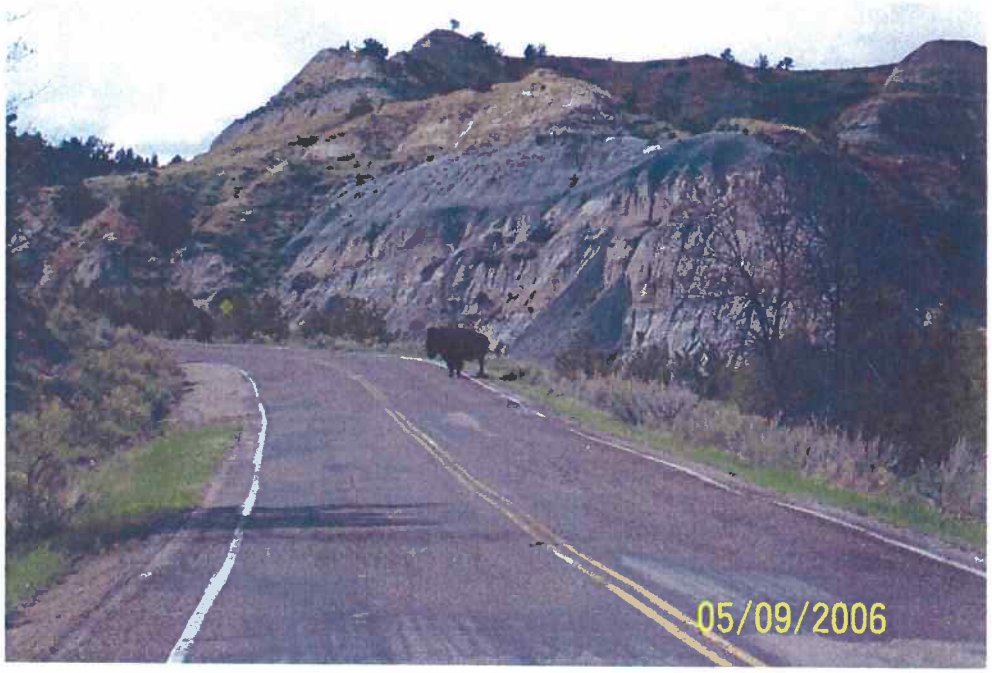
THEODORE ROOSEVELT NATIONAL PARK

ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE

PAVEMENT REPORT

Report # 09-03

Pavement Section
December 2008



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Michael Voth, Division Pavement Engineer

12-10-08
_____
Date

Distribution
Project Management
Project Development (3)
Acquisition and Contracting
Construction
CFLHD, Central Files
CFLHD, Report Room
Pavements (2)
Materials

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I. INTRODUCTION

This report is written to document road conditions for the planned 2010 project, ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE as well as for future projects for this route. THRO 10(3) will rehabilitate mileposts (MP) 0.0 to 4.96. At the time of this writing, December 2008, the project ND PRA THRO 10(4) SPOT REPAIR is being constructed. Those repairs are within MP 6.8 to 7.8 of the route with information for that project being covered in Geotechnical Design Report # ND=PX-THRO-08-01. The North Unit Scenic Drive has been severely damaged due to the construction traffic and hauling of materials. The recommended repairs are discussed in a memo dated 11/4/2008, which is included in Appendix H.

This report incorporates information and data from pervious reports of investigations for pavements and subgrade soils in Theodore Roosevelt National Park, North Unit. The supporting information is in the attached appendices. In addition, during the week of May 9th, 2006 a new pavement and subgrade soil investigation was conducted from the beginning to the end of Scenic Drive.

The Preliminary Pavement Recommendations Memo issued in December 2006 provided pavement structural section recommendations. The pavement recommendations are now finalized in this report in Part VII. Pavement Recommendations and Discussion.

II. CLIMATE

From http://www.nps.gov/thro/naturescience/weather.htm

Summers are warm with temperatures in the 80s and 90s with a few days into the 100s on some years. Evenings can be cool. Average maximum: July is 87.1° F and August is 86.7° F. Average minimum: July is 54.5° F and August is 52.4° F. Annual precipitation is 15 inches.

Table 1: Temperatures are in °F and precipitations are in inches

Month	Average Highs	Record High	Year	Average Lows	Record Low	Year	Average Precip.	Average Snowfall
January	26.9	66	1981	1.2	-49	1950	0.39	6.41
February	34.0	70	1992	8.0	-47	1962	0.36	5.13
March	43.5	80	1993	17.6	-33	1960	0.62	5.48
April	58.3	95	1980	29.1	-13	1975	1.43	3.26
May	70.8	101	1980	40.5	8	1967	2.27	0.71
June	79.5	107	1988	49.8	28	1964	3.36	T
July	87.1	110	1981	54.5	34	1968	2.05	T
August	86.7	105	1988	52.4	28	1964	1.42	T
September	74.6	106	1978	41.1	13	1961	1.40	0.17
October	62.4	95	1953	30.3	-13	1991	0.86	0.76
November	42.9	79	1975	17.5	-31	1985	0.48	4.28
December	31.5	66	1979	6.6	-44	1983	0.45	5.44

III. PREVIOUS PROJECTS

The title sheet for Projects 7(1) 8.1-E(1) Grading, Drainage, Surfacing & Bridges NORTH UNIT ACCESS ROAD 7 SOUTH UNIT ROAD was signed & advertised in 1983 with the North Unit Access Road portion covering the same station for THRO 10(3) although different stationing numbers were assigned and in reverse direction. Length of the North Unit project was 5.09 miles. Final inspection was June 1985. The typical pavement structural section was 0.5 inch open graded friction course on 2 inches bituminous pavement on 6 inches base course on 8 inches subgrade soil stabilization with either lime or for a 1.23 mile section a lime fly-ash mixture was incorporated. The Squaw Creek Bridge was also constructed as well as a 12 feet structural plate pipe at approximately MP 1.25.

NPS Project 1540-0349 was dated January 1974. The length of the project was 8.66 miles. The roadway was graded, base course imported, and paved along with 7 parking areas: Long X Cattle Trail Turnout, Caprock Coulee Turnout, River Bend Overlook, Bentonitic Clay Overlook, Man & Grass Turnout, Edge of Glacier Turnout, and Oxbow Overlook Parking Area at MP 13.87. Typical pavement structural section for all the paved surfaces was 3 inches bituminous pavement on 7 inches base course.

NPS Project No. 1540-1094 constructed Juniper Campground and Cannonball Concretions Pullout in 1976. Typical pavement structural section was 2 inches bituminous pavement on 6 inches base course.

ND THRO 10(2) North Unit Slide Repair was signed and completed in 2002. In addition to the slide repair, a 1.5 inch bituminous pavement overlay was applied to two sections of Scenic Drive from approximately MP 0.3 to MP 1.75, and at the Oxbow Overlook.

IV. EXPLORATION

A pavement and geotechnical investigation occurred May 10 & 11, 2006. The pavement investigation used a truck mounted drill rig, a Longyear BK-81 by Haz Tech Drilling of Billings, MT to auger through the existing pavement and to continue into the subgrade from 1 foot to 5 feet in depth. CFL personnel logged the borings. Pavement thicknesses were recorded, as were the soil description. Samples were labeled from C-1 to C-61. Sampling was generally every ¼-mile. Mileposts were recorded for sample locations.

The geotechnical investigation concentrated on MP 6.8 to 7.8, an area known as Cedar Canyon. One geotech boring was placed at MP 1.27, labeled B-8 in the geotechnical report. The borings indicate the subgrade consists of poor soils to a significant depth.

V. EXISTING PAVEMENT

The following pavement condition was based on conditions as existed during the investigation in May 2006.

Existing pavement was measured at ¼-mile increments, so irregularities could exist between measurements. Good gravel base containing some sand and clay existed typically to a depth of 9 inches for the length of THRO 10(3). A clayey gravel base course then existed until the Cedar Canyon area at MP 7.0. Once on the plateau starting at MP 7.8, the River Bend Overlook, and the better base course returned until MP 12.0. From MP 12.0 to the end of Scenic Drive at MP 13.87 the base course was the lower strength clayey gravel material.

Table 2: Pavement Conditions for Scenic Drive for MP 0.0 to 4.9

Milepost	Pavement Thickness (inches)	Road Width (feet)	Pavement Conditions
0.0 to 0.3	3.25	28	High severity block, edge, & transverse cracking, particularly at utility locations. High severity alligator cracking on park housing roadway.
0.3 to 1.8	5.0	27.2	1 ½ inch overlay applied in 2002 for the THRO 10(2) project. Patch is not continuous as only 1600 tons were laid. Project Engineer related that the pavement was highly distress prior to overlay. At present low severity cracks are reflecting up through.
1.8 to 2.5	3.5	27.9	High severity transverse and edge cracking. Patching, pavement heaving, and 1/2 inch rut in outer wheel line at MP 2.25 are indicative that the subgrade is becoming more moist.
2.5 to 4.9	3.5	27.9	Average subgrade moisture content was 27%. The pavement condition reflects this with ¼ inch to ½ inch rutting in places, high severity alligator, longitudinal, transverse, & edge cracking.

For future projects Table 3 is provided, recording the May 2006 condition of the pavement.

Table 3: Pavement Conditions for Scenic Drive for MP 4.9 to 13.87

Milepost	Pavement Thickness (inches)	Road Width (feet)	Pavement Conditions
4.9 to 6.75	3.25	26.6	Moderate severity transverse and edge cracking. ¼ inch rut at MP 5.0 & 6.25. High severity longitudinal cracking at MP 6.75.
6.75 to 7.80	-	-	Spot repairs being performed summer 2008 by THRO 10(4). Section covered by Geotech Report #ND-PX-THRO-08-01.
7.8 to 13.87	3.0	25.9	High severity transverse cracking and moderate severity longitudinal and edge cracking. Skin patch from MP 8.5 to 9.25.

Typical pavement distresses were recorded and photos were taken to further document the condition of the pavement. Laboratory test results and photographs of the boring locations are provided in the appendices in the back of this report.

