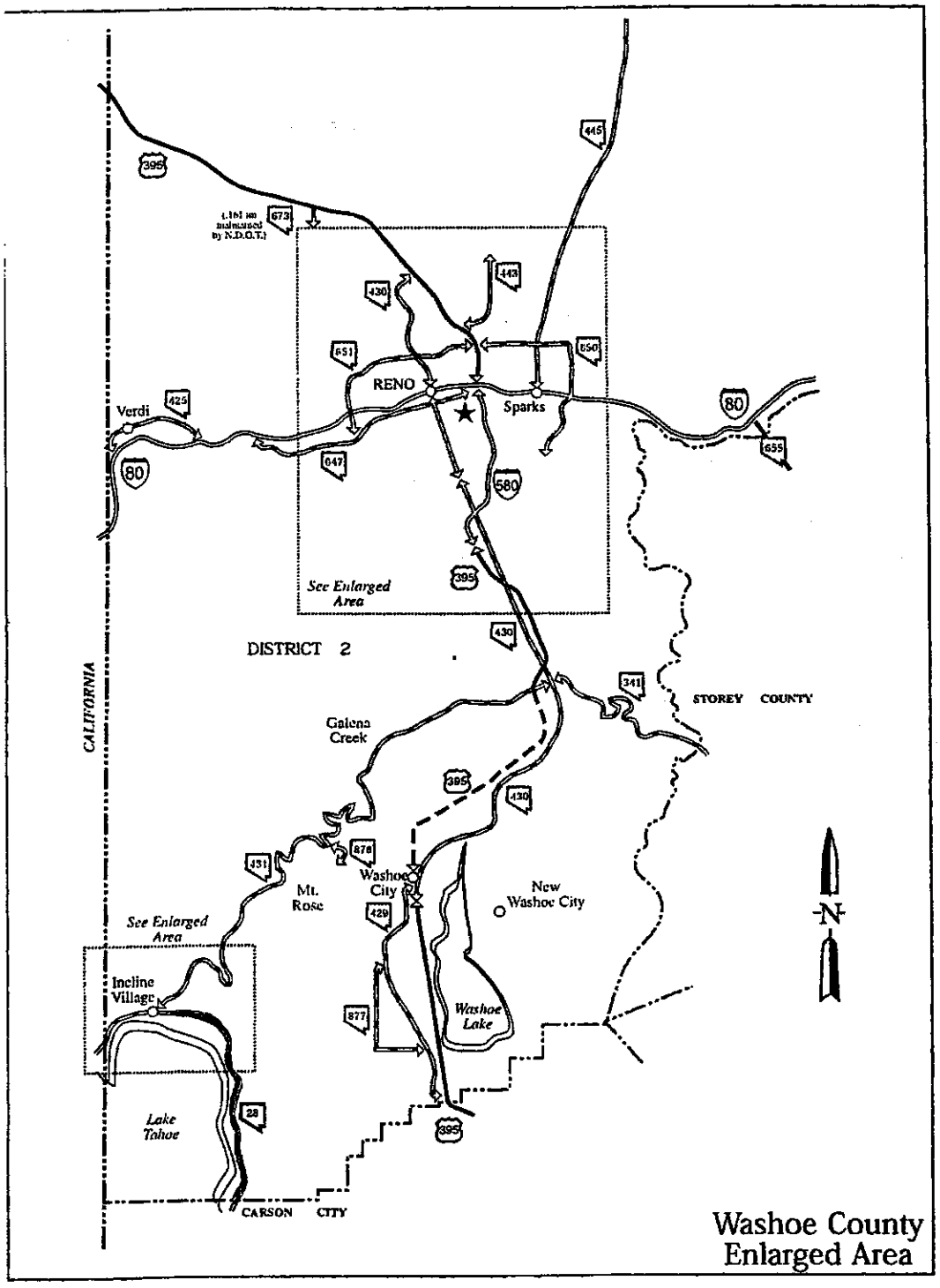


Figure 4.1 Map of Washoe County, Nevada

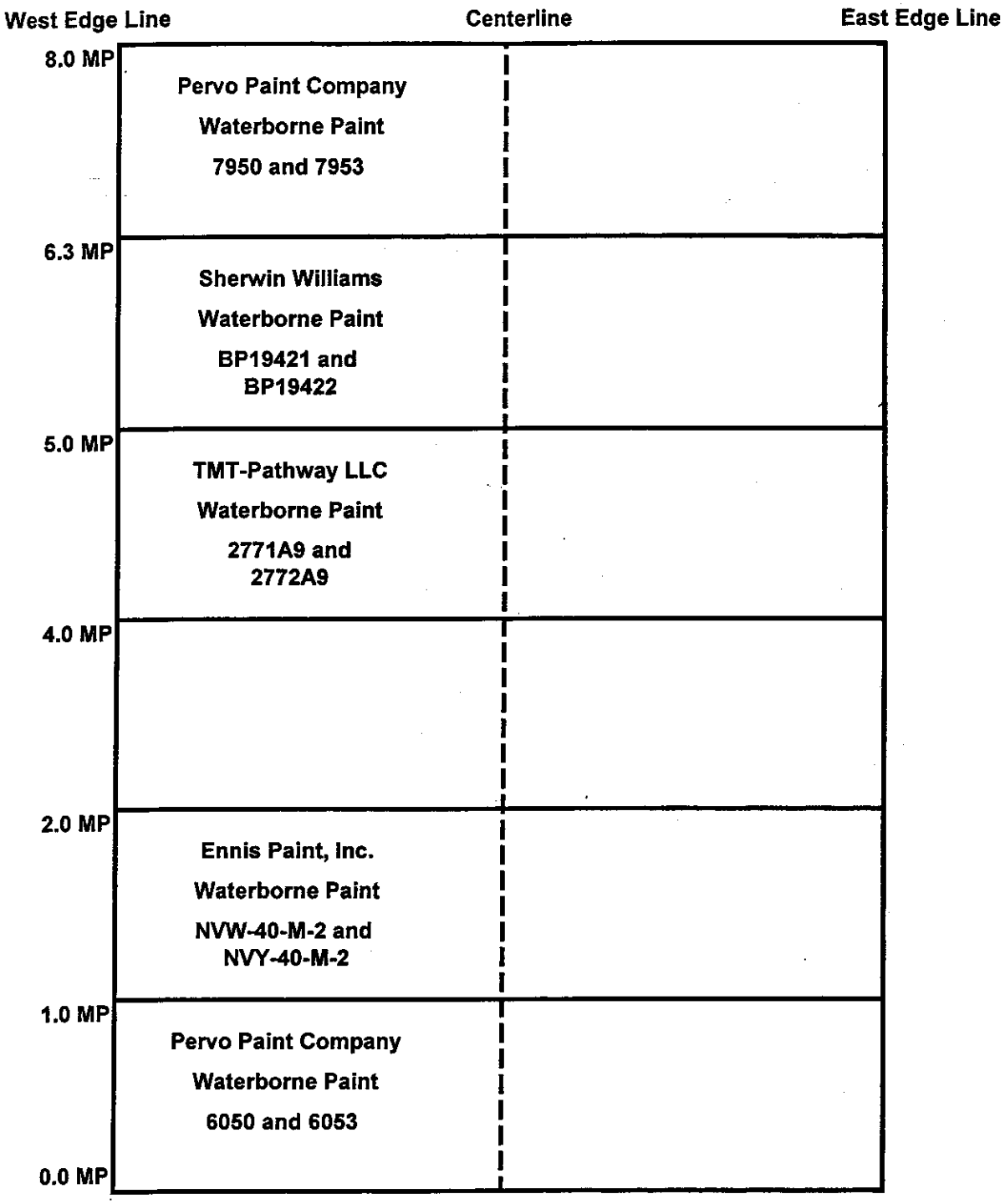


Figure 4.2 SR028 – Washoe County Test Site Layout

Table 4.1 SR028 - Washoe County
Retroreflectivity and Durability Data

Project Code	Material Type	Product Trade Name	Color	Vendor ID	Sep-02 RR	Sep-02 DUR	Nov-02 RR	Nov-02 DUR	Feb-03 RR	Feb-03 DUR
PMRP-02-NV-07	Waterborne Paint	NVW-40-M-2	E Edge White	EPI	291	10	171	10	142	6
PMRP-02-NV-08	Waterborne Paint	NVY-40-M-2	LF Yellow	EPI	174	10	76	10	23	4
PMRP-02-NV-07	Waterborne Paint	NVW-40-M-2	W Edge White	EPI	345	10	134	10	153	6
PMRP-02-NV-15	Waterborne Paint	6050	E Edge White	PPC	347	10	160	10	120	5
PMRP-02-NV-16	Waterborne Paint	6053	LF Yellow	PPC	222	10	64	10	45	3
PMRP-02-NV-15	Waterborne Paint	6050	W Edge White	PPC	392	10	224	10	118	5
PMRP-02-NV-17	Waterborne Paint	7950	E Edge White	PPC	169	10	213	10	84	2
PMRP-02-NV-18	Waterborne Paint	7953	LF Yellow	PPC	154	10	49	10	94	3
PMRP-02-NV-17	Waterborne Paint	7950	W Edge White	PPC	211	10	184	10	56	2
PMRP-02-NV-23	Waterborne Paint	BP19421	E Edge White	SW	338	10	184	10	56	3
PMRP-02-NV-24	Waterborne Paint	BP19422	LF Yellow	SW	194	10	83	10	57	4
PMRP-02-NV-23	Waterborne Paint	BP19421	W Edge White	SW	310	10	200	10	39	3
PMRP-02-NV-25	Waterborne Paint	2771A9	E Edge White	TMT	276	10	187	10	144	5
PMRP-02-NV-26	Waterborne Paint	2772A9	LF Yellow	TMT	133	10	82	10	46	4
PMRP-02-NV-25	Waterborne Paint	2771A9	W Edge White	TMT	293	10	188	10	94	5

Table 4.2 SR028 - Washoe County
Color Data

Project Code	Material Type	Product Trade Name	Color	Vendor ID	November 2002			February 2003		
					Y	x	y	Y	x	y
PMRP-02-NV-07	Waterborne Paint	NVW-40-M-2	E Edge White	EPI	37.65	0.3374	0.3541	31.67	0.3395	0.3547
PMRP-02-NV-08	Waterborne Paint	NVY-40-M-2	LF Yellow	EPI	24.17	0.4302	0.4103	24.15	0.3987	0.3969
PMRP-02-NV-07	Waterborne Paint	NVW-40-M-2	W Edge White	EPI	42.39	0.3391	0.3562	32.92	0.3392	0.3543
PMRP-02-NV-15	Waterborne Paint	6050	E Edge White	PPC	41.25	0.3364	0.3538	28.80	0.3432	0.3578
PMRP-02-NV-16	Waterborne Paint	6053	LF Yellow	PPC	29.29	0.4456	0.4229	23.93	0.3980	0.3951
PMRP-02-NV-15	Waterborne Paint	6050	W Edge White	PPC	39.78	0.3377	0.3548	32.60	0.3400	0.3554
PMRP-02-NV-17	Waterborne Paint	7950	E Edge White	PPC	33.61	0.3400	0.3564	35.40	0.3389	0.3549
PMRP-02-NV-18	Waterborne Paint	7953	LF Yellow	PPC	27.49	0.4151	0.4083	29.92	0.3939	0.3915
PMRP-02-NV-17	Waterborne Paint	7950	W Edge White	PPC	28.55	0.3434	0.3596	29.96	0.3396	0.3547
PMRP-02-NV-23	Waterborne Paint	BP19421	E Edge White	SW	39.86	0.3351	0.3515	22.99	0.3376	0.3529
PMRP-02-NV-24	Waterborne Paint	BP19422	LF Yellow	SW	32.06	0.4351	0.4204	28.04	0.3933	0.3882
PMRP-02-NV-23	Waterborne Paint	BP19421	W Edge White	SW	38.08	0.3379	0.3547	25.21	0.3391	0.3541
PMRP-02-NV-25	Waterborne Paint	2771A9	E Edge White	TMT	47.90	0.3402	0.3574	34.83	0.3395	0.3550
PMRP-02-NV-26	Waterborne Paint	2772A9	LF Yellow	TMT	28.69	0.4356	0.4180	28.15	0.3987	0.3964
PMRP-02-NV-25	Waterborne Paint	2771A9	W Edge White	TMT	40.25	0.3451	0.3615	29.43	0.3415	0.3561

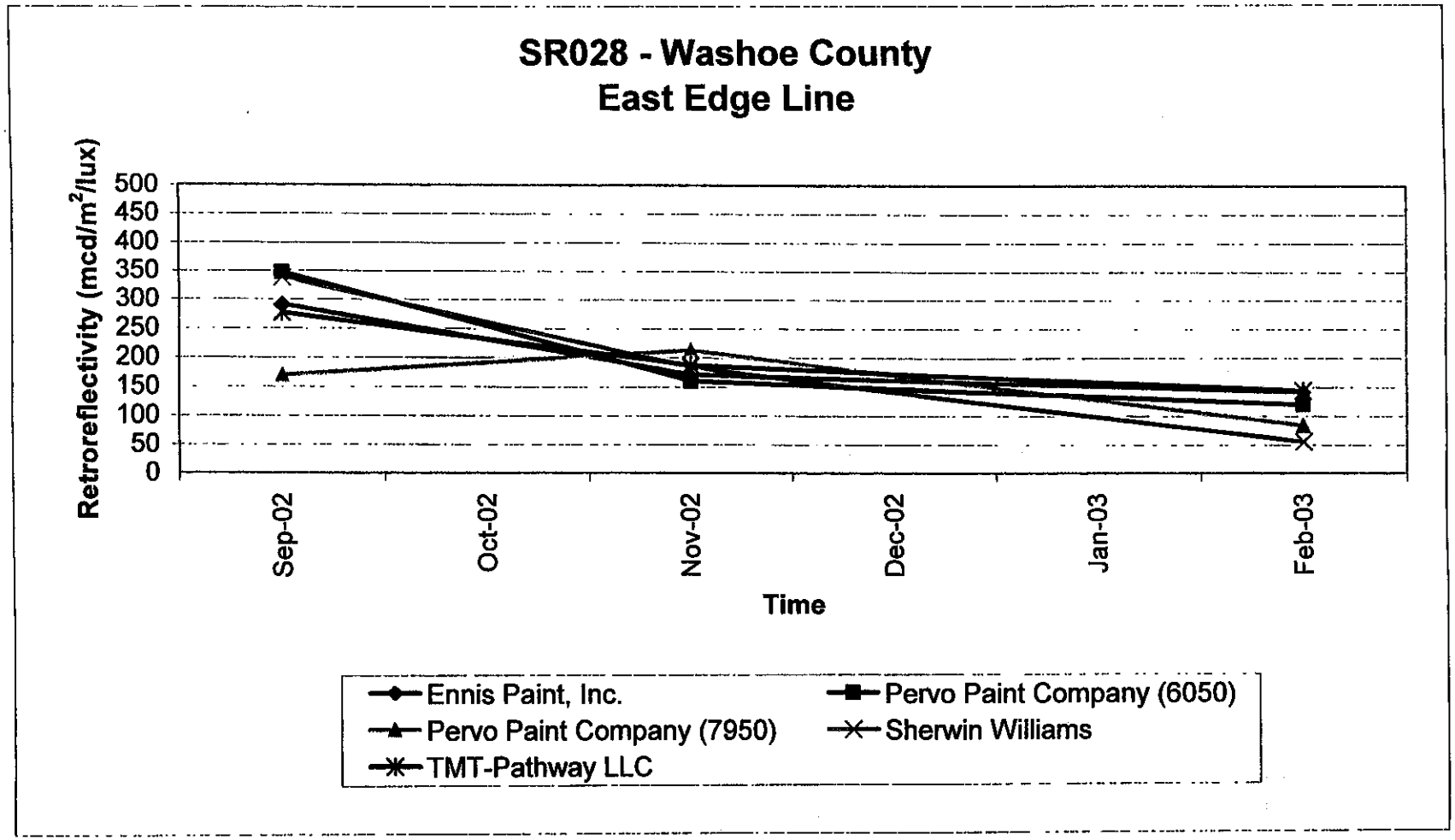


Figure 4.3 SR028 Retroreflectivity Comparison for East Edge Line

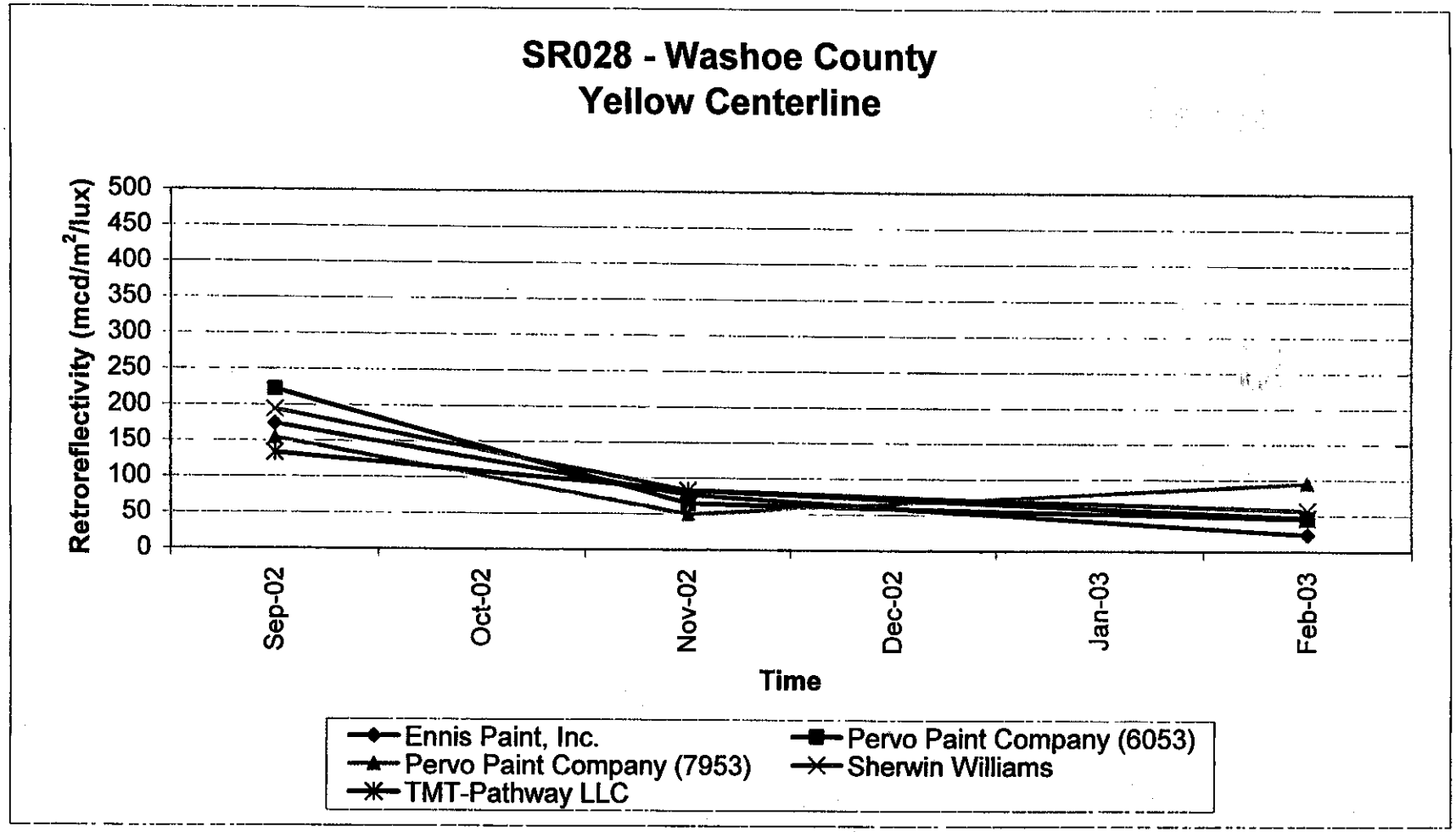


Figure 4.4 SR028 Retroreflectivity Comparison for Centerline

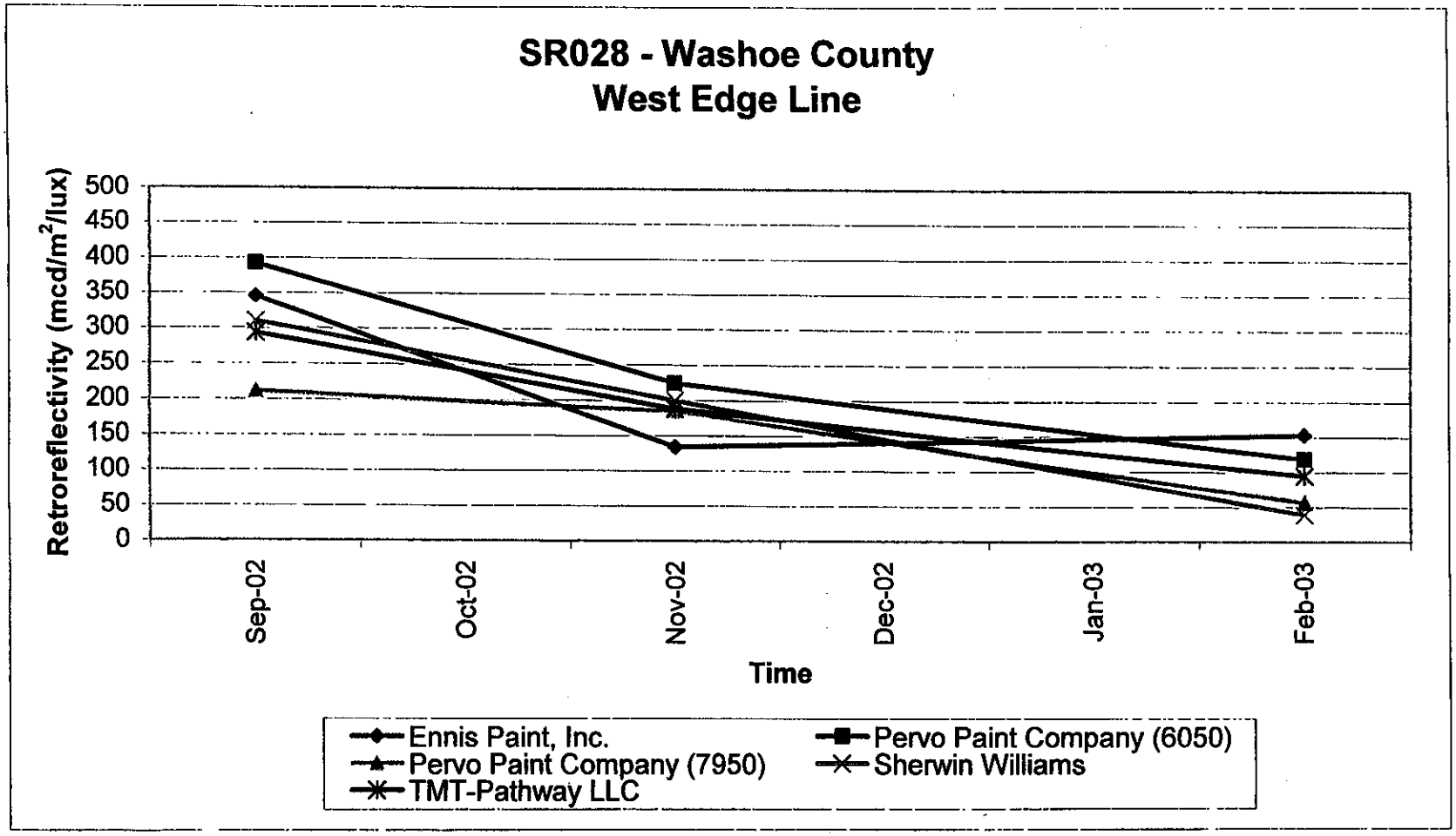


Figure 4.5 SR028 Retroreflectivity Comparison for West Edge Line

Winter Maintenance Activities for the SR028 Test Site

Table 4.3 contains a summary of the estimated number of snowplow passes on the SR028 test site. The site was snowplowed an estimated 327 times from November 2002 until February 2003. NDOT manages maintenance activities with a database containing task descriptions, number of man-hours utilized, and materials and equipment used. Estimates are based upon information contained within the database and discussion with snowplow operators.

Table 4.3 Estimated Number of Snowplow Passes on the SR028 Test Site

Month	Number of Hours per Month of Snowplow Activity	Estimated Number of Snowplow Passes per Month
Nov 2002	26	26
Dec 2002	169	169
Jan 2003	35	35
Feb 2003	97	97
		Total Estimated Snowplow Passes for 02/03 Season: 327

Table 4.4 shows that 43 cubic yards of salt and sand, 3.5 cubic yards of salt and chlorides, and 1225 gallons of salt brine solution were placed on the SR028 test site from November 2002 until February 2003.

Table 4.4 Salt and Sand, Salt and Chlorides, and Salt Brine Quantities

Month	Description of Treatment	Quantity per Month (Cubic Yards / Gallons)
Nov 2002	Salt and Sand	5
Dec 2002	Salt and Sand	28
Jan 2003	Salt and Sand	3
Feb 2003	Salt and Sand	7
		Total for 02/03 Season: 43 CY
Dec 2002	Salt and Chlorides	2
Feb 2002	Salt and Chlorides	1.5
		Total for 02/03 Season: 3.5 CY
Dec 2002	Salt Brine	750
Jan 2003	Salt Brine	50
Feb 2003	Salt Brine	425
		Total for 02/03 Season: 1225 GAL

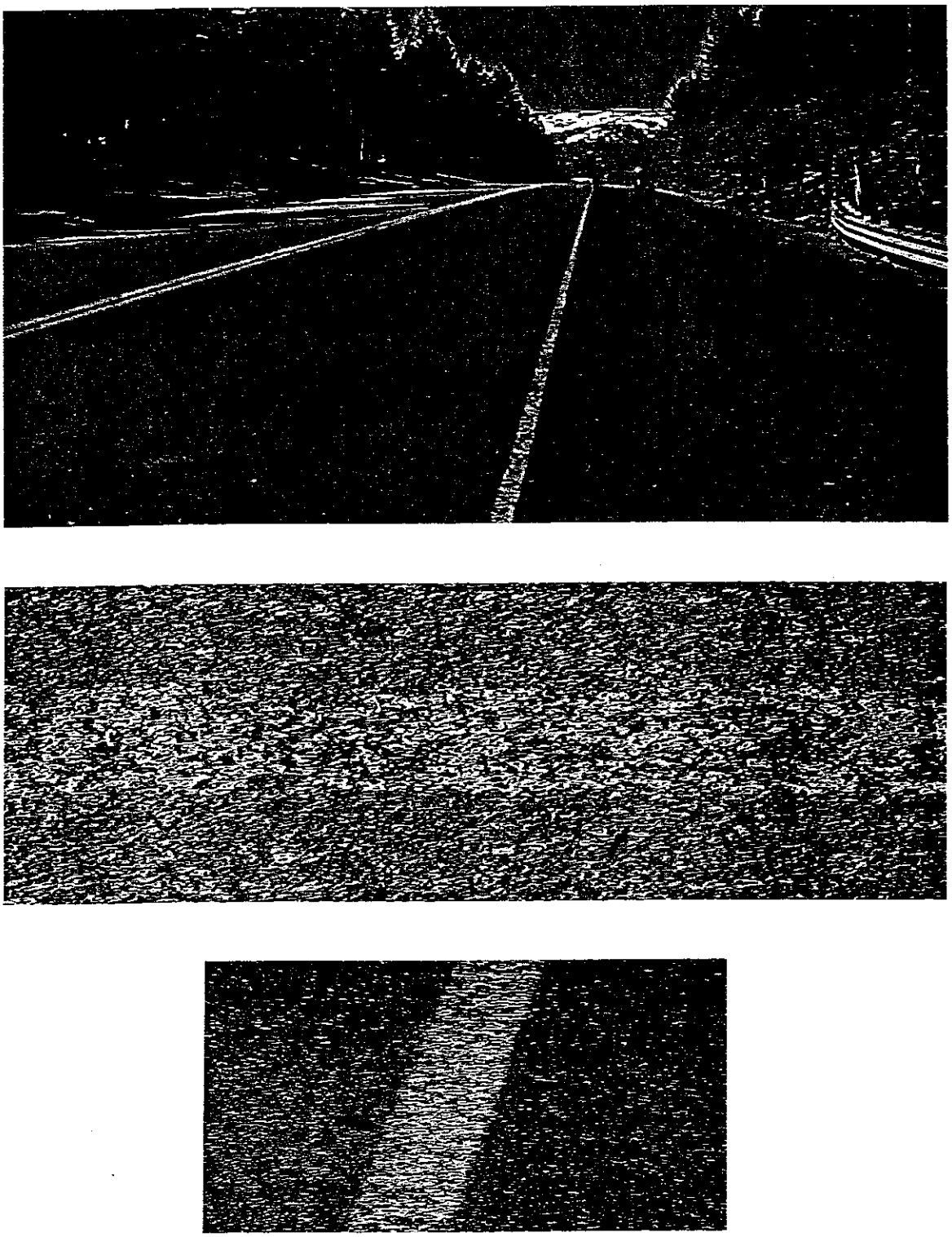


Figure 4.6 SR028 Test Site - White Pavement Markings (February 2003)

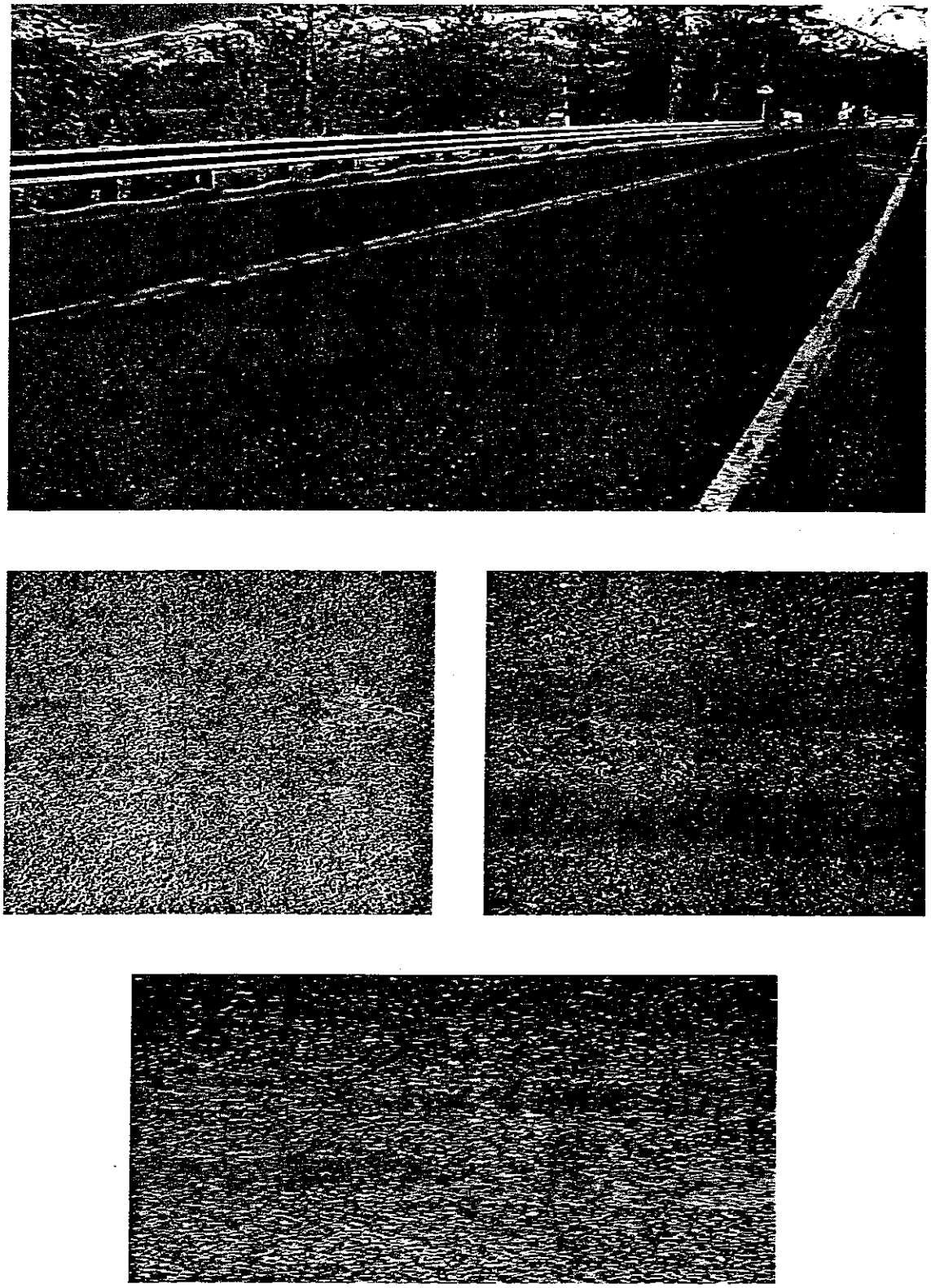


Figure 4.7 SR028 Test Site - Yellow Pavement Markings (February 2003)

CHAPTER 5 – RESULTS FOR SR431 – 2002 TEST SITE

Background

The SR431 2002 test site is located on a two-lane plantmix bituminous with open-grade wearing course roadway in Washoe County, Nevada from mileposts 4.00 to 5.50 (Figure 5.1 near Incline Village).

Epoxy, polyurea, and alkyd thermoplastic pavement marking materials were longitudinally placed as center and edge lines. The materials were recessed in the pavement approximately 60 to 100 mils according to manufacturers' directions. Figure 5.2 shows a diagram of the test site layout. Materials were installed in September 2002 and monitored until May 2004. Contractors were required to place acceptable check stripes before striping the roadway (Figure 5.6). Figure 5.7 shows the equipment used to recess the pavement markings and a view of the recess grind.

Evaluation Based on Durability, Retroreflectivity, and Color

Durability
Table 5.1 presents the durability observations for the pavement marking materials placed on the SR431 2002 test site. A one-year durability evaluation indicates that there was 20% to 60% loss of durability. Several materials were deteriorated to a point where restriping of the east edge line was warranted before a second winter season ensued.

The materials were recessed because it was expected that snow removal activities would be cause for the majority of deterioration. However, there was a noticeable reduction in durability for several products from April through September 2003 despite limited snow removal activities.

Retroreflectivity
Table 5.1 lists the recorded retroreflectivity measurements. Figures 5.3 through 5.5 show retroreflectivity comparisons for the east edge, center, and west edge lines. The seven-month retroreflectivity measurements demonstrate how winter maintenance treatments such as salt, sand, chlorides, and brine solution can affect marking brightness. The late winter measurements for several products were marginal and the benefit of spring and summer rains to wash away residue and sand resulted in a notable increase in brightness for many materials by September of 2003.

A one-year retroreflectivity comparison indicated that the east edge line deteriorated at a faster rate than the west edge line. Engineers decided to restripe the east edge line after one year because of nominal retroreflectivity measurements and a minimum 20% lack of durability for several materials. The center and west edge lines were monitored through a second winter season.

Color
Table 5.2 contains the color measurement results for the pavement marking materials. All yellow colored marking materials were noncompliant with the daytime chromaticity coordinate requirements according to ASTM D 6628, "Standard Specification for Color of Pavement Marking Materials," within 5 months of application (15). The materials drifted in and out of chromaticity coordinate compliance for the duration of the monitoring

process. However, four of the six yellow colored products maintained luminance factor requirements.

The majority of the white colored products maintained chromaticity coordinate and luminance factor requirements throughout the monitoring process. The color measurements displayed with red font and underlined are measurements that do not meet daytime chromaticity coordinate or luminance factor color requirements according to ASTM D 6628.

Monitoring was discontinued in May 2004. Final evaluations were taken on the remaining seven of the original eighteen stripes. The remaining epoxy paint retroreflectivity readings and durability are very similar, with some variation in color results. One polyurea product outperformed all other products with regards to retroreflectivity measurements. However, several other polyurea products were among the first products that required restriping. The polyurea traffic paint results are good examples of the importance of refraining from generalizations about different traffic paint product classes based on one product line in class.

Winter Maintenance Activities

The location was subjected to rigorous winter maintenance activities and the recess grind depth was not substantial enough to protect the pavement marking materials through numerous winter seasons. The inlay grind was barely noticeable after the first winter season and completely worn flush with the road surface by the end of the second winter season.

Pavement markings were subjected to the winter maintenance activities listed in Tables 5.3 and 5.4. Activities included snow removal and application of salt and chlorides, salt and sand, and salt brine solutions. The location was snowplowed an estimated 1620 times from September 2002 until May 2004. In addition, 82 cubic yards of salt and sand, 33 cubic yards of salt and chlorides, and 3500 gallons of salt brine solution were placed on the location from September 2002 until May 2004.