PAVEMENT & BASE COURSE THICKNESSES

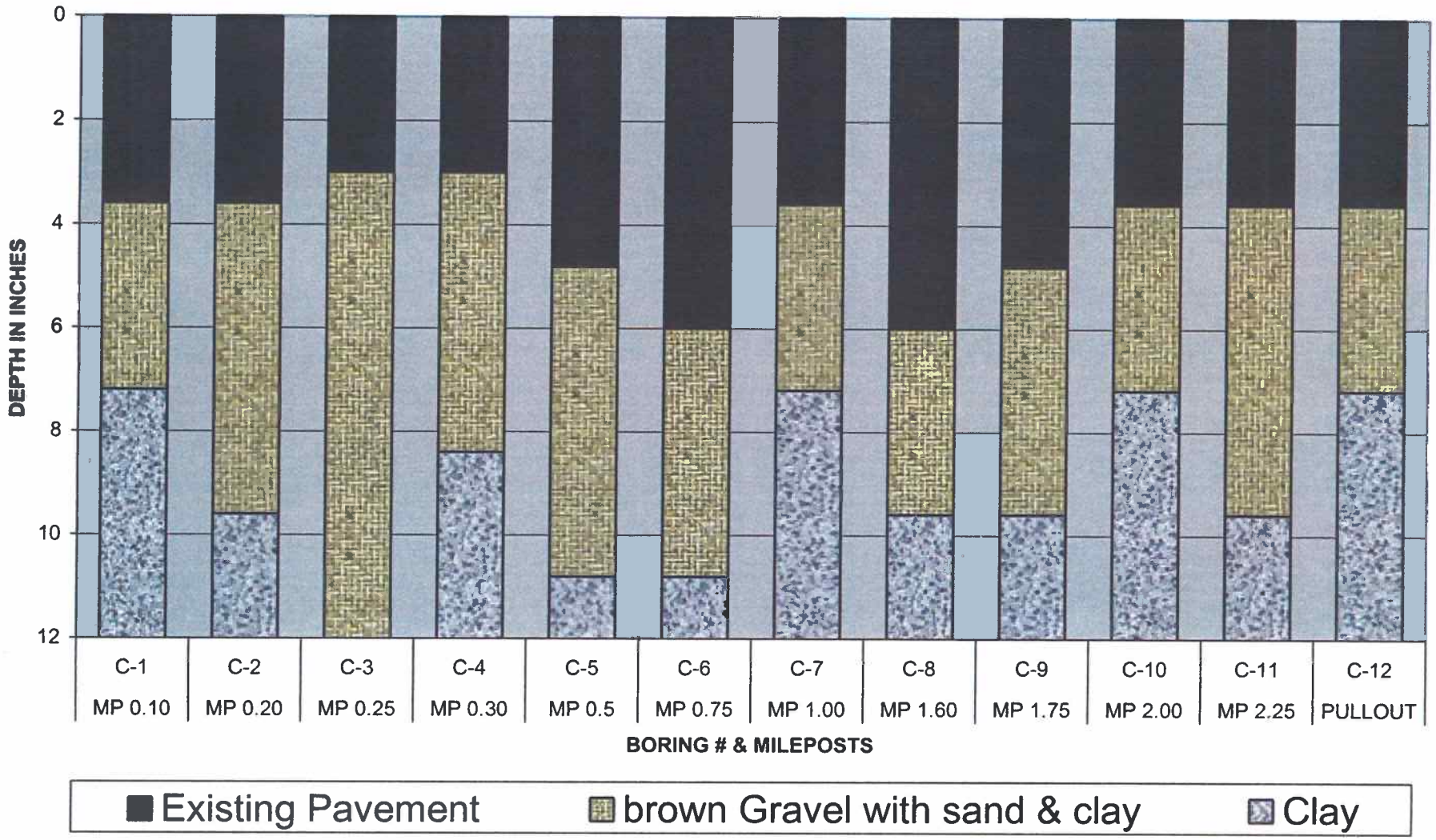


Chart 1

ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE

PAVEMENT & BASE COURSE THICKNESSES

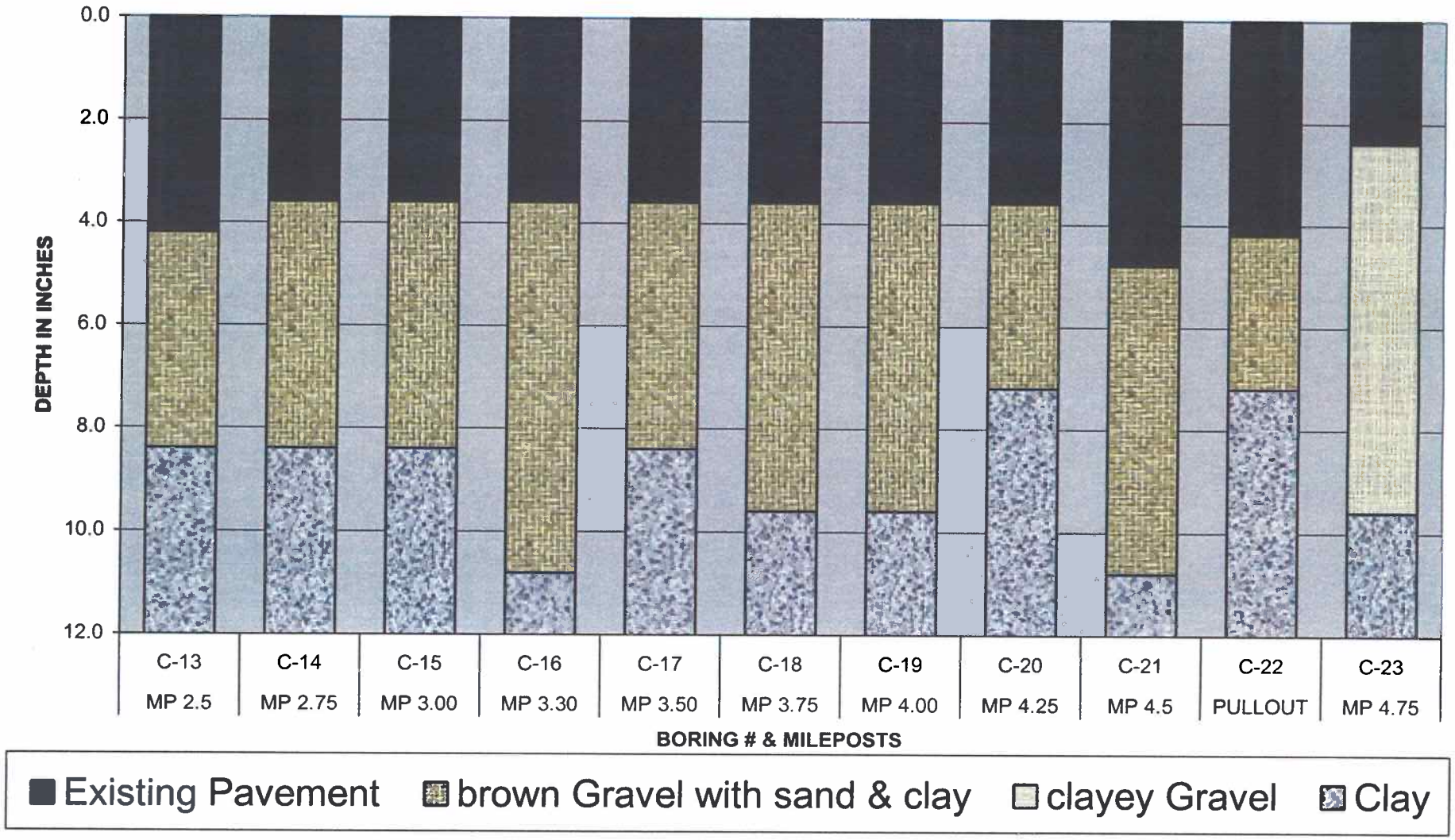


Chart 2

PAVEMENT & BASE COURSE THICKNESSES

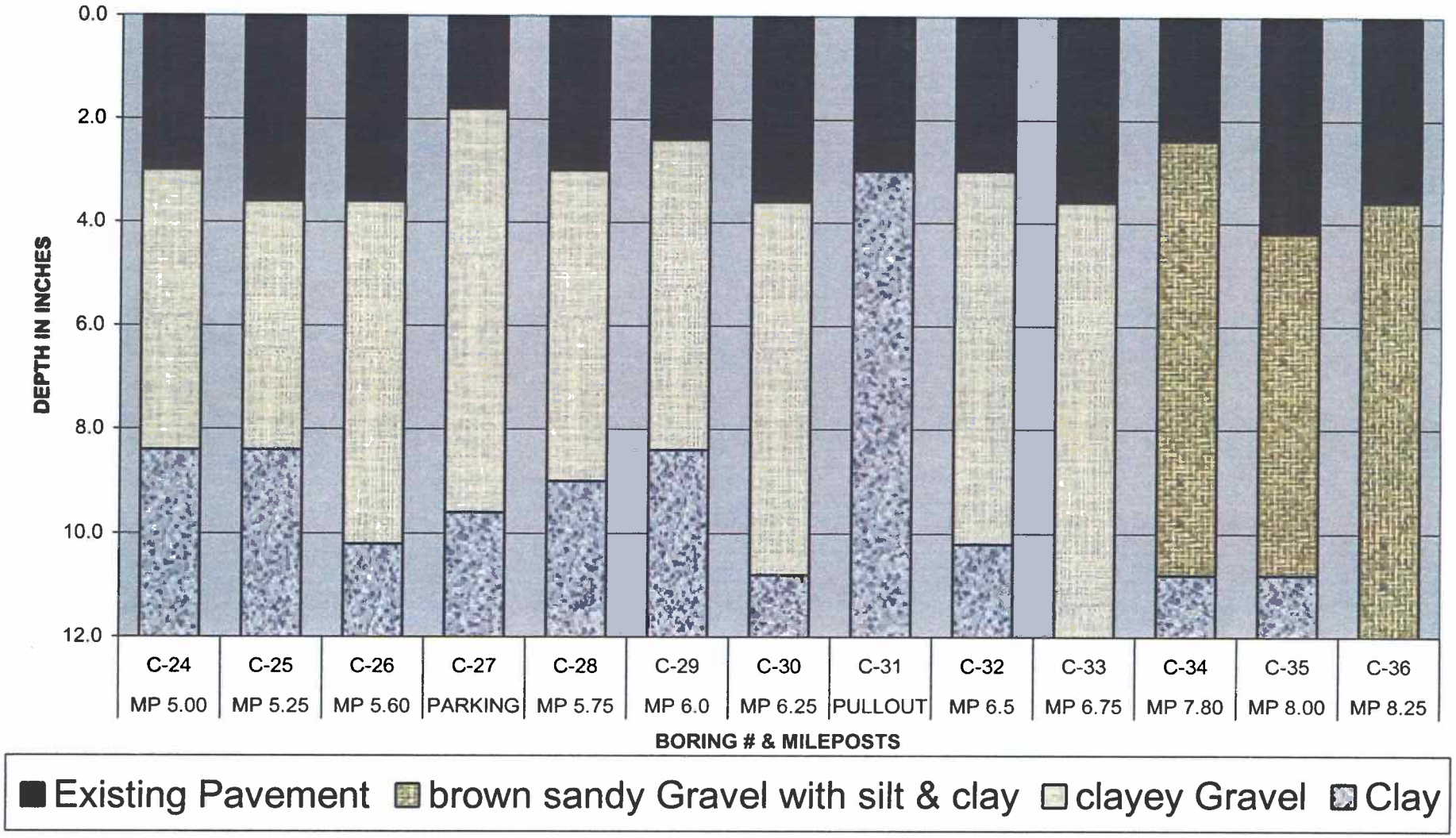


Chart 3

PAVEMENT & BASE COURSE THICKNESSES

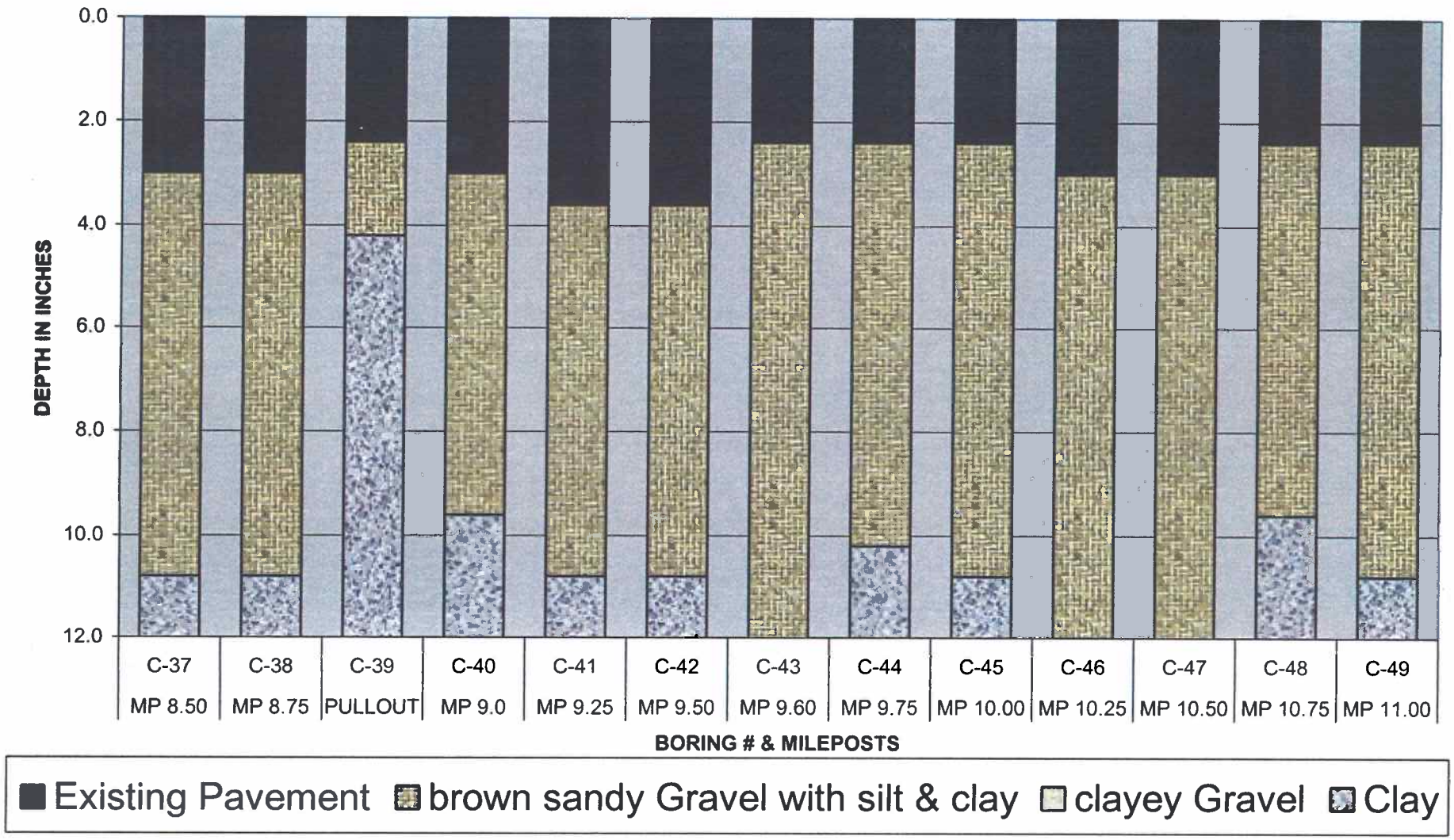


Chart 4

ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE

PAVEMENT & BASE COURSE THICKNESSES

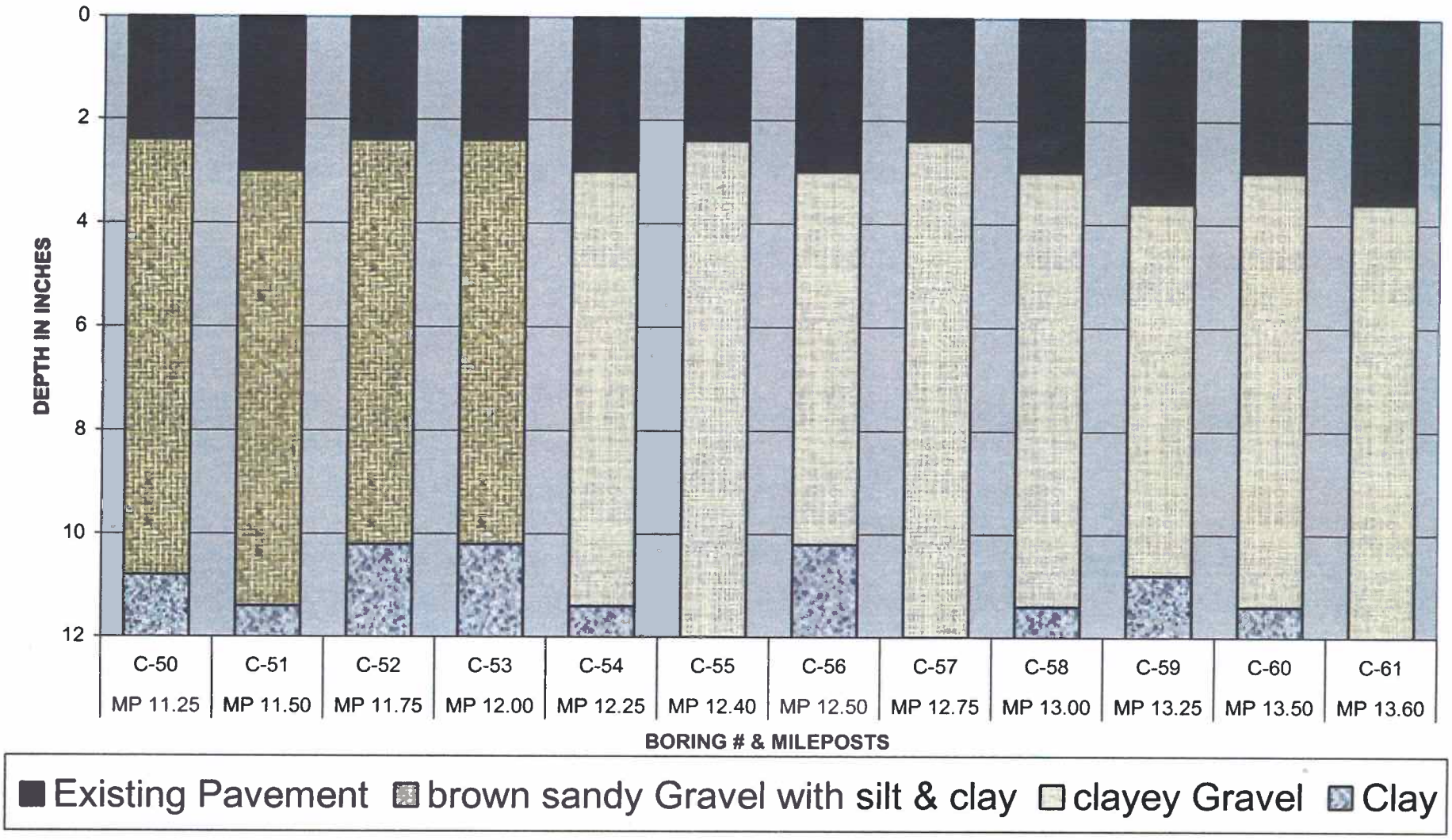


Chart 5

VI. TEST RESULTS

The following soil information was collected from the May 2006 investigation, the Soil and Foundation Investigation 1981 Report, and the Geotechnical Report 93-13. For MP 0.0 to 4.9 the prevalent soil classification per AASHTO M 145 was A-7-6, with some A-6 classifications and one A-4 classification.

Tables 4 & 6 presents the range of values for R-Values, plasticity index (PI), liquid limit (LL), and percent passing the -#4 and #200 sieves. More laboratory results are in Appendix B. As the investigation was for the whole route and the upcoming ND PRA 10(3) NORTH UNIT SCENIC DRIVE project will likely cover MP 0.0 to 4.9, the following tables have been split to highlight MP 0.0 to 4.9.

For the Tables 4 & 6 below: A - Black ink is data from the May 2006 investigation
B - Blue ink is data from 1981 Report
Italicize blue ink is proposed new alignment (built in 1983) from 1981 Report
C - Red ink is data from Report 93-13

Table 4: Scenic Drive Subgrade Summary for MP 0.0 to 4.9

Report Designation	MP	AASHTO M 145	R-Value	PI	LL	- #4	- #200
B	**0.27**	**A-7-6**	**10**	**24**	**42**	**100**	**81**
B	***0.50***	***A-7-6***	***-***	***99***	***132***	***100***	***99***
B	**0.56**	**A-7-6**	**<5**	**56**	**82**	**100**	**99**
B	***0.70***	***A-7-6***	***-***	***71***	***94***	***100***	***99***
B	**0.76**	**A-7-6**	**11**	**26**	**47**	**100**	**98**
A	1.00	A-6	-	23	40	97	70
B	**1.09**	**A-6**	**17**	**21**	**40**	**100**	**88**
B	***1.60***	***A-7-6***	***-***	***110***	***133***	***100***	***99***
B	***1.67***	***A-7-6***	***-***	***84***	***112***	***100***	***93***
B	**1.68**	**A-7-5**	**<5**	**183**	**218**	**100**	**100**
A	2.00	A-6	23	14	35	92	45
B	**2.20**	**A-6**	**18**	**21**	**40**	**99**	**81**
A	3.00	A-6	-	15	39	95	59
B	**3.17**	**A-7-6**	**<5**	**49**	**70**	**100**	**98**
B	**3.18**	**A-7-5**	**<5**	**114**	**144**	**100**	**99**
A	3.50	A-7-6	8	23	42	99	69
B	**3.92**	**A-4**	**20**	**9**	**36**	**99**	**93**
B	**4.57**	**A-7-6**	**<5**	**77**	**96**	**99**	**91**

Tables 5 & 7 contain values from the dynamic cone penetrometers (DCP). The DCP drops a 8 kilogram (17.6 lbs) weight a distance of 575 mm (22.6 inches) to drive a 20 mm (0.79 inches) diameter harden steel cone. As repeated drops are made, the measurements are converted to mm/blow. These values can be converted to in-situ California Bearing

Ratio (CBR) via a chart prepared by the US Army Corp of Engineers. In general, values of 10 mm/blow or less indicate good roadbed supporting soils, those of 10 to 25 mm/blow indicate fair soils, and poor soils have values exceeding 25 mm/blow. The procedure is highly dependent on the in-situ moisture content of the soil and those values are included in Table 5 & 7.

Table 5: DCP values for MP 0.00 to 4.9

MP	DCP mm/blow	DCP Depth	Moisture Content %	Moisture Content Depth	Nearest Soils Classification on either side
1.60	13.0	9.6 inches to 3 feet	5.40	9.6 inches to 12 inches	A-7-5 to A-6
2.50	31.4	10.8 inches to 2.75 feet	30.40	8.4 inches to 1 foot	A-6 to A-7-6
4.5	35.7	1.2 feet to 2.8 feet	25.40	12 inches to 1.5 feet	A-7-6 to A-6

Soil classifications ranged for MP 4.9 to 13.87 from A-7-6 to A-4 with no definable boundary zones. R-Values were higher but still very mixed.

Table 6: Scenic Drive Subgrade Summary MP 4.9 to 13.87

Report Designation	MP	AASHTO M 145	R-Value	PI	LL	- #4	- #200
B	**5.14**	**A-6**	**16**	**18**	**36**	**92**	**63**
A	6.00	A-7-6	3	23	42	97	73
C	**6.50**	**A-4**	**47**	**7**	**31**	**99**	**95**
C	**7.00**	**A-7-6**	**<5**	**67**	**91**	**97**	**85**
C	**8.00**	**A-4**	**28**	**1**	**24**	**100**	**93**
C	**9.5**	**A-6**	**<7**	**17**	**36**	**99**	**84**
C	**10.00**	**A-7-6**	**7**	**27**	**49**	**98**	**84**
A	10.00	A-7-6	9	26	46	98	76
C	**11.00**	**A-6**	**<7**	**20**	**38**	**94**	**76**
C	**12.00**	**A-4**	**21**	**6**	**28**	**98**	**93**
A	12.00	A-6	13	14	31	99	42
C	**13.00**	**A-4**	**18**	**10**	**26**	**99**	**75**

DCP values were still in the poor range with values >25 mm/blow. The sensitivity of the moisture content is demonstrated by the reading at MP 10.5 with 24.0 mm/blow. The moisture content was 7.7 % for soils that were field identified as clay and bracketed by A-7-6 & A-6 soil classification tests.

Table 7: DCP values for MP 4.9 to 13.87

MP	DCP mm/blow	DCP Depth	Moisture Content %	Moisture Content Depth	Nearest Soils Classification on either side
5.60	30.2	10.8 inches to 3.4 feet	10.00	9.6 inches to 1 foot	A-6 to A-7-6
6.50	29.8	12 inches to 3.1 feet	-	-	A-4 to A-7-6
8.50	42.1	10.8 inches to 3.2 feet	16.10	10.8 inches to 1.2 feet	A-4 to A-6
9.50	29.5	10.8 inches to 2.7 feet	11.90	10.8 inches to 1.2 feet	A-6 to A-7-6
10.50	24.0	1.2 feet to 3.2 feet	7.70	11.4 inches to 1.2 feet	A-7-6 to A-6
11.50	27.2	11.4 inches to 3.2 feet	11.80	11.8 inches to 1.1 feet	A-6 to A-4
12.50	33.5	10.8 inches to 3.1 feet	19.60	10.2 inches to 1.25 feet	A-6 to A-4
13.50	43.8	12 inches to 3.3 feet	13.10	10.8 inches to 1.2 feet	A-4

VII. PAVEMENT RECOMMENDATIONS & DISCUSSION

Traffic counts were collected in August 2006 by CFL's traffic counters. Average daily traffic (ADT) was less than 100 with passenger vehicles comprising 94% of the counts. For the pavement design calculations, an ADT of 200 was input with 6% recreational vehicles or trucks and the resulting combined equivalent single axle loads (ESALs) generated was less than federal lands minimum pavement loading, 50,000 ESALs. The minimum federal lands values were thus used in the pavement design. The pavement design calculations are located in Appendix D.

THRO 10(3) and MP 4.9 to 7.8

A soil resilient modulus of 3500 psi was used for the pavement design. This value was based on laboratory testing and field observations. The average existing pavement depth from MP 0.0 to 4.9 was 3.75 inches based on the May 2006 investigation depths. Base course classified as A-1-b averaged 5.0 inches from MP 0.0 to 4.9. Together the existing pavement and base course averaged 9.0 inches for those same mileposts. The required pavement design structural number (SN) is 2.53. The following is the recommended pavement structural sections:

Option 1: Recommended Pavement Structural Section
3.5 inches HACP
7 inches FDR – Pulverize
SN = 2.54
Grade Raise = 3.5 inches
Cost Estimate = $480,000 per mile for HACP & FDR – Pulverize items only

Pros: This process has no cure time and thus lower traffic control costs. FDR – Pulverize is an unbound material allowing for some subgrade movement with a lower potential for cracking. In addition the HACP will be placed in two lifts for a smoother ride.

Cons: The process has potential for pumping/failing subgrade, and is more susceptible to softness due to rain. This option has the potential for higher subexcavation costs.

Option 2
2.5 inches HACP
8 inches FDR – Cement
SN = 2.54
Grade Raise = 2.5 inches
Cost Estimate = $465,000 per mile for HACP & FDR - Cement items only

Pros: This process creates a stiff platform for paving, lowers the potential for subexcavation, and is less susceptible to rain and the resulting softness. This option also has lower initial costs.

Cons: The process requires a curing time, and thus will have higher traffic control costs. The cost estimate above does not include traffic control costs. FDR - Cement has the potential for reflective cracking up through the HACP if the cement-treated base cracks from swelling or shrinking subgrade soils.

The above options are applicable for THRO 10(3), MP 0.0 to 4.9 and also for any future projects from MP 4.9 to MP 7.8, the River Bend Overlook. For MP 4.9 to 7.8 the average existing pavement thickness was 3.25 inches, base course average thickness was 6.25 inches, and together the average was 9.5 inches.

MP 7.8 to 13.87

Juniper Campground is at MP 4.8. Traffic and in particular the heavier recreational vehicles drop off significantly at this locality. For MP 7.8 to 13.87, end of Scenic Drive at the Oxbow Overlook the average existing pavement thickness was 3.0 inches, base course average thickness was 8.0 inches, and together the average was 11.0 inches. Existing cracks have been sealed and one patch noted, but otherwise no other maintenance activities have occurred. Two bore holes from the 1992 investigation were easily found so no overlays or sealing coats have been applied. The pavement is 34 years old. Based on empirical experience the recommended pavement structural section is:

3.0 inches HACP
7.0 inches FDR – Pulverize
Grade Raise = 3.0 inches

This section of roadway is in need of a pavement preservation treatment in the near future. Typically a chip seal is placed 3 years after paving and then every 5 to 8 years after that. It is recommended to place a chip seal for MP 7.8 to 13.87 as part of THRO 10(3).

Pavement Materials

•The HACP should be Item 40101-0500 Supepave, ½ inch nominal maximum size aggregate, with a Type II smoothness level. The unit weight can be estimated at 145 lb/ft^3. This project will be a candidate for the pilot use of a 50 or 65 gyration mix design.
•Hydrated lime (Type III), at 1%, will be the antistrip additive.
•The asphalt cement should be PG 58-34. Quantity can be estimated at 6.0% by weight of mix.
•The 3 inch depth or greater of HACP shall be placed in two lifts.
• A Tack coat will be required between lifts. For estimating purposes specify an emulsion such as CC-1, CSS_1h, SS-1, or SS-1h at an application rate of 0.10 gal/yd^2.
•A fog seal, Item 40920-1000 should be included in the contract. For determining quantities use an application rate of 0.10 gal/yd^2. The emulsion type can be a CSS-1, CSS-1h, SS-1, or SS-1h.
•Bid Item 41101-5000 Prime Coat Grade MC-70 should be applied on the pulverized base material or the base course as soon as possible to aid in shedding rainfall. For determining quantities use an application rate of 0.33 gal/yd^2. An item for blotter material, Item 41105-0000 should be included at 14.75 lb/yd^2.

Drainage, Subexcavation, and other Issues

Due to the clayey subgrade beneath Scenic Drive, it will be imperative that a prime seal be placed immediately onto the pulverized base material once that material is finished to grade. The prime seal will aid, along with proper grading, in shedding rainwater. If water is allowed to penetrate through unsealed base material, the subgrade will deteriorate and subcavation may become necessary.

To prevent saturation of the subgrade soils and structural damage due to hauling on saturated soils, the 303 SCR has been modified to conform to the following limitations:

- Do not begin pulverization operations until the Superpave Asphalt Concrete Pavement mix design has been submitted and approved by the CO.
- Pulverize the roadway in segments no greater than 2.5 lane-miles at any time.
- Apply prime coat to the pulverized material within 5 work days of pulverization beginning.
- Apply the first lift of Superpave Pavement to the primed segment within 14 working days of beginning of pulverization.
- Construction equipment including hauling trucks will be required to travel as much as practical on paved sections and minimize the traffic loading on pulverized material.

If subexcavation becomes necessary, follow the guidelines in the table below. The table is from Chapter 11 of the Project Development Design Manual (PDDM). Based on the soil classification testing it appears most of the subgrade would fall into the 2 feet depth category. As an alternative, the recommendations from the 11/4/2008 memo in Appendix H can be followed, which includes the use of geogrid.