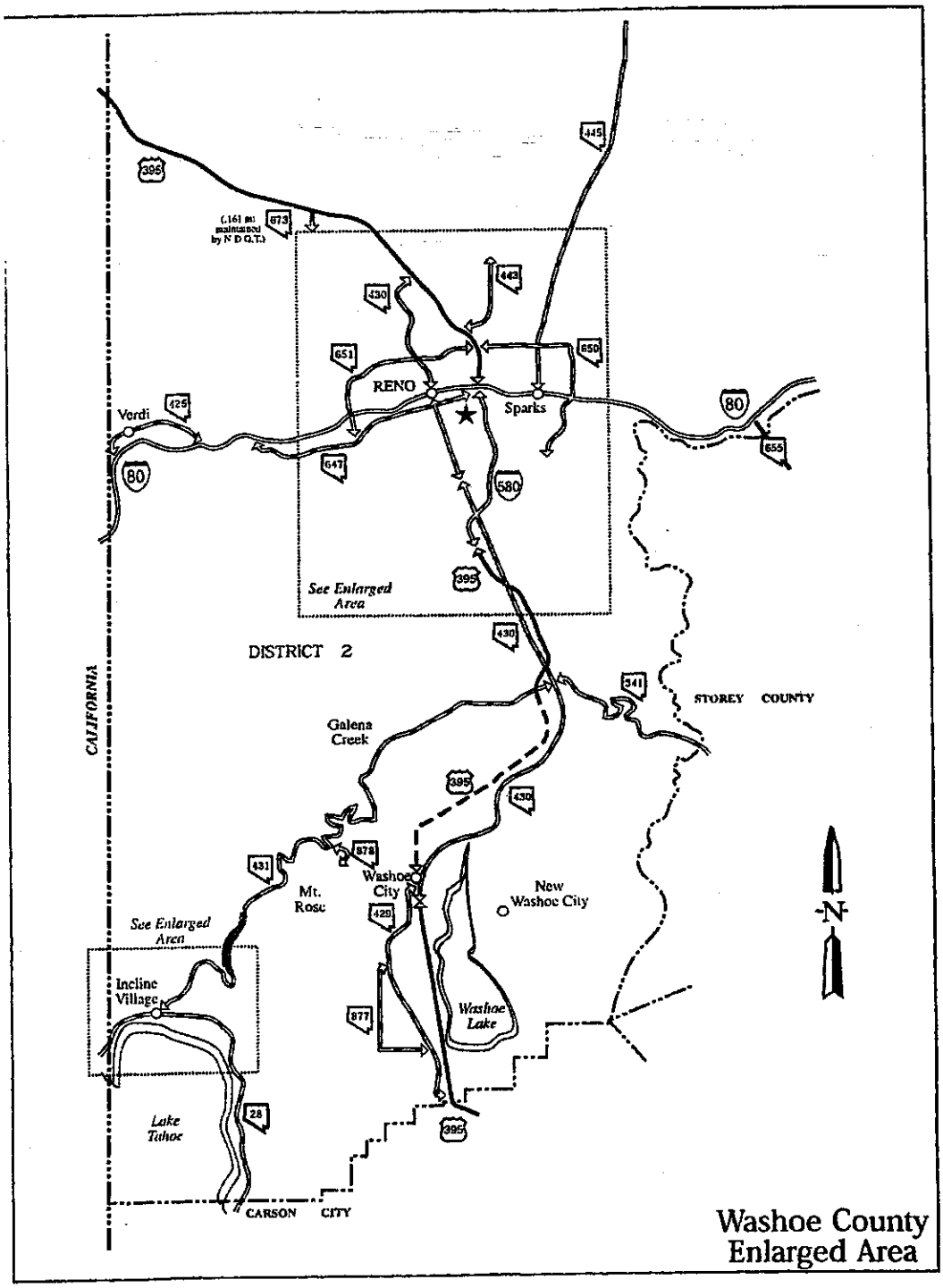


Figure 5.1 Map of Washoe County, Nevada

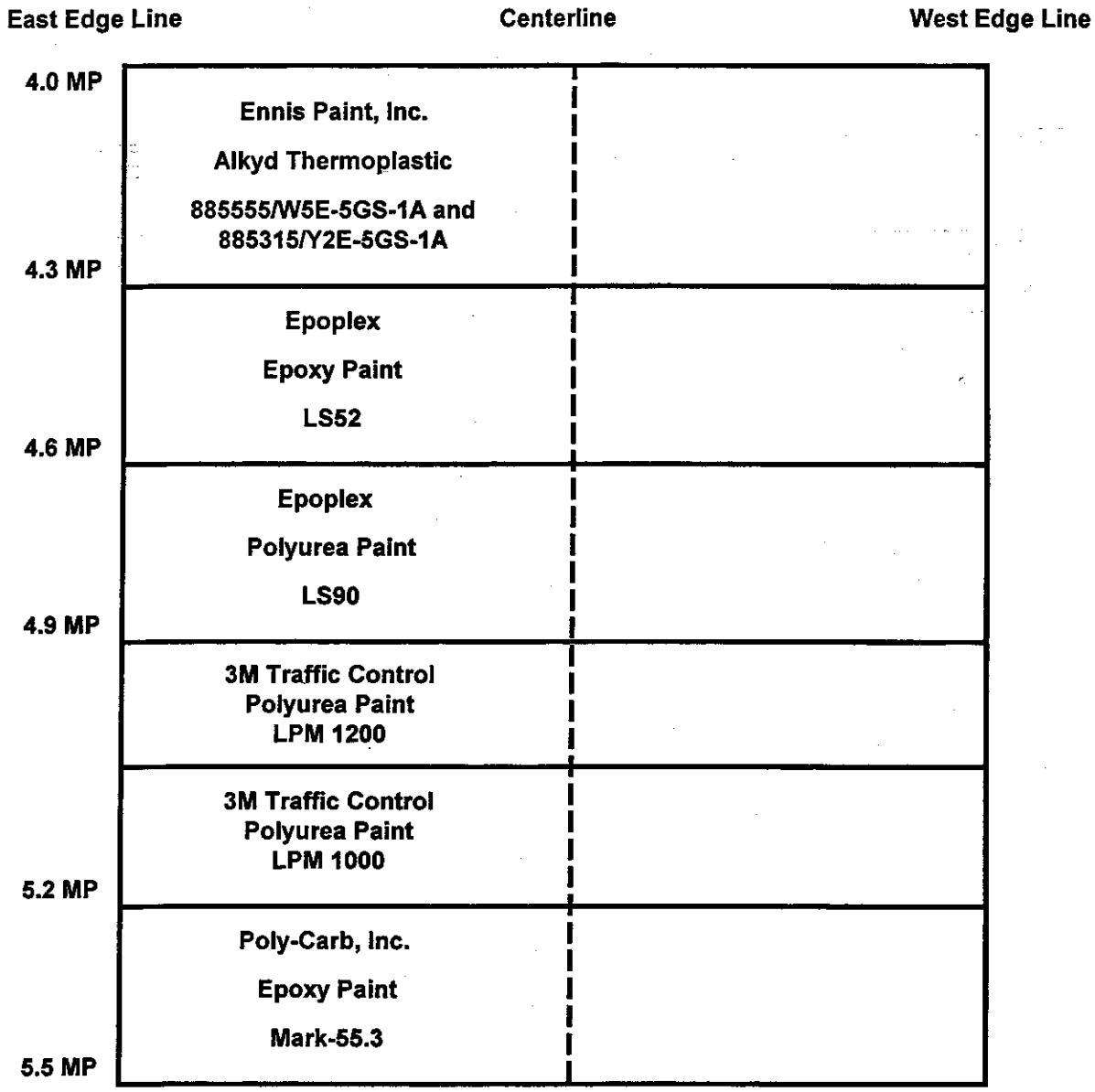


Figure 5.2 SR431 – Washoe County
2002 Test Site Layout

Table 5.1 SR431 - Washoe County - 2002 Test Site
Retroreflectivity and Durability Data (Page 1 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	Sep-02 RR	Sep-02 DUR	Nov-02 RR	Nov-02 DUR	Feb-03 RR	Feb-03 DUR	Apr-03 RR	Apr-03 DUR
PMRP-02-NV-01	Polyurea	LPM 1000	E Edge White	3M	319	10	95	10	60	8	34	6
PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow	3M	181	10	46	10	76	8	34	8
PMRP-02-NV-01	Polyurea	LPM 1000	W Edge White	3M	350	10	144	10	172	8	84	8
PMRP-02-NV-03	Polyurea	LPM 1200	E Edge White	3M	619	10	207	10	135	8	77	6
PMRP-02-NV-04	Polyurea	LPM 1200	LF Yellow	3M	547	10	131	10	182	9	168	9
PMRP-02-NV-03	Polyurea	LPM 1200	W Edge White	3M	888	10	211	10	259	8	150	8
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	E Edge White	EPI	356	10	137	10	108	9	95	9
PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	179	10	77	10	103	10	88	9
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	W Edge White	EPI	332	10	120	10	211	9	131	9
PMRP-02-NV-09	Epoxy	LS52	E Edge White	EPO	448	10	163	10	135	10	93	9
PMRP-02-NV-10	Epoxy	LS52	LF Yellow	EPO	330	10	81	10	147	9	80	9
PMRP-02-NV-09	Epoxy	LS52	W Edge White	EPO	492	10	139	10	222	10	156	9
PMRP-02-NV-13	Polyurea	LS90	E Edge White	EPO	650	10	185	10	213	9	160	8
PMRP-02-NV-14	Polyurea	LS90	LF Yellow	EPO	440	10	133	10	250	9	134	9
PMRP-02-NV-13	Polyurea	LS90	W Edge White	EPO	669	10	229	10	309	9	219	9
PMRP-02-NV-21	Epoxy	Mark-55.3	E Edge White	PCI	497	10	180	10	216	9	113	9
PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow	PCI	313	10	162	10	175	9	56	9
PMRP-02-NV-21	Epoxy	Mark-55.3	W Edge White	PCI	454	10	222	10	192	9	128	9

Table 5.1 SR431 - Washoe County - 2002 Test Site
Retroreflectivity and Durability Data (Page 2 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	Sep-03 RR	Sep-03 DUR	Feb-04 RR	Feb-04 DUR	May-04 RR	May-04 DUR
PMRP-02-NV-01	Polyurea	LPM 1000	E Edge White	3M	N/A	4	N/A	N/A	N/A	N/A
PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow	3M	60	5	N/A	N/A	N/A	N/A
PMRP-02-NV-01	Polyurea	LPM 1000	W Edge White	3M	93	5	N/A	N/A	N/A	N/A
PMRP-02-NV-03	Polyurea	LPM 1200	E Edge White	3M	136	5	N/A	N/A	N/A	N/A
PMRP-02-NV-04	Polyurea	LPM 1200	LF Yellow	3M	30	5	N/A	N/A	N/A	N/A
PMRP-02-NV-03	Polyurea	LPM 1200	W Edge White	3M	255	6	N/A	N/A	N/A	N/A
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	E Edge White	EPI	132	6	N/A	N/A	N/A	N/A
PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	93	9	N/A	N/A	N/A	N/A
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	W Edge White	EPI	152	8	115	8	77	5
PMRP-02-NV-09	Epoxy	LS52	E Edge White	EPO	116	8	N/A	N/A	N/A	N/A
PMRP-02-NV-10	Epoxy	LS52	LF Yellow	EPO	124	9	67	7	99	7
PMRP-02-NV-09	Epoxy	LS52	W Edge White	EPO	185	8	68	7	96	7
PMRP-02-NV-13	Polyurea	LS90	E Edge White	EPO	131	6	N/A	N/A	N/A	N/A
PMRP-02-NV-14	Polyurea	LS90	LF Yellow	EPO	213	8	78	8	121	7
PMRP-02-NV-13	Polyurea	LS90	W Edge White	EPO	237	8	119	8	162	7
PMRP-02-NV-21	Epoxy	Mark-55.3	E Edge White	PCI	158	8	N/A	N/A	N/A	N/A
PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow	PCI	145	8	39	7	94	7
PMRP-02-NV-21	Epoxy	Mark-55.3	W Edge White	PCI	212	7	71	7	95	6

Table 5.2 SR431 - Washoe County - 2002 Test Site
Color Data (Page 1 of 2)

Project Code	Material Type	Product Trade name	Color	Vendor ID	November 2002			February 2003			April 2003		
					Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-01	Polyurea	LPM 1000	E Edge White	3M	52.23	0.3277	0.3451	47.69	0.3253	0.3419	32.03	0.3272	0.3438
PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow	3M	28.88	0.4517	0.4255	40.71	0.4219	0.4085	32.16	0.4440	0.4236
PMRP-02-NV-01	Polyurea	LPM 1000	W Edge White	3M	50.92	0.3273	0.3440	48.01	0.3279	0.3446	52.71	0.3280	0.3452
PMRP-02-NV-03	Polyurea	LPM 1200	E Edge White	3M	47.03	0.3284	0.3453	50.41	0.3272	0.3435	50.46	0.3247	0.3415
PMRP-02-NV-04	Polyurea	LPM 1200	LF Yellow	3M	35.64	0.4565	0.4268	45.02	0.4323	0.4148	38.56	0.4347	0.4179
PMRP-02-NV-03	Polyurea	LPM 1200	W Edge White	3M	45.73	0.3324	0.3487	55.93	0.3258	0.3430	54.56	0.3271	0.3444
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	E Edge White	EPI	40.12	0.3382	0.3562	43.64	0.3323	0.3497	44.88	0.3347	0.3532
PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	25.50	0.4326	0.4183	32.93	0.3981	0.3973	34.54	0.4196	0.4143
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	W Edge White	EPI	38.12	0.3407	0.3581	48.48	0.3357	0.3531	45.42	0.3348	0.3535
PMRP-02-NV-09	Epoxy	LS52	E Edge White	EPO	49.64	0.3288	0.3483	46.53	0.3316	0.3497	45.57	0.3307	0.3496
PMRP-02-NV-10	Epoxy	LS52	LF Yellow	EPO	29.55	0.4557	0.4211	31.13	0.4235	0.4026	33.95	0.4345	0.4103
PMRP-02-NV-09	Epoxy	LS52	W Edge White	EPO	41.48	0.3310	0.3499	44.38	0.3285	0.3469	49.59	0.3279	0.3476
PMRP-02-NV-13	Polyurea	LS90	E Edge White	EPO	39.51	0.3337	0.3507	46.18	0.3317	0.3482	44.81	0.3290	0.3464
PMRP-02-NV-14	Polyurea	LS90	LF Yellow	EPO	20.59	0.4510	0.4267	29.25	0.4122	0.3996	24.37	0.4246	0.4108
PMRP-02-NV-13	Polyurea	LS90	W Edge White	EPO	41.84	0.3322	0.3500	46.13	0.3291	0.3468	48.06	0.3276	0.3460
PMRP-02-NV-21	Epoxy	Mark-55.3	E Edge White	PCI	37.31	0.3277	0.3477	37.15	0.3313	0.3496	28.54	0.3338	0.3522
PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow	PCI	16.44	0.4652	0.4534	26.58	0.3797	0.3838	17.74	0.4359	0.4244
PMRP-02-NV-21	Epoxy	Mark-55.3	W Edge White	PCI	35.17	0.3254	0.3459	41.36	0.3272	0.3467	42.58	0.3307	0.3502

Table 5.2 SR431 - Washoe County - 2002 Test Site
Color Data (Page 2 of 2)

Project Code	Material Type	Product Trade name	Color	Vendor ID	September 2003			February 2004			May 2004		
					Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-01	Polyurea	LPM 1000	E Edge White	3M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow	3M	39.51	0.4288	0.4127	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-01	Polyurea	LPM 1000	W Edge White	3M	59.39	0.3227	0.3407	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-03	Polyurea	LPM 1200	E Edge White	3M	48.56	0.3240	0.3419	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-04	Polyurea	LPM 1200	LF Yellow	3M	36.33	0.4315	0.4126	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-03	Polyurea	LPM 1200	W Edge White	3M	56.11	0.3227	0.3408	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	E Edge White	EPI	45.48	0.3345	0.3523	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	36.03	0.4402	0.4324	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	W Edge White	EPI	47.66	0.3337	0.3520	48.02	0.3355	0.3530	46.72	0.3386	0.3572
PMRP-02-NV-09	Epoxy	LS52	E Edge White	EPO	50.40	0.3309	0.3515	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-10	Epoxy	LS52	LF Yellow	EPO	36.56	0.4429	0.4166	29.99	0.4000	0.3903	36.86	0.4316	0.4108
PMRP-02-NV-09	Epoxy	LS52	W Edge White	EPO	50.70	0.3307	0.3529	37.49	0.3371	0.3536	44.33	0.3382	0.3570
PMRP-02-NV-13	Polyurea	LS90	E Edge White	EPO	53.63	0.3234	0.3414	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-14	Polyurea	LS90	LF Yellow	EPO	34.18	0.4473	0.4238	27.60	0.3930	0.3883	33.82	0.4284	0.4106
PMRP-02-NV-13	Polyurea	LS90	W Edge White	EPO	56.11	0.3228	0.3425	37.79	0.3374	0.3533	47.63	0.3303	0.3475
PMRP-02-NV-21	Epoxy	Mark-55.3	E Edge White	PCI	44.11	0.3299	0.3511	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow	PCI	27.00	0.4589	0.4372	16.79	0.3704	0.3773	24.87	0.4284	0.4182
PMRP-02-NV-21	Epoxy	Mark-55.3	W Edge White	PCI	47.69	0.3295	0.3534	33.13	0.3389	0.3558	40.37	0.3353	0.3540

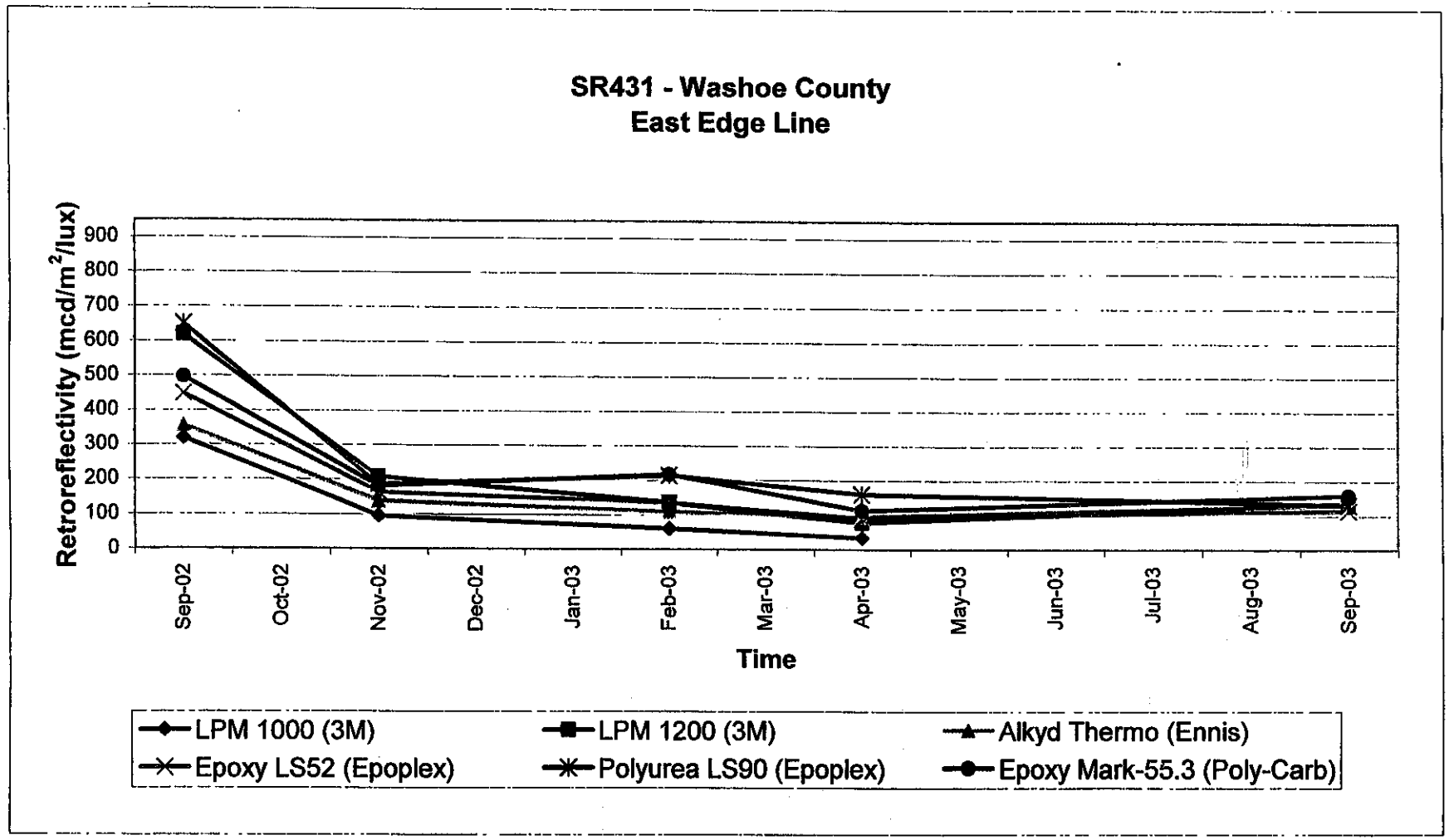


Figure 5.3 SR431 Retroreflectivity Comparison for East Edge Line (2002 Test Site)

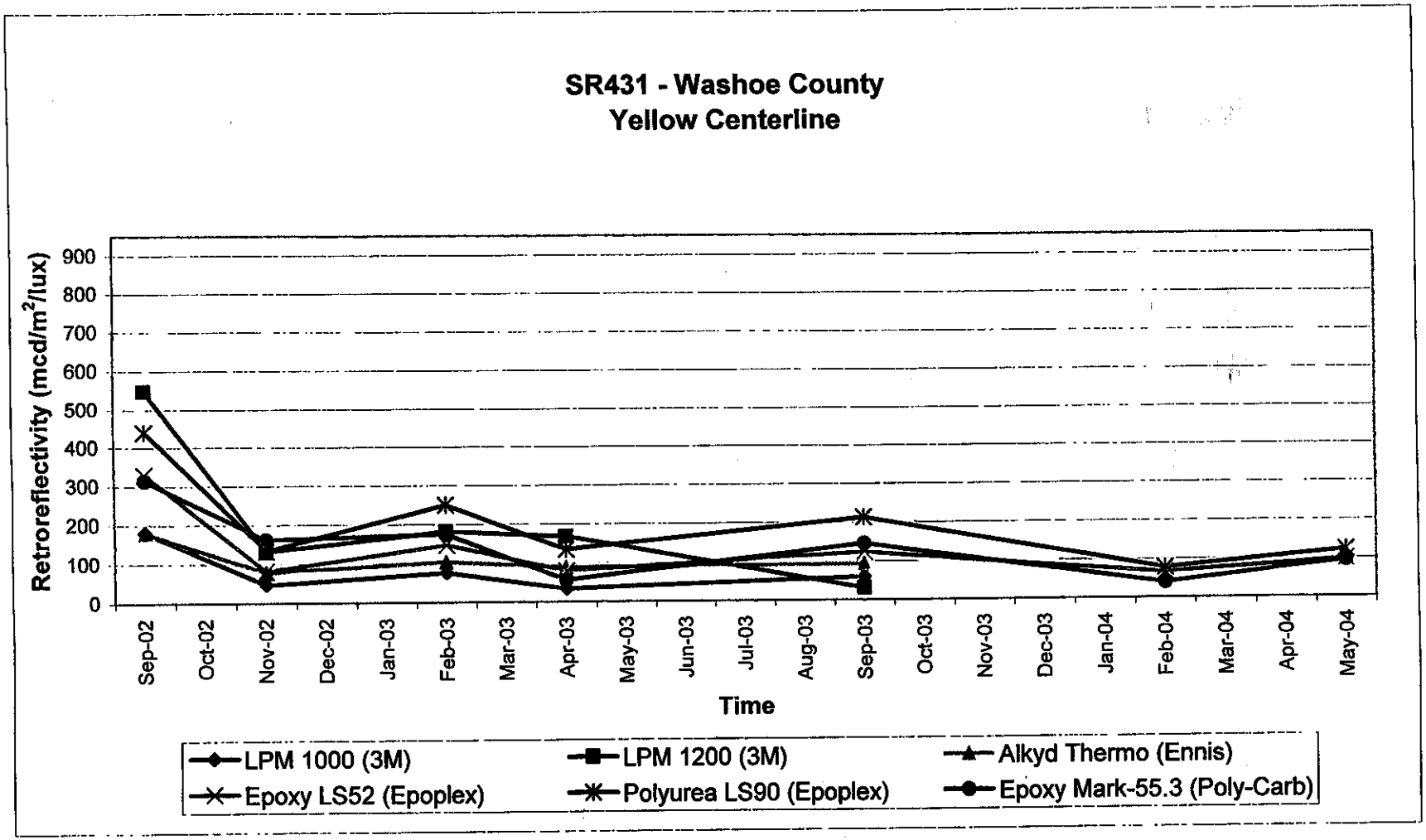


Figure 5.4 SR431 Retroreflectivity Comparison for Centerline (2002 Test Site)

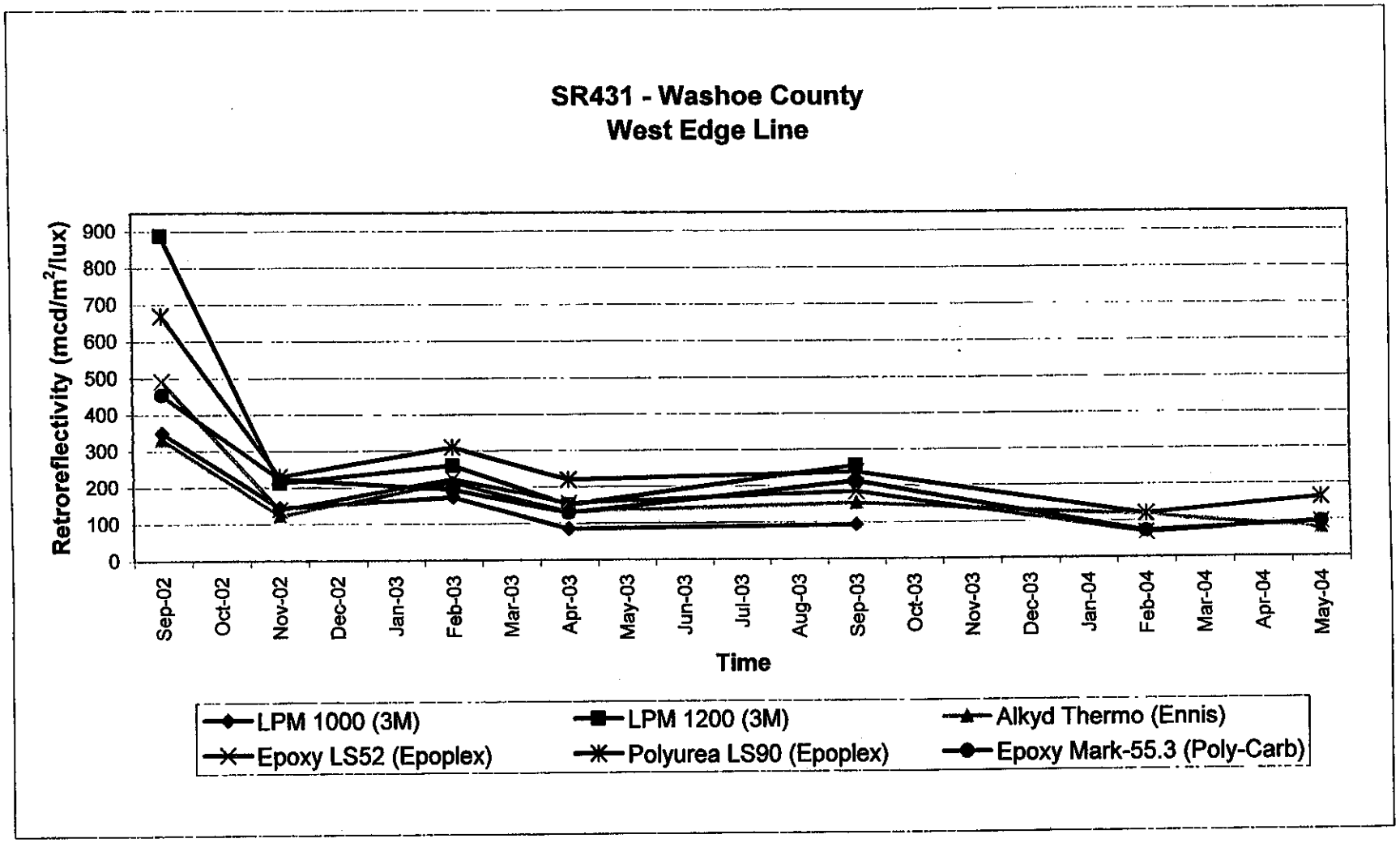


Figure 5.5 SR431 Retroreflectivity Comparison for West Edge Line (2002 Test Site)

Winter Maintenance Activities for the SR431 - 2002 Test Site

Table 5.3 contains a summary of the estimated number of snowplow passes for the SR431 test site. The site was snowplowed an estimated 1620 times from September 2002 until May 2004. NDOT manages maintenance activities with a database containing task descriptions, number of man-hours utilized, and materials and equipment used. Estimates are based upon information contained within the database and discussion with snowplow operators.

Table 5.3 Estimated Number of Snowplow Passes on the SR431 - 2002 Test Site

Month	Number of Hours per Month of Snowplow Activity	Estimated Number of Snowplow Passes per Month
Sep 2002	1	2
Oct 2002	7	14
Nov 2002	42	84
Dec 2002	146	292
Jan 2003	43	86
Feb 2003	46	92
Mar 2003	42	84
Apr 2003	89	178
May 2003	18	36
		Total Estimated Snowplow Passes for 02/03 Season: 868
Oct 2003	21	42
Nov 2003	43	86
Dec 2003	123	246
Jan 2004	56	112
Feb 2004	83	166
Mar 2004	26	52
Apr 2004	19	38
May 2004	5	10
		Total Estimated Snowplow Passes for 03/04 Season: 752

Table 5.4 shows that 17 cubic yards of salt and chlorides, 49 cubic yards of salt and sand, and 2100 gallons of salt brine solution were placed on the SR431 test site from October 2002 until May 2003. In addition, 16 cubic yards of salt and chlorides, 33 cubic yards of salt and sand, and 1400 gallons of salt brine solution were placed on the test site from October 2003 until May 2004.

Table 5.4 Salt and Chlorides, Salt and Sand, and Salt Brine Quantities

Month	Description of Treatment	Quantity per Month (Cubic Yards / Gallons)
Oct 2002	Salt and Chlorides	0.21
Nov 2002	Salt and Chlorides	1.88
Dec 2002	Salt and Chlorides	4.53
Jan 2003	Salt and Chlorides	2.35
Feb 2003	Salt and Chlorides	2.58
Mar 2003	Salt and Chlorides	1.88
Apr 2003	Salt and Chlorides	3.42
May 2003	Salt and Chlorides	0.91
		Total for 02/03 Season: 17 CY
Oct 2002	Salt and Sand	0.28
Nov 2002	Salt and Sand	3.55
Dec 2002	Salt and Sand	14.13
Jan 2003	Salt and Sand	5.50
Feb 2003	Salt and Sand	6.82
Mar 2003	Salt and Sand	10.58
Apr 2003	Salt and Sand	7.86
May 2003	Salt and Sand	0.70
		Total for 02/03 Season: 49 CY
Oct 2002	Salt Brine	26
Nov 2002	Salt Brine	194
Dec 2002	Salt Brine	654
Jan 2003	Salt Brine	215
Feb 2003	Salt Brine	348
Mar 2003	Salt Brine	208
Apr 2003	Salt Brine	395
May 2003	Salt Brine	88
		Total for 02/03 Season: 2128 GAL

(Continued)

Table 5.4 Salt and Chlorides, Salt and Sand, and Salt Brine Quantities

Month	Description of Treatment	Quantity per Month (Cubic Yards / Gallons)
Oct 2003	Salt and Chlorides	0.37
Nov 2003	Salt and Chlorides	1.30
Dec 2003	Salt and Chlorides	4.40
Jan 2004	Salt and Chlorides	3.10
Feb 2004	Salt and Chlorides	5.24
Mar 2004	Salt and Chlorides	0.87
Apr 2004	Salt and Chlorides	1.05
May 2004	Salt and Chlorides	0.50
		Total for 03/04 Season: 16 CY
Oct 2003	Salt and Sand	3.27
Nov 2003	Salt and Sand	3.03
Dec 2003	Salt and Sand	8.48
Jan 2004	Salt and Sand	5.81
Feb 2004	Salt and Sand	8.85
Mar 2004	Salt and Sand	2.41
Apr 2004	Salt and Sand	0.80
May 2004	Salt and Sand	0.37
		Total for 03/04 Season: 33 CY
Oct 2003	Salt Brine	50
Nov 2003	Salt Brine	203
Dec 2003	Salt Brine	571
Jan 2004	Salt Brine	329
Feb 2004	Salt Brine	218
Mar 2004	Salt Brine	37
Apr 2004	Salt Brine	25
		Total for 03/04 Season: 1433 GAL

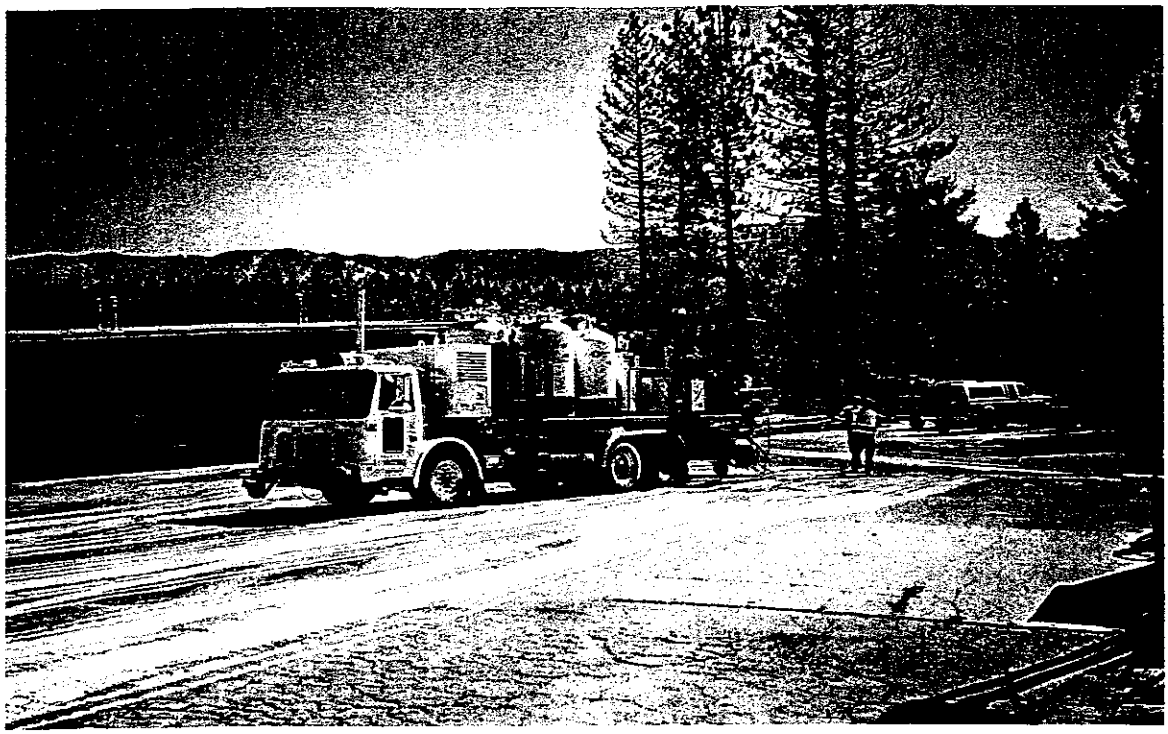


Figure 5.6 Contractors Were Required to Place Acceptable Check Stripes Before Striping the Roadway

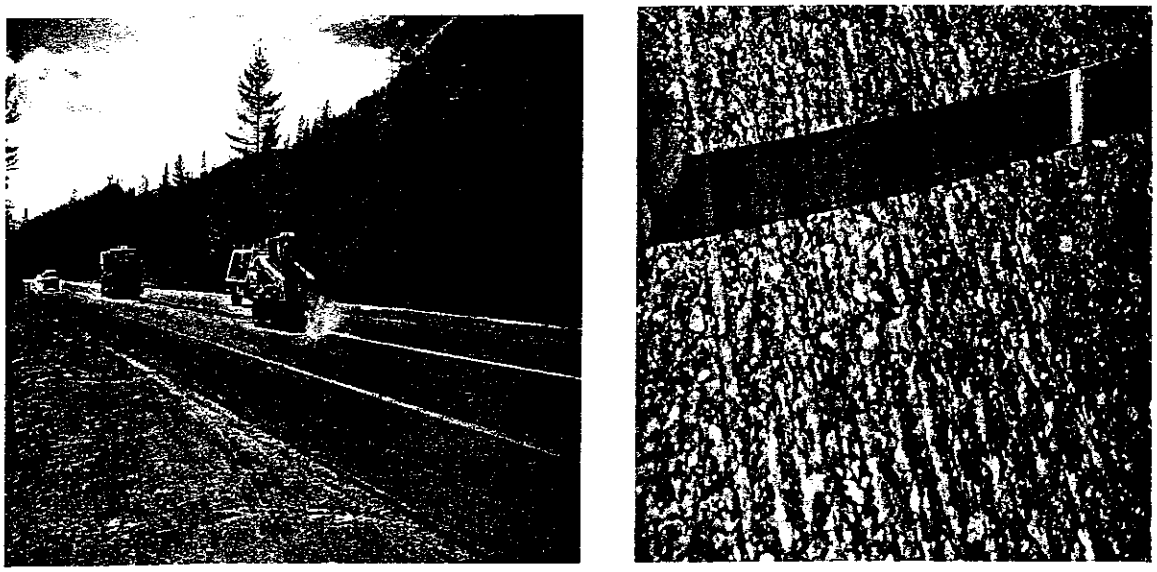


Figure 5.7 Grinding Equipment (Left) and Recess Grind (Right)

CHAPTER 6 – RESULTS FOR SR431 – 2003 TEST SITE

Background

A portion of the SR431 2002 test site was reused to place waterborne traffic paint and permanent tape pavement marking materials. This test site is located on a two-lane plantmix bituminous with open-grade wearing course roadway in Washoe County, Nevada from mileposts 4.90 to 5.20 (Figure 6.1 near Incline Village and Figure 6.5).

Waterborne traffic paint and permanent tape materials were longitudinally placed as center and edge lines, and recessed in the pavement approximately 300 mils. Figure 6.2 shows a diagram of the test site layout. Materials were installed in September 2003 and monitored until May 2004.

Evaluation Based on Durability, Retroreflectivity, and Color

Durability
Table 6.1 presents the durability observations for the pavement marking materials placed on the SR431 2003 test site. The double application of waterborne paint was more durable than the single application of waterborne paint. Moreover, the high performance tape was more durable than the wet reflective tape (Figures 6.6 through 6.8).

Retroreflectivity
Table 6.1 lists the recorded retroreflectivity measurements. Figures 6.3 and 6.4 show retroreflectivity comparisons for the white and yellow colored materials. The results show that a double application of waterborne paint retained higher retroreflectivity readings over a single application of waterborne paint. Furthermore, the high performance tape out performed the wet reflective tape.

Color
Table 6.2 contains the color measurement results for the pavement marking materials. The color measurements displayed with red font and underlined are measurements that do not meet daytime chromaticity coordinate or luminance factor color requirements according to ASTM D 6628 "Standard Specification for Color of Pavement Marking Materials" (15).

Winter Maintenance Activities

The location was subjected to rigorous winter maintenance activities and damage occurred to all products. Damage from snow removal activities occurred despite the fact that the materials were recessed 300 mils into the pavement. Additionally, a noticeable buildup of sand was in the recess grind and varied from month to month.