Table 8: Subexcavation Guidelines

Plasticity Index (PI)	Liquid Limit (LL)	Depth of Subexcavation *
15 – 25	< 50	2 feet
25 – 35	50 – 60	2 – 4 feet
> 35	> 60	4 – 6 feet

* Traffic volume, project significance, and results of AASHTO T 258 and T 92 should influence subexcavation depth.

Due to the subexcavation repairs that will be performed from the ND PRA THRO 10(4) project, the quantities for estimating subexcavation listed in the Preliminary Pavement Recommendation Memo dated 12/8/2006 should now be reduced to 1000 cubic yards. This will allow for 100 feet of subexcavation at 2 feet depth per mile of construction. The subexcavation detail should include a geotextile and geogrid. The geotextile fabric should be a Type 1-C, non-woven for infiltration purposes, a minimum of 6 oz weight meeting the requirements of Table 714-1 of the FP-03 with the added restriction of a maximum of apparent opening size (AOS) of 0.15 mm. The geogrid should be BX1200 or equivalent.

For future projects, estimate subexcavation at 100 feet per mile at 3 feet depth for MP 4.96 to MP 7.8 to be conservative in the Cedar Canyon area, and 100 feet per mile at 2 feet depth for MP 7.8 to 13.87. The geotextile and geogrid requirements from above should also be included.

APPENDICES

A – Location Map

B – Laboratory Test Results

C – Photographs

D – Pavement Design Calculations

E – Field Data Summary

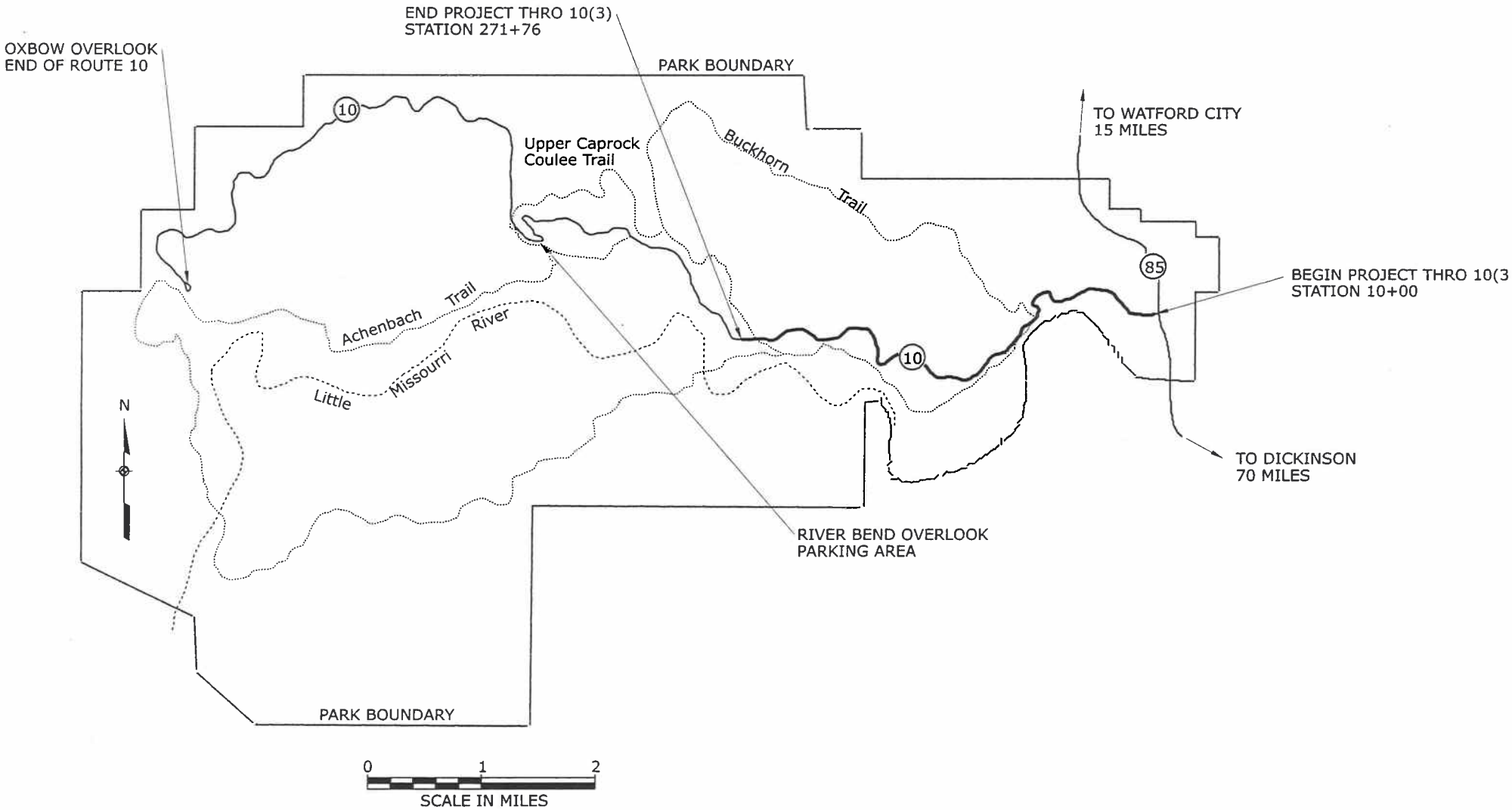
F – Soil and Foundation Investigation, August 1981

G – Geotechnical Report 93-13

H – ND PRA THRO 10(4) Memo dated 11/4/2008

APPENDIX A

LOCATION MAP


END PROJECT THRO 10(3)
STATION 271+76
OXBOW OVERLOOK
END OF ROUTE 10
PARK BOUNDARY
10
Upper Caprock
Coulee Trail
Buckhorn
Trail
TO WATFORD CITY
15 MILES
85
BEGIN PROJECT THRO 10(3
STATION 10+00
Achenbach
Trail
River
Missourri
Little
10
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TO DICKINSON
70 MILES
RIVER BEND OVERLOOK
PARKING AREA
PARK BOUNDARY
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SCALE IN MILES

APPENDIX B

LABORATORY TEST RESULTS

U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

AASHTO R18 ISO/IEC 17025

Report of Moisture Tests

Project: North Dakota PRA THRO 10 (3) North Unit Scenic Drive

Laboratory Numbers: See Below

Date Reported: 6/27/2006

Submitted By: Steve Deppmeier

Material Type: Subgrade and Aggregate Base

Material Source: Bore Holes

Tested For: AASHTO T 265 Moisture Content of Soils

Field Sample Number: See Below

Test Results

Laboratory Number	Baggie	Coring	Milepost	Depth, Ft.	Moisture Content, %
06-429-SB	#1	C-4	0.3	0.7 – 1	4.5
06-430-SB	#2	C-7	1.0	0.6 – 3	21.3
06-431-SB	#3	C-7	1.0	3 – 5	23.1
06-432-SB	#4	C-8	1.6	0.8 – 1.0	5.4
06-433-SB	#5	C-9	1.75	0.4 – 0.8	9.7
06-434-SB	#6	C-10	2.0	0.6 – 3	18.4
06-435-SB	#7	C-10	2.0	3 – 5	17.3
06-436-SB	#8	C-13	2.5	0.7 – 1	30.4
06-437-SB	#9	C-14	2.75	0.3 – 0.7	4.8
06-438-SB	#10	C-15	3.0	0.7 – 1.7	27.8
06-439-SB	#11	C-17	3.5	0.3 – 0.7	7.8
06-440-SB	#12	C-17	3.5	0.7 – 3	26.0
06-441-SB	#13	C-17	3.5	3 – 5	19.0
06-442-SB	#14	C-21	4.5	1 – 1.5	25.4
06-443-SB	#15	C-26	5.6	0.8 – 1	10.0
06-444-SB	#16	C-29	6.0	0.7 – 5	17.6
06-445-SB	#17	C-35	8.0	0.35 – 0.9	5.3
06-446-SB	#18	C-37	8.5	0.9 – 1.2	16.1
06-447-SB	#19	C-42	9.5	0.9 – 1.2	11.9
06-448-SB	#20	C-45	10.0	0.9 – 3.5	23.5
06-449-SB	#21	C-47	10.5	0.95 – 1.2	7.7
06-450-SB	#22	C-51	11.5	0.95 – 1.1	11.8
06-451-SB	#23	C-53	12.0	0.85 – 5	14.3
06-452-SB	#24	C-56	12.5	0.85 – 1.25	19.6
06-453-SB	#25	C-58	13.0	0.25 – 0.9	4.5
06-454-SB	#26	C-58	13.0	0.9 – 4	14.9
06-455-SB	#27	C-60	13.5	0.9 – 1.2	13.1

Distribution:
Laboratory
Pavements
Materials

Num. / Project File
Darrell Harding
Steve Deppmeier
1 Copy

Reported By:

Darrell Harding

Form FHWA 1742 Rev. 12/01

U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

AASHTO R18 ISO/IEC 17025

Report of Soil or Aggregate Tests

Project: North Dakota PRA THRO 10 (3) North Unit Scenic Drive
Submitted By: Steve Deppmeier

Date Reported: 6/27/2006

Sample Number	Lab Number		06-456-RV	06-457-S	06-458-RV	06-459-S	06-460-RV
	Coring Number		C-4, 20 & 33	C-7	C-10	C-15	C-17
	Field Number		Sacks 1, 7 & 9	Sack #2	Sack #3	Sack #4	Sacks #5 & #6
Sample Location	Milepost		0.3, 4.25 & 6.8	1.0	2.0	3.0	3.5
	Depth, Feet		0.25-0.7 0.3-0.7 0.3-1.3	0.6-3	0.6-3	0.7-1.7	0.7-3
AASHTO T 11, T 27 & T 88 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm					
	3/4"	19.0 mm	100	100	100		
	1/2"	12.5 mm	92	99	99	100	
	3/8"	9.5 mm	84	99	97	99	100
	#4	4.75 mm	66	97	92	95	99
	#8	2.36 mm					
	#10	2.00 mm	51	94	84	91	97
	#16	1.18 mm	42	91	78	86	95
	#30	600 µm					
	#40	425 µm	27	86	66	78	91
	#50	300 µm					
	#100	150 µm	16	80	56	69	85
	#200	75 µm	11	70	45	59	69
		20 µm					
		2 µm					
		1 µm					
AASHTO T 255	Moisture, %						
AASHTO T 89 & T 90	Liquid Limit		19	40	35	39	42
	Plasticity Index		2	23	14	15	23
Soil Classification	AASHTO M 145		A-1-b (0)	A-6 (14)	A-6 (3)	A-6 (7)	A-7-6 (14)
	ASTM D 2487		SW-SM	CL	SC	CL	CL
AASHTO T 190	R-Value		68		23		8
AASHTO T 288	Min. Resistivity, ohm-cm						440
AASHTO T 289	pH						8.7
AASHTO T 290	Sulfate Content, % / ppm						0.312 / 3120
AASHTO T 291	Chloride Content, % / ppm						0.0001 / 1

Distribution:

Laboratory	Num. / Project File
	Darrell Harding
Pavements	Steve Deppmeier
Materials	1 Copy

Remarks:
An FHWA consultant, Colorado Analytical Laboratories, performed the sulfate content and chloride content testing.

Laboratory Number 06-456-RV was a base course sample.

Reported By:
Darrell Harding

Form FHWA 1702 Rev. 12/01

U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

AASHTO R18 ISO/IEC 17025

Report of Soil or Aggregate Tests

Project: North Dakota PRA THRO 10 (3) North Unit Scenic Drive
Submitted By: Steve Deppmeier

Date Reported: 6/27/2006

Sample Number	Lab Number		06-461-RV	06-462-RV	06-463-RV	06-464-RV	
	Coring Number		C-29	C-41 & C-61	C-45	C-53	
	Field Number		Sack #8	Sacks 10 & 13	Sack #11	Sack #12	
Sample Location	Milepost		6.0	9.25 & 13.6	10.0	12.0	
	Depth, Feet		0.7-5	0.3-0.9 0.3-1.2	0.9-3.5	0.85-5	
AASHTO T 11, T 27 & T 88 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm					
	3/4"	19.0 mm	100	100			
	1/2"	12.5 mm	99	93	100	100	
	3/8"	9.5 mm	99	87	99	99	
	#4	4.75 mm	97	69	98	99	
	#8	2.36 mm					
	#10	2.00 mm	92	49	93	96	
	#16	1.18 mm	89	39	90	65	
	#30	600 µm					
	#40	425 µm	85	28	86	93	
	#50	300 µm					
	#100	150 µm	81	17	82	71	
	#200	75 µm	73	12	76	42	
		20 µm					
		2 µm					
		1 µm					
AASHTO T 255	Moisture, %						
AASHTO T 89 & T 90	Liquid Limit		42	23	46	31	
	Plasticity Index		23	7	26	14	
Soil Classification	AASHTO M 145		A-7-6 (16)	A-2-4 (0)	A-7-6 (19)	A-6 (2)	
	ASTM D 2487		CL	SW-SC	CL	SC	
AASHTO T 190	R-Value		3	63	9	13	
AASHTO T 288	Min. Resistivity, ohm-cm				860		
AASHTO T 289	pH				8.2		
AASHTO T 290	Sulfate Content, % / ppm				0.100 / 1000		
AASHTO T 291	Chloride Content, % / ppm				<0.0001 / <1		

Distribution:

Laboratory	Num. / Project File
	Darrell Harding
Pavements	Steve Deppmeier
Materials	1 Copy

Remarks:
An FHWA consultant, Colorado Analytical Laboratories, performed the sulfate content and chloride content testing.

Laboratory Number 06-462-RV was a base course sample.

Reported By:

Darrell Harding

Form FHWA 1702 Rev. 12/01

APPENDIX C

PHOTOGRAPHS

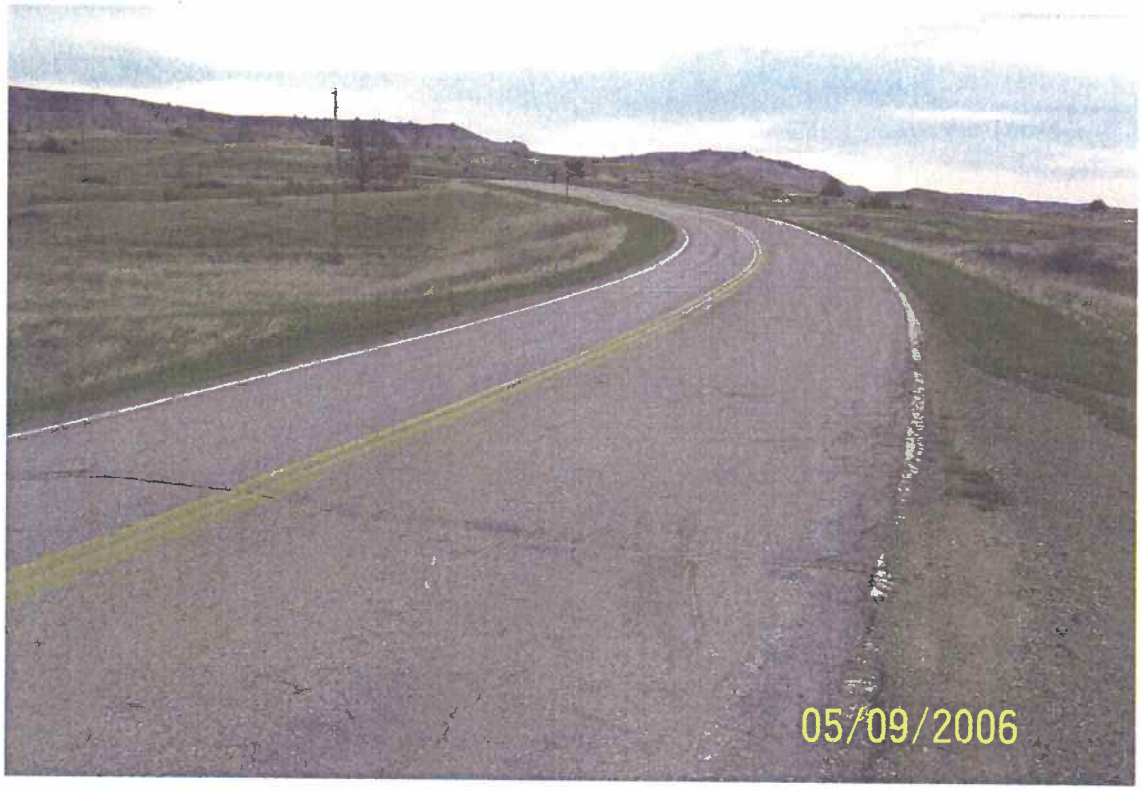

Photo 1: MP 0.10, Looking back to THRO 10(3) project's beginning, Subgrade is A-7-6

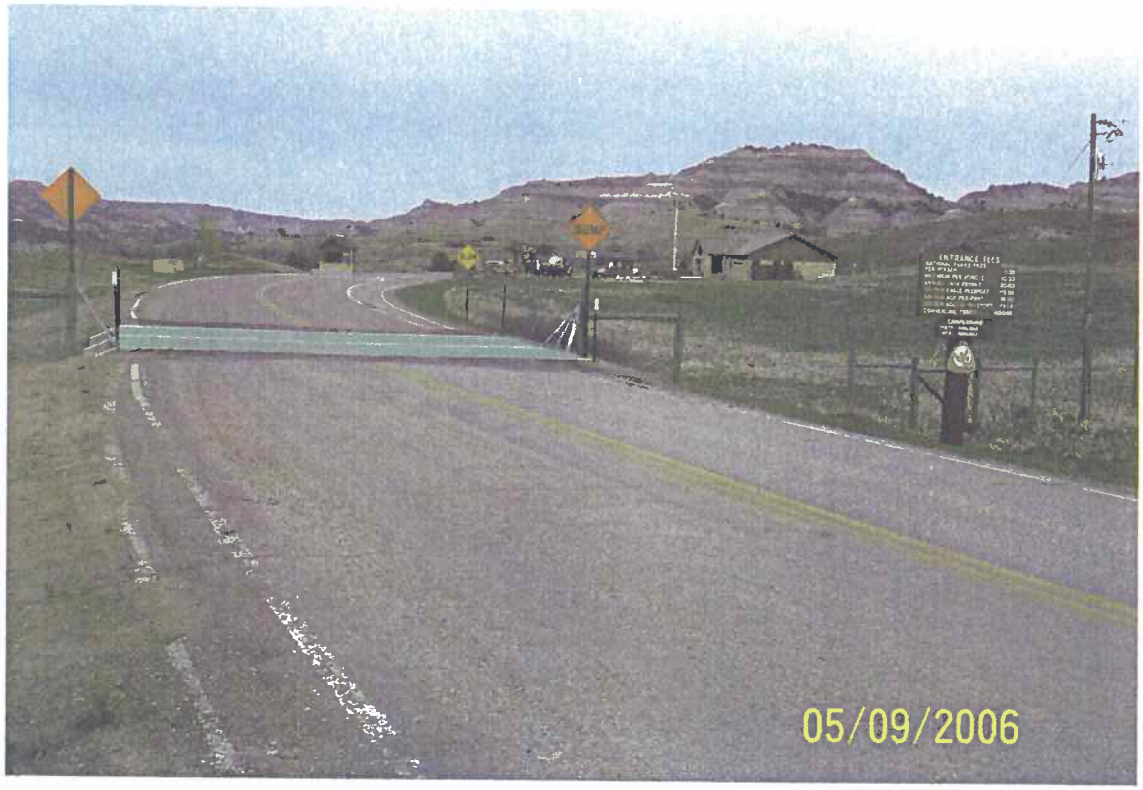

Photo 2: MP 0.10, Looking forward to Entrance Station

Photo 3: Entrance Station, Subgrade is A-7-6

Photo 4: Entrance Station looking forward

Photo 5: MP 0.5, @ Boring C-5, low severity transverse cracking reflecting through overlay placed in 2002

Photo 6: MP 0.75, @ Boring C-6, approximate 11/2 inch overlay

Photo 7: MP 1.0, @ Boring C-7, Subgrade is A-6 w/ 21.3% moisture content

Photo 8: MP 1.6, @ Boring C-8, also patched in 2002

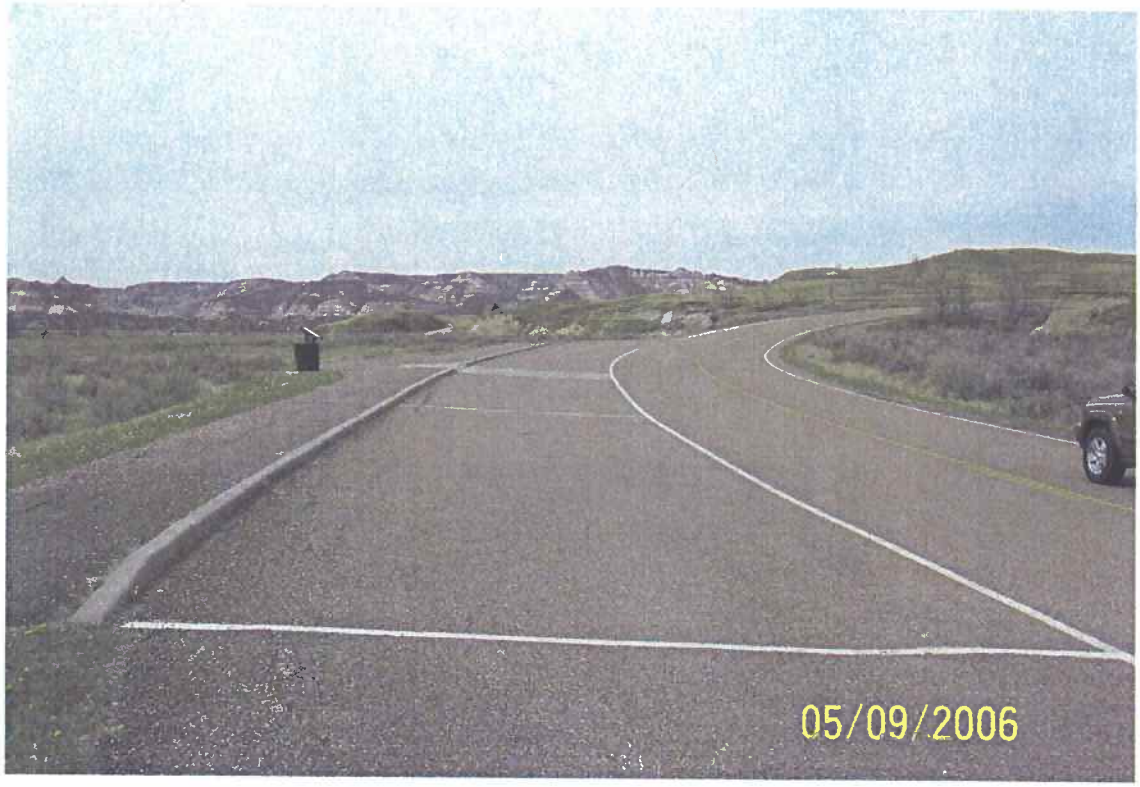

Photo 9: MP 2.25, @ Borings C-11 & C-12

Photo 10: MP 4.0, @ Boring C-19, some HACP stripping, left outbound lane has ¼ inch rutting

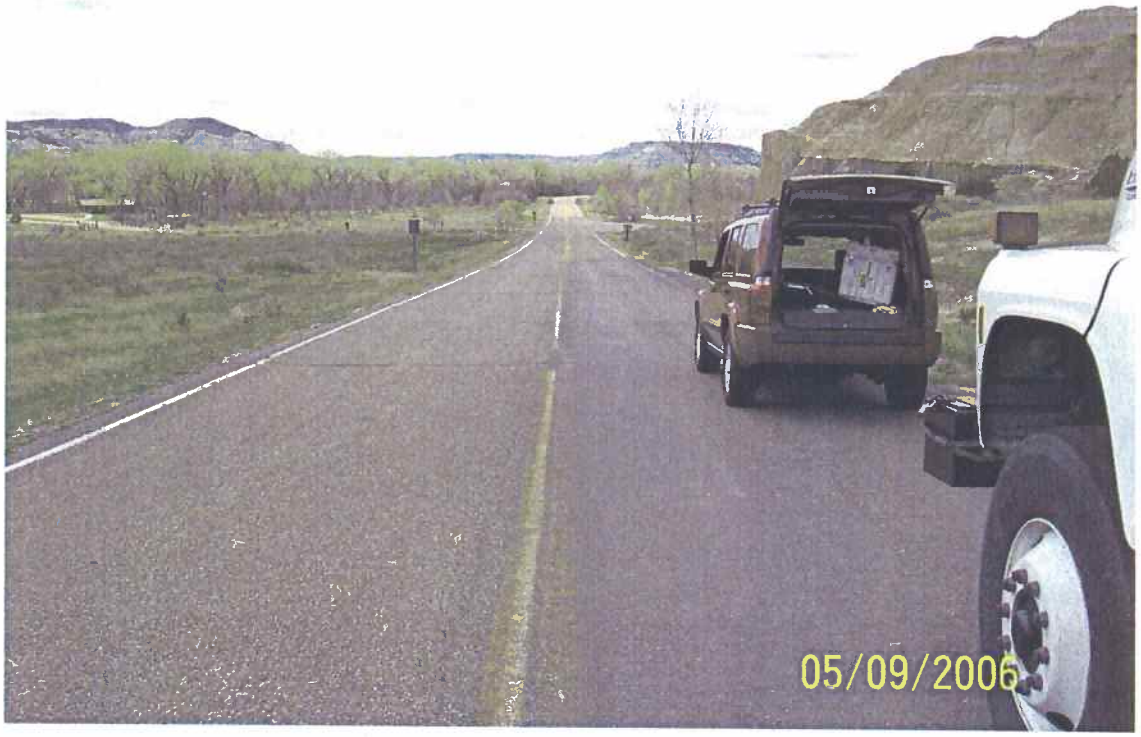

Photo 11: MP 4.5, @ Boring C-21, DCP was 35.7 mm/blow w/ 25.4% moisture content

Photo 12: MP 4.6, @ C-22, looking at THRO 1093) project's end with Squaw Creek Bridge in background