Materials were subjected to winter maintenance activities listed in Tables 6.3 and 6.4. Activities included snow removal and application of salt and chlorides, salt and sand, and salt brine solution. The location was snowplowed an estimated 750 times from October 2003 until May 2004. In addition, 33 cubic years of salt and sand, 16 cubic yards of salt and chlorides, and 1400 gallons of salt brine solution were placed on the location from October 2003 until May 2004.

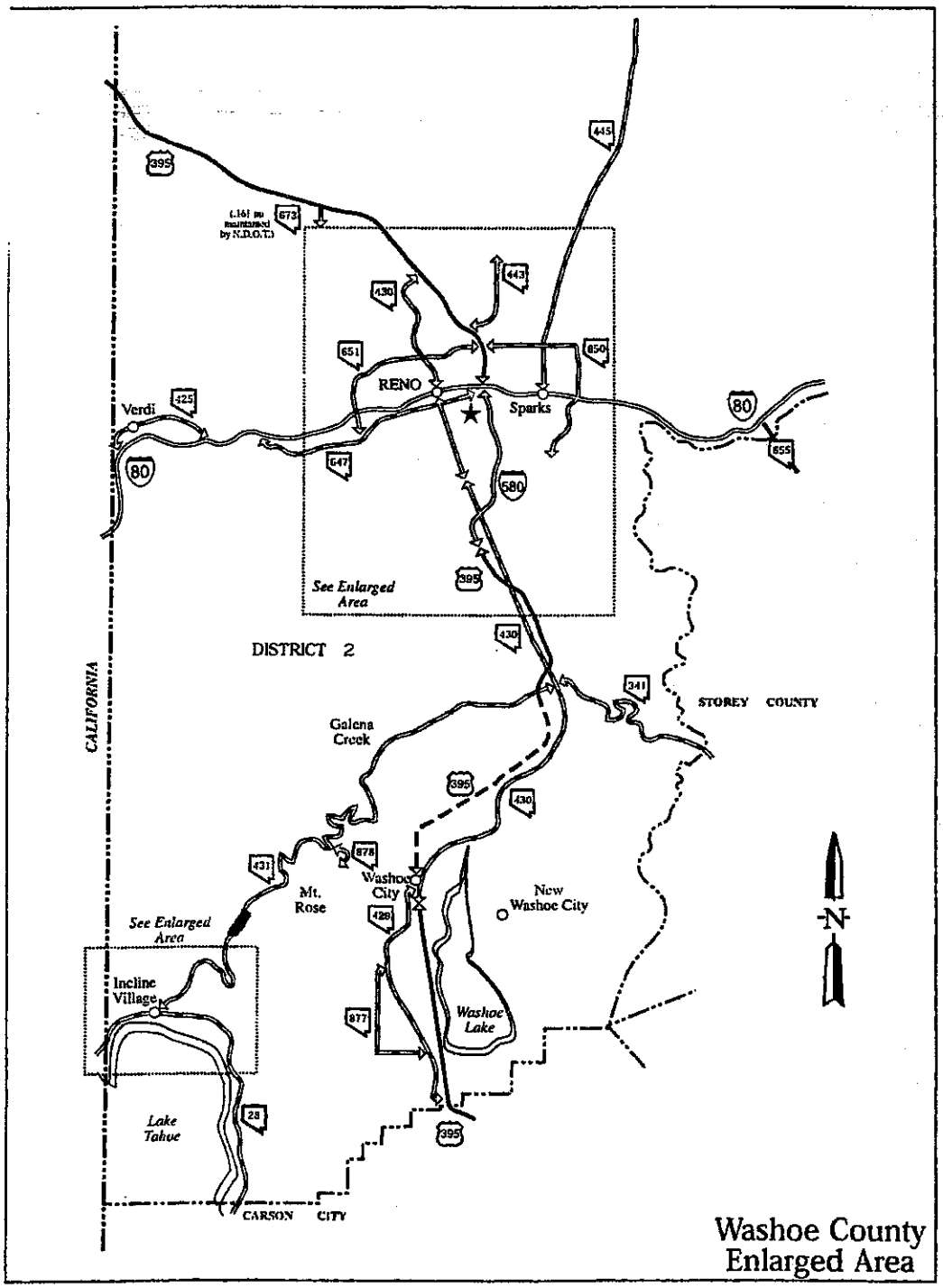


Figure 6.1 Map of Washoe County, Nevada

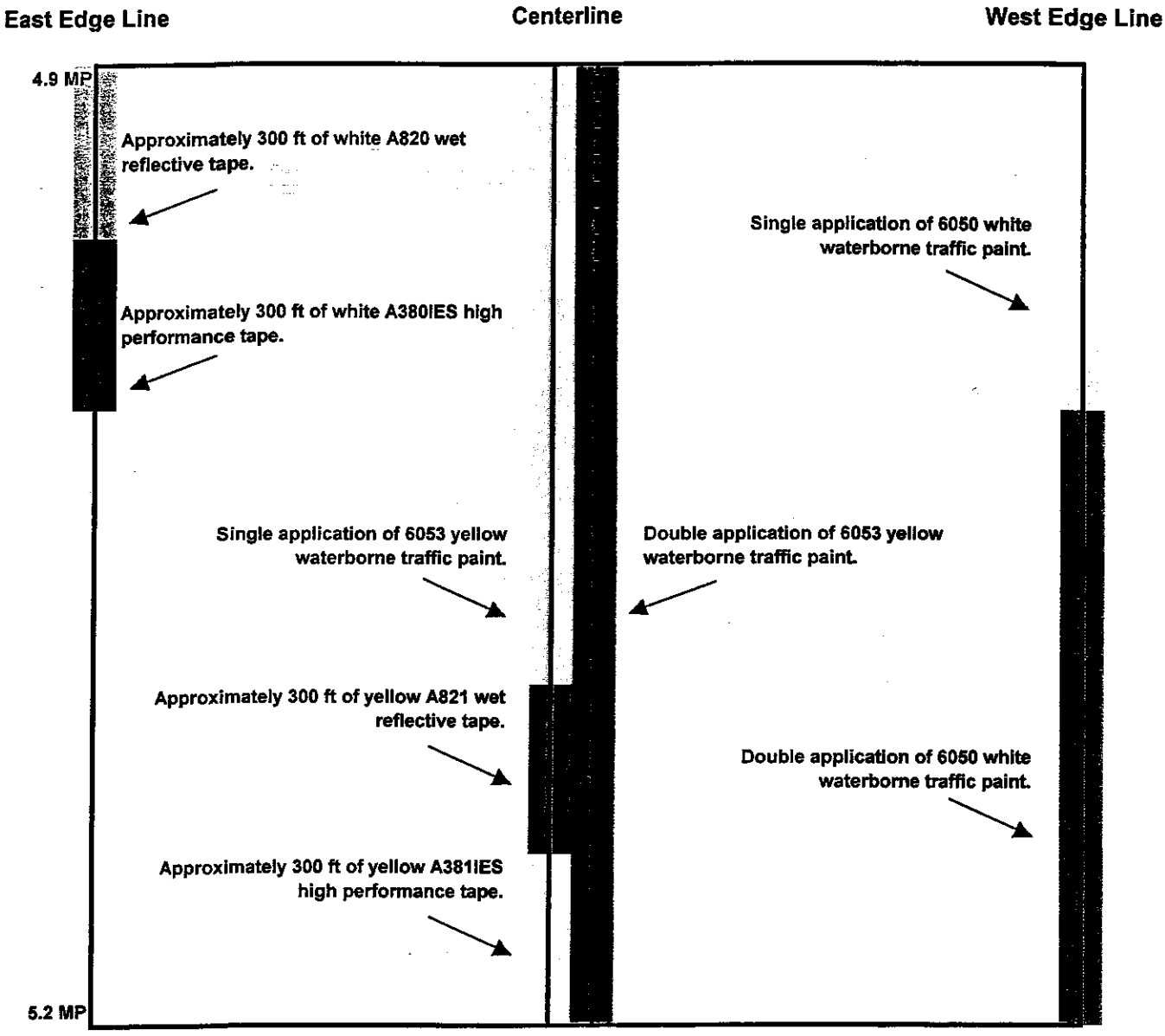


Figure 6.2 SR431 – Washoe County
2003 Test Site Layout

Table 6.1 SR431 - Washoe County - 2003 Test Site
Retroreflectivity and Durability Data

Project Code	Material Type	Product Trade Name	Color	Vendor ID	Oct-03 RR	Oct-03 DUR	Feb-04 RR	Feb-04 DUR	May-04 RR	May-04 DUR
PMRP-02-NV-15	Waterborne Paint (Single Application)	6050	W Edge White	PPC	257	10	118	6	57	5
PMRP-02-NV-16	Waterborne Paint (Single Application)	6053	LF Yellow	PPC	145	10	81	7	49	5
PMRP-02-NV-15	Waterborne Paint (Double Application)	6050	W Edge White	PPC	268	10	109	8	166	6
PMRP-02-NV-16	Waterborne Paint (Double Application)	6053	LF Yellow	PPC	169	10	132	9	79	7
PMRP-02-NV-27	Tape (High Performance)	A380IES	E Edge White	3M	603	10	210	10	131	9
PMRP-02-NV-28	Tape (High Performance)	A381IES	Yellow	3M	386	10	115	10	188	10
PMRP-02-NV-29	Tape (Wet Reflective)	A820	E Edge White	3M	864	10	61	10	44	8
PMRP-02-NV-30	Tape (Wet Reflective)	A821	Yellow	3M	472	10	40	10	56	9

Table 6.2 SR431 - Washoe County - 2003 Test Site
Color Data

Project Code	Material Type	Product Trade Name	Color	Vendor ID	October 2003			February 2004			May-04		
					Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-15	Waterborne Paint (Single Application)	6050	W Edge White	PPC	48.82	0.3277	0.3469	26.41	0.3383	0.3552	30.08	0.3388	0.3541
PMRP-02-NV-16	Waterborne Paint (Single Application)	6053	LF Yellow	PPC	28.99	0.4691	0.4384	26.79	0.3743	0.3779	20.59	0.4178	0.4064
PMRP-02-NV-15	Waterborne Paint (Double Application)	6050	W Edge White	PPC	54.42	0.3326	0.3515	39.82	0.3384	0.3555	38.41	0.3367	0.3523
PMRP-02-NV-16	Waterborne Paint (Double Application)	6053	LF Yellow	PPC	32.08	0.4748	0.4385	30.18	0.3768	0.3776	27.26	0.4328	0.4192
PMRP-02-NV-27	Tape (High Performance)	A380IES	E Edge White	3M	63.71	0.3178	0.3387	48.69	0.3246	0.3431	46.65	0.3365	0.3548
PMRP-02-NV-28	Tape (High Performance)	A381IES	Yellow	3M	37.40	0.4704	0.4376	21.25	0.3832	0.3835	30.97	0.4278	0.4126
PMRP-02-NV-29	Tape (Wet Reflective)	A820	E Edge White	3M	44.56	0.3138	0.3328	34.83	0.3286	0.3466	35.31	0.3305	0.3485
PMRP-02-NV-30	Tape (Wet Reflective)	A821	Yellow	3M	32.44	0.4688	0.4462	21.73	0.3670	0.3754	33.37	0.4515	0.4360

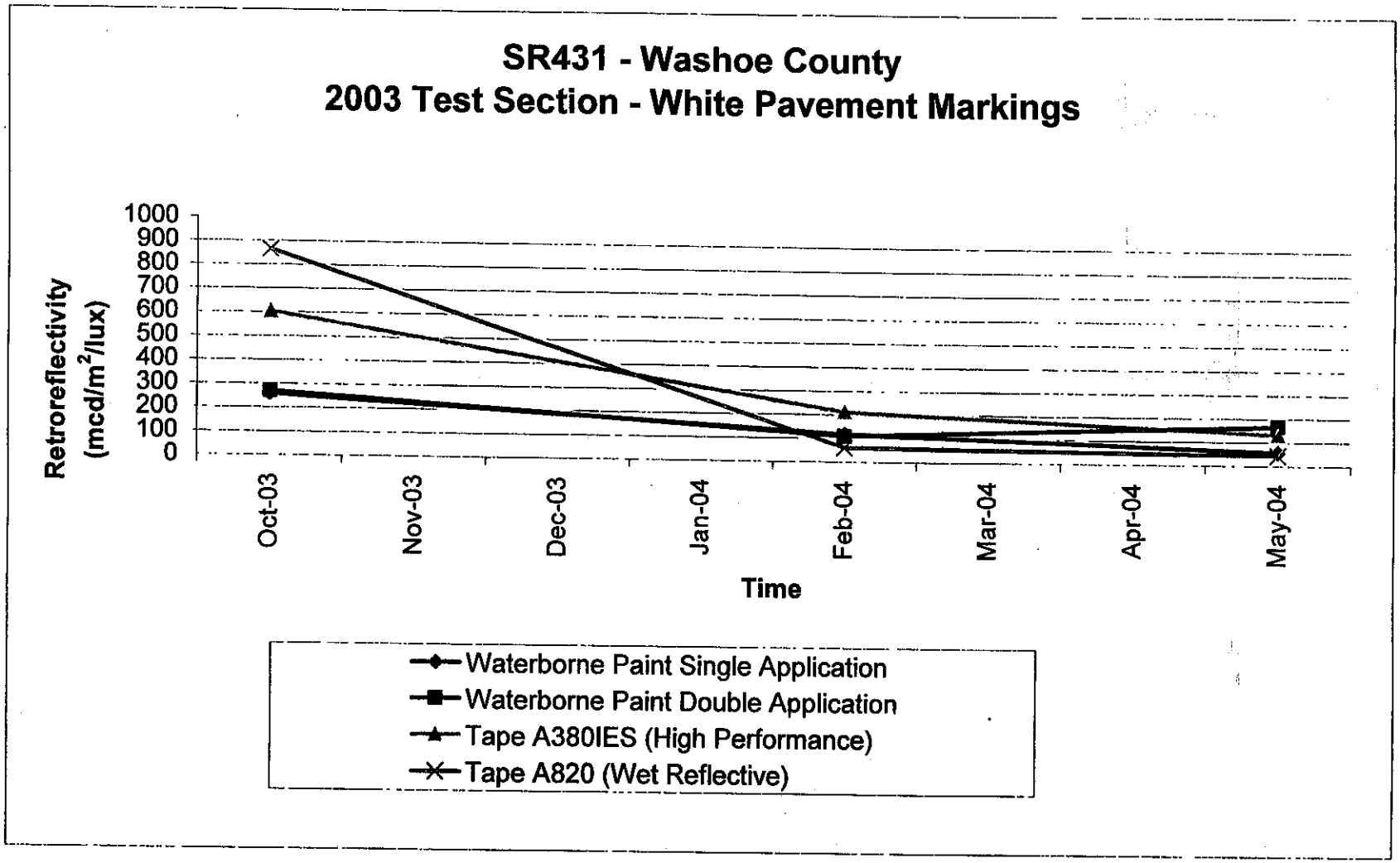


Figure 6.3 SR431 Retroreflectivity Comparison for White Pavement Markings (2003 Test Site)

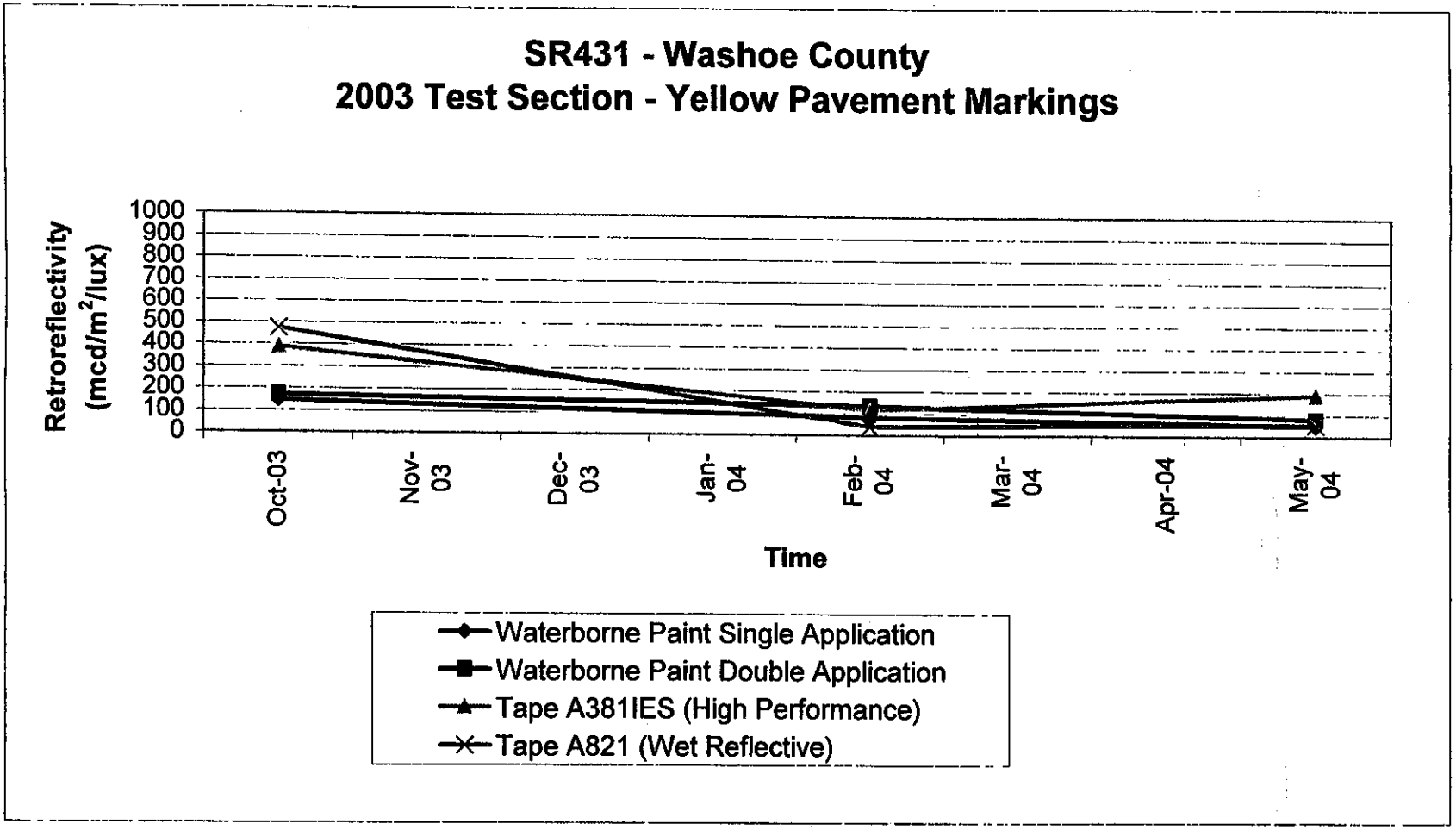


Figure 6.4 SR431 Retroreflectivity Comparison for Yellow Pavement Markings (2003 Test Site)

Winter Maintenance Activities for the SR431 - 2003 Test Site

Table 6.3 contains a summary of the estimated number of snowplow passes for the SR431 test site. The site was snowplowed an estimated 752 times from October 2003 until May 2004. NDOT manages maintenance activities with a database containing task descriptions, number of man-hours utilized, and materials and equipment used. Estimates are based upon information contained within the database and discussion with snowplow operators.

Table 6.3 Estimated Number of Snowplow Passes on the SR431 - 2003 Test Site

Month	Number of Hours per Month of Snowplow Activity	Estimated Number of Snowplow Passes per Month
Oct 2003	21	42
Nov 2003	43	86
Dec 2003	123	246
Jan 2004	56	112
Feb 2004	83	166
Mar 2004	26	52
Apr 2004	19	38
May 2004	5	10
		Total Estimated Snowplow Passes for 03/04 Season: 752

Table 6.4 shows that 16 cubic yards of salt and chlorides, 33 cubic yards of salt and sand, and 1400 gallons of salt brine solution were placed on the SR431 test site from October 2003 until May 2004.

Table 6.4 Salt and Chlorides, Salt and Sand, and Salt Brine Quantities

Month	Description of Treatment	Quantity per Month (Cubic Yards / Gallons)
Oct 2003	Salt and Chlorides	0.37
Nov 2003	Salt and Chlorides	1.30
Dec 2003	Salt and Chlorides	4.40
Jan 2004	Salt and Chlorides	3.10
Feb 2004	Salt and Chlorides	5.24
Mar 2004	Salt and Chlorides	0.87
Apr 2004	Salt and Chlorides	1.05
May 2004	Salt and Chlorides	0.50
		Total for 03/04 Season: 16 CY
Oct 2003	Salt and Sand	3.27
Nov 2003	Salt and Sand	3.03
Dec 2003	Salt and Sand	8.48
Jan 2004	Salt and Sand	5.81
Feb 2004	Salt and Sand	8.85
Mar 2004	Salt and Sand	2.41
Apr 2004	Salt and Sand	0.80
May 2004	Salt and Sand	0.37
		Total for 03/04 Season: 33 CY
Oct 2003	Salt Brine	50
Nov 2003	Salt Brine	203
Dec 2003	Salt Brine	571
Jan 2004	Salt Brine	329
Feb 2004	Salt Brine	218
Mar 2004	Salt Brine	37
Apr 2004	Salt Brine	25
		Total for 03/04 Season: 1433 GAL

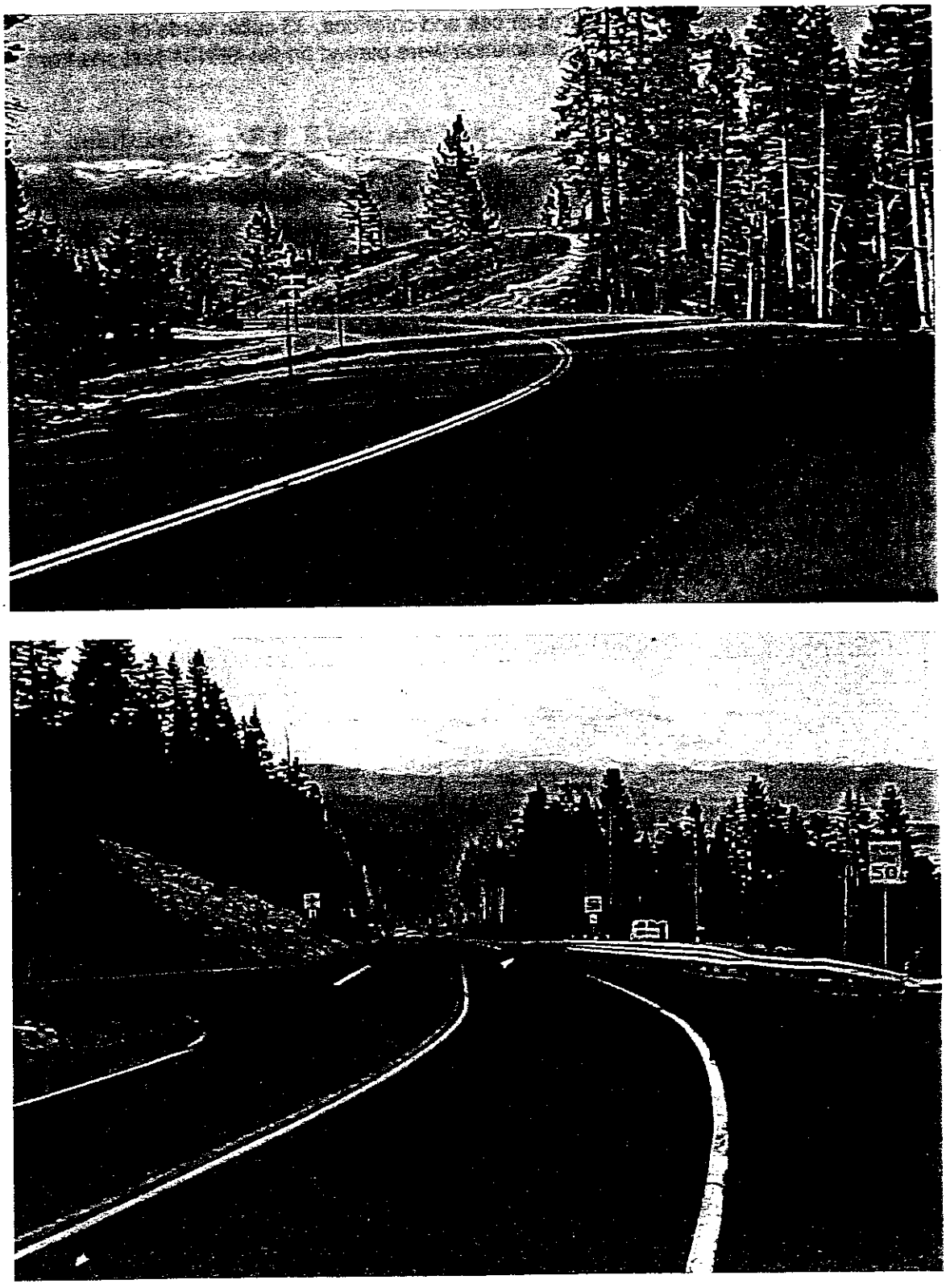


Figure 6.5 SR431 Test Site Location

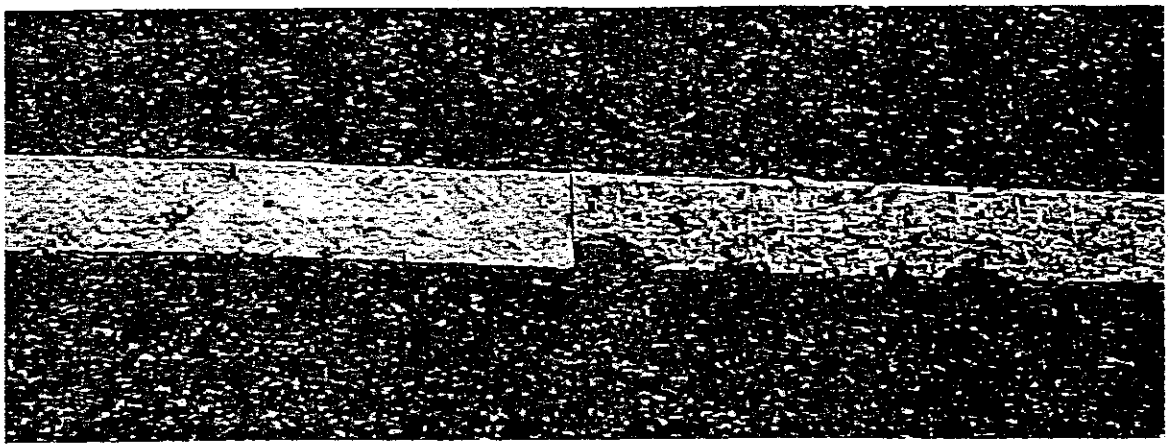


Figure 6.6 Joint at High Performance Tape (Left) and Wet Reflective Tape (Right)

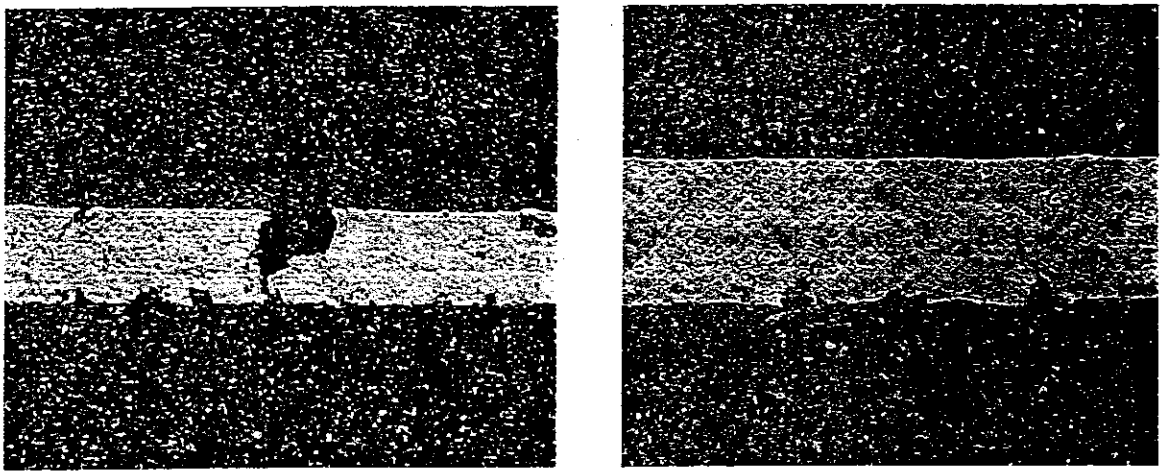


Figure 6.7 High Performance Tape (May 2004)

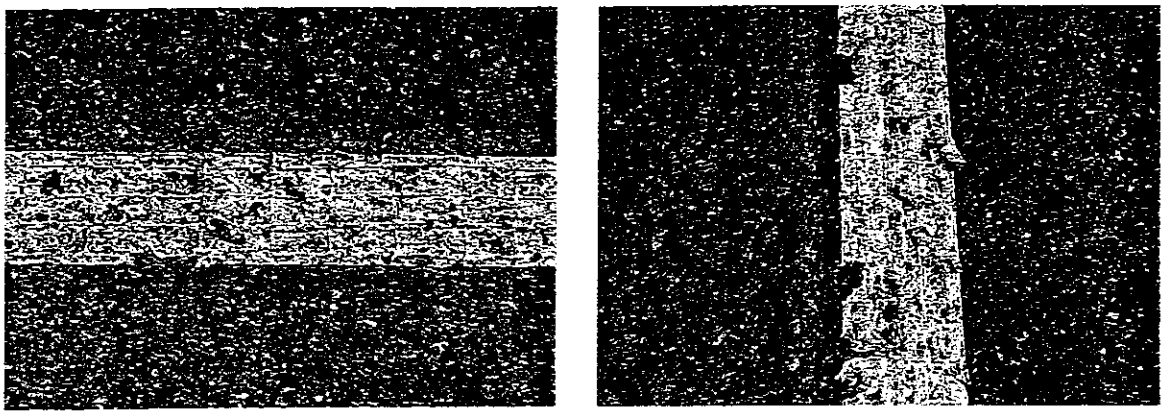


Figure 6.8 Wet Reflective Tape (May 2004)

CHAPTER 7 – RESULTS FOR US050 TEST SITE

Background

The US050 test site is located on a two-lane plantmix bituminous with open-grade wearing course roadway in Churchill County, Nevada from mileposts 31.42 to 43.76 (Figure 7.1 near Salt Wells and Figure 7.11).

Waterborne traffic paint materials were longitudinally placed as center and edge lines three weeks after a newly applied roadway surface. The materials were applied using various bead gradations, bead application rates, and paint coating thicknesses. Figure 7.2 shows a diagram of the test site layout. Materials were installed in August 2002 and monitored until May 2004.

Evaluation Based on Durability, Retroreflectivity, and Color

Durability

Table 7.1 presents the durability observations for the pavement marking materials placed on the US050 test site. Sections placed with an 18 wet mils paint coating thickness showed signs of wear within three months of placement. These sections were deteriorated after one winter season and restriping was recommended. Engineers determined that the sections placed with 25 wet mils paint coating thickness were in condition to withstand a second winter season after being in place for over a year.

Retroreflectivity

Table 7.1 lists the recorded retroreflectivity measurements. Figures 7.3 through 7.5 illustrate retroreflectivity comparisons for the center and edge lines for all products placed between mileposts 31.42 to 39.00. The materials were installed with 25 wet mils paint coating thickness and Type B beads applied at 9 pounds per gallon. All white colored marking products exhibited measurements over 135 mcd/m^2/lux after 21 months. The yellow colored marking products demonstrated measurements over 105 mcd/m^2/lux after 21 months.

Figure 7.6 shows a retroreflectivity comparison for white waterborne paint using 25 wet mils paint coating thickness and Type A and Type B beads applied at 9 pounds per gallon. The information indicates that Type A beads have an average of 67% higher retroreflectivity measurements over Type B beads when similarly placed.

Figure 7.7 presents a retroreflectivity comparison for yellow waterborne paint using 25 wet mils paint coating thickness and Type A and Type B beads applied at 9 pounds per gallon. Results show that Type A beads have an average of 50% higher retroreflectivity measurements over Type B beads when similarly placed.

Figure 7.8 displays a retroreflectivity comparison for white waterborne paint using 25 wet mils paint coating thickness and Type A and Type B beads applied at 12 pounds per gallon. Evidence suggests that Type A beads have an average of 17% higher retroreflectivity readings over Type B beads when similarly placed, despite the higher initial measurement for the Type B bead.

Figure 7.9 shows a retroreflectivity comparison for white waterborne paint using 25 wet mils paint coating thickness and Type A beads applied at 9 and 12 pounds per gallon. Results demonstrate that the Type A beads placed at 9 pounds per gallon have an average of 22% higher retroreflectivity readings than Type A beads placed at 12 pounds per gallon.

Figure 7.10 illustrates a retroreflectivity comparison for white waterborne paint using 25 wet mils paint coating thickness and Type B beads applied at 9 and 12 pounds per gallon. The information illustrates that the Type B beads applied at 9 pounds per gallon have an average of 14% lower retroreflectivity readings than Type B beads applied at 12 pounds per gallon.

Sections applied with 18 wet mils paint coating thickness showed a substantial reduction in retroreflectivity readings within 6 months of placement compared to sections applied with 25 wet mils paint coating thickness. There was not a significant improvement in retroreflectivity with the use of 12 pounds of beads per gallon over the use of 9 pounds of beads per gallon.

Color

Table 7.2 contains the color measurement results for the pavement marking materials. A review of color data shows that all thirteen white colored 25 wet mils edge lines maintained acceptable daytime chromaticity coordinate and luminance factor requirements according to ASTM D 6628, "Standard Specification for Color of Pavement Marking Materials," throughout the monitoring process (15). The yellow colored products display color degradation to various extents as noticed by inspection. The color measurements displayed with red font and underlined are measurements that do not meet daytime chromaticity coordinate or luminance factor color requirements according to ASTM D 6628.

Winter Maintenance Activities

Materials were subjected to the winter maintenance activities listed in Tables 7.3 and 7.4. Activities included snow removal and application of salt brine solution and salt and sand. The location was snowplowed an estimated 59 times from December 2002 until March 2004. In addition, 160 cubic yards of salt and sand and 515 gallons of salt brine solution and were placed throughout the area from December 2002 to February 2004.

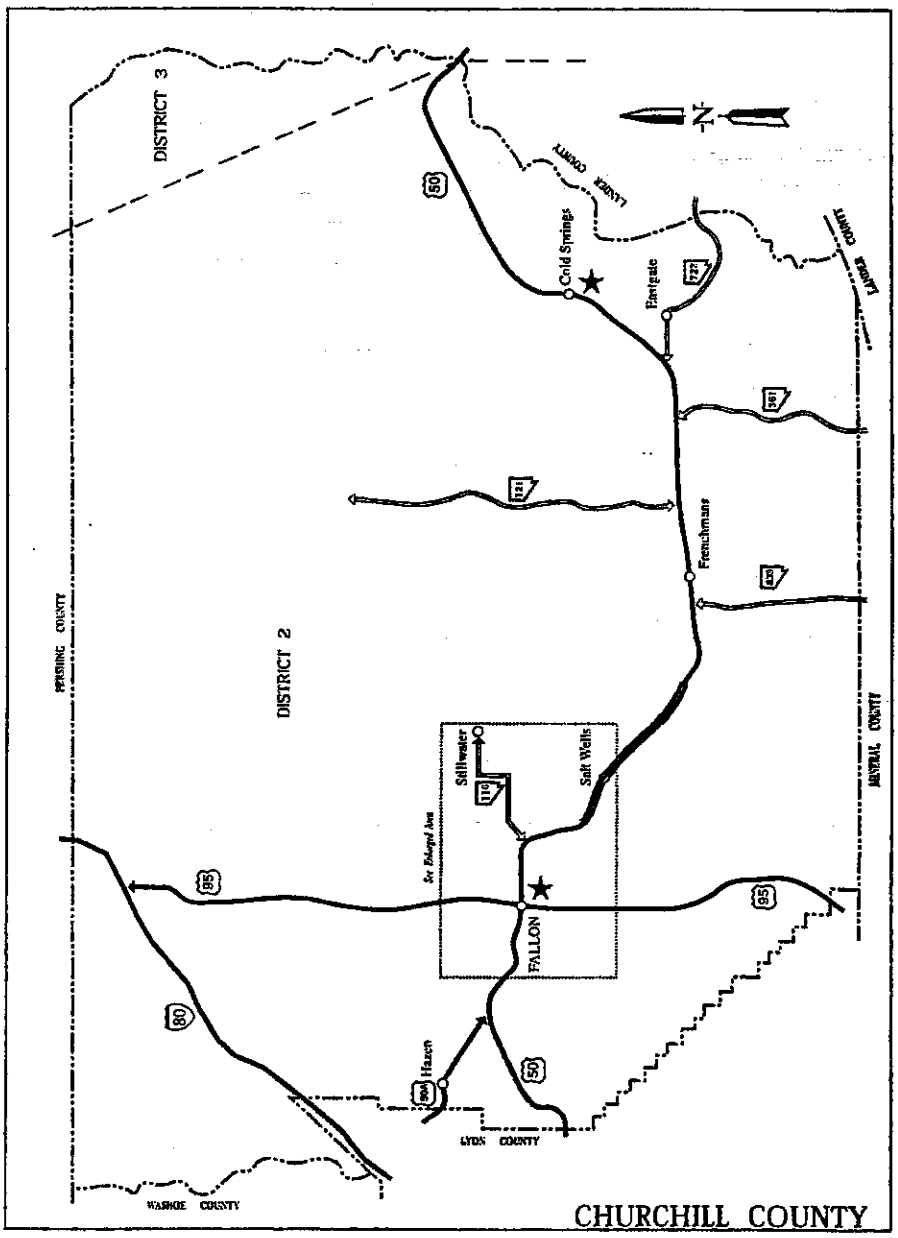


Figure 7.1 Map of Churchill County, Nevada

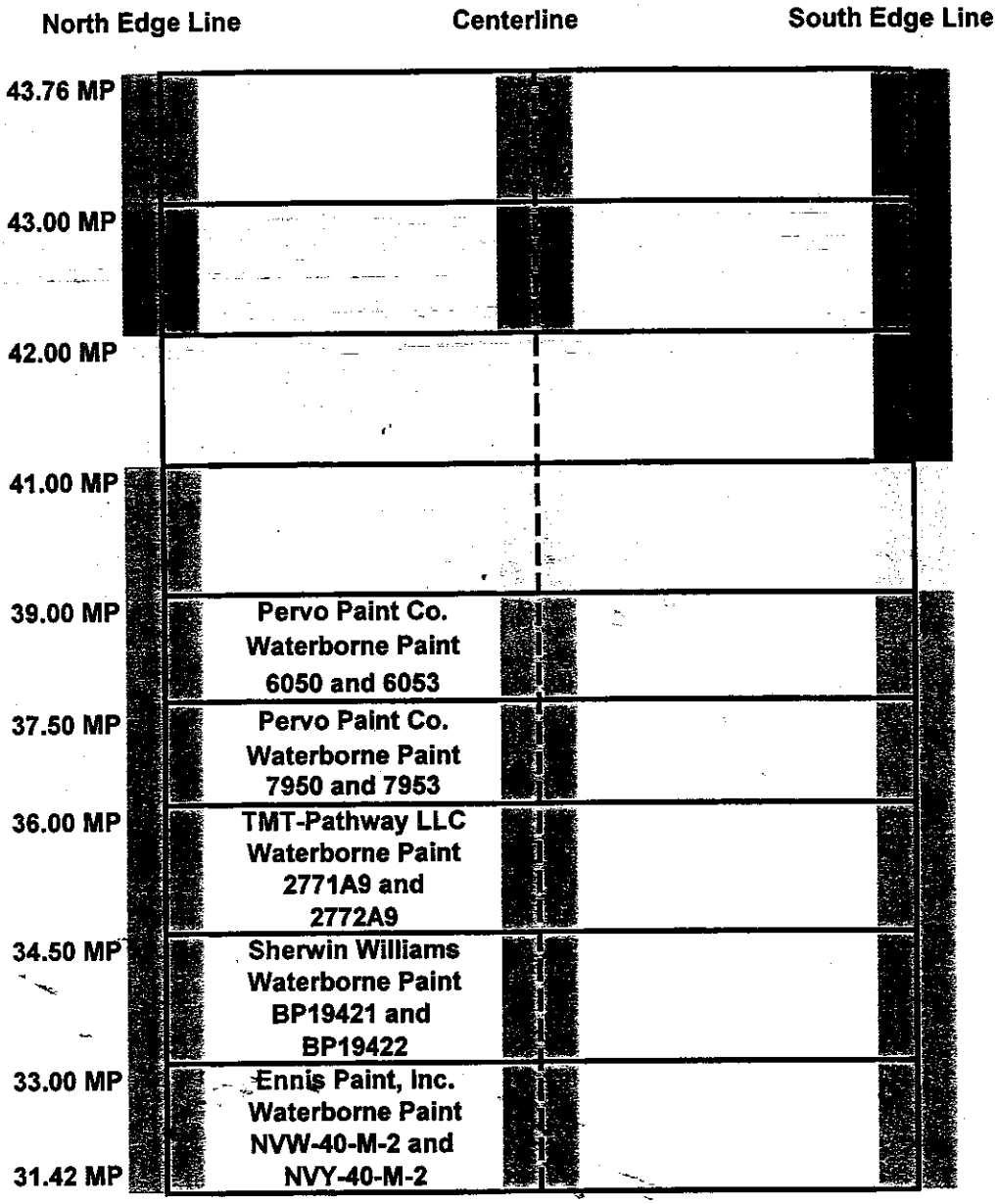


Figure 7.2 US050 – Churchill County
Test Site Layout

Table 7.1 US050 - Churchill County
Retroreflectivity and Durability Data (Page 1 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	Aug-02 RR	Aug-02 DUR	Nov-02 RR	Nov-02 DUR	Feb-03 RR	Feb-03 DUR	Apr-03 RR	Apr-03 DUR
PMRP-02-NV-07	Waterborne	NVW-40-M-2	S Edge White	EPI	223	10	126	10	208	10	182	10
PMRP-02-NV-08	Waterborne	NVY-40-M-2	LF Yellow	EPI	199	10	100	10	211	10	189	10
PMRP-02-NV-07	Waterborne	NVW-40-M-2	N Edge White	EPI	262	10	146	10	205	10	219	10
PMRP-02-NV-15	Waterborne	6050 (MP 37.5 - 39.0)	S Edge White	PPC	206	10	123	10	156	10	163	9
PMRP-02-NV-16	Waterborne	6053 (MP 37.5 - 39.0)	LF Yellow	PPC	130	10	86	10	126	10	129	9
PMRP-02-NV-15	Waterborne	6050 (MP 37.5 - 39.0)	N Edge White	PPC	213	10	131	10	148	10	183	10
PMRP-02-NV-15	Waterborne	6050 (MP 39.0 - 41.0)	S Edge White	PPC	284	10	214	10	266	10	272	10
PMRP-02-NV-16	Waterborne	6053 (MP 39.0 - 41.0)	LF Yellow	PPC	204	10	136	10	166	10	197	10
PMRP-02-NV-15	Waterborne	6050 (MP 41.0 - 42.0)	N Edge White	PPC	246	10	169	10	162	10	174	9
PMRP-02-NV-16	Waterborne	6053 (MP 41.0 - 42.0)	LF Yellow	PPC	169	10	102	10	138	10	148	9
PMRP-02-NV-15	Waterborne	6050 (MP 42.0 - 43.0)	N Edge White	PPC	168	10	113	9	103	7	110	6
PMRP-02-NV-16	Waterborne	6053 (MP 42.0 - 43.0)	LF Yellow	PPC	144	10	50	9	70	6	67	5
PMRP-02-NV-15	Waterborne	6050 (MP 43.0 - 43.76)	N Edge White	PPC	234	10	102	9	99	7	107	6
PMRP-02-NV-16	Waterborne	6053 (MP 43.0 - 43.76)	LF Yellow	PPC	127	10	64	9	70	6	76	5
PMRP-02-NV-15	Waterborne	6050 (MP 41.0 - 43.76)	S Edge White	PPC	177	10	174	10	242	10	228	10
PMRP-02-NV-17	Waterborne	7950	S Edge White	PPC	249	10	138	10	190	10	201	10
PMRP-02-NV-18	Waterborne	7953	LF Yellow	PPC	167	10	105	10	162	10	157	10
PMRP-02-NV-17	Waterborne	7950	N Edge White	PPC	242	10	136	10	189	10	196	10
PMRP-02-NV-23	Waterborne	BP19421	S Edge White	SW	281	10	130	10	192	10	218	10
PMRP-02-NV-24	Waterborne	BP19422	LF Yellow	SW	196	10	84	10	177	10	176	9
PMRP-02-NV-23	Waterborne	BP19421	N Edge White	SW	266	10	129	10	193	10	194	9
PMRP-02-NV-25	Waterborne	2771A9	S Edge White	TMT	224	10	133	10	180	10	176	10
PMRP-02-NV-26	Waterborne	2772A9	LF Yellow	TMT	194	10	82	10	180	10	195	9
PMRP-02-NV-25	Waterborne	2771A9	N Edge White	TMT	233	10	124	10	138	10	142	9

Table 7.1 US050 - Churchill County
Retroreflectivity and Durability Data (Page 2 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	Jul-03 RR	Jul-03 DUR	Sep-03 RR	Sep-03 DUR	Feb-04 RR	Feb-04 DUR	May-04 RR	May-04 DUR
PMRP-02-NV-07	Waterborne	NVW-40-M-2	S Edge White	EPI	145	10	165	10	150	9	158	8
PMRP-02-NV-08	Waterborne	NVY-40-M-2	LF Yellow	EPI	148	9	181	9	187	8	206	7
PMRP-02-NV-07	Waterborne	NVW-40-M-2	N Edge White	EPI	157	9	186	9	160	9	196	8
PMRP-02-NV-15	Waterborne	6050 (MP 37.5 - 39.0)	S Edge White	PPC	145	9	153	9	123	9	137	7
PMRP-02-NV-16	Waterborne	6053 (MP 37.5 - 39.0)	LF Yellow	PPC	100	9	115	9	108	8	106	7
PMRP-02-NV-15	Waterborne	6050 (MP 37.5 - 39.0)	N Edge White	PPC	169	9	158	9	122	9	175	8
PMRP-02-NV-15	Waterborne	6050 (MP 39.0 - 41.0)	S Edge White	PPC	245	10	234	10	219	10	262	9
PMRP-02-NV-16	Waterborne	6053 (MP 39.0 - 41.0)	LF Yellow	PPC	157	9	156	9	150	9	177	8
PMRP-02-NV-15	Waterborne	6050 (MP 41.0 - 42.0)	N Edge White	PPC	183	9	161	8	129	8	189	7
PMRP-02-NV-16	Waterborne	6053 (MP 41.0 - 42.0)	LF Yellow	PPC	148	8	134	8	86	8	116	6
PMRP-02-NV-15	Waterborne	6050 (MP 42.0 - 43.0)	N Edge White	PPC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-16	Waterborne	6053 (MP 42.0 - 43.0)	LF Yellow	PPC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-15	Waterborne	6050 (MP 43.0 - 43.76)	N Edge White	PPC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-16	Waterborne	6053 (MP 43.0 - 43.76)	LF Yellow	PPC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-15	Waterborne	6050 (MP 41.0 - 43.76)	S Edge White	PPC	222	10	202	10	179	9	221	8
PMRP-02-NV-17	Waterborne	7950	S Edge White	PPC	173	10	158	9	151	9	152	8
PMRP-02-NV-18	Waterborne	7953	LF Yellow	PPC	125	10	130	9	116	9	110	7
PMRP-02-NV-17	Waterborne	7950	N Edge White	PPC	189	10	187	10	171	9	211	9
PMRP-02-NV-23	Waterborne	BP19421	S Edge White	SW	139	10	165	10	159	9	212	8
PMRP-02-NV-24	Waterborne	BP19422	LF Yellow	SW	128	9	147	8	124	8	130	6
PMRP-02-NV-23	Waterborne	BP19421	N Edge White	SW	156	9	188	9	153	9	181	8
PMRP-02-NV-25	Waterborne	2771A9	S Edge White	TMT	127	10	135	10	146	9	167	8
PMRP-02-NV-26	Waterborne	2772A9	LF Yellow	TMT	157	8	191	8	114	8	107	6
PMRP-02-NV-25	Waterborne	2771A9	N Edge White	TMT	140	9	154	9	153	8	190	8

Table 7.2 US050 - Churchill County
Color Data (Page 1 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	November 2002			February 2003			April 2003		
					Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-07	Waterborne	NVW-40-M-2	S Edge White	EPI	49.83	0.3296	0.3465	51.86	0.3258	0.3424	49.81	0.3263	0.3430
PMRP-02-NV-08	Waterborne	NVY-40-M-2	LF Yellow	EPI	26.83	0.4614	0.4324	28.95	0.4565	0.4324	28.37	0.4592	0.4307
PMRP-02-NV-07	Waterborne	NVW-40-M-2	N Edge White	EPI	50.38	0.3299	0.3470	53.56	0.3253	0.3424	55.80	0.3244	0.3419
PMRP-02-NV-15	Waterborne	6050 (MP 37.5 - 39.0)	S Edge White	PPC	51.91	0.3360	0.3527	50.76	0.3314	0.3485	52.88	0.3302	0.3474
PMRP-02-NV-16	Waterborne	6053 (MP 37.5 - 39.0)	LF Yellow	PPC	29.36	0.4632	0.4347	27.63	0.4579	0.4348	25.38	0.4550	0.4307
PMRP-02-NV-15	Waterborne	6050 (MP 37.5 - 39.0)	N Edge White	PPC	49.08	0.3385	0.3553	55.16	0.3322	0.3494	57.96	0.3313	0.3489
PMRP-02-NV-15	Waterborne	6050 (MP 39.0 - 41.0)	S Edge White	PPC	44.93	0.3416	0.3578	42.00	0.3352	0.3525	48.74	0.3338	0.3514
PMRP-02-NV-16	Waterborne	6053 (MP 39.0 - 41.0)	LF Yellow	PPC	28.55	0.4615	0.4319	26.80	0.4553	0.4315	28.02	0.4567	0.4294
PMRP-02-NV-15	Waterborne	6050 (MP 41.0 - 42.0)	N Edge White	PPC	48.47	0.3359	0.3524	47.83	0.3314	0.3489	47.40	0.3299	0.3479
PMRP-02-NV-16	Waterborne	6053 (MP 41.0 - 42.0)	LF Yellow	PPC	23.69	0.4543	0.4311	26.75	0.4500	0.4306	22.30	0.4436	0.4237
PMRP-02-NV-15	Waterborne	6050 (MP 42.0 - 43.0)	N Edge White	PPC	40.72	0.3373	0.3553	42.41	0.3287	0.3469	37.60	0.3282	0.3465
PMRP-02-NV-16	Waterborne	6053 (MP 42.0 - 43.0)	LF Yellow	PPC	23.72	0.4528	0.4332	20.74	0.4438	0.4288	17.68	0.4342	0.4180
PMRP-02-NV-15	Waterborne	6050 (MP 43.0 - 43.76)	N Edge White	PPC	40.60	0.3358	0.3535	42.36	0.3291	0.3469	35.67	0.3280	0.3460
PMRP-02-NV-16	Waterborne	6053 (MP 43.0 - 43.76)	LF Yellow	PPC	23.98	0.4531	0.4341	21.67	0.4449	0.4302	16.74	0.4295	0.4157
PMRP-02-NV-15	Waterborne	6050 (MP 41.0 - 43.76)	S Edge White	PPC	44.06	0.3392	0.3551	46.40	0.3301	0.3473	46.21	0.3301	0.3474
PMRP-02-NV-17	Waterborne	7950	S Edge White	PPC	55.09	0.3270	0.3439	54.29	0.3235	0.3405	55.51	0.3239	0.3411
PMRP-02-NV-18	Waterborne	7953	LF Yellow	PPC	29.89	0.4505	0.4264	29.06	0.4454	0.4259	29.68	0.4428	0.4233
PMRP-02-NV-17	Waterborne	7950	N Edge White	PPC	54.38	0.3285	0.3458	57.20	0.3226	0.3399	58.43	0.3232	0.3408
PMRP-02-NV-23	Waterborne	BP19421	S Edge White	SW	54.47	0.3252	0.3425	48.66	0.3238	0.3407	49.31	0.3241	0.3411
PMRP-02-NV-24	Waterborne	BP19422	LF Yellow	SW	29.41	0.4552	0.4322	29.79	0.4507	0.4321	28.23	0.4484	0.4277
PMRP-02-NV-23	Waterborne	BP19421	N Edge White	SW	55.18	0.3263	0.3438	54.43	0.3228	0.3402	57.24	0.3221	0.3400
PMRP-02-NV-25	Waterborne	2771A9	S Edge White	TMT	52.35	0.3326	0.3495	50.70	0.3281	0.3449	51.86	0.3275	0.3445
PMRP-02-NV-26	Waterborne	2772A9	LF Yellow	TMT	28.72	0.4532	0.4306	28.56	0.4461	0.4293	27.27	0.4389	0.4213
PMRP-02-NV-25	Waterborne	2771A9	N Edge White	TMT	52.01	0.3314	0.3485	56.24	0.3259	0.3435	54.04	0.3271	0.3448

Table 7.2 US050 - Churchill County
Color Data (Page 2 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	July 2003			September 2003			February 2004			May 2004		
					Y	x	y	Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-07	Waterborne	NVW-40-M-2	S Edge White	EPI	47.66	0.3283	0.3456	49.83	0.3270	0.3441	46.97	0.3288	0.3455	53.90	0.3251	0.3422
PMRP-02-NV-08	Waterborne	NVY-40-M-2	LF Yellow	EPI	26.47	0.4524	0.4253	24.72	0.4440	0.4219	26.02	0.4207	0.4080	28.67	0.4304	0.4104
PMRP-02-NV-07	Waterborne	NVW-40-M-2	N Edge White	EPI	52.53	0.3273	0.3454	53.73	0.3264	0.3440	46.45	0.3290	0.3456	53.41	0.3251	0.3425
PMRP-02-NV-15	Waterborne	6050 (MP 37.5 - 39.0)	S Edge White	PPC	51.53	0.3305	0.3487	47.94	0.3276	0.3448	48.97	0.3284	0.3452	48.00	0.3258	0.3425
PMRP-02-NV-16	Waterborne	6053 (MP 37.5 - 39.0)	LF Yellow	PPC	25.70	0.4481	0.4233	25.55	0.4450	0.4233	24.66	0.4318	0.4168	27.04	0.4359	0.4160
PMRP-02-NV-15	Waterborne	6050 (MP 37.5 - 39.0)	N Edge White	PPC	56.17	0.3274	0.3464	53.22	0.3291	0.3471	52.74	0.3273	0.3440	55.62	0.3259	0.3432
PMRP-02-NV-15	Waterborne	6050 (MP 39.0 - 41.0)	S Edge White	PPC	45.86	0.3305	0.3498	47.83	0.3279	0.3462	45.56	0.3307	0.3481	47.00	0.3276	0.3453
PMRP-02-NV-16	Waterborne	6053 (MP 39.0 - 41.0)	LF Yellow	PPC	27.37	0.4488	0.4226	27.20	0.4480	0.4218	28.24	0.4335	0.4165	28.60	0.4384	0.4163
PMRP-02-NV-15	Waterborne	6050 (MP 41.0 - 42.0)	N Edge White	PPC	49.80	0.3276	0.3465	50.28	0.3258	0.3438	44.89	0.3284	0.3453	46.63	0.3253	0.3427
PMRP-02-NV-16	Waterborne	6053 (MP 41.0 - 42.0)	LF Yellow	PPC	25.50	0.4402	0.4199	24.57	0.4389	0.4195	23.58	0.4167	0.4065	22.76	0.4222	0.4081
PMRP-02-NV-15	Waterborne	6050 (MP 42.0 - 43.0)	N Edge White	PPC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-16	Waterborne	6053 (MP 42.0 - 43.0)	LF Yellow	PPC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-15	Waterborne	6050 (MP 43.0 - 43.76)	N Edge White	PPC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-16	Waterborne	6053 (MP 43.0 - 43.76)	LF Yellow	PPC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMRP-02-NV-15	Waterborne	6050 (MP 41.0 - 43.76)	S Edge White	PPC	46.16	0.3301	0.3481	47.27	0.3277	0.3457	42.91	0.3313	0.3481	46.96	0.3286	0.3458
PMRP-02-NV-17	Waterborne	7950	S Edge White	PPC	56.15	0.3226	0.3404	53.99	0.3252	0.3428	49.70	0.3253	0.3424	54.78	0.3212	0.3390
PMRP-02-NV-18	Waterborne	7953	LF Yellow	PPC	26.57	0.4322	0.4155	25.22	0.4268	0.4131	29.03	0.4189	0.4101	29.58	0.4244	0.4097
PMRP-02-NV-17	Waterborne	7950	N Edge White	PPC	54.85	0.3243	0.3424	53.90	0.3249	0.3428	46.50	0.3271	0.3437	53.55	0.3229	0.3409
PMRP-02-NV-23	Waterborne	BP19421	S Edge White	SW	45.73	0.3312	0.3492	46.01	0.3271	0.3445	46.32	0.3268	0.3437	48.39	0.3240	0.3411
PMRP-02-NV-24	Waterborne	BP19422	LF Yellow	SW	25.58	0.4371	0.4184	27.84	0.4359	0.4195	27.63	0.4208	0.4107	28.85	0.4229	0.4089
PMRP-02-NV-23	Waterborne	BP19421	N Edge White	SW	51.12	0.3283	0.3469	53.87	0.3245	0.3425	48.15	0.3270	0.3438	57.71	0.3218	0.3397
PMRP-02-NV-25	Waterborne	2771A9	S Edge White	TMT	50.89	0.3282	0.3463	49.35	0.3304	0.3479	46.78	0.3289	0.3456	55.54	0.3254	0.3429
PMRP-02-NV-26	Waterborne	2772A9	LF Yellow	TMT	25.14	0.4338	0.4170	23.77	0.4304	0.4159	21.80	0.4053	0.4000	25.97	0.4202	0.4070
PMRP-02-NV-25	Waterborne	2771A9	N Edge White	TMT	55.08	0.3283	0.3468	52.04	0.3283	0.3463	47.39	0.3302	0.3465	56.30	0.3254	0.3432

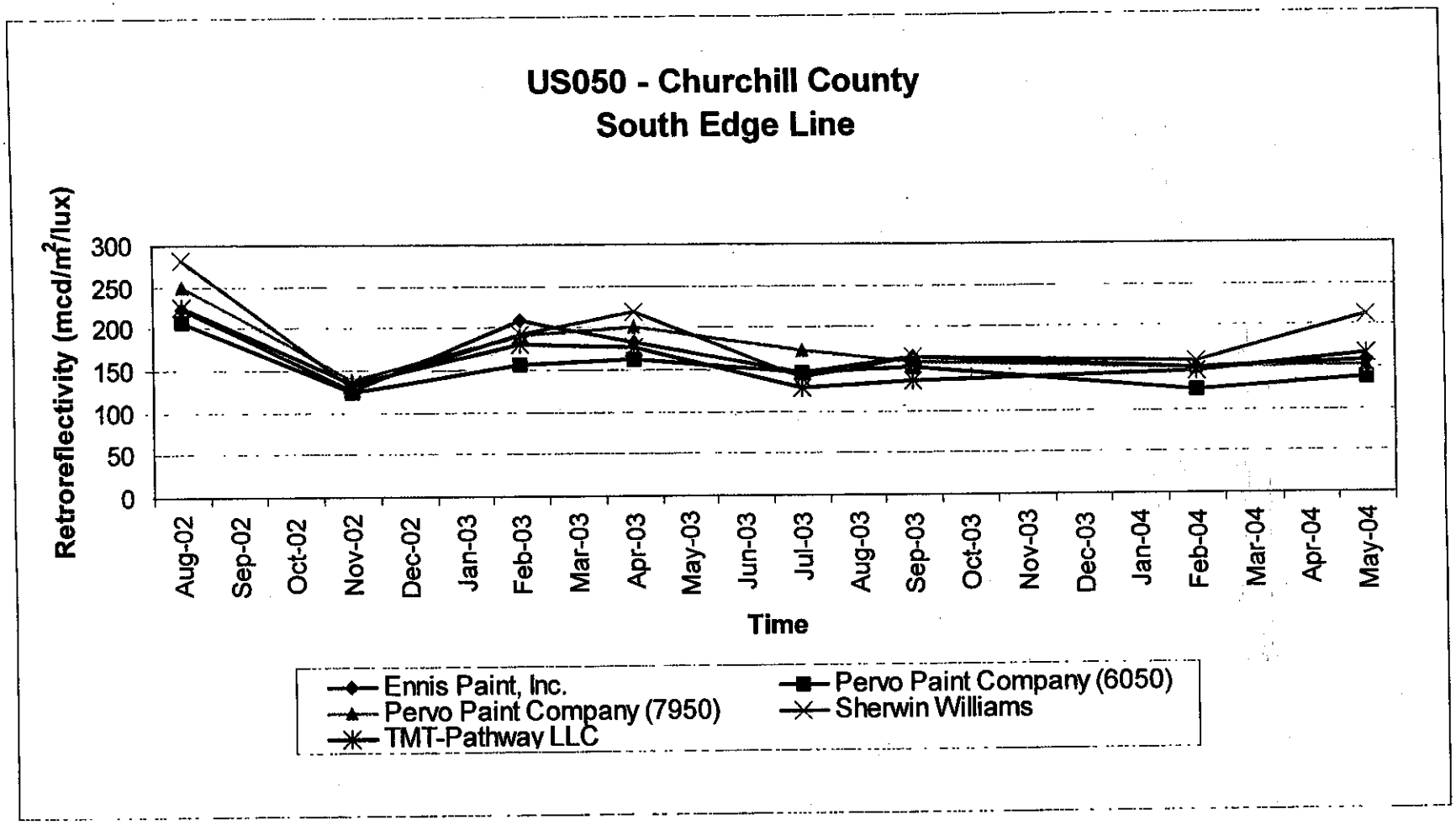


Figure 7.3 US050 Retroreflectivity Comparison for South Edge Line
Milepost 31.42 to Milepost 39.00
Products placed at 25 wet mils with Type B beads at 9 pounds per gallon.

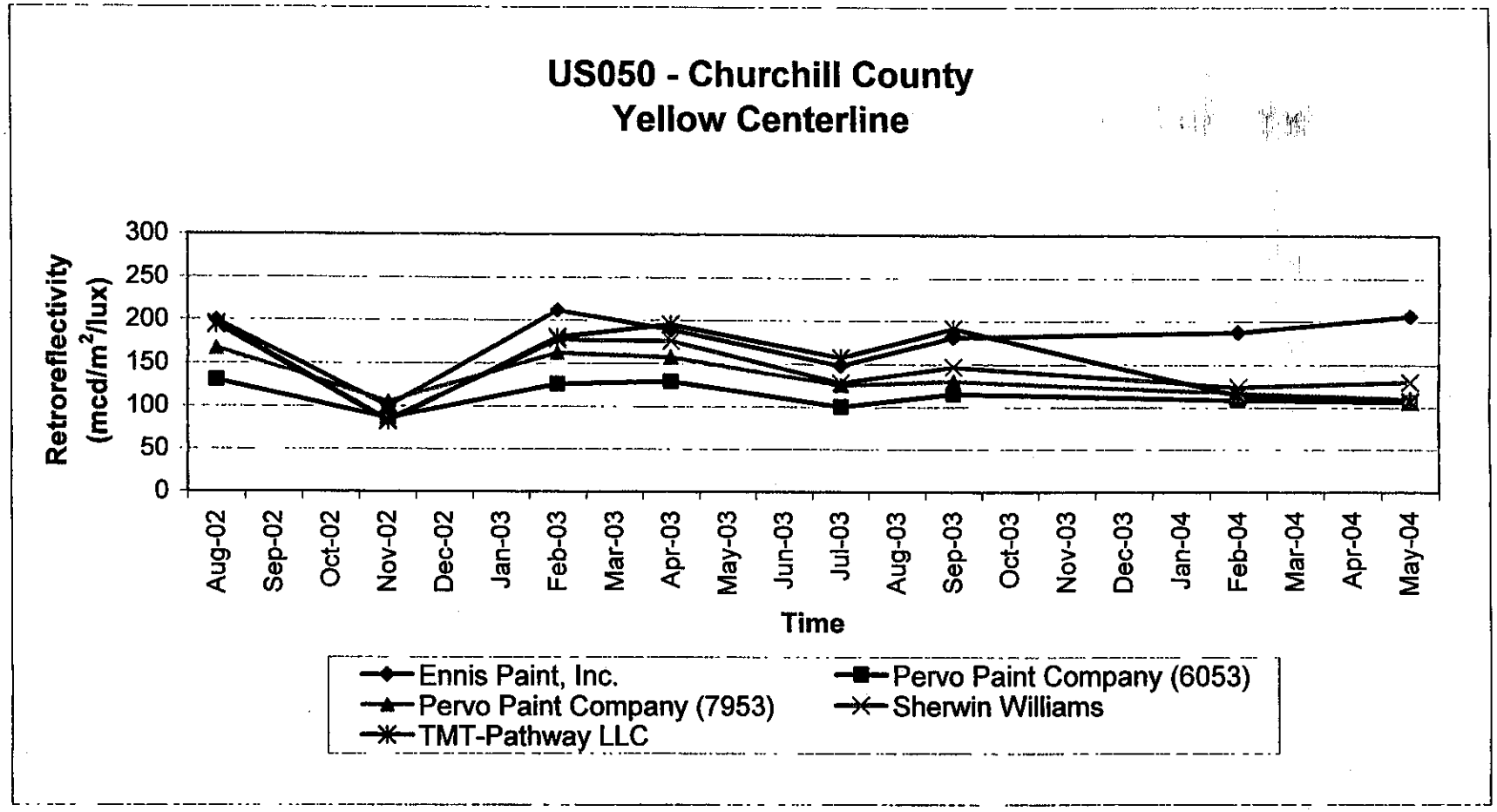


Figure 7.4 US050 Retroreflectivity Comparison for Centerline
Milepost 31.42 to Milepost 39.00
Products placed at 25 wet mils with Type B beads at 9 pounds per gallon.

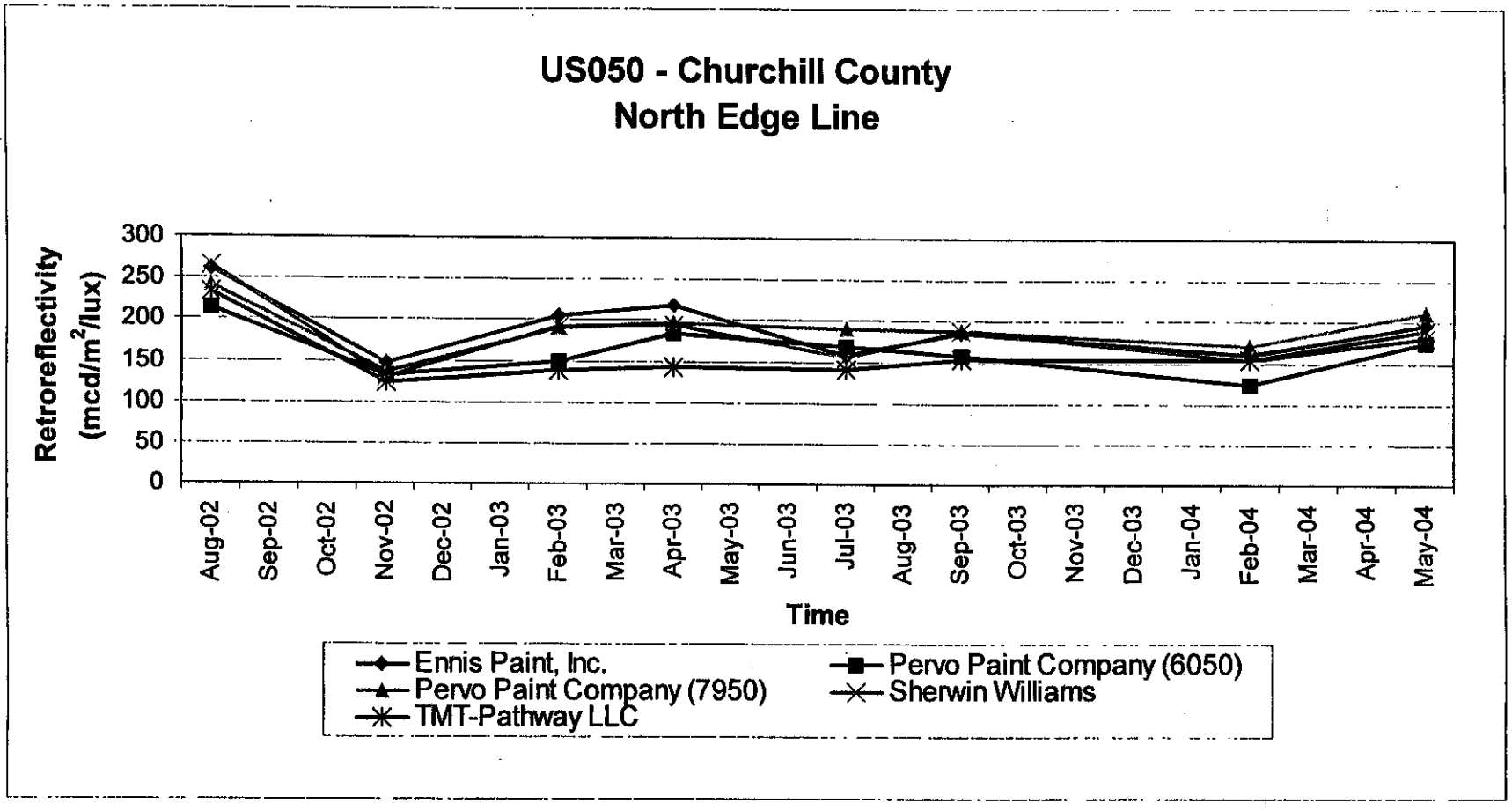


Figure 7.5 US050 Retroreflectivity Comparison for North Edge Line
Milepost 31.42 to Milepost 39.00
Products placed at 25 wet mils with Type B beads at 9 pounds per gallon.

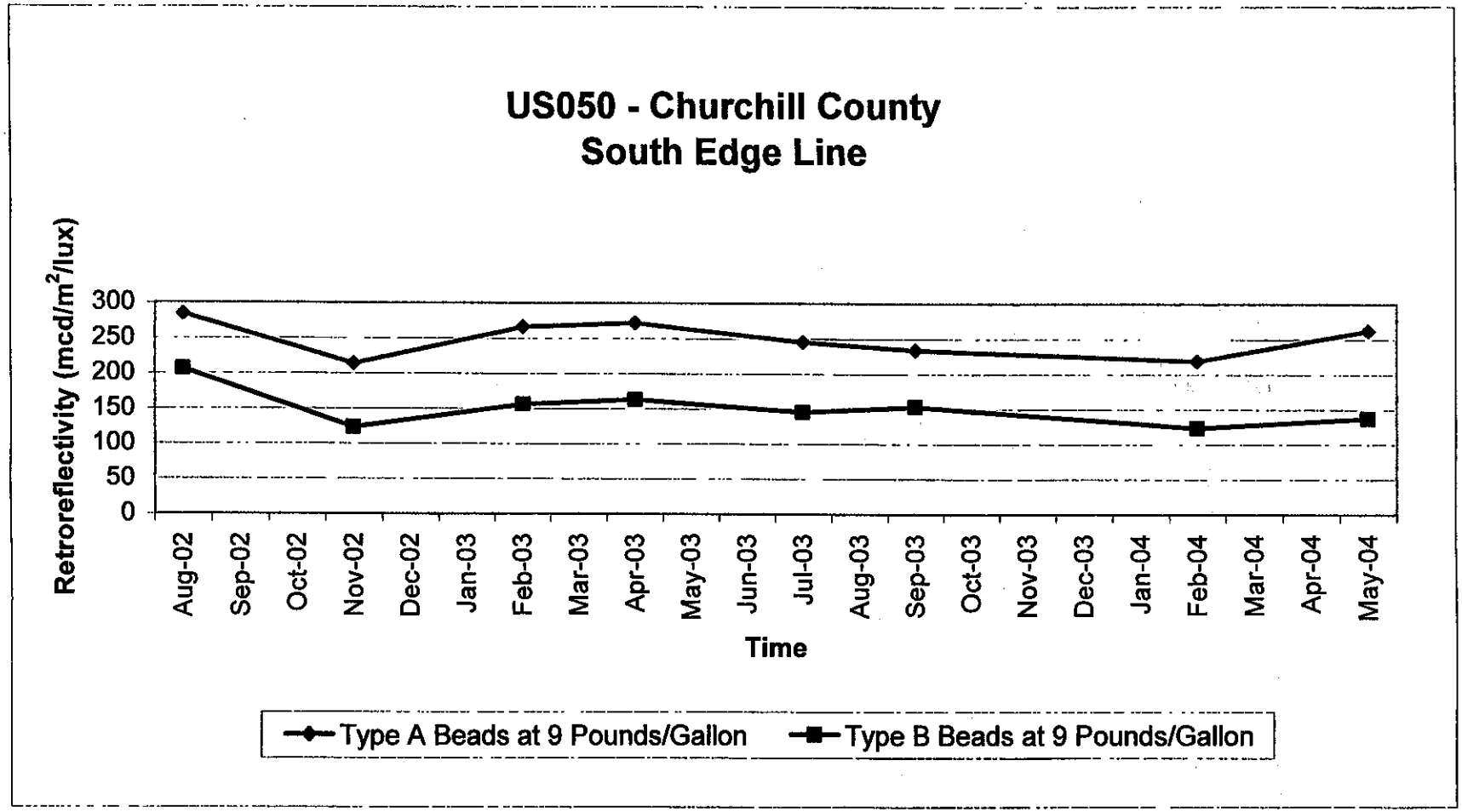


Figure 7.6 US050 Retroreflectivity Comparison for Type A and Type B Beads Applied at 9 Pounds/Gallon White Pavement Marking (Type 6050 Paint at 25 wet mils)

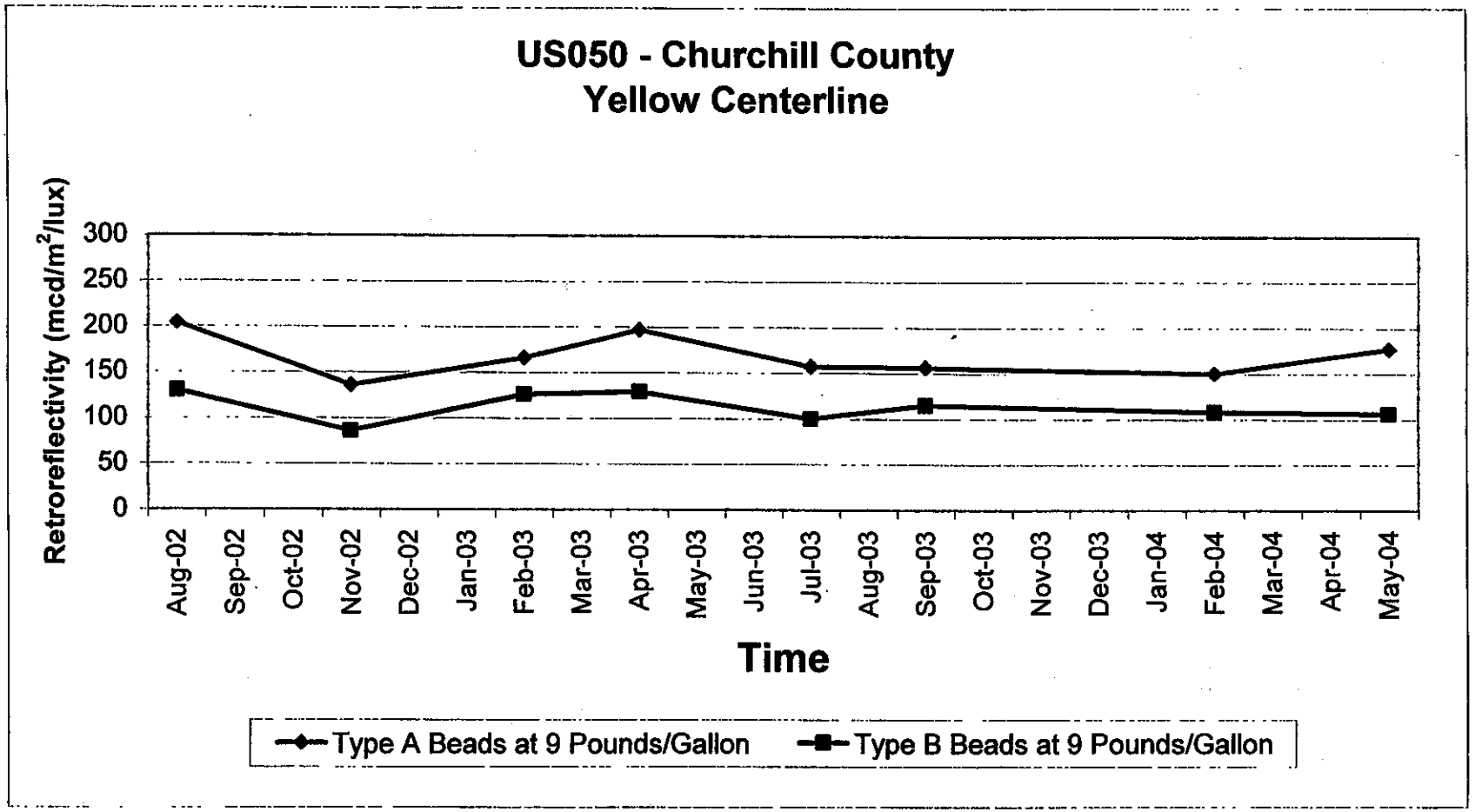


Figure 7.7 US050 Retroreflectivity Comparison for Type A and Type B Beads Applied at 9 Pounds/Gallon Yellow Pavement Marking (Type 6053 Paint at 25 wet mils)