Photo 13: MP 5.0, @ Boring C-24, ¼ inch rut, moist foreslopes left & right

Photo 14: MP 5.6, @ Boring C-26, DCP was 30.2 mm/blow @ 10.0% moisture

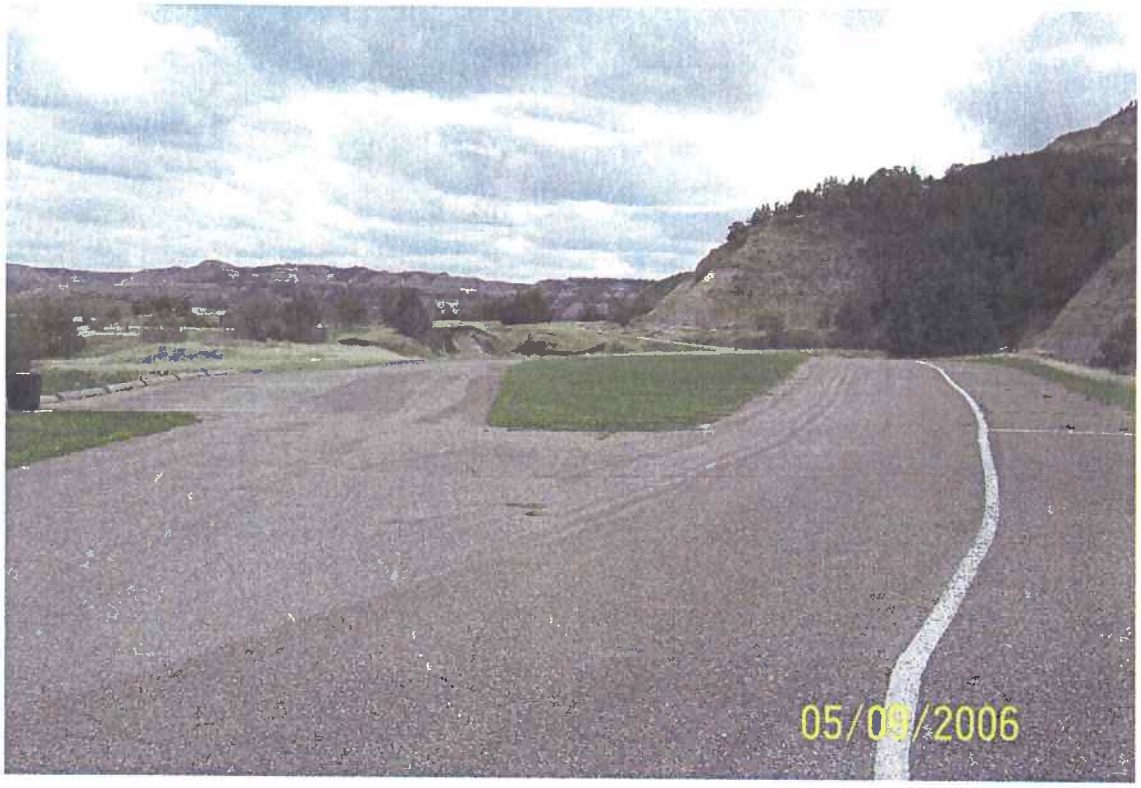

Photo 15: @ C-27, looking at Long X Cattle Trail Parking Area

Photo 16: MP 5.75, @ Boring C-28

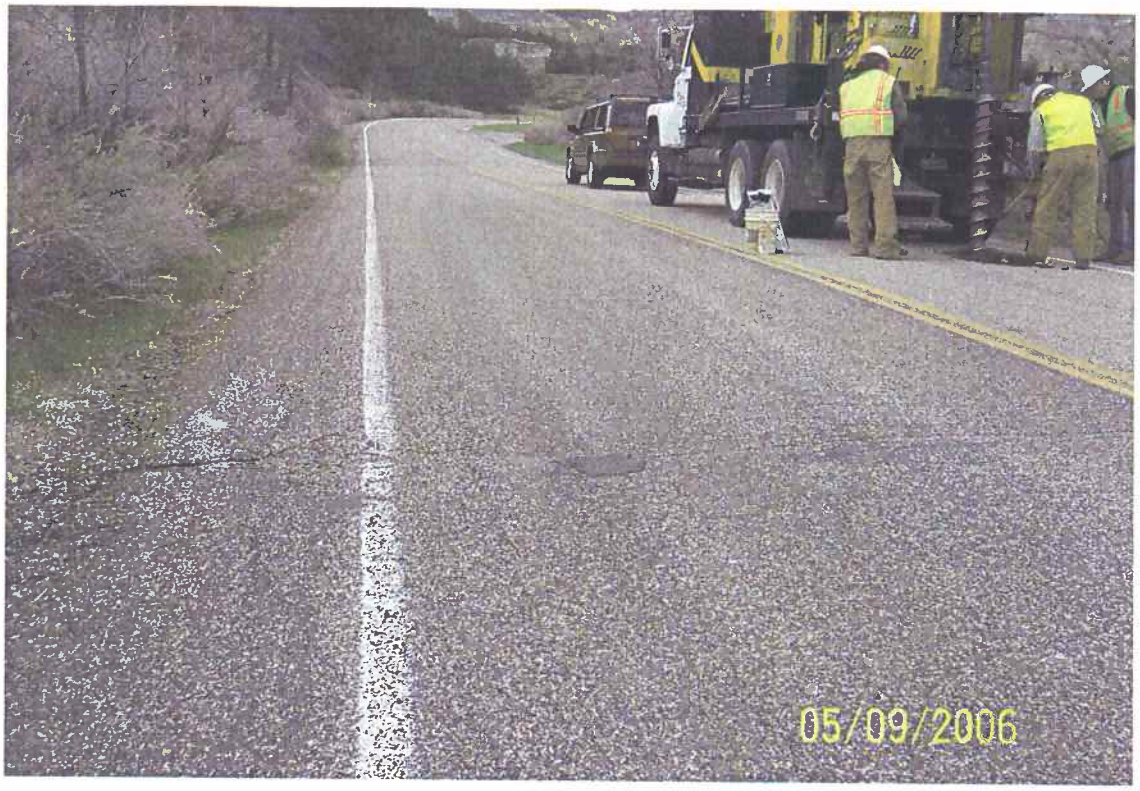

Photo 17: MP 6.25, @ Boring C-30, less ¼ inch rutting

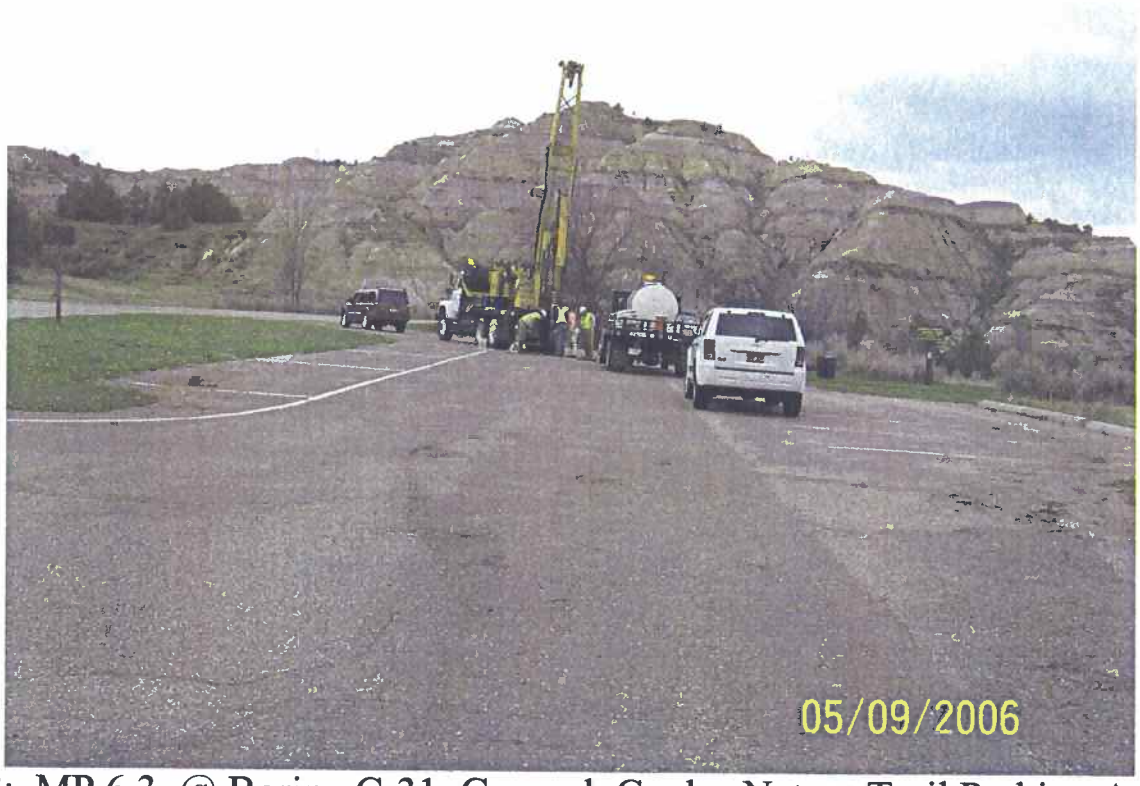

Photo 18: MP 6.3, @ Boring C-31, Caprock Coulee Nature Trail Parking Area, high severity alligator cracking

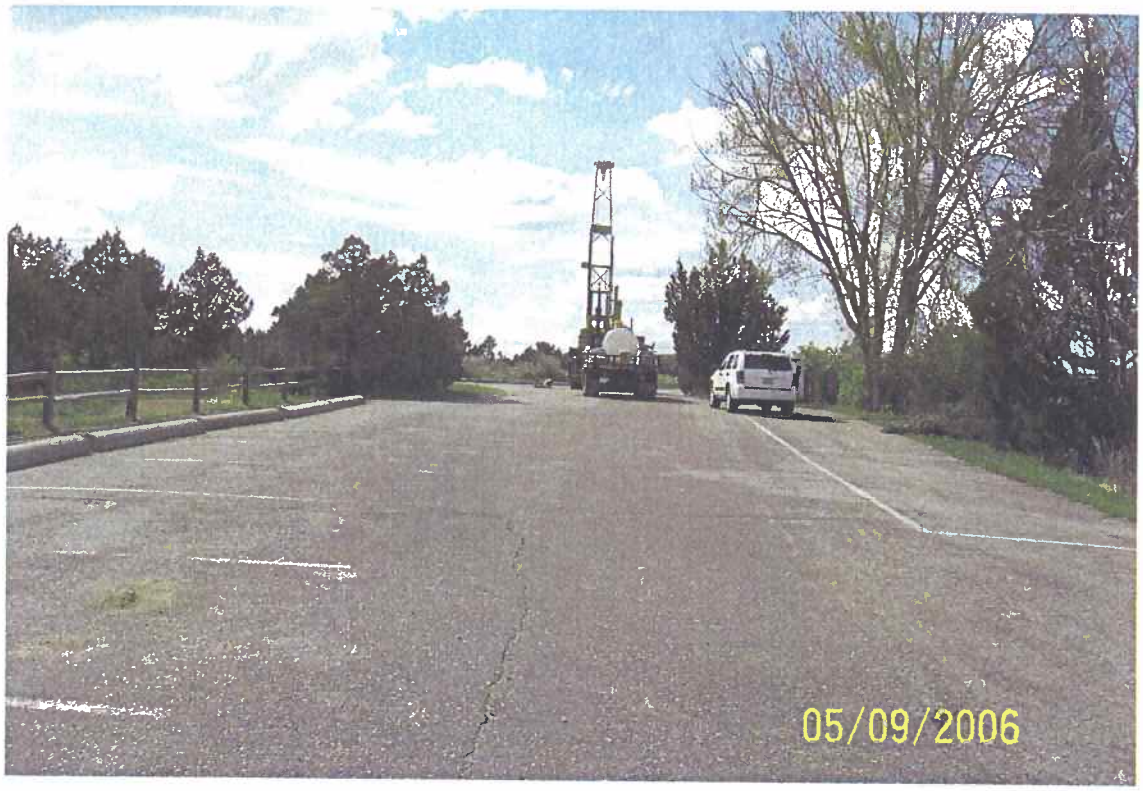

Photo 19: MP 7.8, @ Boring C-34, River Bend Overlook Parking

Photo 20: MP 8.0, @ Boring C-35, begin proposed Chip Seal

Photo 21: MP 8.25, @ C-36, high severity transverse cracking

Photo 22: MP 8.75, @ C-38, less ¼ inch rut in outer wheel line for both lanes

Photo 23: @ C-39, Bentonic Clay Overlook Parking Area

Photo 24: MP 9.0, @ C-40, high severity transverse cracking

Photo 25: MP 9.5, @ C-42, DCP was 29.5 mm/blow @ 11.9% moisture content

Photo 26: MP 9.6, @ C-43, Man & Grass Overlook Parking Area

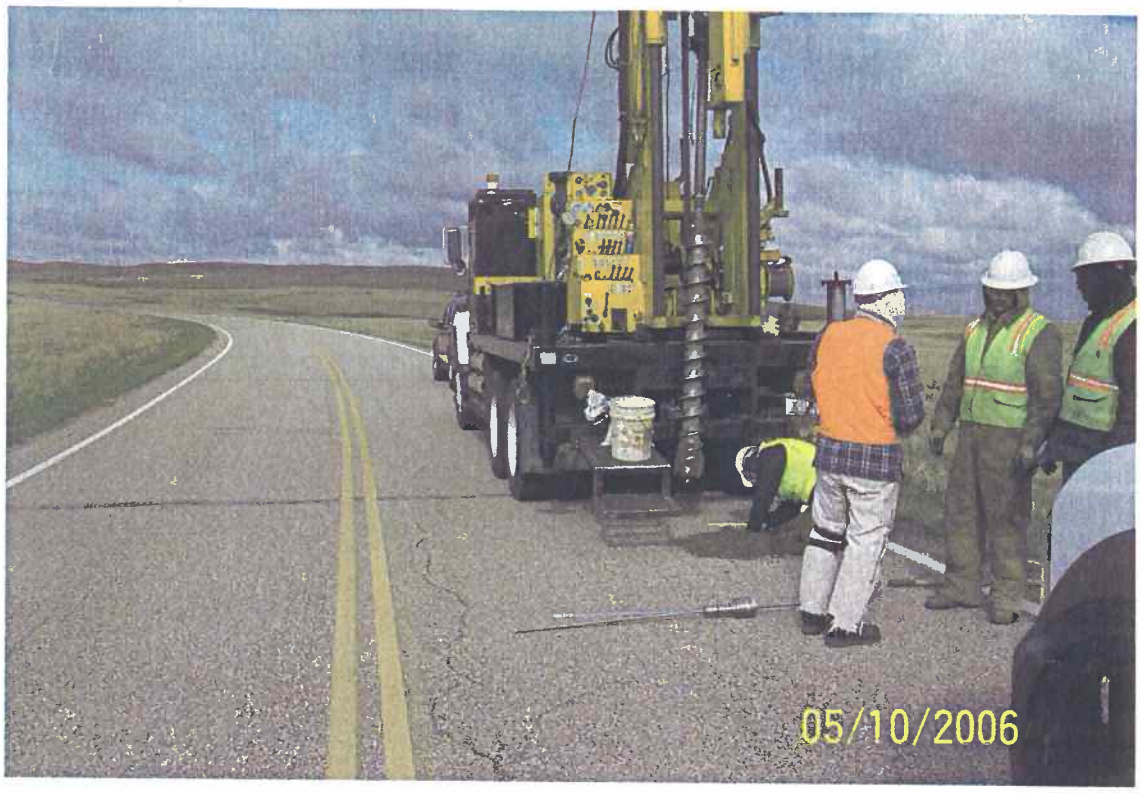

Photo 27: MP 10.5, @ C-47, old borehole from 1992 in the left mid-lane, DCP was 24.0 mm/blow @ 7.7% moisture content

Photo 28: MP 11.5, @ C-51, DCP was 27.2 mm/blow @ 11.8% moisture content

Photo 29: MP 12.0, @ C-53, again a Borehole from 1992 in the left mid-lane.