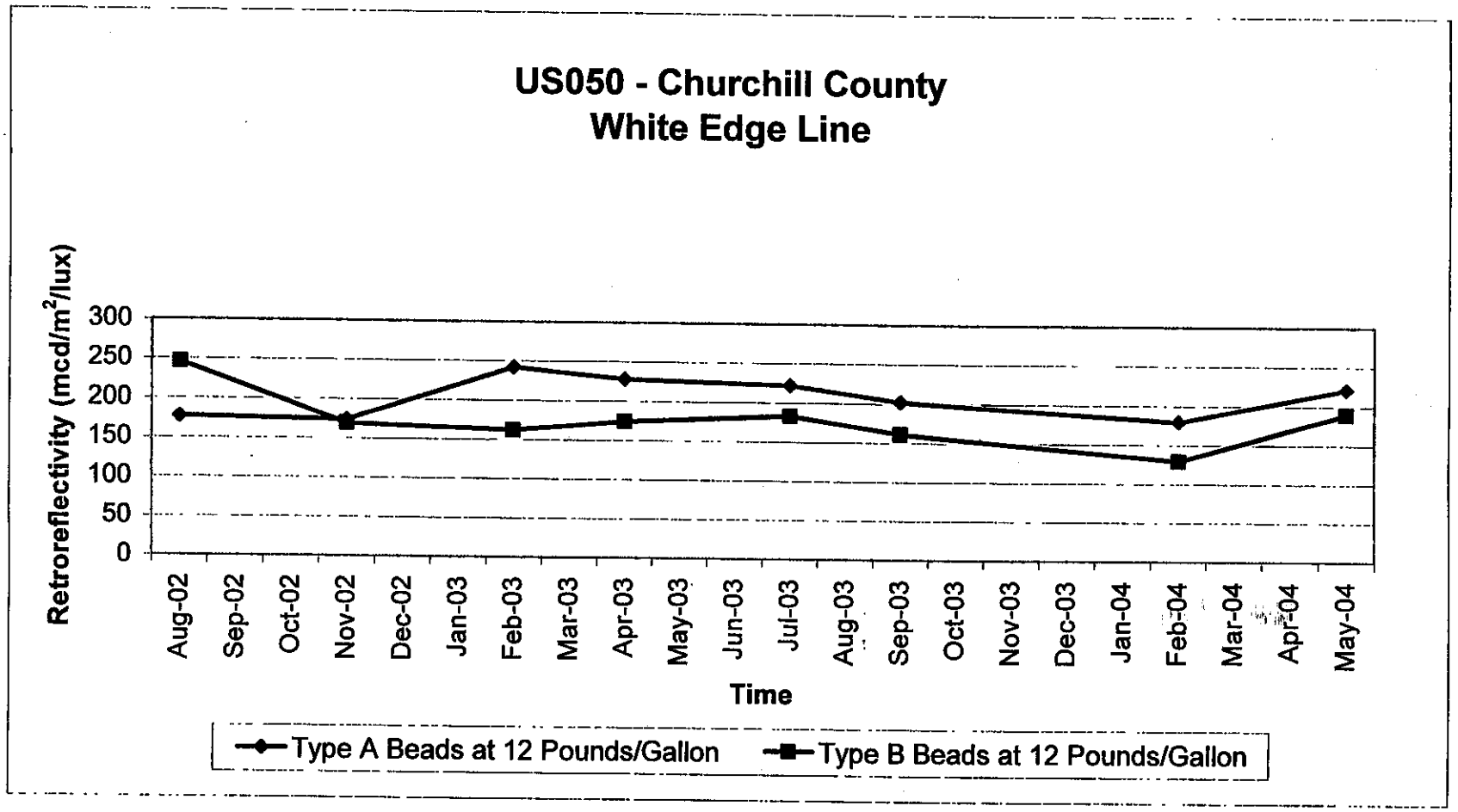


Figure 7.8 US050 Retroreflectivity Comparison for Type A and Type B Beads Applied at 12 Pounds/Gallon White Pavement Marking (Type 6050 Paint at 25 wet mils)

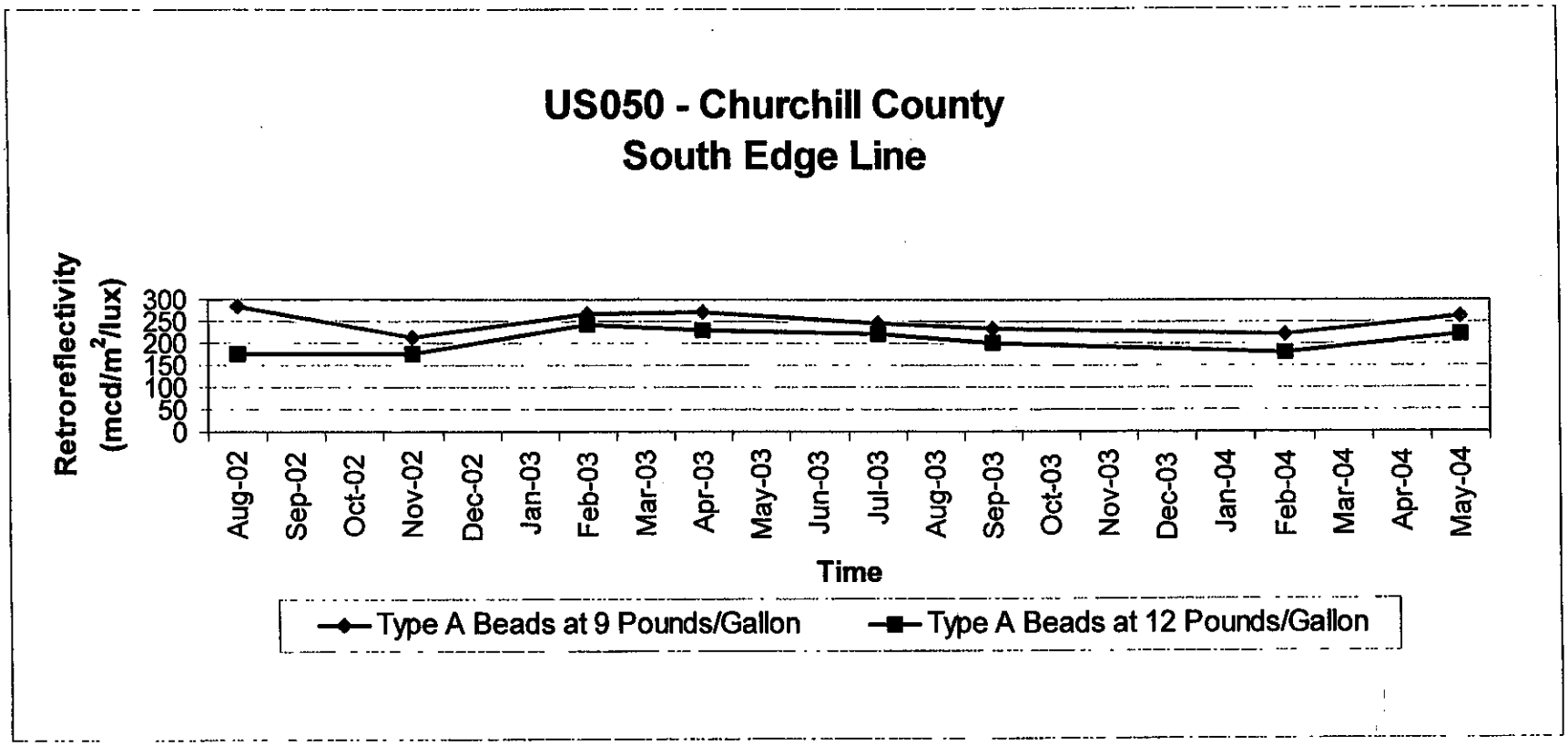


Figure 7.9 US050 Retroreflectivity Comparison for Type A Beads Applied at 9 and 12 Pounds/Gallon White Pavement Marking (Type 6050 Paint at 25 wet mils)

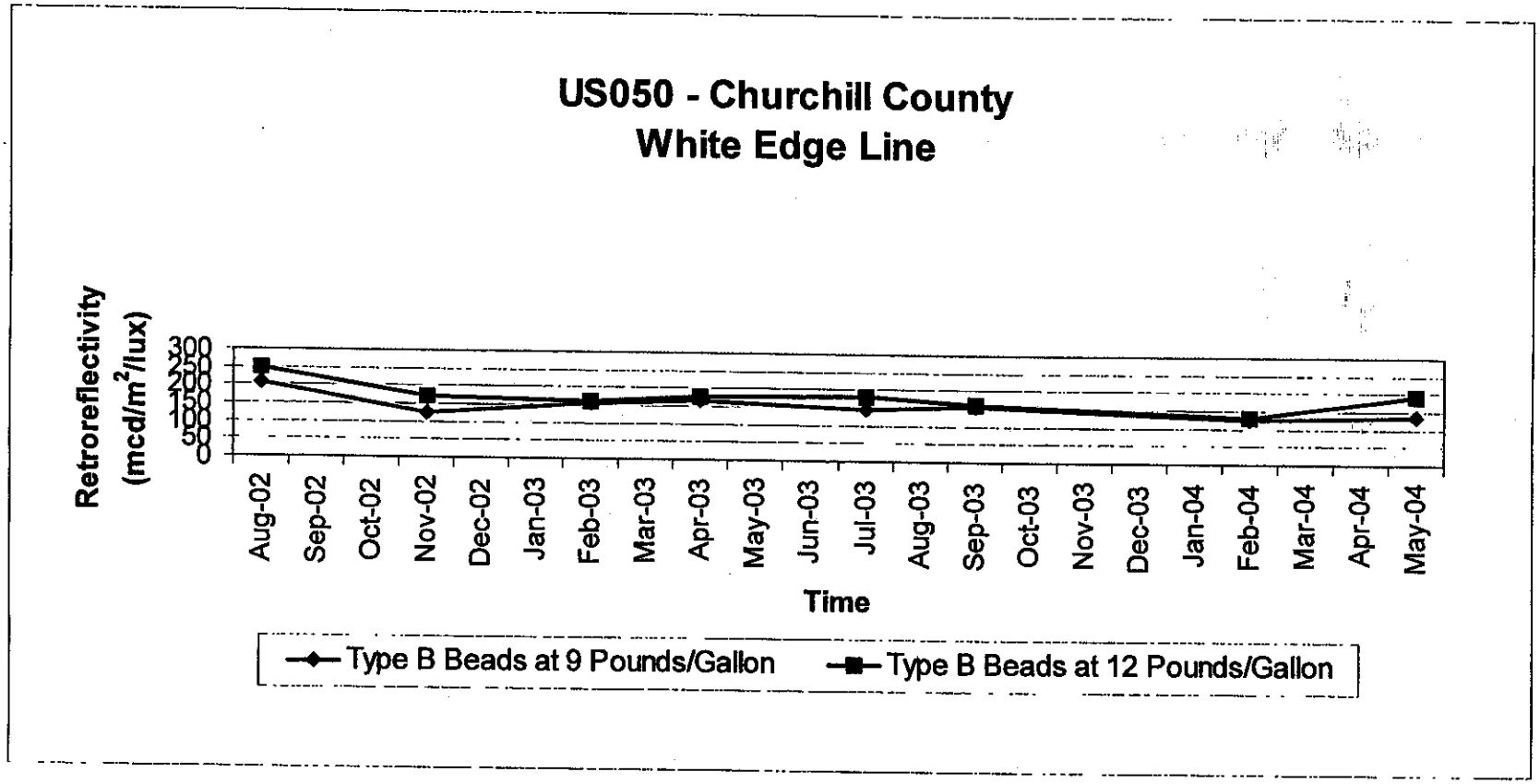


Figure 7.10 US050 Retroreflectivity Comparison for Type B Beads Applied at 9 and 12 Pounds/Gallon White Pavement Marking (Type 6050 Paint at 25 wet mils)

Winter Maintenance Activities for the US050 Test Site

Table 7.3 contains a summary of the estimated number of snowplow passes for the US050 test site. The site was snowplowed an estimated 59 times from December 2002 until March 2004. NDOT manages maintenance activities with a database containing task descriptions, number of man-hours utilized, and materials and equipment used. Estimates are based upon information contained within the database and discussion with snowplow operators.

Table 7.3 Estimated Number of Snowplow Passes on the US050 Test Site

Month	Number of Hours per Month of Snowplow Activity	Estimated Number of Snowplow Passes per Month
Dec 2002	13.5	12
Feb 2003	4.5	4
Mar 2003	3.6	4
		Total Estimated Snowplow Passes for 02/03 Season: 20
Oct 2003	1.86	2
Nov 2003	0.93	1
Dec 2003	18.29	16
Jan 2004	12.07	9
Feb 2004	11.16	10
Mar 2004	0.62	1
		Total Estimated Snowplow Passes for 03/04 Season: 39

Table 7.4 shows that 42 cubic yards of salt and sand and 30 gallons of salt brine solution were placed on the US050 test site from December 2002 until March 2003. In addition, 121 cubic yards of salt and sand and 485 gallons of salt brine solution were placed on the test site from November 2003 to February 2004.

Table 7.4 Salt and Sand and Salt Brine Quantities

Month	Description of Treatment	Quantity per Month (Cubic Yards / Gallons)
Dec 2002	Salt and Sand	25.60
Feb 2003	Salt and Sand	5.00
Mar 2003	Salt and Sand	11.29
		Total for 02/03 Season: 42 CY
Nov 2003	Salt and Sand	1.55
Dec 2003	Salt and Sand	42.37
Jan 2004	Salt and Sand	44.23
Feb 2004	Salt and Sand	32.47
Mar 2004	Salt and Sand	0.62
		Total for 03/04 Season: 121 CY
Dec 2002	Salt Brine	30
		Total for 02/03 Season: 30 GAL
Dec 2003	Salt Brine	440
Feb 2004	Salt Brine	45
		Total for 03/04 Season: 485 GAL

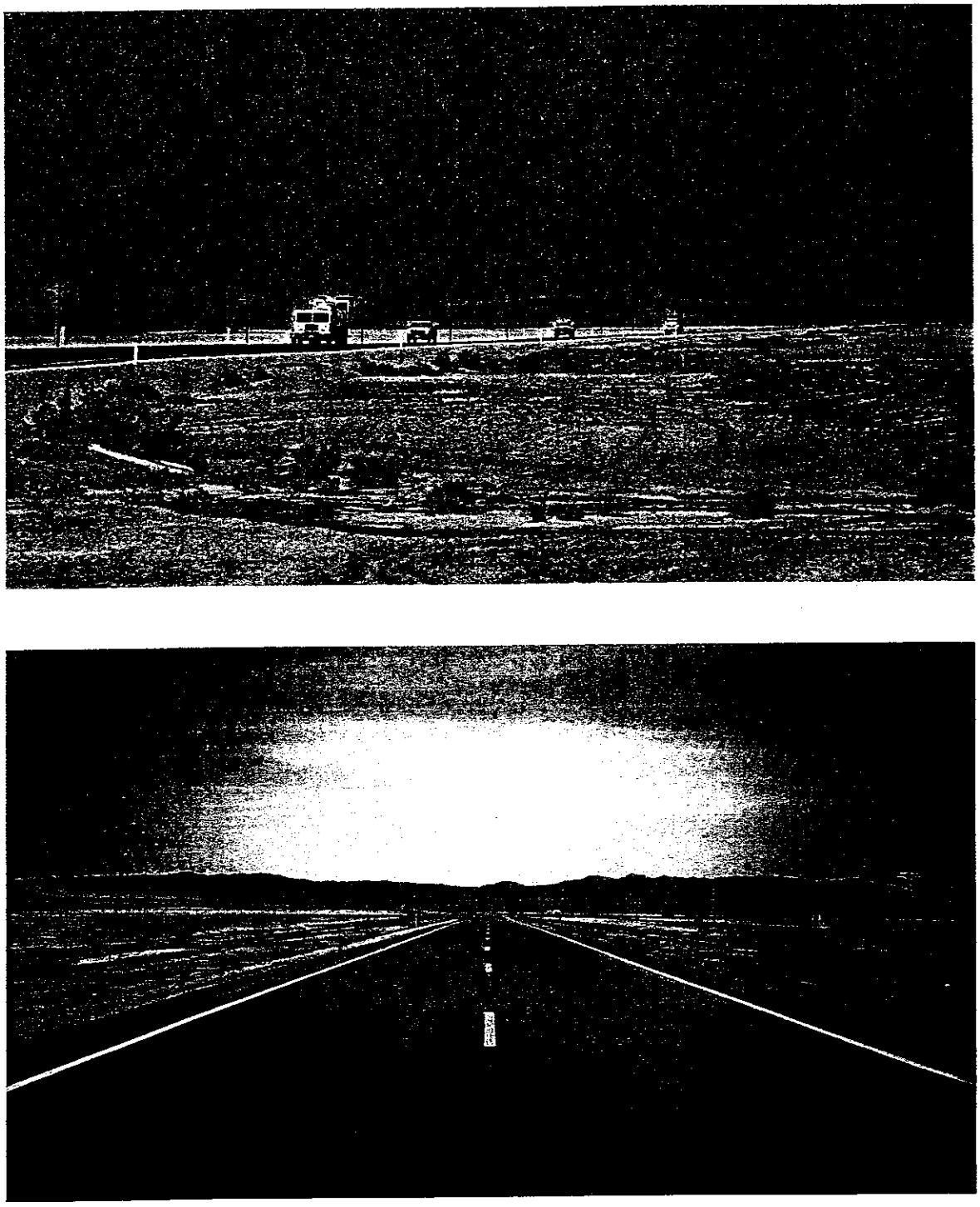


Figure 7.11 NDOT Maintenance Crews Stripe US050 Test Site (Top)

The US050 Test Site is Located on the "Loneliest Road in America" in the Salt Wells Basin Area (Bottom)

CHAPTER 8 – RESULTS FOR US093 TEST SITE

Background

The US093 test site is located on a two-lane plantmix bituminous with open-grade wearing course roadway in Clark County, Nevada from mileposts 59.00 to 70.00 (Figure 8.1 between north of I-15 to south of SR168 and Figure 8.6).

Waterborne paint materials were longitudinally placed as center and edge lines over worn out paint in the same manner that occurs for typical NDOT maintenance restriping operations. Figure 8.2 shows a diagram of the test site layout. Materials were installed in October 2002 and monitored until May 2004.

Evaluation Based on Durability, Retroreflectivity, and Color

Durability
Table 8.1 presents the durability observations. All materials remained durable throughout the monitoring process.

Retroreflectivity
Table 8.1 lists the recorded retroreflectivity measurements. Figures 8.3 through 8.5 show retroreflectivity comparisons for the east edge, center, and west edge lines. All white colored marking materials exhibited measurements over 340 mcd/m^2/lux after nineteen months. All yellow colored marking products demonstrated measurements over 140 mcd/m^2/lux at the end of 19 months.

Color
Table 8.2 contains the color measurement results for the pavement marking materials. A review of color data indicates that nine of the ten white colored edge lines maintained acceptable daytime chromaticity coordinates and luminance factor requirements according to ASTM D 6628, "Standard Specification for Color of Pavement Marking Materials," throughout the monitoring process (15).

The yellow colored pavement marking materials display similar trends of color degradation starting from approximately 4 months after placement. Within eleven months of placement, four of five yellow colored materials were noncompliant with chromaticity coordinate requirements and all materials were noncompliant with luminance factor requirements. The color measurements displayed with red font and underlined are measurements that do not meet daytime chromaticity coordinate or luminance factor requirements according to ASTM D 6628.

Winter Maintenance Activities

There were no winter maintenance activities at this location.

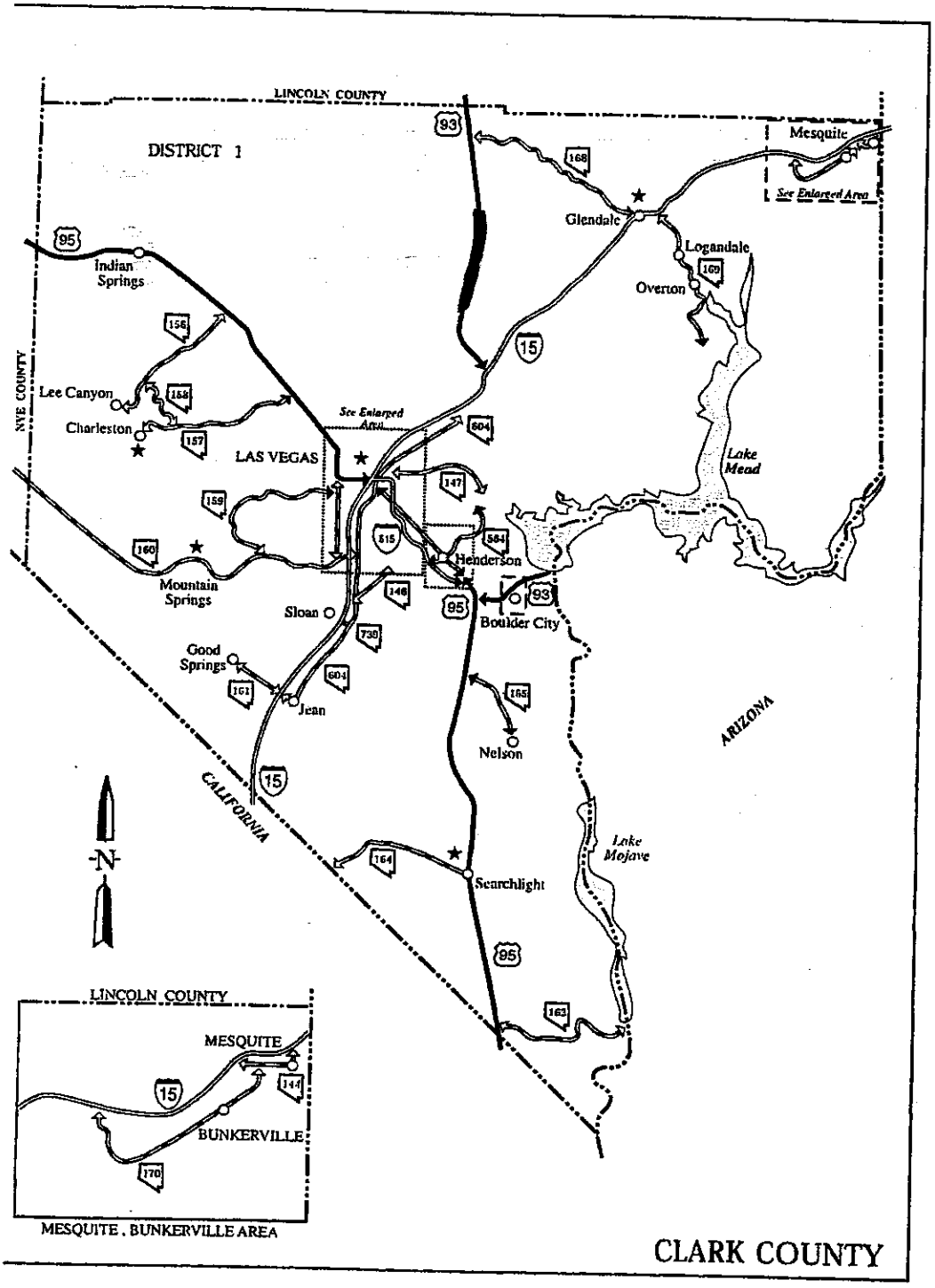


Figure 8.1 Map of Clark County, Nevada

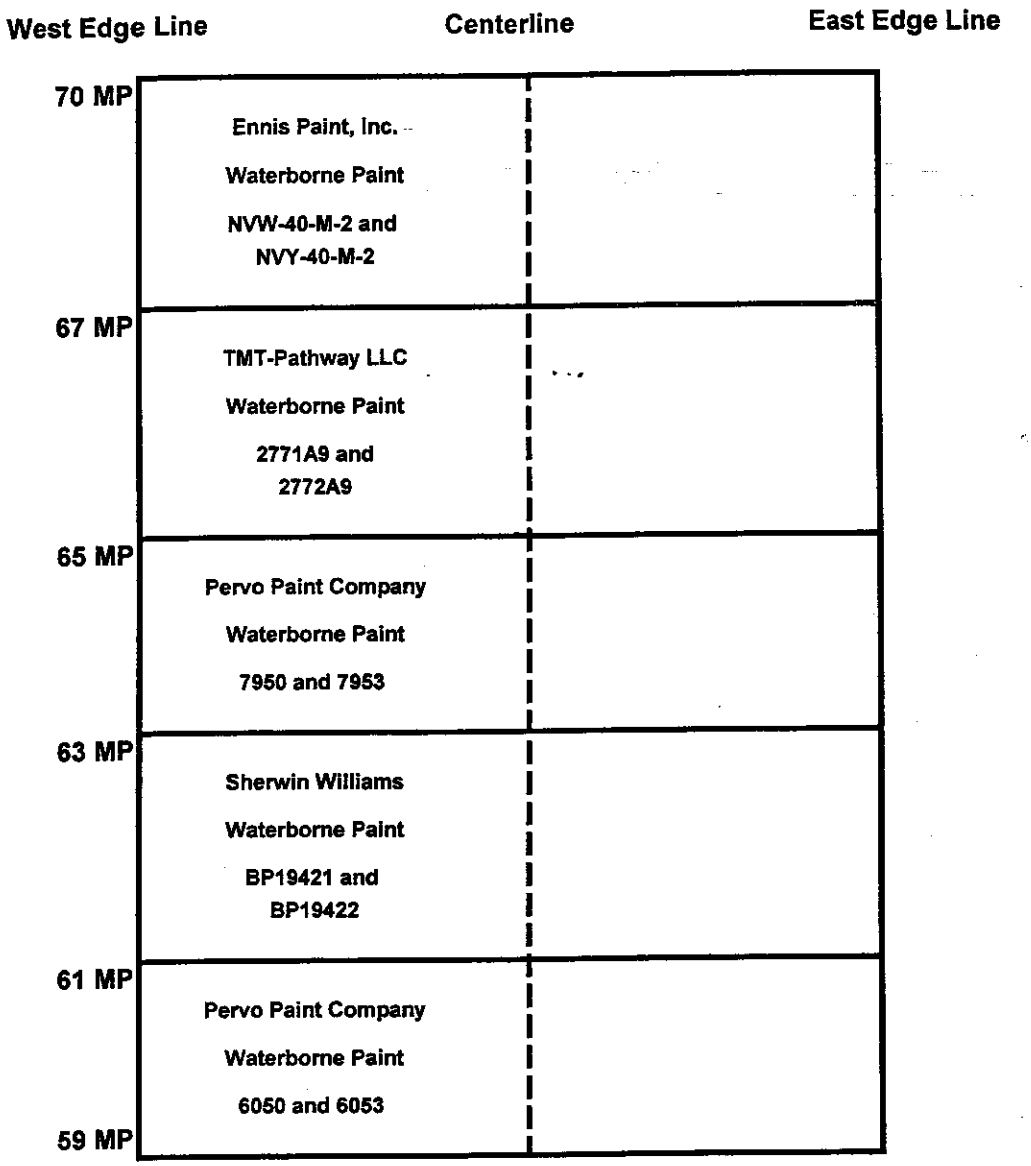


Figure 8.2 US093 - Clark County
Test Site Layout

Table 8.1 US093 - Clark County
Retroreflectivity and Durability Data (Page 1 of 2)

Project Code	Material Type	Project Code	Color	Vendor ID	Oct-02 RR	Oct-02 DUR	Nov-02 RR	Nov-02 DUR	Feb-03 RR	Feb-03 DUR	May-03 RR	May-03 DUR
PMRP-02-NV-07	Waterborne	NVW-40-M-2	E Edge White	EPI	485	10	460	10	432	10	404	10
PMRP-02-NV-08	Waterborne	NVY-40-M-2	LF Yellow	EPI	282	10	262	10	252	10	226	10
PMRP-02-NV-07	Waterborne	NVW-40-M-2	W Edge White	EPI	382	10	347	10	325	10	358	10
PMRP-02-NV-15	Waterborne	6050	E Edge White	PPC	374	10	343	10	346	10	297	10
PMRP-02-NV-16	Waterborne	6053	LF Yellow	PPC	198	10	162	10	144	10	158	10
PMRP-02-NV-15	Waterborne	6050	W Edge White	PPC	370	10	334	10	305	10	344	10
PMRP-02-NV-17	Waterborne	7950	E Edge White	PPC	394	10	397	10	404	10	367	10
PMRP-02-NV-18	Waterborne	7953	LF Yellow	PPC	214	10	195	10	208	10	194	10
PMRP-02-NV-17	Waterborne	7950	W Edge White	PPC	432	10	414	10	371	10	405	10
PMRP-02-NV-23	Waterborne	BP19421	E Edge White	SW	402	10	391	10	409	10	380	10
PMRP-02-NV-24	Waterborne	BP19422	LF Yellow	SW	269	10	262	10	223	10	192	10
PMRP-02-NV-23	Waterborne	BP19421	W Edge White	SW	396	10	370	10	351	10	359	10
PMRP-02-NV-25	Waterborne	2771A9	E Edge White	TMT	405	10	416	10	402	10	405	10
PMRP-02-NV-26	Waterborne	2772A9	LF Yellow	TMT	242	10	219	10	207	10	189	10
PMRP-02-NV-25	Waterborne	2771A9	W Edge White	TMT	353	10	335	10	312	10	341	10

Table 8.1 US093 - Clark County
Retroreflectivity and Durability Data (Page 2 of 2)

Project Code	Material Type	Project Code	Color	Vendor ID	Sep-03 RR	Sep-03 DUR	Jan-04 RR	Jan-04 DUR	May-04 RR	May-04 DUR
PMRP-02-NV-07	Waterborne	NVW-40-M-2	E Edge White	EPI	439	10	451	10	387	10
PMRP-02-NV-08	Waterborne	NVY-40-M-2	LF Yellow	EPI	243	10	241	10	245	10
PMRP-02-NV-07	Waterborne	NVW-40-M-2	W Edge White	EPI	344	10	302	10	371	10
PMRP-02-NV-15	Waterborne	6050	E Edge White	PPC	346	10	338	10	344	10
PMRP-02-NV-16	Waterborne	6053	LF Yellow	PPC	166	10	146	10	143	10
PMRP-02-NV-15	Waterborne	6050	W Edge White	PPC	391	10	305	10	345	10
PMRP-02-NV-17	Waterborne	7950	E Edge White	PPC	392	10	380	10	364	10
PMRP-02-NV-18	Waterborne	7953	LF Yellow	PPC	190	10	214	10	193	10
PMRP-02-NV-17	Waterborne	7950	W Edge White	PPC	446	10	370	10	431	10
PMRP-02-NV-23	Waterborne	BP19421	E Edge White	SW	415	10	410	10	406	10
PMRP-02-NV-24	Waterborne	BP19422	LF Yellow	SW	181	10	255	10	224	10
PMRP-02-NV-23	Waterborne	BP19421	W Edge White	SW	392	10	321	10	345	10
PMRP-02-NV-25	Waterborne	2771A9	E Edge White	TMT	445	10	369	10	358	10
PMRP-02-NV-26	Waterborne	2772A9	LF Yellow	TMT	209	10	240	10	237	10
PMRP-02-NV-25	Waterborne	2771A9	W Edge White	TMT	370	10	309	10	352	10

Table 8.2 US093 - Clark County
Color Data (Page 1 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	October 2002			November 2002			February 2003			May 2003		
					Y	x	y	Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-07	Waterborne	NVW-40-M-2	E Edge White	EPI	68.00	0.3192	0.3387	57.77	0.3206	0.3390	52.77	0.3228	0.3403	52.42	0.3219	0.3396
PMRP-02-NV-08	Waterborne	NVY-40-M-2	LF Yellow	EPI	34.79	0.4788	0.4377	28.70	0.4694	0.4354	23.65	0.4592	0.4269	21.91	0.4566	0.4264
PMRP-02-NV-07	Waterborne	NVW-40-M-2	W Edge White	EPI	67.71	0.3174	0.3367	60.43	0.3206	0.3385	53.97	0.3217	0.3394	52.20	0.3211	0.3390
PMRP-02-NV-15	Waterborne	6050	E Edge White	PPC	58.48	0.3168	0.3361	49.95	0.3193	0.3377	43.98	0.3206	0.3389	31.19	0.3221	0.3395
PMRP-02-NV-16	Waterborne	6053	LF Yellow	PPC	30.59	0.4789	0.4429	25.94	0.4616	0.4313	20.01	0.4498	0.4242	19.27	0.4537	0.4262
PMRP-02-NV-15	Waterborne	6050	W Edge White	PPC	62.83	0.3165	0.3363	59.67	0.3189	0.3376	57.98	0.3188	0.3377	54.36	0.3198	0.3385
PMRP-02-NV-17	Waterborne	7950	E Edge White	PPC	67.94	0.3158	0.3345	58.66	0.3173	0.3354	53.92	0.3190	0.3368	45.35	0.3197	0.3373
PMRP-02-NV-18	Waterborne	7953	LF Yellow	PPC	34.98	0.4687	0.4386	29.80	0.4546	0.4308	24.62	0.4461	0.4244	23.16	0.4440	0.4236
PMRP-02-NV-17	Waterborne	7950	W Edge White	PPC	69.45	0.3167	0.3356	65.28	0.3185	0.3364	59.63	0.3190	0.3371	54.91	0.3196	0.3377
PMRP-02-NV-23	Waterborne	BP19421	E Edge White	SW	59.93	0.3161	0.3352	51.52	0.3180	0.3363	49.77	0.3192	0.3373	46.17	0.3200	0.3381
PMRP-02-NV-24	Waterborne	BP19422	LF Yellow	SW	34.11	0.4709	0.4407	31.61	0.4602	0.4336	23.02	0.4455	0.4239	20.16	0.4440	0.4233
PMRP-02-NV-23	Waterborne	BP19421	W Edge White	SW	61.72	0.3161	0.3357	58.22	0.3182	0.3365	50.29	0.3193	0.3380	50.99	0.3208	0.3394
PMRP-02-NV-25	Waterborne	2771A9	E Edge White	TMT	67.94	0.3195	0.3385	57.65	0.3205	0.3388	53.76	0.3221	0.3400	47.68	0.3220	0.3399
PMRP-02-NV-26	Waterborne	2772A9	LF Yellow	TMT	36.44	0.4606	0.4361	30.53	0.4515	0.4323	23.41	0.4377	0.4214	23.35	0.4395	0.4219
PMRP-02-NV-25	Waterborne	2771A9	W Edge White	TMT	68.60	0.3191	0.3381	59.40	0.3217	0.3395	55.53	0.3217	0.3398	51.57	0.3214	0.3397

Table 8.2 US093 - Clark County
Color Data (Page 2 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	September 2003			January 2004			May 2004		
					Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-07	Waterborne	NVW-40-M-2	E Edge White	EPI	48.62	0.3234	0.3406	45.95	0.3228	0.3397	43.14	0.3242	0.3419
PMRP-02-NV-08	Waterborne	NVY-40-M-2	LF Yellow	EPI	21.23	0.4415	0.4174	20.60	0.4331	0.4131	21.92	0.4329	0.4104
PMRP-02-NV-07	Waterborne	NVW-40-M-2	W Edge White	EPI	46.04	0.3233	0.3405	48.91	0.3227	0.3400	38.45	0.3228	0.3407
PMRP-02-NV-15	Waterborne	6050	E Edge White	PPC	28.80	0.3228	0.3402	31.32	0.3225	0.3396	35.30	0.3227	0.3408
PMRP-02-NV-16	Waterborne	6053	LF Yellow	PPC	16.68	0.4447	0.4174	17.22	0.4361	0.4160	16.38	0.4327	0.4129
PMRP-02-NV-15	Waterborne	6050	W Edge White	PPC	49.74	0.3210	0.3393	47.38	0.3219	0.3399	48.52	0.3212	0.3400
PMRP-02-NV-17	Waterborne	7950	E Edge White	PPC	44.35	0.3201	0.3377	39.22	0.3208	0.3376	42.69	0.3198	0.3378
PMRP-02-NV-18	Waterborne	7953	LF Yellow	PPC	19.49	0.4317	0.4124	22.11	0.4293	0.4129	22.32	0.4229	0.4086
PMRP-02-NV-17	Waterborne	7950	W Edge White	PPC	47.46	0.3206	0.3381	48.17	0.3215	0.3390	52.74	0.3199	0.3383
PMRP-02-NV-23	Waterborne	BP19421	E Edge White	SW	36.47	0.3213	0.3388	38.68	0.3211	0.3382	39.33	0.3210	0.3392
PMRP-02-NV-24	Waterborne	BP19422	LF Yellow	SW	18.43	0.4365	0.4152	19.87	0.4333	0.4148	21.34	0.4283	0.4108
PMRP-02-NV-23	Waterborne	BP19421	W Edge White	SW	41.41	0.3213	0.3395	40.56	0.3218	0.3395	42.60	0.3206	0.3393
PMRP-02-NV-25	Waterborne	2771A9	E Edge White	TMT	44.94	0.3231	0.3408	39.68	0.3229	0.3397	43.76	0.3231	0.3413
PMRP-02-NV-26	Waterborne	2772A9	LF Yellow	TMT	20.61	0.4281	0.4114	24.09	0.4262	0.4121	24.58	0.4180	0.4052
PMRP-02-NV-25	Waterborne	2771A9	W Edge White	TMT	46.91	0.3233	0.3409	42.24	0.3235	0.3407	47.53	0.3220	0.3404

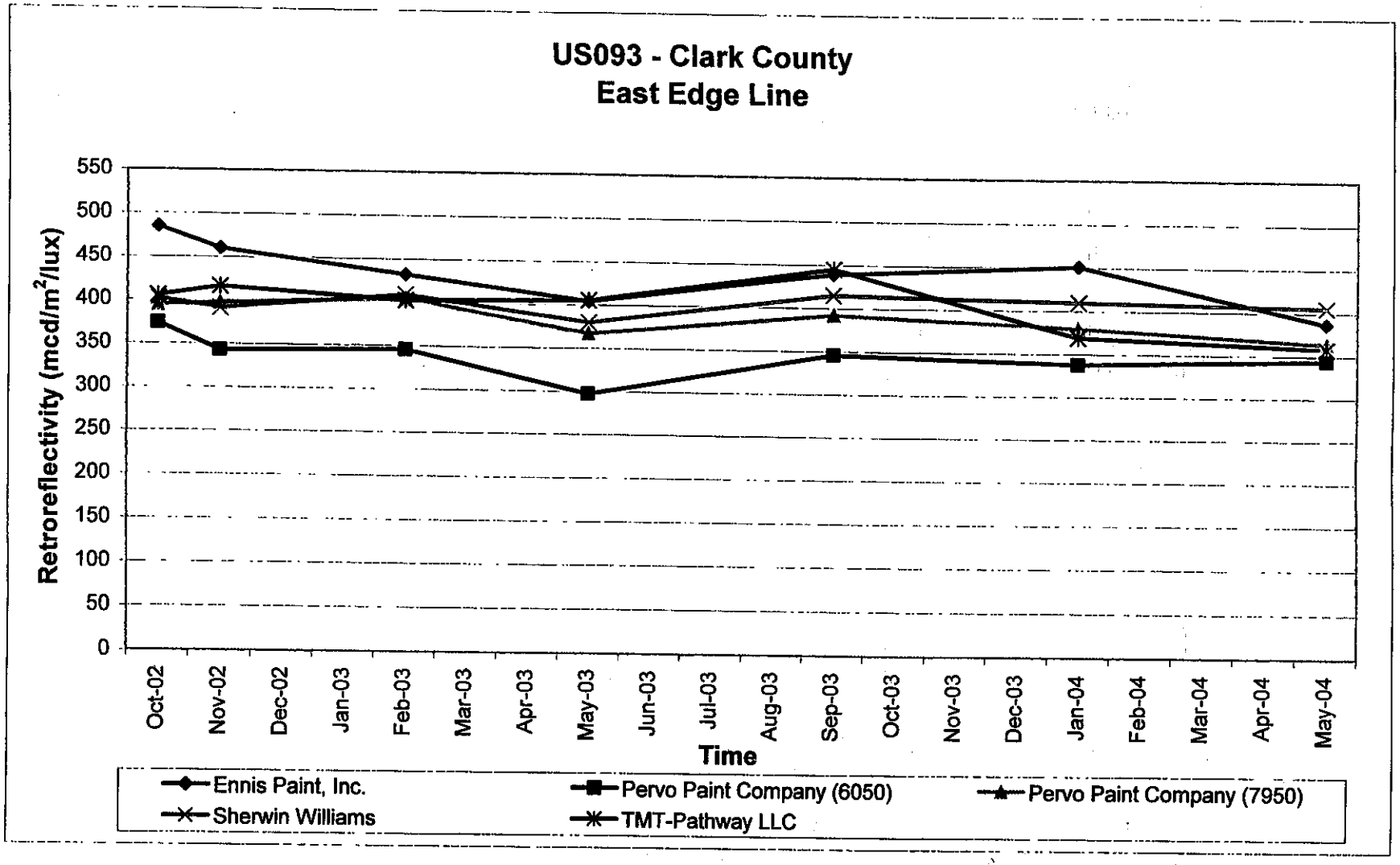


Figure 8.3 US093 Retroreflectivity Comparison for East Edge Line

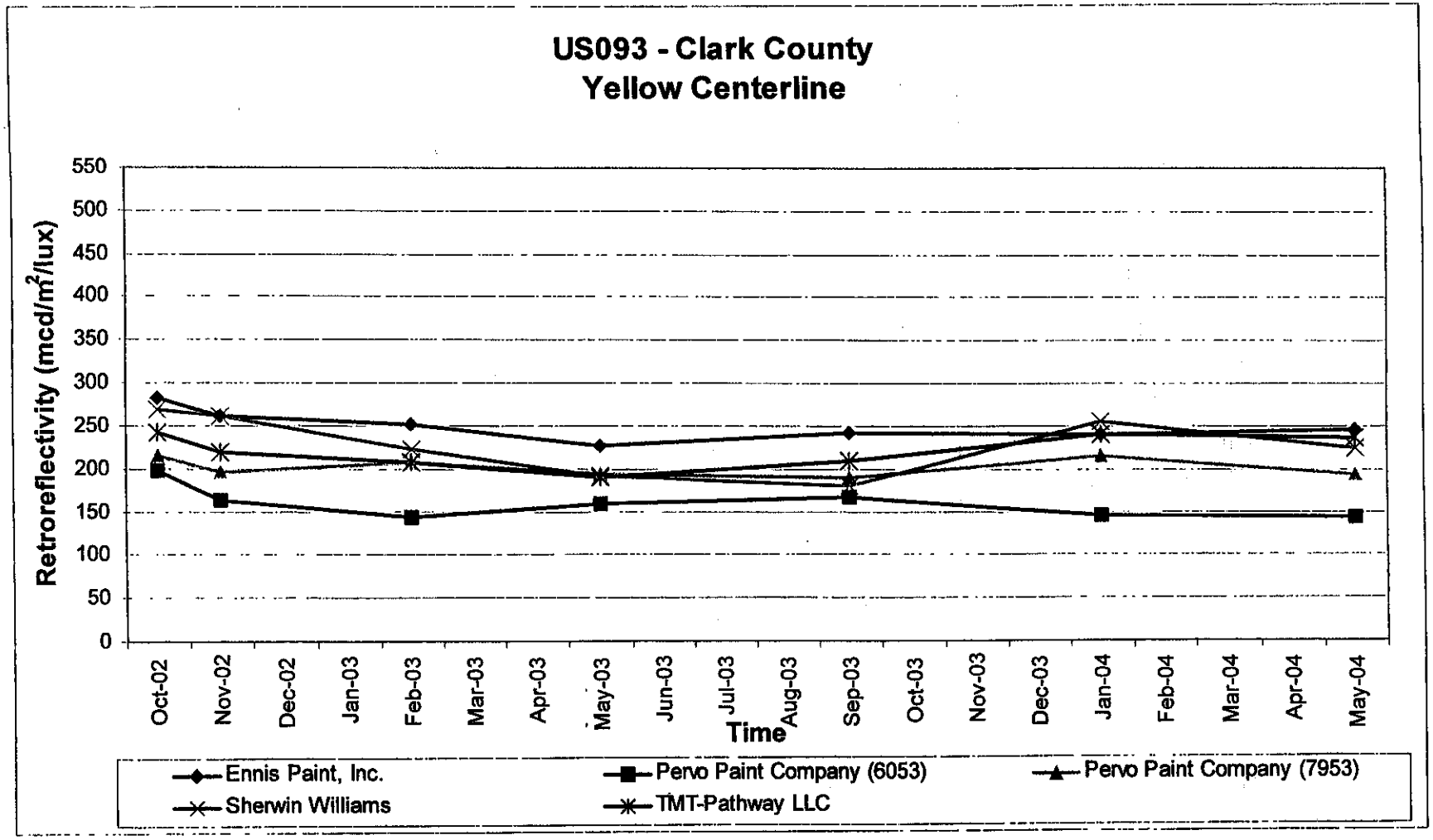


Figure 8.4 US093 Retroreflectivity Comparison for Centerline

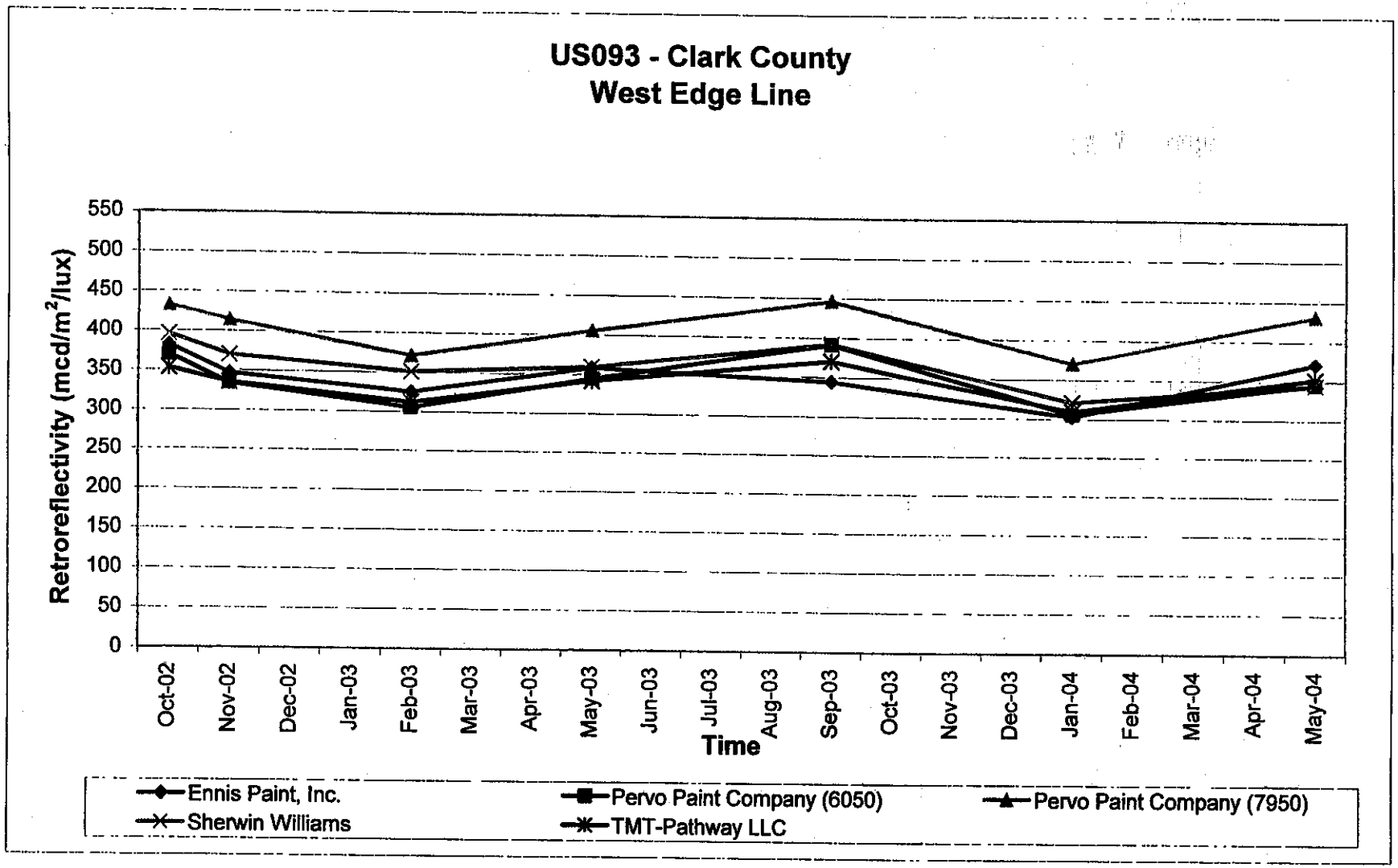


Figure 8.5 US093 Retroreflectivity Comparison for West Edge Line

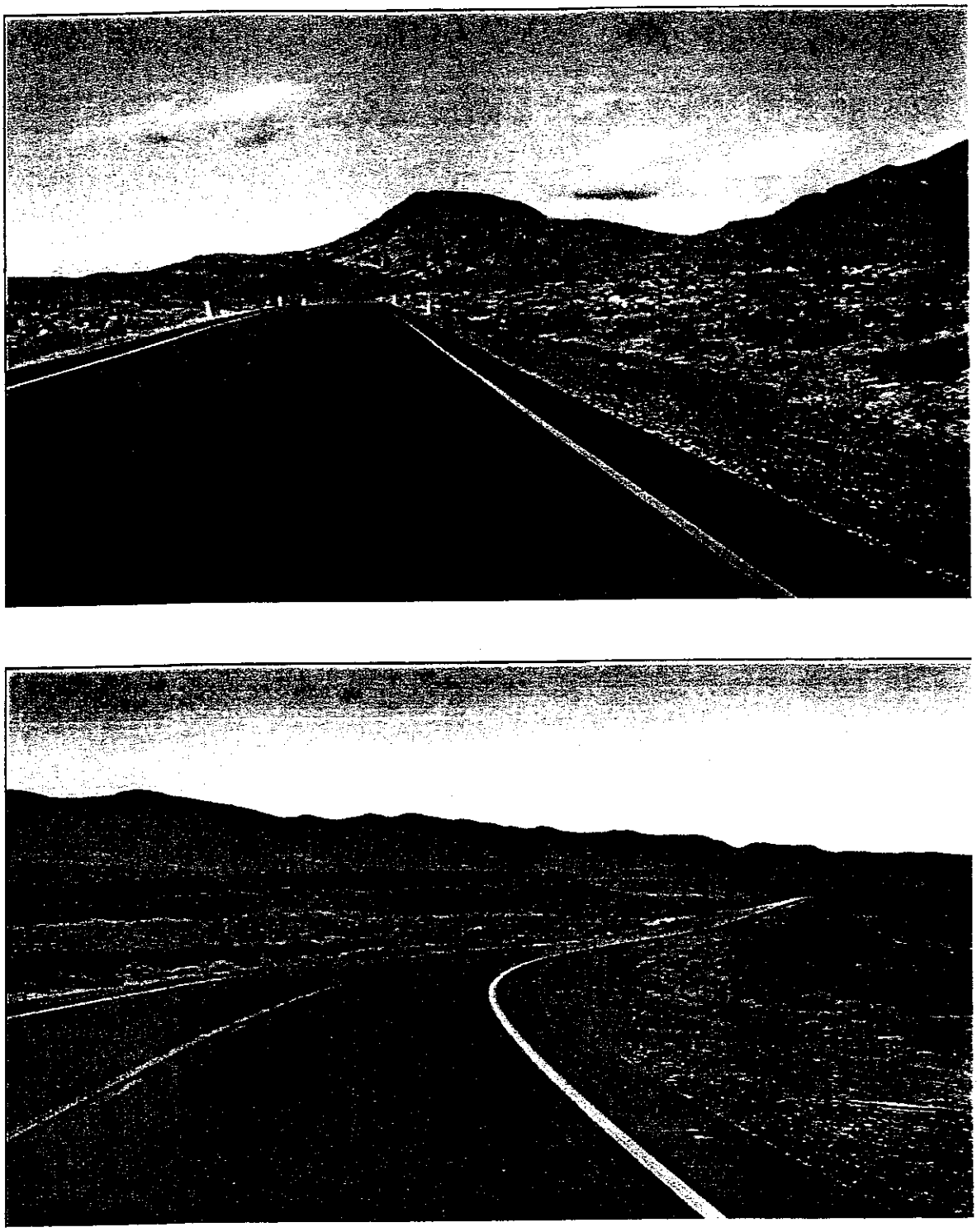


Figure 8.6 US093 - Clark County Road View

CHAPTER 9 – RESULTS FOR US095 TEST SITE

Background

The US095 test site is located on a six-lane PCCP roadway in urban Las Vegas, Nevada from mileposts 63.50 to 66.50 (Figure 9.1 between Sunset Road and Tropicana Avenue and Figure 9.5).

Waterborne, epoxy, polyurea, and alkyd thermoplastic pavement marking materials were longitudinally placed for the median and edge lines in the northbound lane. Figure 10.2 shows a diagram of the test site layout. Products were installed in September 2002 and monitored until June 2004.

Evaluation Based on Durability, Retroreflectivity, and Color

Durability
Table 9.1 presents the durability observations for the pavement marking materials placed on the US095 test site. The waterborne paint was the first material to display signs of wear. One alkyd thermoplastic product line and both epoxy paint product lines remained durable throughout the monitoring process.

Retroreflectivity
Table 9.1 lists the recorded retroreflectivity measurements. Figures 9.3 and 9.4 illustrate retroreflectivity comparisons for the median and edge lines. Only the epoxy paint marking materials exhibit measurements over 150 mcd/m^2/lux for white products and 100 mcd/m^2/lux for yellow products at the end of twenty-one months.

Color
Table 9.2 contains the color measurement results for the pavement marking materials. All white colored materials met daytime chromaticity coordinate requirements according to ASTM D 6628, "Standard Specification for Color of Pavement Marking Materials," throughout the monitoring process (15). However, the luminance factor for several products demonstrated reduced lightness within two months of placement. All white colored products were noncompliant for luminance factor requirements within eight months of product placement.

The majority of the yellow colored pavement marking materials were noncompliant with the daytime chromaticity coordinate and luminance factor requirements within eight months of placement. Only one yellow epoxy paint material maintained acceptable daytime chromaticity coordinates throughout the monitoring process. The color measurements displayed with red font and underlined are measurements that do not meet daytime chromaticity coordinate or luminance factor color requirements according to ASTM D 6628.

Winter Maintenance Activities

There were no winter maintenance activities at this location.

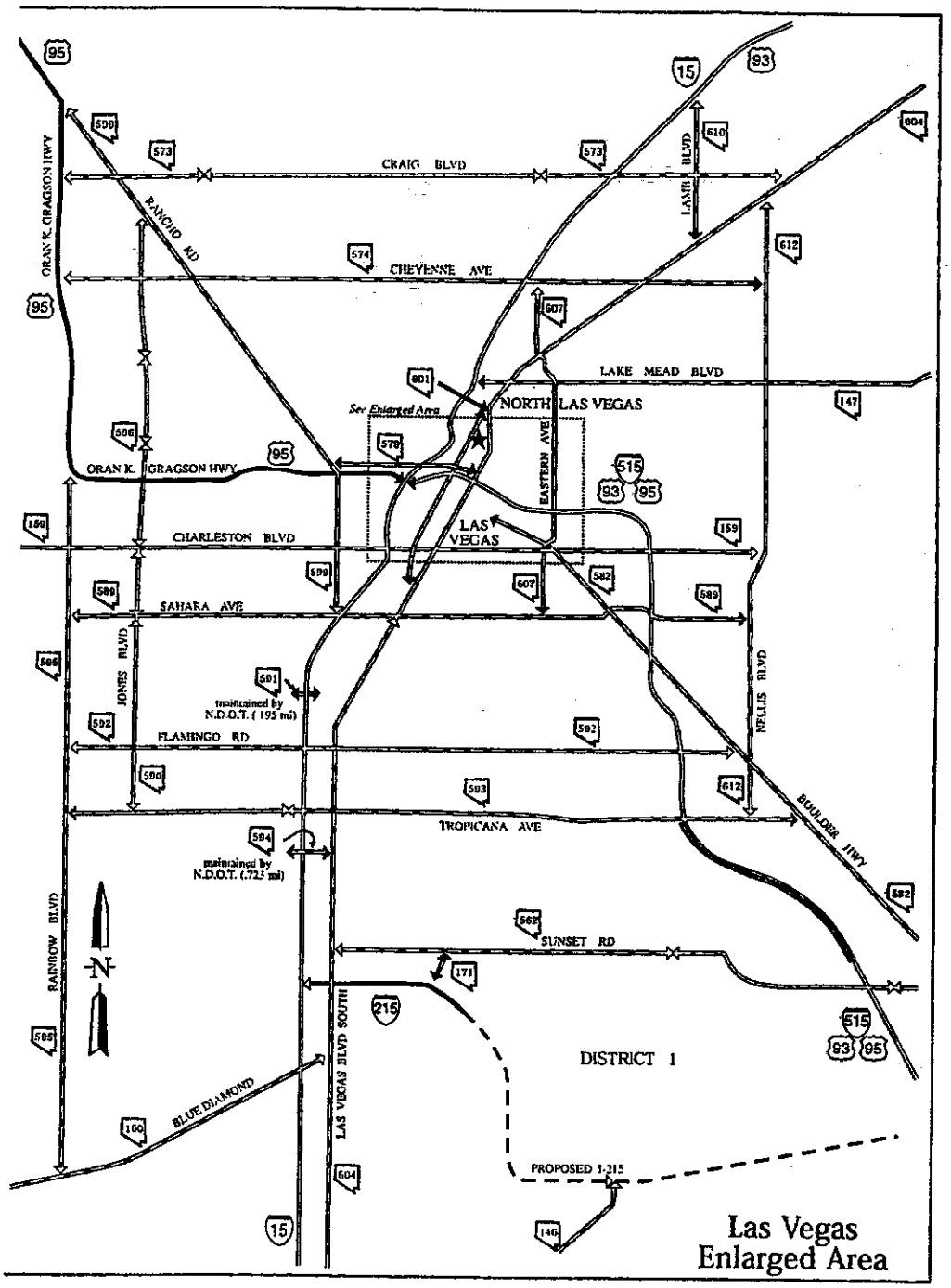


Figure 9.1 Map of Las Vegas, Nevada

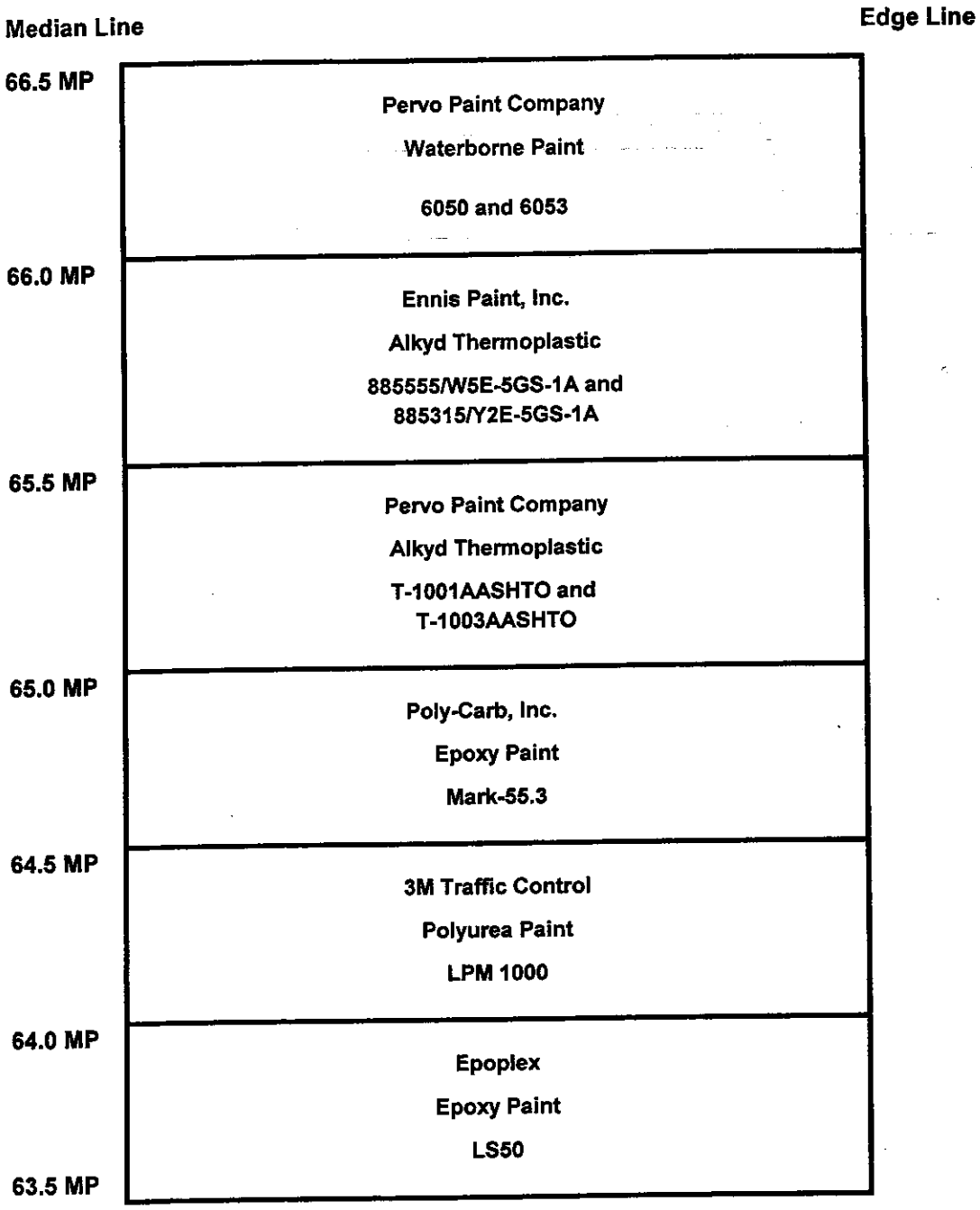


Figure 9.2 US095 – Clark County Test Site Layout

Table 9.1 US095 - Clark County
Retroreflectivity and Durability Data (Page 1 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	Oct-02 RR	Oct-02 DUR	Nov-02 RR	Nov-02 DUR	Feb-03 RR	Feb-03 DUR	May-03 RR	May-03 DUR
PMRP-02-NV-01	Polyurea	LPM 1000	White	3M	297	10	222	10	247	10	142	10
PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow	3M	252	10	239	10	204	10	157	10
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	White	EPI	282	10	251	10	257	10	172	10
PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	115	10	114	10	109	10	124	10
PMRP-02-NV-11	Epoxy	LS50	White	EPO	265	10	203	10	225	10	131	10
PMRP-02-NV-12	Epoxy	LS50	Yellow	EPO	178	10	180	10	161	10	117	10
PMRP-02-NV-15	Waterborne Paint	6050	White	PPC	N/A	N/A	263	10	241	10	180	9
PMRP-02-NV-16	Waterborne Paint	6053	LF Yellow	PPC	244	10	236	10	189	10	175	10
PMRP-02-NV-19	Alkyd Thermoplastic	T-1001AASHTO	White	PPC	280	10	260	10	286	10	254	10
PMRP-02-NV-20	Alkyd Thermoplastic	T-1003AASHTO	LF Yellow	PPC	144	10	146	10	139	10	153	10
PMRP-02-NV-21	Epoxy	Mark-55.3	White	PCI	382	10	291	10	317	10	236	10
PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow	PCI	299	10	295	10	268	10	231	10

Table 9.1 US095 - Clark County
Retroreflectivity and Durability Data (Page 2 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	Sep-03 RR	Sep-03 DUR	Jan-04 RR	Jan-04 DUR	Jun-04 RR	Jun-04 DUR
PMRP-02-NV-01	Polyurea	LPM 1000	White	3M	128	10	150	10	45	9
PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow	3M	156	10	130	10	66	9
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	White	EPI	214	10	231	10	27	10
PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	139	10	58	10	46	10
PMRP-02-NV-11	Epoxy	LS50	White	EPO	139	10	179	10	175	10
PMRP-02-NV-12	Epoxy	LS50	Yellow	EPO	128	10	114	10	124	10
PMRP-02-NV-15	Waterborne Paint	6050	White	PPC	134	9	166	9	80	9
PMRP-02-NV-16	Waterborne Paint	6053	LF Yellow	PPC	137	10	112	9	84	8
PMRP-02-NV-19	Alkyd Thermoplastic	T-1001AASHTO	White	PPC	226	10	182	10	52	9
PMRP-02-NV-20	Alkyd Thermoplastic	T-1003AASHTO	LF Yellow	PPC	188	10	136	10	40	9
PMRP-02-NV-21	Epoxy	Mark-55.3	White	PCI	239	10	348	10	166	10
PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow	PCI	192	10	235	10	192	10

Table 9.2 US095 - Clark County
Color Data (Page 1 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	November 2002			February 2003			May 2003		
					Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-01	Polyurea	LPM 1000	White	3M	53.70	0.3216	0.3383	41.46	0.3244	0.3408	34.58	0.3231	0.3403
PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow	3M	43.39	0.4580	0.4232	38.66	0.4521	0.4197	37.45	0.4460	0.4131
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	White	EPI	28.49	0.3372	0.3530	24.51	0.3381	0.3545	16.98	0.3370	0.3540
PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	30.00	0.4458	0.4379	25.95	0.4300	0.4239	28.87	0.4287	0.4238
PMRP-02-NV-11	Epoxy	LS50	White	EPO	55.85	0.3237	0.3443	45.87	0.3277	0.3478	29.18	0.3353	0.3547
PMRP-02-NV-12	Epoxy	LS50	Yellow	EPO	34.98	0.4797	0.4464	31.18	0.4717	0.4423	27.09	0.4621	0.4304
PMRP-02-NV-15	Waterborne Paint	6050	White	PPC	43.26	0.3183	0.3358	25.10	0.3256	0.3421	16.75	0.3243	0.3416
PMRP-02-NV-16	Waterborne Paint	6053	LF Yellow	PPC	27.38	0.4490	0.4171	24.54	0.4424	0.4135	24.80	0.4303	0.4035
PMRP-02-NV-19	Alkyd Thermoplastic	T-1001AASHTO	White	PPC	22.20	0.3306	0.3461	22.04	0.3317	0.3479	21.43	0.3323	0.3492
PMRP-02-NV-20	Alkyd Thermoplastic	T-1003AASHTO	LF Yellow	PPC	27.80	0.4389	0.4309	24.80	0.4271	0.4210	24.97	0.4159	0.4101
PMRP-02-NV-21	Epoxy	Mark-55.3	White	PCI	31.63	0.3231	0.3432	28.85	0.3252	0.3453	21.97	0.3275	0.3495
PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow	PCI	27.88	0.4647	0.4366	24.32	0.4586	0.4338	20.92	0.4240	0.4048

Table 9.2 US095 - Clark County
Color Data (Page 2 of 2)

Project Code	Material Type	Product Trade Name	Color	Vendor ID	September 2003			January 2004			June 2004		
					Y	x	y	Y	x	y	Y	x	y
PMRP-02-NV-01	Polyurea	LPM 1000	White	3M	38.49	0.3243	0.3410	36.59	0.3246	0.3407	27.16	0.3236	0.3403
PMRP-02-NV-02	Polyurea	LPM 1000	LF Yellow	3M	33.01	0.4340	0.4035	32.21	0.4302	0.4060	30.97	0.4191	0.3970
PMRP-02-NV-05	Alkyd Thermoplastic	885555/W5E-5GS-1A	White	EPI	14.54	0.3352	0.3515	22.31	0.3341	0.3508	7.87	0.3273	0.3437
PMRP-02-NV-06	Alkyd Thermoplastic	885315/Y2E-5GS-1A	Yellow	EPI	30.44	0.4299	0.4279	30.46	0.4282	0.4310	23.35	0.4327	0.4259
PMRP-02-NV-11	Epoxy	LS50	White	EPO	33.54	0.3370	0.3566	32.08	0.3355	0.3541	30.33	0.3416	0.3597
PMRP-02-NV-12	Epoxy	LS50	Yellow	EPO	28.91	0.4710	0.4430	28.19	0.4631	0.4460	22.54	0.4587	0.4303
PMRP-02-NV-15	Waterborne Paint	6050	White	PPC	16.02	0.3237	0.3399	16.35	0.3229	0.3388	11.58	0.3230	0.3395
PMRP-02-NV-16	Waterborne Paint	6053	LF Yellow	PPC	23.74	0.4253	0.3993	23.62	0.4162	0.3967	24.41	0.4125	0.3904
PMRP-02-NV-19	Alkyd Thermoplastic	T-1001AASHTO	White	PPC	20.22	0.3314	0.3468	29.55	0.3313	0.3470	19.51	0.3313	0.3476
PMRP-02-NV-20	Alkyd Thermoplastic	T-1003AASHTO	LF Yellow	PPC	30.67	0.4312	0.4279	31.49	0.4226	0.4267	30.82	0.4256	0.4217
PMRP-02-NV-21	Epoxy	Mark-55.3	White	PCI	27.77	0.3367	0.3579	24.94	0.3356	0.3552	21.34	0.3386	0.3588
PMRP-02-NV-22	Epoxy	Mark-55.3	Yellow	PCI	24.51	0.4557	0.4349	20.07	0.4340	0.4263	17.35	0.4115	0.4020

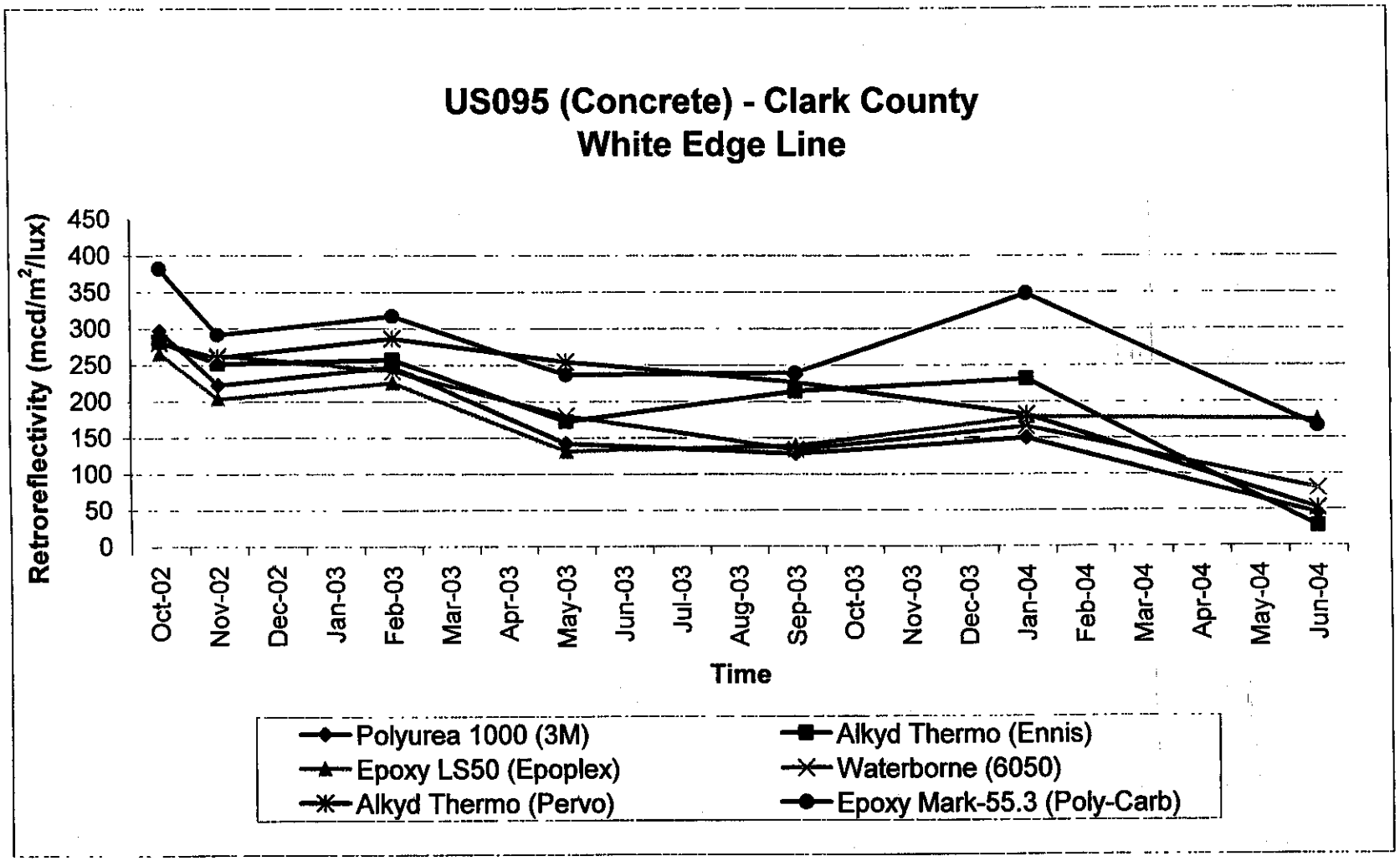


Figure 9.3 US095 Retroreflectivity Comparison for White Edge Line

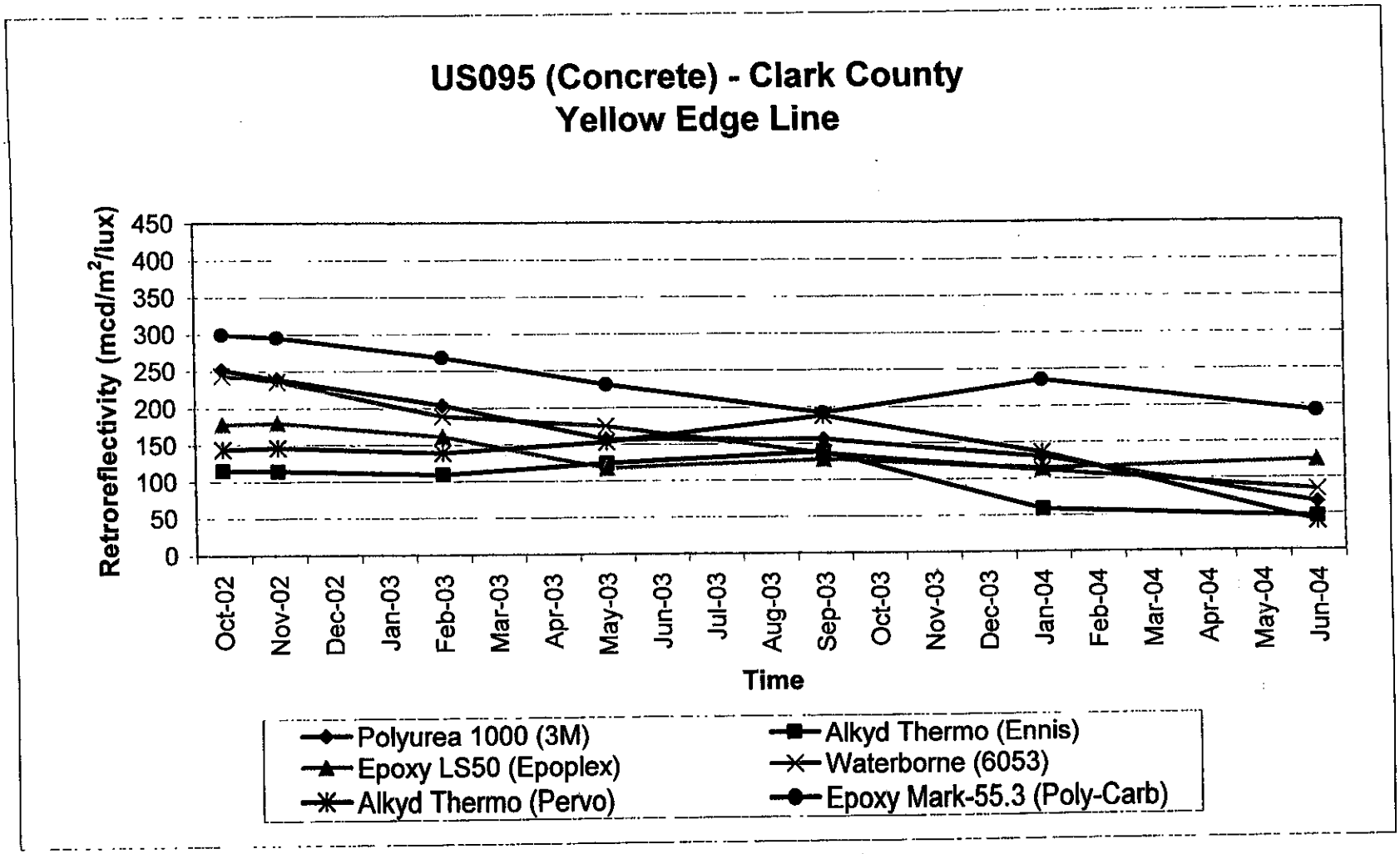


Figure 9.4 US095 Retroreflectivity Comparison for Yellow Median Line

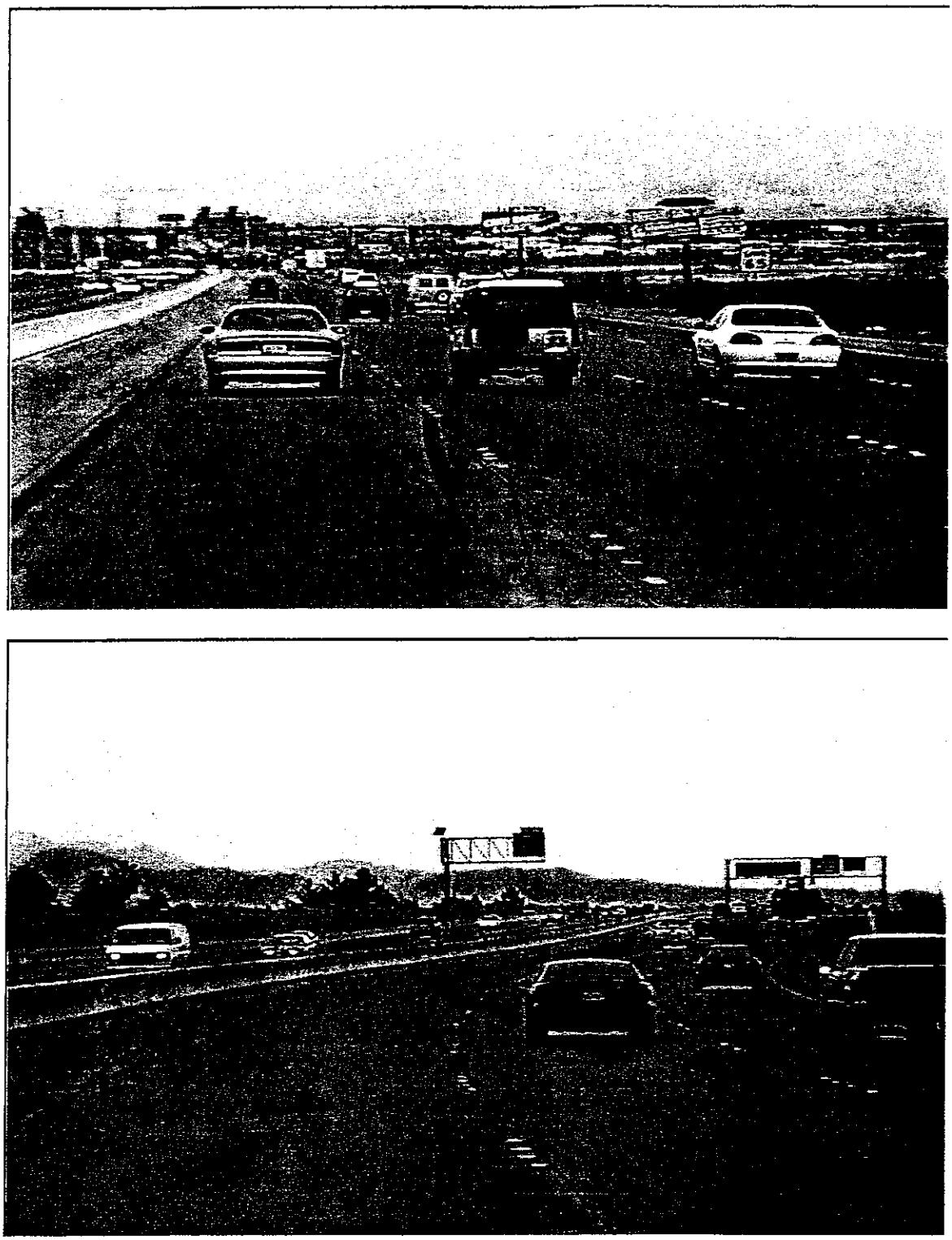


Figure 9.5 US095 – Clark County Road View

CHAPTER 10 - LABORATORY EVALUATION

Laboratory Results

NDOT's Materials Division tested the pavement marking products evaluated on the test sites. The products were sampled and tested according to procedures that NDOT uses for all striping materials. The materials were evaluated for compliance to the specifications outlined in NDOT's Standard Specifications for Road and Bridge Construction, Sections 729 - Traffic Paint and 730 - Traffic Beads (34).

Before traffic paint formulations are approved for use on NDOT's roadways, the manufacturer must submit certification, product specification, sample, and Infrared Spectra of each component for each color. The samples taken in the field are then tested for spectral analysis and results are compared to the file spectra. If a product sample does not match the file spectra, the Materials Division may choose to pursue more testing such as pigment content, density, or total solids in attempt to identify what problems exist with the material.

Field samples were taken for all liquid paint products and traffic beads used at the test sites. Table 10.1 lists the acceptance criteria and tests performed on the materials. Table 10.2 shows that all waterborne paints, with exception of three paints, passed the viscosity and spectra analysis testing. Based upon available data from laboratory reports, the three waterborne paint failures may be indicative of a systematic sampling error at the location. The same paint batches were used at other test site locations and passed testing requirements. Table 10.3 indicates that all spectra analysis testing results are passing for products placed on the SR431 and US095 test sites. Additionally, Table 10.4 presents the passing test results for traffic beads. The traffic beads were tested for sieve analysis, moisture content, and visual inspection.

Table 10.1 Tests and Acceptance Criteria for Pavement Marking Materials and Traffic Beads

MATERIAL	TEST	ACCEPTANCE CRITERIA
Waterborne Traffic Paint	ASTM D 562 "Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer"	80 – 95 KU
Waterborne Traffic Paint	NDOT modified version of ASTM D 2621 "Test Method for Infrared Identification of Vehicle Solids from Solvent-Reducible Paints" for FT-IR Spectral Analysis using Universal ATR (UATR)	Compared to manufacturer's Infrared Spectra on file with Materials Division. Manufacturer must certify that materials meet formulation and compositional requirements as listed in NDOT's Standard Specifications for Road and Bridge Construction.
Epoxy Traffic Paint	ASTM D 2621 "Test Method for Infrared Identification of Vehicle Solids from Solvent-Reducible Paints" FT-IR Spectral Analysis using Referee Method: KBr Disc or Alternative Method: UATR	Compared to manufacturer's Infrared Spectra on file with Materials Division. Manufacturer must certify that materials meet formulation and compositional requirements as listed in NDOT's Standard Specifications for Road and Bridge Construction.
Polyurea Traffic Paint	ASTM D 2621 "Test Method for Infrared Identification of Vehicle Solids from Solvent-Reducible Paints" FT-IR Spectral Analysis using Referee Method: KBr Disc or Alternative Method: UATR	Compared to manufacturer's Infrared Spectra on file with Materials Division. Manufacturer must certify that materials meet formulation and compositional requirements as listed in NDOT's Standard Specifications for Road and Bridge Construction.
Alkyd Thermoplastic	Not Applicable	Acceptance based on certification and performance specification supplied by the manufacturer.
Traffic Beads	ASTM D 1214 "Test Method for Sieve Analysis of Glass Spheres"	Beads shall conform to gradation requirements according to Section 730 Traffic Beads in NDOT's Standard Specifications for Road and Bridge Construction.
Traffic Beads	Nevada Test Method Moisture Content	Moisture content shall not exceed 0.01% when tested at 105 °C for three hours.
Traffic Beads	Nevada Test Method Visual Inspection	Beads shall be colorless, clean, transparent, and free from milkiness, pits, or excessive air bubbles.

Table 10.2 Results for Waterborne Traffic Paint Laboratory Testing

Test Site Location	Product Trade Name	Color	Test	
			Viscosity	Spectra Analysis
SR028	NVW-40-M-2	White	Pass	Pass
SR028	NVY-40-M-2	LF Yellow	Pass	Pass
SR028	6050	White	Pass	Pass
SR028	6053	LF Yellow	Pass	Pass
SR028	7950	White	Pass	Pass
SR028	7953	LF Yellow	Pass	Pass
SR028	BP19421	White	Pass	Pass
SR028	BP19422	LF Yellow	Pass	Pass
SR028	2771A9	White	Pass	Pass
SR028	2772A9	LF Yellow	Pass	Pass
US050	NVW-40-M-2	White	Pass	Pass
US050	NVY-40-M-2	LF Yellow	Pass	Pass
US050	6050	White	Pass	Pass
US050	6053	LF Yellow	Pass	Pass
US050	7950	White	Pass	Pass
US050	7953	LF Yellow	Pass	Pass
US050	BP19421	White	Pass	Pass
US050	BP19422	LF Yellow	Pass	Pass
US050	2771A9	White	Pass	Pass
US050	2772A9	LF Yellow	Pass	Pass
US093	NVW-40-M-2	White	Pass	Pass
US093	NVY-40-M-2	LF Yellow	Pass	Pass
US093	6050	White	Pass	Pass
US093	6053	LF Yellow	Fail	Fail
US093	7950	White	Pass	Pass
US093	7953	LF Yellow	Pass	Pass
US093	BP19421	White	Fail	Fail
US093	BP19422	LF Yellow	Pass	Pass
US093	2771A9	White	Pass	Pass
US093	2772A9	LF Yellow	Fail	Fail
US095	6050	White	Pass	Pass
US095	6053	LF Yellow	Pass	Pass
SR431 - 2003	6050	White	Pass	Pass
SR431 - 2003	6053	LF Yellow	Pass	Pass

Table 10.3 Results for Epoxy and Polyurea Traffic Paint Laboratory Testing

Test Site Location	Product Trade Name	Color	Test Spectra Analysis
SR431 - 2002	LPM 1000 Polyurea	White	Pass
SR431 - 2002	LPM 1000 Polyurea	LF Yellow	Pass
SR431 - 2002	LPM 1200 Polyurea	White	Pass
SR431 - 2002	LPM 1200 Polyurea	LF Yellow	Pass
SR431 - 2002	LS90 Polyurea	White	Pass
SR431 - 2002	LS90 Polyurea	LF Yellow	Pass
SR431 - 2002	LS52 Epoxy	White	Pass
SR431 - 2002	LS52 Epoxy	LF Yellow	Pass
SR431 - 2002	Mark-55.3	White	Pass
SR431 - 2002	Mark-55.3	Yellow	Pass
US095	LPM 1000 Polyurea	White	Pass
US095	LPM 1000 Polyurea	LF Yellow	Pass
US095	LS50	White	Pass
US095	LS50	Yellow	Pass
US095	Mark-55.3	White	Pass
US095	Mark-55.3	Yellow	Pass

Table 10.4 Results for Traffic Bead Laboratory Testing

Test Site Location	Type of Traffic Bead	Products Where Traffic Bead Was Placed	Test		
			Sieve Analysis	Moisture Content	Visual Inspection
SR028	NV Spec Type A	Waterborne Paint Products	Pass	Pass	Pass
SR431 - 2002	NV Spec Types I and II	LS52	Pass (Type I) Pass (Type II)	Pass	Pass
SR431 - 2002	NV Spec Types I and II	LS90	Pass (Type I) Pass (Type II)	Pass	Pass
SR431 - 2002	NV Spec Type III	LPM 1000	Pass	Pass	Pass
SR431 - 2002	NV Spec Type III	LPM 1200	Pass	Pass	Pass
SR431 - 2002	Megalux FP-96 Type 3 and AASHTO M-247-81 Type I	Mark-55.3	Pass (Type 3) Pass (AASHTO)	Pass	Pass
SR431 - 2003	NV Spec Type A	Waterborne Paint Products	Pass	Pass	Pass
US050	NV Spec Type A	Waterborne Paint Products	Pass	Pass	Pass
US050	NV Spec Type B	Waterborne Paint Products	Pass	Pass	Pass
US093	NV Spec Type A	Waterborne Paint Products	Pass	Pass	Pass
US095	NV Spec Types I and II	LS50	Pass (Type I) Pass (Type II)	Pass	Pass
US095	NV Spec Type III	LPM 1000	Pass	Pass	Pass
US095	Megalux FP-96 Type 3 and ASSHTO M-247-81 Type I	Mark-55.3	Pass (Type 3) Pass (Type I)	Pass	Pass
US095	NV Spec Type A	Waterborne Paint Products	Pass	Pass	Pass

CHAPTER 11 – ESTIMATED SERVICE LIFE, COST ANALYSIS, AND MATRIX

11.1 Estimated Service Life for Test Sites

Pavement marking service life has been a subject of study for many years. One notable research project contained 85 study sites in 19 states, with 362 longitudinal pavement marking lines. The sites were evaluated to determine the longevity of durable pavement markings. Statistical and regression modeling were used for each separate pavement marking line and ranges of expected service life in months were developed. It was stated that the end of the service life of a particular pavement marking is defined as the point in time at which its retroreflectivity falls below an acceptable level. The minimum acceptable retroreflectivity values used to determine the end of pavement marking service lives for the project varied based on roadway type, speed classification, and color. The white markings were considered to have an end of service life at 85 to 150 mcd/m^2/lux and the yellow markings were considered to be at the end of service life at 55 to 100 mcd/m^2/lux (30).

Other research proposes mathematical models for determining the service life of pavement markings. The assumption for these models is that deterioration is not linear, and some form of regression is required (1, 38). Although minimum retroreflectivity requirements for roadways have not been established in the Manual on Uniform Traffic Control Devices, there is research that recommends acceptable minimum threshold values (2, 39, 43). Additionally, there is research available that estimates the end of pavement marking service life by assuming that the reduction in retroreflectivity over time is linear (22).

The end of pavement marking service life determinations for this project is the combination of lack of durability, color, and retroreflectivity performance. End of service life is based on the objective results of the monitoring process, the investigators' estimation of failure, and discussion with NDOT staff responsible for maintenance. For most products, retroreflectivity measurements of 125 mcd/m^2/lux for white pavement markings and 100 mcd/m^2/lux for yellow pavement markings were used as service life minimum threshold values. Basing the end of pavement marking service life solely upon retroreflectivity measurements is not justified in several cases where retroreflectivity measurements were considered acceptable, and the marking was determined to be ineffective due to lack of durability and visually poor colors.

Table 11.1 lists the average estimated service life for each product class at the test site locations. The service life varies considerably and is dependent upon roadway type, traffic volume, climate, snow removal activities, and if the product was recessed in pavement. Many test sites were located in areas of extreme environmental consequence and the product serviceability is specific to the test site location and is not indicative of possible statewide averages.

Table 11.1 Estimated Service Life of Product Classes at Test Site Locations

Location (Elevation)	Type of Product	Average Estimated Service Life (Months)
SR028 (6250)	Waterborne White Yellow	 5.0 2.5
SR431- 2002 (7250)	Alkyd Thermoplastic * White *Yellow	 13 - 17 7
SR431- 2002 (7250)	Epoxy *White *Yellow	 12 - 16 15
SR431- 2002 (7250)	Polyurea *White *Yellow	 2.5 - 21 2 - 21
SR431 – 2003 (7250)	Waterborne *Single White Application *Double White Application *Single Yellow Application *Double Yellow Application	 4.5 8+ 4 7
SR431 – 2003 (7250)	Tape *White *Yellow	 4.5 - 8+ 4.5 - 8+
US050 (3750)	Waterborne (18 wet mils) White Yellow	 3.5 3.5
US050 (3750)	Waterborne (25 wet mils) White Yellow	 22 22
US093 (2250)	Waterborne White Yellow	 20+ 20+
US095 (2250)	Waterborne White Yellow	 18 18
US095 (2250)	Polyurea White Yellow	 17 18
US095 (2250)	Alkyd Thermoplastic White Yellow	 18 14 - 18
US095 (2250)	Epoxy White Yellow	 21+ 21+

* Indicates product was recessed in pavement for protection from snowplow damage.

11.2 Cost Analysis

Table 11.2 displays the initial installation cost with placement by NDOT or contractor forces, service life, and annualized installation cost (time value of money excluded) for the recommended white striping materials to be used on NDOT's roadways. The service lives were chosen based on current and expected NDOT practice for striping with varying environmental and traffic conditions throughout the state. Cost data for the traffic paints were based on average prices paid by NDOT for pavement markings and estimates from manufacturers. Since alkyd thermoplastic and permanent tape products were not recommended for long line pavement marking use due to availability and constructability issues, these costs were not included. This data is provided for informational purposes only.

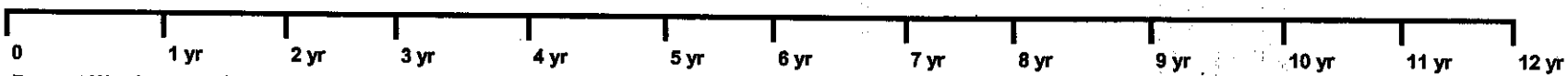
Table 11.2 *Initial Installation Cost and Service Life

MATERIAL	TYPE OF LINE	INSTALLATION COST ($/LF)	SERVICE LIFE	ANNUAL INSTALLATION COST ($/LF/YR)
Waterborne	4-inch solid	0.04 (NDOT) 0.14 (Contractor)	6 Months	0.08 (NDOT) 0.28 (Contractor)
Waterborne	8-inch solid	0.07 (NDOT) 0.19 (Contractor).	6 Months	0.14 (NDOT) 0.38 (Contractor)
Waterborne	4-inch solid	0.04 (NDOT) 0.14 (Contractor)	1 Year	0.04 (NDOT) 0.14 (Contractor)
Waterborne	8-inch solid	0.07 (NDOT) 0.19 (Contractor)	1 Year	0.07 (NDOT) 0.19 (Contractor)
Waterborne	4-inch solid	0.04 (NDOT) 0.14 (Contractor)	2 Years	0.02 (NDOT) 0.07 (Contractor)
Waterborne	8-inch solid	0.07 (NDOT) 0.19 (Contractor)	2 Years	0.04 (NDOT) 0.10 (Contractor)
Epoxy	4-inch solid	0.38 (Contractor)	2 Years	0.19 (Contractor)
Epoxy	8-inch solid	0.53 (Contractor)	2 Years	0.27 (Contractor)
Epoxy	4-inch solid	0.38 (Contractor)	3 Years	0.13 (Contractor)
Epoxy	8-inch solid	0.53 (Contractor)	3 Years	0.18 (Contractor)
**Polyurea	8-inch solid	0.85 (Contractor)	4 Years	0.22 (Contractor)

* User delay, traffic control, eradication, and mobilization costs were not included.
** NDOT does not have long-term experience with polyurea and service life is based on other states' experience.

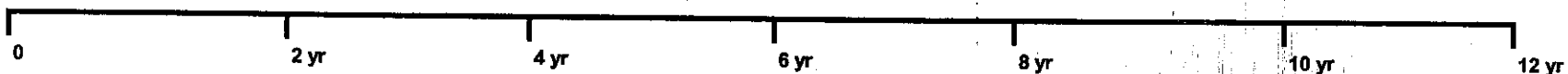
Figure 11.1 illustrates the estimated present worth life cycle costs for one-mile of 8-inch white pavement marking using various striping and restriping scenarios. These scenarios were described based on current and expected NDOT striping practices. The 12-year life cycle cost analysis values range from $2,470 to $28,300 per mile and are dependent upon type of material and required surface preparation. The analysis is provided for informational purposes only.

Scenario 1: **Waterborne paint service life of 1 year. Initial waterborne striping by contractor and waterborne restriping by NDOT maintenance forces every year.**
Costs for user delay, mobilization, traffic control, and eradication are not included.



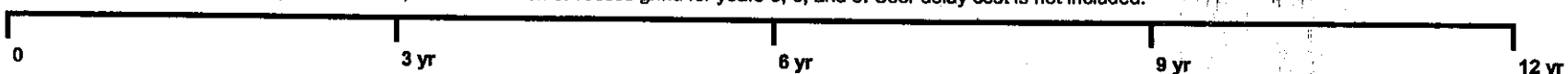
Present Worth Cost = $4,240 per mile

Scenario 2: **Waterborne paint service life of 2 years. Initial waterborne striping by contractor and waterborne restriping by NDOT maintenance forces every two years.**
Costs for user delay, mobilization, traffic control, and eradication are not included.



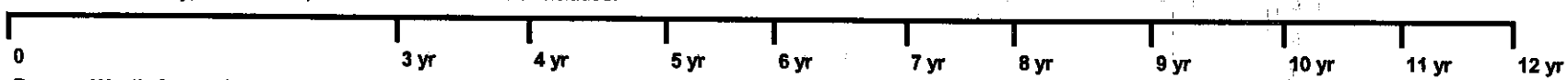
Present Worth Cost = $2,470 per mile

Scenario 3: **Epoxy paint service life of 3 years. Initial epoxy striping and epoxy restriping by contractor every three years.**
Includes costs for mobilization, traffic control, and eradication or recess grind for years 3, 6, and 9. User delay cost is not included.



Present Worth Cost = $28,300 per mile

Scenario 4: **Epoxy paint service life of 3 years. Initial epoxy striping by contractor and waterborne restriping by NDOT maintenance forces every year.**
Costs for user delay, mobilization, and traffic control are not included.



Present Worth Cost = $5,345 per mile

Scenario 5: **Polyurea paint service life of 4 years. Initial polyurea striping and polyurea restriping by contractor every four years.**
Includes costs for mobilization, traffic control, and eradication or recess grind for years 4 and 8. User delay cost is not included.

Present Worth Cost = $24,160 per mile (NDOT does not have long-term experience with polyurea traffic paint and service life is based on other states' experience)

Figure 11.1 12-Year Life Cycle Cost Analysis for One Linear Striping Mile (8-inch White)

11.3 Matrix

The primary objective of this research project was to develop a pavement marking matrix for NDOT use based on given traffic and environmental conditions. Table 11.3 contains the proposed matrix to be used as a guide for pavement marking application on NDOT's roadway system. The matrix is separated into two guides. One guide lists the recommended permanent pavement markings to be used for major rehabilitation projects and the other guide lists the permanent pavement markings to be used for the restriping of roadways. The guides provide for varying elevations, projected pavement life, and traffic volumes. It is recommended that NDOT use waterborne, epoxy, and polyurea traffic paints as permanent pavement markings for long line use. This recommendation is associated with traffic volumes used for prioritization categories from NDOT's pavement management system. NDOT divides its roadway network into five categories based on average daily traffic and equivalent single axle loads. This network division and the resulting named categories are familiar to NDOT personnel tasked with constructing and maintaining the state highway system. The elevation break was chosen based on the experience of knowledgeable NDOT personnel about where a noticeable increase in snowplow activities exists in the state.

The matrix was not developed as a direct consequence of the research test site results. The matrix is the outcome of research and Pavement Marking Task Force effort to advance durable pavement markings in Nevada by obtaining group consensus about how pavement marking operations should better serve state needs. Group consensus among managers, engineers, and supervisors involved with pavement marking placement resulted in the decision to use waterborne, epoxy, and polyurea traffic paint products for long line use on NDOT's roadways.

The use of permanent tape for long line markings has not been successful for NDOT due to constructability issues. Communication with engineers about the future use of permanent tape for long line pavement markings resulted in agreement over discontinuing its use until a better placement technique is developed. Alkyd thermoplastic products were placed by out of state contractors. Local contractors do not have experience with alkyd thermoplastic placement, nor do they have equipment to place these products. If there were prominent results regarding the alkyd thermoplastic placed on the test sections, it might have been feasible to pursue a market for this product class. However, the use of alkyd thermoplastic for long lines is not recommended at this time.

Use of thermoplastics and tape or marking film for transverse lines, symbols, or legends is acceptable. The use of nonreflective and reflective pavement markers for lane lines in urban Las Vegas area is advised as that system of operations has proved successful over the years with no complaints.

Table 11.3 Guidelines for Pavement Marking Application on NDOT's Roadway System

*NEW CONSTRUCTION PAVEMENT MARKING GUIDELINES

Elevation	ROAD CATEGORY 1 Controlled Access	ROAD CATEGORY 2 ESAL > 540 or ADT > 10,000	ROAD CATEGORY 3 540 >= ESAL > 405 or 1,600 < ADT <= 10,000 + NHS	ROAD CATEGORY 4 405 >= ESAL > 270 or 400 < ADT <= 1,600	ROAD CATEGORY 5 ADT <= 400
Elevation Over 5000 ft	Epoxy	Epoxy	Waterborne	Waterborne	Waterborne
Elevation Under 5000 ft	Epoxy or [4]Polyurea	Epoxy or [4]Polyurea	Waterborne	Waterborne	Waterborne

*RESTRIPING PAVEMENT MARKING GUIDELINES

Projected Pavement Life and Elevation	ROAD CATEGORY 1 Controlled Access	ROAD CATEGORY 2 ESAL > 540 or ADT > 10,000	ROAD CATEGORY 3 540 >= ESAL > 405 or 1,600 < ADT <= 10,000 + NHS	ROAD CATEGORY 4 405 >= ESAL > 270 or 400 < ADT <= 1,600	ROAD CATEGORY 5 ADT <= 400
Projected Pavement Life of 2-5 Years (Elevation Over 5000 ft)	Epoxy or Waterborne	Epoxy or Waterborne	Waterborne	Waterborne	Waterborne
Projected Pavement Life of 2-5 Years (Elevation Under 5000 ft)	Epoxy, [4]Polyurea, or Waterborne	Epoxy, [4]Polyurea, or Waterborne	Waterborne	Waterborne	Waterborne
Projected Pavement Life 2 years or Less (Elevation Over/Under 5000 ft)	Waterborne	Waterborne	Waterborne	Waterborne	Waterborne

***NOTES**

1. Transverse lines, symbols, and legends may be waterborne paint, thermoplastic, or pavement marking film/tape for all districts.
2. Nonreflective and reflective pavement markers for lane lines in District I when required.
3. ADT and ESALs are two directional traffic.
4. Polyurea traffic paint can be used in areas with less than 10 snowplow passes per year.

CHAPTER 12 – SUMMARY AND RECOMMENDATIONS

12.1 Summary

The Advancing Durable Pavement Marking Materials in Nevada project was the cornerstone of NDOT's effort to improve pavement marking durability and provide cost-effective, quality pavement markings to Nevada's traveling public. The project prompted the investigation of all policy and procedures involved with pavement marking application. The investigation included the perusal of contract specification requirements, testing and sampling guidelines, inspection procedures, quality control protocols, pavement marking application procedures, and test site results.

Based on the investigation, pavement marking system improvements were discussed, approved, and implemented through approval by qualified group consensus of the Pavement Marking Task Force members and this research project. These improvements were also dependant upon the experience gained while working with industry specialists placing the test sections and the actions of the Research Technical Panel. The experience of working together to achieve the common goal of improving pavement marking durability has created a momentum for pavement marking system advancement that continues today. Renewed awareness of the important safety aspects of effective markings and new expectations regarding pavement marking contractor performance are other benefits of the project.

Pavement marking system improvements include changes to NDOT's standard specifications. New or improved qualified products lists were created for distribution to contractors along with contract documents. Constructability enhancements include the development of yearly pavement marking inspection training for NDOT field personnel. The materials, sampling, and testing procedures were modified to further improve the quality of pavement markings throughout the state.

The following is a list of pavement marking system improvements that were discussed, approved, and implemented due to group consensus of the Pavement Marking Task Force and this research project:

Specification Improvements

- Allowed more lenient time frames for permanent paint application
- Developed a polyurea traffic paint specification
- Increased infrared spectra comparison correlation to 92%
- Developed minimum retroreflectivity requirements for temporary traffic paint:

Color	Specific Luminance, mcd/(m^2 · lux)
White	175 Minimum
Yellow	125 Minimum

- Developed minimum retroreflectivity requirements for contract acceptance of polyurea, epoxy and waterborne traffic paint products:

		Specific Luminance, mcd / (m^2 · lux)
Polyurea	White	550 Minimum
Polyurea	Yellow	300 Minimum
Epoxy	White	375 Minimum
Epoxy	Yellow	275 Minimum
Waterborne	White	250 Minimum
Waterborne	Yellow	175 Minimum

- Improved waterborne specification by revising compositional requirements
- Changed traffic bead specification for waterborne paint to exclusive use of Type A traffic bead
- Allowance for lead free yellow-based pigments in epoxy paint formulations

Qualified Product List (QPL) Changes

- Waterborne traffic paints – An approved waterborne paint products list was established. Previously, there was only an approved resin list.
- Polyurea traffic paints – An approved polyurea paint products list was established. Previously, polyurea paint was not used on NDOT roadways.
- Epoxy traffic paints – Increased the number of qualified epoxy traffic paint products for use on NDOT roadways.

Constructability Enhancements

- Modified requirements for temporary painted pavement markings to allow temporary waterborne paint in lieu of temporary epoxy paint, this improved logistics of striping staged construction projects and keeps costs down
- Eliminated use of rumble strip seal
- Initiated yearly inspection training for construction crew personnel that includes videos, discussion, and training on the use of retroreflectometers

Materials, Sampling, and Testing Modifications

- Developed NDOT Test Method Nev. T511A to enforce project retroreflectivity minimums
- Developed NDOT Test Method T510A to determine the dry film thickness of epoxy or waterborne paint, a wet mil thickness test did not work well for field personnel

- Communicated with paint companies on recommended material sampling procedures and circulated information throughout the community
- Purchased retroreflectometers for state maintenance and construction personnel
- Worked with the bead manufacturing industry to make bead bag labels more user friendly for striping contractors

12.2 Recommendations

The pavement marking system changes have improved the quality of pavement marking operations and allowed NDOT to quantify the condition of contract pavement marking work. However, there are additional system advancements that would contribute to more optimal construction operations. The following modifications are recommended to further advance NDOT's pavement marking operations:

Specification Improvements

- Provide allowable speed of application rates for pavement marking placement
- Require test or check stripes from striping contractors before allowing pavement marking operations to occur
- Require striping contractors to give a 48-hour notice before arrival in project limits

Constructability Enhancements

- Commit to standardized practices for choosing pavement marking products by adopting the pavement marking matrix in Chapter 11 for use on all contract and restriping work
- Create a standard policy to address the failures of contract performance requirements for retroreflectivity
- Require contractors to have at least one pavement marking specialist and pavement marking technician certified through the American Traffic Safety Services Association (ATSSA) on site for all pavement marking operations
- Use the provided life cycle cost analysis in Chapter 11 to assist in selecting the most viable product and placement methods for striping in rural and urban areas
- Contract district or statewide pavement marking contracts that make striping contractors responsible for fulfilling performance requirements

Materials, Sampling, and Testing Modifications

- Create a standard policy to address traffic paint material failures
- Consider use of a high-speed mobile retroreflectometer to evaluate NDOT's roadway network and get status of statewide pavement marking conditions

- Investigate better traffic bead technology such as the use of direct melt glass in traffic bead gradations

- Develop a Pavement Marking Management System (PMMS) policy to restripe roadways based on objective data including retroreflectivity

- Pursue testing of technologically advanced pavement marking products

12.3 Strength and Limitation of Research

The strength of this research was the value that in-house personnel provided to the findings and resulting pavement marking system improvements that transpired. A great deal of communication occurred among the various manufacturers, contractors, and NDOT divisions and districts. By sharing their perspectives and experiences, a group consensus developed regarding what pavement marking system modifications could be made to improve operations. Subsequently, the resulting operational improvements were practical and applicable, since everyone was part of the decision-making process.

The limitation of this research was due to the restricted number of constructed test sections. Conclusive results could not be established for estimated service life for each product class. Many test sites were located in areas of extreme environmental consequence and the service life is not indicative of statewide averages. Often, the pavement markings deteriorated over the winter months when monitoring was not feasible. There were subjective variables included in the end of service life determinations. Although many pavement marking performance models rely only on minimum retroreflectivity threshold values to determine the end of service life, this was not practiced for end of life determinations in this project. Basing end of service life determinations on minimum threshold values reduces the importance that adequate durability and color have on an aesthetically acceptable marking.

APPENDIX A - REFERENCES

Introduction

Research is conducted within the context of the current depth of knowledge shared by the professionals for a given discipline. As such, it was imperative for the investigators to become familiar with the historical and current status of pavement marking research and practice in order to make sound decisions based on relevant information.

A review of pavement marking information resources was completed to show the background from which the investigators thought processes have developed and the information from which decisions were based. The review for this project included documents that discuss pavement marking test section design, monitoring procedures, interpretation of results, recent pavement marking materials research, and state of the practice. Important sources for information include the Transportation Research Information Services database, the American Association of State Highway and Transportation Officials (AASHTO), the FHWA, Transportation Research Board, National Cooperative Highway Research Program, and American Society for Testing and Materials International. In addition, other states and knowledgeable professionals were contacted to augment information.

Informative References

The following organizations are not an inclusive list of the resources reviewed. However, these organizations are discussed because the information gathered from these sources was especially valuable for meeting research objectives. A list of documents reviewed for the project can be found in the selected bibliography.

AASHTO's National Transportation Product Evaluation Program (NTPEP)

An important and ongoing pavement marking program is AASHTO's NTPEP. The purpose of NTPEP is to consolidate the professional and physical resources of participating AASHTO member organizations in order to test materials of interest and improve cost-effectiveness. AASHTO's NTPEP is involved in field and laboratory testing of pavement marking materials, sign materials, and snowplowable markers. Although NTPEP does not provide recommendations for the acceptance or rejection of materials, it does provide results of materials testing.

The test procedures used by NTPEP for evaluating pavement marking materials were developed by an AASHTO Oversight Committee and have been revised since inception. These procedures are listed in NTPEP's *Project Work Plan for the Field and Laboratory Evaluation of Pavement Marking Materials*. Pavement marking material field tests using these procedures have been conducted in various states including Pennsylvania, Wisconsin, Utah, California, Texas, and Mississippi. Liquid traffic paint products, thermoplastic material, and temporary and permanent tapes are transversely placed on test decks and monitored for retroreflectivity, color, and durability.

Many states rely on the NTPEP evaluation program to identify products for addition to agency Qualified Products List or Approved Products List. Since the presentation format for the results of NTPEP testing are familiar to many individuals concerned with

pavement marking effectiveness, a similar format is used in the presentation of the results for this project (3, 4, 5, 6, 7, 8, 9).

American Society for Testing and Materials International (ASTM)

ASTM is a standards development organization that was formed in 1898. Its original mission was to standardize the steel used in the railroad industry. Since its inception, the organization has grown into one of the largest voluntary technical standards development organizations in the world. Approximately 30,000 ASTM members accomplish all technical work and testing.

ASTM publishes more than 11,400 standards each year on subjects such as materials, products, systems, and services. ASTM is a recognized leading authority on standards. Thousands of public agencies and private entities, including NTPEP, reference the ASTM standards in regulations, codes, laws, and contracts.

A typical published ASTM standard includes, but is not limited to: scope, referenced documents, significance and use, apparatus, calibration, procedures, calculations, report, precision and bias, pictures, and keywords.

Several ASTM standards were reviewed for information that pertains to the design, equipment, monitoring, and evaluation of pavement marking test sections (11, 12, 13, 14, 15, 16, 17, 18, 19).

Transportation Research Board (TRB)

The TRB is an independent advisor to the federal government that makes recommendations on transportation matters of importance. The TRB is a major proponent of transportation engineering innovation and improvement. The organization facilitates information sharing for transportation policy and engineering practice. The TRB sponsors and manages research as well as disseminates the results.

Engineers, researchers, academia, planners, private enterprise, and state and local government agencies support this organization. TRB hosts a website that links to an online database of transportation research information. This website is a valuable source of information displaying pavement marking related articles from a variety of magazines, journals, and other noted data. The organization publishes the noteworthy *Transportation Research Record* that is cover for hundreds of articles related to state of the practice research and practice for numerous transportation related subjects. TRB also hosts an annual meeting that draws participants from all over the world (1, 2, 23, 27, 29, 30, 35, 36, 38, 40, 41, 43).

National Cooperative Highway Research Program (NCHRP)

The NCHRP is administered by the TRB and sponsored by the FHWA and state departments of transportation. The program was initiated in 1962 to provide research for critical problem areas related to all areas of highway engineering.

Highway related engineering problems are submitted to NCHRP and reviewed by member states and committees. If the research problem is accepted by a two-thirds majority of the states and various committees, a panel of experts is assigned to the

candidate project. Based on the research objectives, the TRB will request research proposals from qualified public and private organizations capable of providing the research expertise. Technical panels will review proposals, award contracts, and monitor the research in progress. The research findings are published in the NCHRP Reports series and the NCHRP Synthesis of Highway Practice series. The NCHRP is a reputable source for pavement marking related research findings (32, 33).

SELECTED BIBLIOGRAPHY

1. Abboud, N., and B.L. Bowman. Cost-and Longevity-Based Scheduling of Paint and Thermoplastic Striping. In *TRB 81st Annual Meeting*. CD-ROM. Transportation Research Board, National Research Council, Washington, D.C., 2002.

2. Abboud, N., and B.L. Bowman. Establishing a Crash-Based Retroreflectivity Threshold. In *TRB 81st Annual Meeting*. CD-ROM. Transportation Research Board, National Research Council, Washington, D.C., 2002.

3. American Association of State Highway and Transportation Officials. *AASHTO's National Transportation Product Evaluation Program NTPEP Report 1020.1. 2001 NTPEP – Pavement Marking Materials. First Year Field Performance & Lab Test Results (2001 Utah Test Deck)*. Washington, D.C., 2003.

4. American Association of State Highway and Transportation Officials. *AASHTO's National Transportation Product Evaluation Program Report 02 NTPEP 221. First Year Field Performance & Laboratory Test Results of Pavement Marking Materials. 2000 Pennsylvania Deck.* Washington, D.C., 2002.

5. American Association of State Highway and Transportation Officials. *AASHTO's National Transportation Product Evaluation Program Report 00 NTPEP 214. First Year Interim Report on Field Performance Evaluation & Lab Test Results of Pavement Marking Materials (1999 Wisconsin Test Deck)*. Washington D.C., 2001.

6. American Association of State Highway and Transportation Officials. *AASHTO's National Transportation Product Evaluation Program Report 00 NTPEP 205. Volume I: Field Evaluation – First Year Interim Report on Field Performance Evaluation of Pavement Marking Materials (1999 Mississippi Test Deck)*. Washington D.C., 2000.

7. American Association of State Highway and Transportation Officials. *AASHTO's National Transportation Product Evaluation Program Report 99 NTPEP 164. First Year Field Evaluation & Laboratory Test Results of Pavement Marking Materials. 1998 Texas Test Deck.* Washington, D.C., 2000.

8. American Association of State Highway and Transportation Officials. *AASHTO's National Transportation Product Evaluation Program Report 99 NTPEP 153. First Year Summary of Results of 1998 Coordinated Evaluation of Pavement Marking Materials Volume I – Field Evaluations.* Washington D.C., 1999.

9. American Association of State Highway and Transportation Officials. *AASHTO's National Transportation Product Evaluation Program Project Work Plan for the Field and Laboratory Evaluation of Pavement Marking Materials.* Washington D.C., 1997.

10. Andrle, S.J., K.Knapp, T. McDonald, and D. Smith. Development of a Traffic Control Devices and Pavement Markings Manual for Iowa's Cities and Counties With a Survey of Common Practices, Iowa DOT Project TR-441 and CTRE Management Project 99-57. Iowa Department of Transportation, Iowa Highway Research Board, Center for Transportation Research and Education. Ia., 2001.

11. ASTM D 713, "Standard Practice for Conducting Road Service Tests on Fluid Traffic Marking Materials," ASTM International. West Conshohocken, Pa., 2004.

12. ASTM D 913, "Standard Test Method for Evaluating Degree of Resistance to Wear of Traffic Paint," ASTM International. West Conshohocken, Pa., 2004.

13. ASTM D 2205, "Standard Guide for Selection of Tests for Traffic Paints," ASTM International. West Conshohocken, Pa., 2004.

14. ASTM D 6359, "Standard Specification for Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments," ASTM International. West Conshohocken, Pa., 2004.

15. ASTM D 6628, "Standard Specification for Color of Pavement Marking Materials," ASTM International. West Conshohocken, Pa., 2004.

16. ASTM E 284, "Standard Terminology of Appearance," ASTM International. West Conshohocken, Pa., 2004.

17. ASTM E 1710, "Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer," ASTM International. West Conshohocken, Pa., 2004.

18. ASTM E 1743, "Standard Practice for Selection and Use of Portable Retroreflectometers for the Measurement of Pavement Marking Materials," ASTM International. West Conshohocken, Pa., 2004.

19. ASTM E 2176, "Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Continuous Wetting," ASTM International. West Conshohocken, Pa., 2004.

20. Casey, B., and B. Zollinger. An Evaluation of the Epoxy Pavement Markings in the Nevada Department of Transportation District Three Area. Maple Shade, NJ: Epoplex, 2001.

21. Conner, B., and J. Bennett. *Selection of Pavement Marking Materials.* Publication FHWA-AK-RD-00-01. Alaska Department of Transportation & Public Facilities. Fairbanks, Ak., 2001.

22. Cottrell, B.H. Jr., and R.A. Hanson. *Determining the Effectiveness of Pavement Marking Materials.* Report No. VTRC 01-R9. Virginia Transportation Research Council. Charlottesville, Va., 2001.

23. Davis, C.F., and G.M. Campbell. Selection of Pavement Markings Using Multicriteria Decision Making. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1509*, TRB, National Research Council, Washington, D.C., 1995, pp. 28-37.

24. Dunn, C., and T.A. Bold. *Evaluation of Water-Borne Pavement Marking Paints.* Report No. MR 98-01. North Dakota Department of Transportation. Bismarck, Nd., 2001.

25. Durant, Y.G. *Waterborne Traffic Paints A study for the potential improvement in drying time and cost-effectiveness.* Report No. SPR- 004(24) 12323 T. State of New Hampshire, Department of Transportation. Concord, Nh., 2000.

26. Kaseko, M.S., W.C. Vodrazka, and S.S. Nambisan. *Evaluation of Pavement Marking Materials Performance and Specifications for Clark County Roads.* Report No. UNLV/TRC/01-01. Regional Transportation Commission of Southern Nevada. Las Vegas, Nv., 2001.

27. Loetterle, F.E., R.A. Beck, and J. Carlson. Public Perception of Pavement-Marking Brightness. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1715*, TRB, National Research Council, Washington, D.C., 2000, pp. 51-59.

28. McGinnis, R. G. *Pavement Markings Benchmarking.* Report No. FHWA-PA-2001-027-97-04(83). Pennsylvania Transportation Institute. University Park, Pa., 2001.

29. Migletz, J., J.L. Graham, K.M. Bauer, and D.W. Harwood. Field Surveys of Pavement-Marking Retroreflectivity. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1657*, TRB, National Research Council, Washington, D.C., 1999, pp. 71-78.

30. Migletz, J., J.L. Graham, K.M. Bauer, and D.W. Harwood. Service Life of Durable Pavement Markings. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1749*, TRB, National Research Council, Washington, D.C., 2000, pp. 13-21.

31. Migletz, J., J.K. Fish, and J.L. Graham. *Roadway Delineation Practices Handbook.* Report No. FHWA-SA-93-001. Federal Highway Administration. Washington, D.C., 1994.

32. *National Cooperative Highway Research Program A Synthesis of Highway Practice 306: Long-Term Pavement Marking Practices.* Transportation Research Board, National Research Council, Washington, D.C., 2002, pp 1-154.

33. *National Cooperative Highway Research Program Synthesis of Highway Practice 138: Pavement Markings: Materials and Application for Extended Service Life.* Transportation Research Board, National Research Council, Washington, D.C., 1988, pp. 1-45.

34. Nevada Department of Transportation. *Standard Specifications for Road and Bridge Construction.* State of Nevada Department of Transportation. Carson City, Nv., 2001.

35. Schnell, T., and P.J. Ohme. Evaluation of Various Strategies to Increase Pavement Marking Visibility for Older Drivers. In *TRB 81st Annual Meeting.* CD-ROM. Transportation Research Board, National Research Council, Washington, D.C., 2002.

36. Schnell, T., H.T. Zwahlen, and R. Smith. Reflective Properties of Selected Road Surfaces for and Automobile Headlamp Geometry. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1657*, TRB, National Research Council, Washington, D.C., 1999, pp. 79-89.

37. Texas Transportation Institute. Pavement Marking Conference on Performance and Warranty Specifications. Texas Department of Transportation. Austin, Tx., 2001.

38. Thamizharasan, A., W.A. Sarasua, W.J. Davis, and D.B. Clarke. A Methodology for Estimating the Lifecycle of Interstate Highway Pavement Marking Retroreflectivity. In *TRB 82nd Annual Meeting*. CD-ROM. Transportation Research Board, National Research Council, Washington, D.C., 2003.

39. Thomas, G.B., and C. Schloz. Durable, Cost-Effective Pavement Markings Phase I: Synthesis of Current Research, Iowa DOT Project TR-454 and CTRE Management Project 00-75. Iowa Department of Transportation, Iowa Highway Research Board, Center for Transportation Research and Education. Ia., 2001.

40. Transportation Research Board of the National Academies. Home page. http://www.trb.org/. Accessed repeatedly.

41. U.S. Department of Transportation. TRIS Online v 2.7. Home page. http://trisonline.bts.gov/search.cfm. Accessed repeatedly.

42. U.S. Department of Transportation. Federal Highway Administration. Home page. http://www.fhwa.dot.gov/. Accessed repeatedly.

43. Zwahlen, H.T., and T. Schnell. Minimum In-Service Retroreflectivity of Pavement Markings. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1715*, TRB, National Research Council, Washington, D.C., 2000, pp. 60-70.

APPENDIX B – SURVEY OF STATE DOTs

Nevada DOT Survey on Pavement Marking Materials - State Response				
Agency	**What type of pavement marking materials does your agency use for striping?**	**What is the expected service life?**	**Are there any specific criteria used for determining the use of this product?**	**Comments regarding this product:**
AK	Solventborne paint	6 months to 1.5 years	ADT, presence of stripe, and expected pavement life.	Difficult to maintain presence in high ADT areas beyond 6 months.
	Methacrylate-based paint	1 to 7 years	ADT, presence of stripe, and expected pavement life.	Difficulty in retaining retroreflectivity beyond one year Product is also very slick.
	Hot-applied thermoplastic	1 to 6 years	ADT, presence of stripe, and expected pavement life.	Susceptible to thermal cracking and loss of retroreflectivity.
CT	Epoxy	2 to 3 years	Longevity and initial wet night retroreflectivity.	Durable and cost effective, the product is contractor installed.
	Waterborne acrylic	10 to 14 months	ConnDOT employees are capable of installing product.	Product is cost effective, however short service life.
	Permanent tape	3 to 4 years	Used for skips on expressways, the tape is rolled-in on new pavements only.	Product is durable but expensive and difficult to deal with when worn out. Product pulls out with bituminous when epoxy is used over it.
GA	Waterborne acrylic	1.5 years	Used on 2-lane roads with less than 10,000 ADT.	More durable than solvent paint. The product can be placed by Maintenance forces.
	Permanent tape	6 to 10 years	Multi-lane roadways with 10,000 ADT or greater. Mostly placed on PCC. May have some wet night retroreflectivity attributes.	Performance life is 3 to 5 times longer on PCC pavements than thermoplastic. Product is applied by contractors.
	Spray thermoplastic	4 to 6 years on AC 2 years or less on PCC	Multi-lane roadways with 10,000 ADT or greater. Primarily placed on AC pavements.	More durable than waterborne paint. Application by Maintenance forces.
	Polyurea	3 to 6 years	Placed on asphalt concrete pavement on let resurfacing projects. The product has some wet night retroreflective attributes.	Retroreflectivity values higher than paint and thermoplastic with greater performance life. Product is applied by contractors.
IL	Solventborne paint	1 year	Used by contractors for late season paving projects when temperatures do not permit the application of durable markings.	
	Epoxy	3 to 4 years		
	Waterborne acrylic	1 year		Economic, versatile, and State forces can apply anywhere depending upon weather conditions.
	Permanent tape	4 to 5 years	Used as an inlaid material for centerlines on resurfacing projects and at high ADT intersections.	
	Spray thermoplastic	2 years	Used as a top coat to extend the life of existing markings until pavement is resurfaced.	
	Polyurea	3 to 4 years		The agency is just starting to use the material.
	Hot-applied thermoplastic	3 to 4 years	Used on bituminous concrete surfaces.	
IN	Epoxy	3 to 5 years	Placed mostly on concrete four-lane roads.	
	Permanent tape	3 to 5 years	Used mostly in cities and towns.	Use of preformed plastic.
	Hot-applied thermoplastic	3 to 5 years	Used in cities and towns.	

Nevada DOT Survey on Pavement Marking Materials - State Response

Agency	What type of pavement marking materials does your agency use for striping?	What is the expected service life?	Are there any specific criteria used for determining the use of this product?	Comments regarding this product:
IA	Solventborne paint	6 months to 1 year	This product is only used in the early and late part of the season when the temperature is expected to drop below 40 degrees F.	
	Epoxy	2 to 4 years	Used where waterborne paint is not expected to last at least 12 months, based on field observations.	Product is applied by contractors.
	Waterborne acrylic	6 months to 2 years	Standard striping used on 95% of Iowa's highways.	If the temperature drops below 40 degrees F before product has a chance to cure at least 24 hours, the agency's observation is that the service life will be significantly shortened. Application by agency staff.
	Permanent tape	4 to 8 years	Placed in very high traffic areas.	
	Polyurea	2 to 4 years	Used where waterborne paint is not expected to last at least 12 months, based on field observations.	Used experimentally up to this time.
	Modified urethane	2 to 4 years	Used where waterborne paint is not expected to last at least 12 months, based on field observations.	Used experimentally up to this time.
	Hot-applied thermoplastic	N/A		Agency does not use thermoplastic because of poor experience with the product on PCC. About 50% of the highways are PCC in Iowa.
KY	Epoxy	3+ years	Currently experimenting with some epoxy on high ADT routes, especially with PCC pavement.	
	Waterborne acrylic	1+ year	Used extensively in nearly all conditions.	Very good results with some lines holding reflectivity for 2+ years in low ADT and rural environments.
	Permanent tape	3+ years	Used in urban areas and on PCC pavement.	Good results with some minor problems in the last couple of years.
	Spray thermoplastic	3+ years	Used sparingly as corrective work on problem extruded thermoplastic installation.	Varied results with no plans to use except as corrective measure.
	Polyurea	3+ years	Experimental use only at this time.	Great initial retroreflectivity values.
	Hot-applied thermoplastic	5+ years	Placed extensively on new asphalt pavement as a durable marking material.	Product has provided good results.
MI	Solventborne paint	1 year	Spring and fall application only.	
	Epoxy	3 years	Product is placed primarily on new construction.	
	Waterborne acrylic	1 year	Product is placed statewide.	
	Permanent tape	3 to 4 years	Used for new construction skips only.	
	Spray thermoplastic	1 year	Placed where tracking problems in high ADT areas preclude using waterborne paint.	
	Polyurea	3 years	Used for new construction.	Expected service life is estimate.
	Hot-applied thermoplastic	3 years	Placed on new bituminous surfaces and for special markings.	
NE	Solventborne paint	4 months to 1 year	Will be switching to waterborne striping when the striping vehicles can be replaced.	Acetone-based paint.
	Epoxy	2 to 4 years		
	Waterborne acrylic	1 year		
	Permanent tape	4 years		
	Hot-applied thermoplastic	8 years		

Nevada DOT Survey on Pavement Marking Materials - State Response				
Agency	**What type of pavement marking materials does your agency use for striping?**	**What is the expected service life?**	**Are there any specific criteria used for determining the use of this product?**	**Comments regarding this product:**
NH	Waterborne acrylic	1 year	Use methanol free paint.	
NM	Waterborne acrylic	6 months to 1 year	Maintenance striping	The performance is seasonally and geographically sensitive.
	Polyurea	3 to 5 years	Typically used on new construction. Used on a case-by-case basis.	Very select locations and not widely used.
	High durable acrylic	1 to 1.5 years	New construction	
NV	Solventborne paint	4 months to 1 year	Maintenance striping	One District prefers to use solventborne, however, will be changing to waterborne paint when new striping truck arrives.
	Epoxy	3 months to 4 years	Used on Interstates and high ADT routes (Reno and Las Vegas areas). Contract striping for all epoxy markings.	Agency is trying to improve the service life by implementing a training program for inspectors and working to improve application procedures.
	Waterborne acrylic	6 months to 1 year	Maintenance striping	
	Permanent tape	2 to 3 years	Typically used in new construction on high ADT routes in Las Vegas area.	Expected service life is an estimate. Inlaid tape stays better than the glue down, but still blackens early.
OH	Solventborne paint	1 year		
	Epoxy	4 to 5 years	PCC in new or good condition, new asphalt, and asphalt in good condition if ADT is 6,000 or more vehicles/lane; otherwise paint.	Epoxy should only be used on pavements in good condition after surface preparation by mechanical grinding has been accomplished.
	Waterborne paint	1 year	Used for asphalt in poor condition, PCC in poor condition with a smooth finish, or containing curing compound.	Fast dry waterbase paint for lane and channelizing lines as well as edge lines. Fast dry alkyd paint for auxiliary markings.
	Permanent tape	2 years		
	Polyester	3 years	Asphalt in good condition if ADT is 6,000 or more vehicles/lane.	Due to poor bonding qualities, polyester should not be used on open graded courses, slurry seal, rubberized sand asphalt, and SS 807 latex modified emulsified asphalt pavement course. Any asphalt concrete surface should be questioned before considering placement of polyester material on it.
	Spray thermoplastic	N/A		Spray application of thermoplastic is not permitted in Ohio.
	Hot-applied thermoplastic	4 to 5 years	PCC in new or good condition, new asphalt, and asphalt in good condition if ADT is 6,000 or more vehicles/lane; otherwise paint.	Primer is required for PCC in new or good condition, with rough finish, and no curing compound.
	Preformed plastic	2 years	Type A3 may be used if ADT is 6,000 or more vehicles/lane and the surfaces are PCC in new condition, PCC in good condition, or new asphalt.	Some heat fused preformed plastic markings are inlaid during paving for auxiliary markings. Due to high cost of Type A3 material, it should only be considered for use where extra long life is needed in certain applications, such as bridge decks where thermoplastic has not adhered well.

Nevada DOT Survey on Pavement Marking Materials - State Response

Agency	What type of pavement marking materials does your agency use for striping?	What is the expected service life?	Are there any specific criteria used for determining the use of this product?	Comments regarding this product:
OR	Waterborne acrylic	2 months to 1.5 years	Used as a standard product.	
	Permanent tape	Undetermined	ADT, weather, and geography	Not a lot of experience with permanent tape. Presently only allowing ground-in or rolled-in.
	Methacrylate-based paint	6 to 12 years	ADT, weather, and geography	Installation of this product is complicated. Product is applied at 90 to 120 mils thickness.
	Spray thermoplastic	4 to 10 years	ADT, weather, and geography	Product applied at 90 to 120 mils thickness.
	Hot-applied thermoplastic	4 to 10 years	ADT, weather, and geography	Product applied at 90 to 120 mils thickness.
PA	Epoxy	3 years	During the past four years, the Department has specified a 3-year warranty on many freeways. In all cases, the contractor used epoxy.	Warranty contracts require a lot of inspection.
	Waterborne acrylic	1 year	This is the primary pavement marking material. The Department has 21 large paint trucks, plus some work done by contractors.	Waterborne is more durable than solvent-based markings.
	Hot-applied thermoplastic	3 years	Sometimes specified on freeway, expressway, and major arterial construction contracts.	Provides better daytime contrast than epoxy, especia on PCC roadways.
RI	Solventborne paint	3 months	Sometimes used on newly paved roads when epoxy will be applied within 6 to 9 months. Normal application is 13-15 mils. Also used as interim stripe, prior to epoxy application at 8 mils.	Quick and easy, however durability is questionable.
	Epoxy	1 year or until snow-plowing removes beads	Current statewide striping program uses epoxy pavement markings for all roadways.	Performance is good on new riding surfaces. Loses retroreflectivity on open mixes and surfaces where old striping was ground off.
	Permanent tape	1 to 3+ years	Current policy is to use on newly paved limited access facilities for skip lines.	Good performance, no room for error.
SC	Epoxy	3 years	Placed on concrete pavement.	Expected life is for high speed and high volume roads.
	Waterborne acrylic	6 months to 1.5 years		Acrylic emulsion resin
	Permanent tape	5 years	Used for intersection markings and for long lines on concrete Interstates.	
	Spray thermoplastic	4 years	Placed on asphalt concrete surfaces.	
	Hot-applied thermoplastic	Undetermined	Used for intersection markings.	
TN	Permanent tape	6 years	Interstates and freeways where the ADT is greater than 75,000.	High cost
	Spray thermoplastic	2 years - 20 mils 3 years - 40 mils	Concrete roadways and all conventional highways where the ADT is greater than 5,000.	Currently in "test" stage, contemplating use as maintenance item for existing thermo, concrete roadways, and a replacement for water based paint.
	Hot-applied thermoplastic	4 to 5 years	Asphalt Interstates, freeways, and conventional highways where ADT is less than 75,000.	Problems when used on concrete bridge decks.
	Water-based paint	1 year	Asphalt two-lane roads with ADT less than 5,000.	Short life and drying problems.

Nevada DOT Survey on Pavement Marking Materials - State Response

Agency	What type of pavement marking materials does your agency use for striping?	What is the expected service life?	Are there any specific criteria used for determining the use of this product?	Comments regarding this product:
TX	Waterborne acrylic	6 months to 2 years	Used on lower ADT rural roads and in parts of the state where thermoplastic contractors are not available. Placed as a sealer on some surfaces pri to putting down thermoplastic. Usually on seal coats, concrete, and older asphalt.	Life varies depending upon the ADT.
	Permanent tape	3 to 6 years	Used in some high ADT areas where no other products last and a warranty is offered.	Product has performed with mixed results. Proper application and clean surface is critical. Suggest that manufacturer's representative be present for a large installation to observe contractor and insure product is applied properly. Life varies depending upon ADT.
	Spray thermoplastic	1 to 4 years	Most of striping is with spray thermoplastic. Competitive pricing because of large amount used. Will probably use thicker application of 100 mils in the future - especially on seal coats.	Agency has considered using ribbon gun application to get thicker lines but the contractors are concerned about reducing their production rate and safety at the slower speeds.
	Profile markings	3 to 5 years	Agency has used more profile markings since the FHWA allowed it as a rumble strip.	Agency is not sure how well it performs for wet-night reflectivity.
UT	Solventborne paint	3 months	ADT and weather	Low VOC
	Epoxy	2 years	ADT	
	Waterborne acrylic	3 to 6 months	ADT	
	Permanent tape	6 to 8 years	Pavement surface	
	Hot-applied thermoplastic	5 to 7 years	Pavement surface and ADT	
VT	Epoxy	N/A	Used in limited experimental applications.	Performed adequately in semi-urban area.
	Waterborne acrylic	6 to 8 months	Used in remarking applications.	Performance of material is disappointing. Marking two times a year is necessary sometimes.
	Permanent tape	2 to 3 years	Placed on occasion when requested by a municipality or on PCC.	Only used in city/village settings. Performance depends upon application.
	Hot-applied thermoplastic	2 to 3 years	Placed on "all" new pavement unless otherwise specified or pavement application is completed afte October 15.	Application is a key factor. Material is augmented with crushed glass.
	Other	N/A		Spray thermoplastic and polyurea have been used in a couple of experimental applications.
WI	Acetone solvent	1 year	One County prefers using this product.	
	Epoxy	3+ years		
	Waterborne acrylic	1 year	Easy application process for State and County crews.	Fast dry
	Permanent tape	3+ years		
WY	Epoxy	1 to 3 years	Placed in areas where markings do not last through the winter.	
	Waterborne acrylic	3 months to 2 years		This product is most cost effective, more durable than solventborne, safe, and there is ease of use.
	Permanent tape	4+ years	Used for new concrete and urban areas.	
	Methacrylate-based paint	2 to 5 years	Placed on new concrete.	Most durable topically applied material.

Nevada DOT Survey on Pavement Marking Materials - State Response

Agency	Does agency have a pavement marking management system in place?	What does management system consist of if applicable?	Is striping replaced on an as-needed basis or predetermined schedule?	Please describe striping schedule if applicable.	Criteria for Restriping		
					Observation	Retroreflectivity Readings	Other
AK	NO	N/A	As-Needed	Maintenance forces replace based upon visual inspection and as funding and schedules allow.	YES	N/A	N/A
CT	NO	N/A	As-Needed	N/A	YES	N/A	N/A
GA	NO	N/A	As-Needed	See "expected service life" for pavement marking materials.	YES	YES	Schedule is cyclic depending upon expected service life.
IL	NO	N/A	As-Needed	N/A	YES	N/A	N/A
IN	YES	Agency plans number of miles to paint each year, tracks the costs, and has a QC/QA program.	Schedule	Repaint all waterborne paint long lines each year.	N/A	N/A	Yearly schedule
IA	NO	N/A	Schedule	For most roads, centerlines are repainted every year and edgelines are repainted every other year. On heavier traveled highways, all centerlines and edgelines are remarked every year. Areas that cannot hold waterborne paint for at least a year get epoxy.	YES	N/A	N/A
KY	NO	N/A	Schedule	All major routes with paint are restriped annually and remainder is on a 2-year schedule. Agency is moving towards more of an as-needed basis due to overwhelming quantity of lines applied.	YES	YES	N/A
MI	YES	Waterborne paint is used statewide unless there are tracking problems, then use sprayable thermo. Durable products used on new construction at discretion of region staff. Recessed waffle tape skips and epoxy edgelines is combination of choice for new concrete sections.	Schedule	See "expected service life" for pavement marking materials.	N/A	N/A	Schedule is cyclic depending upon expected service life.

Nevada DOT Survey on Pavement Marking Materials - State Response

Agency	Does agency have a pavement marking management system in place?	What does management system consist of if applicable?	Is striping replaced on an as-needed basis or predetermined schedule?	Please describe striping schedule if applicable.	Criteria for Restriping		
					Observation	Retroreflectivity Readings	Other
NE	NO	N/A	Schedule	Low volume rural districts once per year; higher volume twice per year; Omaha Interstate was three times per year and is now taped.	YES	N/A	YES
NH	YES	Restripe all long lines on a yearly basis beginning in April and finishing in November.	Schedule	Yearly, the Interstates are striped first followed by the primary and secondary roads.	N/A	N/A	Yearly schedule
NM	NO	N/A	As-Needed & Schedule	All roads a minimum schedule of once per year; more often on an as-needed basis.	YES	N/A	N/A
NV	NO	N/A	As-Needed & Schedule	Some Maintenance crews stripe on an as-needed basis, and other crews stripe on a yearly schedule.	YES	N/A	Yearly schedule
OH	NO	N/A	As-Needed	Traffic Paint - 1 year Polyester - 3 years Epoxy and Thermoplastic - 4 to 5 years	YES	N/A	N/A
OR	YES	Statewide goals, application databases, 10-year plans, & monthly meetings of managers and coordinators.	As-Needed	N/A	YES	YES	N/A
PA	NO	N/A	As-Needed & Schedule	Replace painted lines every year. Due to work load, replacement is done with a systematic approach.	YES	YES	N/A
RI	YES	Roadways are restriped every other year.	Schedule	Remark every two years.	YES	N/A	Schedule is every two years.

Nevada DOT Survey on Pavement Marking Materials - State Response

Agency	Does agency have a pavement marking management system in place?	What does management system consist of if applicable?	Is striping replaced on an as-needed basis or predetermined schedule?	Please describe striping schedule if applicable.	Criteria for Restriping		
					Observation	Retroreflectivity Readings	Other
SC	NO	N/A	As-Needed & Schedule	N/A	YES	Starting to take some readings.	N/A
TN	YES	Regional offices keep a database on marking types and installation data. An Excel or Access type database is used. A total Maintenance Management System is in the works.	As-Needed & Schedule	TDOT retraces all painted lines each year and retraces all other lines on an as-needed basis.	YES	N/A	Painted lines on yearly schedule.
TX	NO	N/A	As-Needed & Schedule	Some as-needed and some scheduled. Some Districts have their own striping crews and this gives more flexibility. At this time the administration would like to phase out TxDOT striping crews except for small emergency applications.	YES	Some Districts are beginning to specify jobs with minimum retroreflectivity values, but are not at the point of using readings for restriping.	N/A
UT	NO	N/A	As-Needed & Schedule	Replace epoxy every 2-3 years and waterborne every 3 to 6 months as-needed.	YES	YES	YES
VT	NO	N/A	Schedule	All highways are remarked annually; except those with durable markings which are remarked as-needed.	YES	N/A	N/A
WI	NO	N/A	As-Needed & Schedule	Waterborne paint centerlines are striped every year, and edgelines every other year.	YES	N/A	N/A
WY	YES	The Interstate is striped twice a year. NHS is striped once a year for the centerlines and every other year for the edgelines. Urban areas are striped on an as-needed basis.	As-Needed & Schedule	The Interstate is striped twice a year. NHS is striped once a year for the centerlines and every other year for the edgelines. Urban areas are striped on an as-needed basis.	YES	N/A	Scheduled striping yearly and every other year.

Nevada DOT Survey on Pavement Marking Materials - State Response							
Agency	Does agency use any retroreflectivity equipment?	What type of retroreflectivity equipment does agency use?	What primary type of specification does agency use for pavement markings?	Please specify primary bead type or size used in pavement marking material.	Does Agency Staff (AS), Contractors (C), or a combination of Agency Staff and Contractors (AS & C) primarily apply pavement markings?	Does agency have a policy for striping in snow-plow areas?	Additional Comments:
AK	YES	LTL 2000	Composition	Traffic paint: AASHTO M-247 Type 1, with a moisture resistant coating Methyl Methacrylate: Gradation specified in agency specs: 712-2.18	AS & C	All areas are snowplow areas. See agency matrix for product selection on the web site listed in "additional comments."	Alaska DOT is working on a pavement marking project. Get specifics at http://www.dot.state.ak.us/stwddes/research/rt_index.html and click on Research/ Project Descriptions.
CT	YES	Division of Research and Maintenance personnel have equipment. However, the equipment is not used to monitor needs for remarking.	Composition	Paint: M-247-81 Epoxy: 50/50 large Visibeads and M-247-81	AS & C	No difference between striping in snow-plow or non snow-plow areas.	N/A
GA	YES	LTL 2000	Performance & Composition	AASHTO M-247-81 Modified	AS & C	N/A	Agency is looking at all wet-night retroreflectivity readings for pavement markings to be placed on all "On System" roadways in Georgia.
IL	NO	Department recently purchased a unit and is in process of developing a data base.	Composition	N/A	AS & C	All areas are snow-plow areas in this state.	N/A
IN	YES	LTL 2000	Agency uses APL for paint. Agency has minimum retroreflectivity numbers that must be met in lab test before they award contract.	AASHTO M-247	AS	All areas are snow-plow areas in this state.	Agency will start field testing products and use an approved products list for beads. Only the vendors on the APL will be allowed.

Nevada DOT Survey on Pavement Marking Materials - State Response							
Agency	Does agency use any retroreflectivity equipment?	What type of retroreflectivity equipment does agency use?	What primary type of specification does agency use for pavement markings?	Please specify primary bead type or size used in pavement marking material.	Does Agency Staff (AS), Contractors (C), or a combination of Agency Staff and Contractors (AS & C) primarily apply pavement markings?	Does agency have a policy for striping in snow-plow areas?	Additional Comments:
IA	YES	LTL 2000 and Laser Lux van	Waterborne paint is combination of performance and composition specification. Epoxy paint specification is strictly performance.	Waterborne paint: AASHTO Type 1 beads with dual coating Epoxy: Gradation and coating left to manufacturers	AS & C	State has a "clear pavement" policy regarding snow and ice. They try to clear snow and ice in a short time by using "under-belly" ice blades, with tungsten carbide tips. These types of plows exert tremendous downward pressure and are very hard on all types of striping materials.	Bead coatings are an important variable. Agency has found that dual coating (silicone/silane) on beads in waterborne paint significantly increase the retained retroreflectivity of the line.
KY	YES	LTL 2000 and contract mobile readings	Performance	Contract applied lines are evaluated as part of the system. State forces use beads that conform to AASHTO M-247 with some additional requirements for gradation and percentage rounds (70% min for +50 beads).	AS & C	N/A	A Performance Specification Booklet was prepared for a TTI conference. The link is as follows: http://tcd.tamu.edu/ (click on Pavement Markings Conference and then Conference booklet)
MI	YES	Mirolux handheld and Laser Lux mobile	Performance	M-247 moisture resistant for waterborne and manufacturers recommended bead for other products.	C	Limit use of sprayable thermo in heavy snow-plow areas.	Performance specifications based on initial retroreflectivity readings have helped increase performance and make contractors responsible for final results. Incentives/disincentives apply based on retro levels.
NE	NO	N/A	Composition	Solventborne: AASHTO M-247 Type 1 flotation Epoxy: Double drop AASHTO M-247 Type 1 & Type 4 dual coated Waterborne: AASHTO M-247 Type 1 dual coated Hot-applied thermoplastic: AASHTO M-247 Type 1 (intermix) and Type 1 Modified (drop-on)	AS & C	No policy, however, some plowable raised pavement markers are used to supplement dashed lines.	N/A

Nevada DOT Survey on Pavement Marking Materials - State Response							
Agency	**Does agency use any retroreflectivity equipment?**	**What type of retroreflectivity equipment does agency use?**	**What primary type of specification does agency use for pavement markings?**	**Please specify primary bead type or size used in pavement marking material.**	**Does Agency Staff (AS), Contractors (C), or a combination of Agency Staff and Contractors (AS & C) primarily apply pavement markings?**	**Does agency have a policy for striping in snow-plow areas?**	**Additional Comments:**
NH	YES	LTL 2000	In-house paint supplier and contractors submit samples of paint to Department to be tested for approval. If approved, batch number is recorded on approved list. Contractor's paint supply must be on approved list in order to get paid. Some contractors that do not meet requirements receive no pay.	Adherence coated glass beads that follow AASHTO M-247-81 (1996) specification.	AS	No specific policies. Interstate/Turnpikes are striped with 6" lines and all other roads are 4" lines. Areas of the state with fog problems are striped with 6" lines.	N/A
NM	YES	LTL 2000	Performance & Composition	Recycled glass beads (US sieve nos. from 100 to 20), 70% round; Polyurea: dual drop (first drop is AASHTO standard specs, second drop is megalux or ceramic beads) Some high durable acrylics use the larger Visibeads.	C	Agency is in process of implementing a new program that incorporates deicing in conjunction with snow plow areas to minimize blade contact with stripe. However, maintenance crews typically still contact with stripe during snow-plow operations.	N/A
NV	YES	LTL 2000	Composition	Agency specification (730 for traffic beads)	AS & C	In heavily plowed areas, crews restripe as much as 2-3 times per year if necessary. Agency is working on finding improved products or methodology (i.e. inlay) to extend striping life in these areas.	Agency is in the process of a pavement marking research project. The objective of the project is to expand the Qualified Products List, find the best performing products for the area, and rewrite specifications. Specifications will be more performance and warranty based, rather than compositional. Recent experimental test sections included polyurea and modified urethane products.
OH	YES	LTL 2000	Composition with Supplement (See Pavement Marking Specification Items 640 & 740 for Composition at http://www.dot.state.oh.us/spec/ and see Supplement 828 & 829 at http://www.dot.state.oh.us/construction/OCA/Specs/ss/default.htm)	Agency specification (740.10 for glass beads)	C	Agency limits application thickness to 3 to 5 mm of thermoplastic in snow-plow areas.	In 1999, the agency tried a warranty specification for pavement markings. Due to the raise in contract bid price, the agency stepped the warranty program for pavement markings.

Nevada DOT Survey on Pavement Marking Materials - State Response							
Agency	Does agency use any retroreflectivity equipment?	What type of retroreflectivity equipment does agency use?	What primary type of specification does agency use for pavement markings?	Please specify primary bead type or size used in pavement marking material.	Does Agency Staff (AS), Contractors (C), or a combination of Agency Staff and Contractors (AS & C) primarily apply pavement markings?	Does agency have a policy for striping in snow-plow areas?	Additional Comments:
OR	YES	Agency uses 15 meter handheld, but is moving towards 30 meter geometry. Agency has access to a Laser Lux van for research purposes.	Performance & Warranty	Pavement marking manufacturers warrant the marking materials and the bead choice is discretion of manufacturer. Typically, combination of small and large virgin glass beads are used.	AS & C	No written policy, but factor this in when deciding what product to use in snow-plow areas.	Warranty requirements have helped agency to get better projects. Copies of specifications and warranties are on the web at http://www.odot.state.or.us/techserv/roadway/specs/00800.htm. Look at sections 850, 851, and 862 for information.
PA	YES	One Ecodyne mobile retroreflectometer, plus 12 Mirolux 30 handheld retroreflectometers	Performance and Warranty (PENNDOT purchases paint based on a combination of price and performance on PA's NTPEP test deck)	Basically, AASHTO Type A glass beads. Several Districts use slightly larger bead called Type D, based on a West Virginia gradation. Also experimenting with larger Visibeads.	AS	N/A	N/A
RI	YES	Delta Light and Optics LTL 2000	Performance	N/A	C	N/A	Inspections and well maintained equipment are very important.
SC	YES	LTL 2000	Composition	Thermoplastic and paint: AASHTO M-247(Type 1) Epoxy: Drop System (Types 1 and 5 on interstates)	AS & C	N/A	N/A
TN	YES	Mirolux 30 retroreflectometer	Composition	Type 1	AS & C	N/A	N/A

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Agency	Does agency use any retroreflectivity equipment?	What type of retroreflectivity equipment does agency use?	What primary type of specification does agency use for pavement markings?	Please specify primary bead type or size used in pavement marking material.	Does Agency Staff (AS), Contractors (C), or a combination of Agency Staff and Contractors (AS & C) primarily apply pavement markings?	Does agency have a policy for striping in snow-plow areas?	Additional Comments:
TX	YES	LTL 2000 and MX 30 portable units	Performance for cold tape and preformed thermoplastic. Composition for paint and thermoplastic. Agency formulation for traffic paint.	Agency gradation which may be slightly larger than AASHTO. Agency is starting to use more of the larger beads. The current gradation has been used without adhesive coating, and agency will try to use with a coating.	AS & C	Districts use both thermoplastic and paint along with snow-plowable raised pavement markers. Agency does not have much of a problem in this area as other states.	Agency has investigated the use of warranty specs but it appears this route may have more problems than benefits at this time. This includes complexity of specifications, need for extensive acceptance testing and monitoring, and need for some type of bonding.
UT	YES	LTL 2000	Performance	Various sizes are used according to paint type.	AS & C	N/A	Better surface preparation is required for durable two component markings.
VT	YES	Handheld retroreflectometers	Composition: Agency uses an APL for durable markings and have materials testing spec for waterborne paint. Material on APL is modified by replacing 10% of the filler material with crushed glass in an effort to improve skid resistance.	Agency specification calls for 95% of the beads to pass the #20 sieve with a majority being retained on the #80 sieve.	AS & C	No special policy as entire state is within a snow-plow area.	N/A
WI	YES	LTL 2000	Performance	Contractor: AASHTO M-247 (Type 1) Maintenance: State's own gradation (variation of Type 1)	AS & C	Same striping policy throughout the state regardless of snow conditions.	N/A
WY	YES	Mirolux 30	Warranty and Composition	AASHTO M-247 Type 1 with dual coating (silane and moisture resistant)	AS	N/A	N/A

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