Photo 30: MP 13.6, @ C-61, Oxbow River Bend Overlook Parking, end of Scenic Drive

APPENDIX D

PAVEMENT DESIGN CALCULATIONS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

ND THRO 10(3)
MP 0.0 to 4.9 and MP 4.9 to 7.8 Recommended Structural Section

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	50,000
Initial Serviceability	4.2
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,500 psi
Stage Construction	1
Calculated Design Structural Number	2.53 in

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	200
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	60 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
2	94	2	0.0004	0	392
3	3	2	0.004	0	125
5	2	2	1	0	20,863
6	1	2	2	0	20,863
Total	100	-	-	-	42,244

Growth	Simple
Total Calculated Cumulative ESALs	42,244

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	HACP	0.44	1	3.5	-	1.54
2	FDR - Pulverize	0.12	1	7	-	0.84
3	Existing Base Course	0.08	1	2	-	0.16
Total	-	-	-	12.50	-	2.54

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

ND PRA THRO 10(3)
MP 0.0 to 4.9 Alternative Structural Section

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	50,000
Initial Serviceability	4.2
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,500 psi
Stage Construction	1
Calculated Design Structural Number	2.53 in

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	200
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	60 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
2	94	2	0.0004	0	392
3	3	2	0.004	0	125
5	2	2	1	0	20,863
6	1	2	2	0	20,863
Total	100	-	-	-	42,244

Growth	Simple
Total Calculated Cumulative ESALs	42,244

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	HACP	0.44	1	2.5	-	1.10
2	FDR - Cement	0.18	1	8	-	1.44
Total	-	-	-	10.50	-	2.54

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

ND PRA THRO upper section
MP 7.8 to 13.87

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	50,000
Initial Serviceability	4.2
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,500 psi
Stage Construction	1
Calculated Design Structural Number	2.53 in

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	200
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	60 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
2	97	2	0.0004	0	405
5	2	2	1	0	20,863
6	1	2	2	0	20,863
Total	100	-	-	-	42,131

Growth	Simple
Total Calculated Cumulative ESALs	42,131

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	HACP	0.44	1	3	-	1.32
2	PULVERIZE	0.12	1	8	-	0.96
3	Existing Base Course	0.1	1	2	-	0.20
Total	-	-	-	13.00	-	2.48

ND PRA 10(3) NORTH UNIT SCENIC DRIVE 12/8/2008

Paved width = 28 ft.
Route = 4.96 miles

Option Items	inches convert to feet				length of route (ft)		width (ft)		unit weight		lbs to tons		tons		$ / ton		
3.5" HACP	3.5	x	0.0833	x	26,200	x	28	x	145.2	/	2000	=	15528	x $	120	=	$1,863,332
Lime	1%												155	x $	200	=	$31,056
2.5" HACP	2.5	x	0.0833	x	26,200	x	28	x	145.2	/	2000	=	11091	x $	120	=	$1,330,951
Lime	1%												111	x $	200	=	$22,183

		square feet convert to square yards							application rate		density		tons		$ / ton		
Tack	26,200	x	28	x	0.1111	=	81,503	x	0.1	/	241	=	34	x $	600	=	$20,291
Fog	26,200	x	28	x	0.1111	=	81,503	x	0.1	/	241	=	34	x $	600	=	$20,291
Prime	26,200	x	28	x	0.1111	=	81,503	x	0.33	/	253	=	106	x $	775	=	$82,389
Blotter	26,200	x	28	x	0.1111	=	81,503	x	14.75	/	2000	=	601	x $	40	=	$24,043
															SUBTOTAL		$147,015

		square feet convert to square yards													$ / sq yd		
7" Pulverizing	26,200	x	28	x	0.1111	=	81,503							x $	4	=	$326,012

		square feet convert to square yards													$ / sq yd		
8" Cement Treated	26,200	x	28	x	0.1111	=	81,503							x $	6	=	$489,018

	inches convert to feet				length of route (ft)		width (ft)		unit weight		lbs to tons		tons				
Cement @ 6%	8	x	0.0833	x	26,200	x	28	x	139	/	2000	=	33,977				
	33,977	x	0.06									=	2039	x $	200	=	$407,718

Option #1 3.5" HACP + 7" FDR - Pulverizing

$2,367,414 **total cost**

$477,301 **per mile**

Option #2 2.5" HACP + 8" FDR - Cement

$2,290,453 **total cost**

$461,785 **per mile**

Theodore Roosevelt National Park

Weather

Weather

"In midsummer the storms are rarely of long duration, bnut are very severe while they last."

Theodore Roosevelt

AVERAGE TEMPERATURES

Average	Max. Temp.	Min. Temp.
January	26.9	1.2
February	34.0	8.0
March	43.5	17.6
April	58.3	29.1
May	70.8	40.5
June	79.5	49.8
July	87.1	54.5
August	86.7	52.4
September	74.6	41.1
October	62.4	30.3
November	42.9	17.5
December	31.5	6.6

All temperatures in Fahrenheit

RECORD TEMPERATURES

	Max. Temp.	Year	Min. Temp.	Year
January	66	1981	-49	1950
February	70	1992	-47	1962
March	80	1993	-33	1960
April	95	1980	-13	1975
May	101	1980	8	1967
June	107	1988	28	1964

July	110	1981	34	1968
August	105	1988	28	1964
September	106	1978	13	1961
October	95	1953	-13	1991
November	79	1975	-31	1985
December	66	1979	-44	1983

All temperatures are in Fahrenheit and are the extremes for the 46-year period between 1950-2006.

AVERAGE PRECIPITATION

	Average Precip.	Average Snowfall	Year-to-Date Avg. Precip.
January	0.39"	6.41"	0.39"
February	0.36"	5.13"	0.75"
March	0.62"	5.48"	1.37"
April	1.43"	3.26"	2.8"
May	2.27"	0.71"	5.07"
June	3.36"	T	8.43"
July	2.05"	T	10.48"
August	1.42"	T	11.9"
September	1.4"	0.17"	13.3"
October	0.86"	0.76"	14.16"
November	0.48"	4.28"	14.64"
December	0.45"	5.44"	15.09"
		Ave. Annual Snowfall 31.64 inches	Ave. Annual Precip. 15.09 inches

Did You Know?
Theodore Rooevelt had two ranch operations along the Little Missouri River, the Maltese Cross Ranch and the Elkhorn Ranch, yet did not own any land in what is now known as North Dakota.

Last Updated: October 01, 2007 at 00:54 EST

The Little Missouri River has shaped the land which is home to a variety of prairie plants and animals including bison, elk and feral (wild) horses.

Write to

Superintendent
PO Box 7
Medora, ND 58645

E-mail Us

Phone

Visitor Information - Park Headquarters
(701) 623-4466

Visitor Information - North Unit
(701) 842-2333

Fax

(701) 623-4840

Climate

Summers are warm with temperatures in the 80s and 90s with a few days into the 100s on some years. Evenings can be cool. Average maximum: July is 87.1 degrees and August is 86.7 degrees. Average minimum: July 54.5 degrees and August is 52.4 degrees. Annual precipitation is 15 inches.

Winters are generally cold with brief warming periods.

Did You Know?
Theodore Rooevelt had two ranch operations along the Little Missouri River, the Maltese Cross Ranch and the Elkhorn Ranch, yet did not own any land in what is now known as North Dakota.

Last Updated: January 03, 2008 at 14:04 EST

APPENDIX E

FIELD DATA SUMMARY

ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE

Black ink is data from May 2006 investigation
Blue ink is data from 1981 Report
Italicize blue ink is proposed new alignment (built in 1983) from 1981 Report
Red ink is data from Report 93-13

Coring	MP	HACP in Inches	Base in Inches	HACP + Base in Inches	Base	Subgrade	Soil	R-Value	PI	Depth	Note	DCP	Moisture Content & Depth
C-1	0.10	3.6	3.6	7.2	small gravel - non angular med to dark	silty sand lighter color					no shoulder		
C-2	0.20	3.6	6.0	9.6	different - reddish small gravel w/sand & clay	gray clay, moist med to hi PI					@ kiosok		
C-3	0.25	3.0	+7.2	10.2	different base - darker larger gravel (1" non angular) w/clay	base goes deeper than 12 inches					High severity cracks @ utility locates		
SP-10	0.27						A-7-6	10	24	8"-4'			
C-4	0.30	3.0	5.4	8.4	hacp stripping? Base is nice med brown gravel w/ sand & clay	gray clay, moist med to hi PI	A-1-b	68	2	0.25 - 0.7	MP 0.3-1.0 just before patch		4.50% 0.7' - 1'
81-882-S	*0.50*						*A-7-6*	-	*99*	-			
C-5	0.50	4.8	6.0	10.8	gravel w/sand & clay less clay	gray clay	base course				cracks sealed		
SP-9	0.56						A-7-6	<5	56	5"-4'			
81-881-S	*0.70*						*A-7-6*	-	*71*	-			
C-6	0.75	6.0	4.8	10.8	Base is nice med brown gravel w/ sand & clay	gray clay as before					1" overlay inbound lane		
SP-8	0.76						A-7-6	11	26	8"-4'			
C-7	1.00	3.6	3.6	7.2	Base is nice med brown gravel w/ sand & clay	Subgrade 0.6' - 3' med brown med PI slightly moist to moist Subgrade 3' - 5' dark brown Hi PI moist	A-6	-	23	0.6 - 3	out of patch		21.30% 0.6' - 3' 23.10% 3' - 5'
SP-7	1.09						A-6	17	21	6"-3'			
81-880-S	*1.60*						*A-7-6*	-	*110*	-			
C-8	1.60	6.0	3.6	9.6	Base is nice, med brown small gravels -1/2" one frac face						in patch	13.0 mm/blow 0.8' - 3.0'	5.40% 0.8' - 1.0'
81-879-S	*1.67*						*A-7-6*	-	*84*	-			
SP-6	1.68						A-7-5	<5	183	-			
C-9	1.75	4.8	4.8	9.6	med brown small gravels w/sand & more clay	gray clay as before					still in patch just before ends		9.70% 0.4'.- 0.8'
C-10	2.00	3.6	3.6	7.2	med brown small gravels w/sand & more clay	Subgrade 0.6' - 3' clay w/gravel dark med PI Subgrade 3' - 5' darker higher PI	A-6	23	14	0.6 - 3	stripping 0.2' - 0.3'		18.40% 0.6' - 3' 17.30% 3' - 5'
SP-5	2.20						A-6	18	21	5"-3'			
C-11	2.25	3.6	6.0	9.6	nice med brown -3/4" gravel w/sand & some clay, frac faces	dark gray clay					med long crack center of travel lane		

ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE

Black ink is data from May 2006 investigation
Blue ink is data from 1981 Report
Italicize blue ink is proposed new alignment (built in 1983) from 1981 Report
Red ink is data from Report 93-13

Coring	MP	HACP in inches	Base in inches	HACP + Base in inches	Base	Subgrade	Soil	R-Value	PI	Depth	Note	DCP	Moisture Content & Depth
C-12	*Pullout*	*3.6*	*3.6*	*7.2*	*base*	*clay*					*stripping 0.2' - 0.3'*		
C-13	2.50	4.2	4.2	8.4	nice med brown gravel w/sand & clay, frac face slightly moist to moist	gray clay benonite - like clay					0.05' skin patch alligator/rut @ culvert	31.4 mm/blow 0.9' - 2.75'	30.40% 0.7' - 1'
C-14	2.75	3.6	4.8	8.4	nice gravel w/sand & clay	gray clay					rut		4.80% 0.3' - 0.7'
C-15	3.00	3.6	4.8	8.4	nice gravel w/sand & clay	dark clay High PI moist scoric layer @ 1.7' dark clay 1.7' - 3.5' yellow clay 3.5' - 5'	A-6	-	15	0.7 - 1.7	stripping 0.2' - 0.3' scoric layer was probably original road		27.80% 0.7' - 1.7'
SP-4	3.17						A-7-6	<5	49	5"-3'			
SP-4A	3.18						A-7-5	<5	114	-			
C-16	3.30	3.6	7.2	10.8	med brown gravel w/ sand & clay	lighter color silty clay w/less PI					no clear transitition base to subgrade		
C-17	3.50	3.6	4.8	8.4	med brown gravel w/ sand & clay	subgrade 0.7' - 3' lighter silty clay Subgrade 3' - 5' silt/clay	A-7-6	8	23	0.7 - 3	#6 3 - 5 Noticable harder drilling @ 3'		7.80% 0.3' - 0.7' 26.0% 0.7' - 3' 19.0% 3' - 5'
C-18	3.75	3.6	6.0	9.6	med brown gravel w/ sand & clay	gray clay w/chunks of coal in it					all been chipped except shldr		
SP-3	3.92						A-4	20	9	6"-4.5'			
C-19	4.00	3.6	6.0	9.6	med brown gravel w/ sand & clay but w/more clay	med brown clay					stripping @ 0.3' rutting 1/4"		
C-20	4.25	3.6	3.6	7.2	med brown gravel w/ sand & clay	med brown clay	A-1-b base course	68	2	0.3 - 0.7	MP 3 - 4.25 right ditch shoving		
C-21	4.50	4.8	6.0	10.8	med brown gravel w/ sand & clay	light to med brown High PI moist					patch	35.7 mm/blow 1.2' - 2.8'	25.40% 1' - 1.5'
SP-2	4.57						A-7-6	<5	77	8"-3'			
C-22	*4.6 Pullout*	*4.2*	*3.0*	*7.2*	med brown gravel w/ sand & clay	*clayey gravel*					*Canon Ball*		
C-23	4.75	2.4	7.2	9.6	clayey gravel	med brown clay					1/4" rut most stripping wet soils on left water on right		
C-1 to C-23 averages		**3.91**	**5.10**	**9.11**									

ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE

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Italicize blue ink is proposed new alignment (built in 1983) from 1981 Report
Red ink is data from Report 93-13

Coring	MP	HACP in inches	Base in inches	HACP + Base in inches	Base	Subgrade	Soil	R-Value	PI	Depth	Note	DCP	Moisture Content & Depth
C-24	5.00	3.0	5.4	8.4	clayey gravel	med brown clay med to high PI moist					1/4" rut or settle soils wet left & right		
SP-1	5.14						A-6	16	18	8"-3'			
C-25	5.25	3.6	4.8	8.4	clayey gravel	gray clay							
C-26	5.60	3.6	6.6	10.2	clayey gravel - nice	gray clay					X to Long X Cattle Trail	30.2 mm/blow 0.9' - 3.4'	10.0% 0.8' - 1'
C-27	*Parking*	*1.8*	*7.8*	*9.6*	*brown clayey gravel -3/4" one frac face*	*gray silty clay less PI still med PI*					*Long X Parking*		
C-28	5.75	3.0	6.0	9.0	nice brown clayey gravel	gray silty clay							
C-29	6.00	2.4	6.0	8.4	brown clayey gravel	med to dark clay med to high PI	A-7-6	3	23	0.7 - 5			17.60% 0.7' - 5'
C-30	6.25	3.6	7.2	10.8	brown clayey gravel	gray gravelly clay med PI					rut < 1/4"		
C-31	*Pullout*	*3.0*	-	*3.0*	brown clayey gravel	gray clay					*Cap Rock Coulee*		
B-14	6.50						A-4	47	7	10"-5'			
C-32	6.50	3.0	7.2	10.2	nice - less clay more silt brown gravel w/sand & silt/clay -3/4" one frac face	gray clay						29.8 mm/blow 1' - 3.1'	
C-33	6.75	3.6	12.0	15.6	brown clayey gravel	gray clay	A-1-b base course	68	2	0.3 - 1.3	MP 6.25 - 6.75		
B-13	7.00						A-7-6	<5	67	10"-5'			
C-34	*7.80*	*2.4*	*8.4*	*10.8*	*nice gravel w/sand w/silt/clay*	*weathered scoria pearlite*					***River Bend Parking***		
B-11	8.00						A-4	28	1	9"-5'			
C-35	8.00	4.2	6.6	10.8	gravel w/sand & silt/clay more dirty & drier	gray clay							5.30% 0.35' - 0.9'
C-36	8.25	3.6	9.0	12.6	more moist so seemed more stickier (PI) gravel w/sand w/silt/clay	gray clay more dry							
C-37	8.50	3.0	7.8	10.8	nice slightly moist to moist gravel w/sand w/silt/clay	gray clay						42.1 mm/blow 0.9' - 3.2'	16.10% 0.9' - 1.2'
C-38	8.75	3.0	7.8	10.8	nice slightly moist to moist gravel w/sand w/silt/clay	gray clay							
C-39	*Pullout*	*2.4*	*1.8*	*4.2*	gravel w/sand w/silt/clay	gray clay					*Bentonic Clay Overlook*		
C-40	9.00	3.0	6.6	9.6	gravel w/sand w/silt/clay more clay	gray clay/silt high PI							

ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE

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Italicize blue ink is proposed new alignment (built in 1983) from 1981 Report
Red ink is data from Report 93-13

Coring	MP	HACP in Inches	Base in Inches	HACP + Base in Inches	Base	Subgrade	Soil	R-Value	PI	Depth	Note	DCP	Moisture Content & Depth
C-41	9.25	3.6	7.2	10.8	gravel w/sand w/silt/clay more clay	blue gray benonite clay slightly moist, stiff	A-2-4 base course	63	7	0.3 - 0.9	MP 8.5 - 9.25 in a patch area		
B-8	9.50						A-6	<7	17	1'-5'			
C-42	9.50	3.6	7.2	10.8	gravel w/sand w/silt/clay more clay, drier than previous	brown silty clay only slightly moist						29.5 mm/blow 0.9' - 2.7'	11.90% 0.9' - 1.2'
C-43	*9.60*	*2.4*	*13.2*	*15.6*	*gravel w/sand w/silt/clay more clay, slightly moist*	*gray clay w/coal chunks only slightly moist, stiff*					*Man and Grass Parking*		
C-44	9.75	2.4	7.8	10.2	gravel w/sand w/silt/clay more clay, slightly moist	gray clay/silt slightly moist, stiff							
B-7	10.00						A-7-6	7	27	10"-5'			
C-45	10.00	2.4	8.4	10.8	gravel w/sand w/silt/clay more clay, slightly moist	Subgrade 0.9' - 3.5' brown clay Subgrade 3.5' - 5' lighter clay, more moist, higher PI?	A-7-6	9	26	0.9 - 3.5			23.50% 0.9' - 3.5'
C-46	10.25	3.0	8.4	11.4	gravel w/sand w/silt/clay	gray clay slighlty moist med to high PI as before					low longitudinal crack center of travel lane		
C-47	10.50	3.0	12.0	15.0	gravel w/sand w/silt/clay	dark brown clay					old borehole left	24.0 mm/blow 1.2' - 3.2'	7.70% 0.95' - 1.2'
C-48	10.75	2.4	7.2	9.6	gravel w/sand w/silt/clay	dark brown clay only slightly moist med to high PI not as stiff							
B-5	11.00						A-6	<7	20	11"-5'			
C-49	11.00	2.4	8.4	10.8	gravel w/sand w/silt/clay	gray to brown clay med to high PI a little more moist							
C-50	11.25	2.4	8.4	10.8	gravel w/sand w/silt/clay	gray to brown clay med to high PI					most distress area & really not bad		
C-51	11.50	3.0	8.4	11.4	gravel w/sand w/silt/clay	gray to brown clay w/ larger sand, med to high PI, only slightly moist						27.2 mm/blow 0.95' - 3.2'	11.80% 0.95' - 1.1'
C-52	11.75	2.4	7.8	10.2	gravel w/sand w/silt/clay	brown clay							
B-3	12.00						A-4	21	6	10"-5'			
C-53	12.00	2.4	7.8	10.2	gravel w/sand w/silt/clay	brown clay	A-6	13	14	0.85 - 5	old borehole		14.30% 0.85' - 5'
C-54	12.25	3.0	8.4	11.4	clayey gravel	gray clay, slightly moist to moist, med to high PI, soft to stiff							

ND PRA THRO 18(3) NORTH UNIT SCENIC DRIVE

Black ink is data from May 2006 investigation
Blue ink is data from 1981 Report
Italicize blue ink is proposed new alignment (built in 1983) from 1981 Report
Red ink is data from Report 93-13

Coring	MP	HACP in Inches	Base in Inches	HACP + Base in Inches	Base	Subgrade	Soil	R-Value	PI	Depth	Note	DCP	Moisture Content & Depth
C-55	*12.40*	*2.4*	*9.6*	*12.0*	*clayey gravel*	*brown clay*					*Edge of Glacier Pullout*		
C-56	12.50	3.0	7.2	10.2	clayey gravel	gray clay w/chunks of scoria, med to high PI slightly moist to moist						33.5 mm/blow 0.9' - 3.1'	19.60% 0.85' - 1.25'
C-57	12.75	2.4	9.6	12.0	clayey gravel	gray clay w/chunks of scoria, med to high PI slightly moist to moist							
B-1	13.00						A-4	18	10	9"-5'			
C-58	13.00	3.0	7.8	10.8	clayey gravel	gray clay w/chunks of scoria, med to high PI							4.5% of base 0.25' - 0.9'
													14.90% 0.9' - 4'
C-59	13.25	3.6	7.2	10.8	clayey gravel	gray clay w/chunks of scoria, med to high PI					med longitudinal crack center of travel lane		
C-60	13.50	3.0	8.4	11.4	clayey gravel	gray clay						43.8 mm/blow 1' - 3.3'	13.10% 0.9' - 1.2'
C-61	*13.60*	*3.6*	*10.8*	*14.4*	*clayey gravel*	*dark clay* high PI slightly moist to moist	*A-2-4* base course	*63*	*7*	*0.3 - 1.2*	*MP 9.25 - 13.6* Oxbow Bend Parking		
B-1 to B-14	6.5-13				composite sample of base course		A-1-a	72	NP	base	MP 6.5 - 13.0		
C-24 to C-61 average		**3.0**	**7.7**	**10.7**									

APPENDIX F

SOIL and FOUNDATION INVESTIGATION, AUGUST 1981

SOIL and FOUNDATION INVESTIGATION

ROUTE 14 - NORTH UNIT

THEODORE ROOSEVELT NATIONAL MEMORIAL PARK

NORTH DAKOTA

August 1981

Investigation by Sergius N. Hanson, Engineering Geologist

Report by Sergius N. Hanson and Wayne C. Folkman

Materials Division
Central Direct Federal Division
Federal Highway Administration

Denver, Colorado

Distribution:
Preconstruction Division
Construction Division
Structural Engineer
Project Engineer (through Area Designer)
Planning & Coordination Division
CDFD Central Files
Materials Division (2)

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and	
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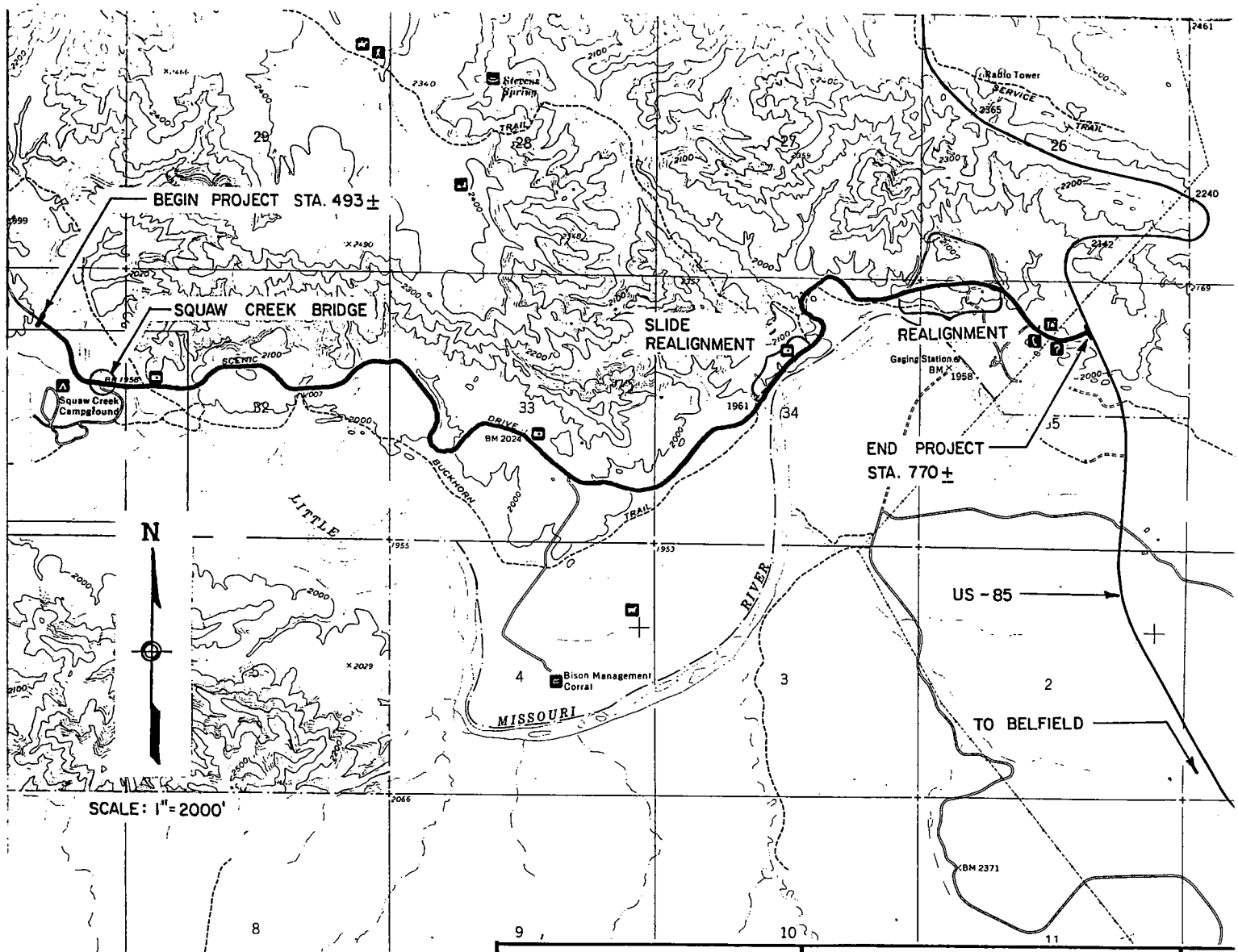
INTRODUCTION

This report presents soil and materials information obtained from Route 14 in the North Unit of Theodore Roosevelt National Memorial Park, North Dakota. This study covers approximately 5.2 miles of roadway proposed for reconstruction and partial realignment.

The project section, shown in figure 1, extends from State Highway 85 (station 770+07) at the entrance to the North Unit, into the Park for 5.2 miles along the north side of the Little Missouri River, to a point at approximately station 493±.

Two areas of realignment are proposed: one to avoid an area of slides along the Little Missouri River, and the other to eliminate several tight curves and steep grades. The roadway crosses one small bridge over Squaw Creek which is scheduled for replacement.



FEDERAL HIGHWAY ADMINISTRATION CENTRAL DIRECT FEDERAL DIVISION MATERIALS DIVISION Date: _____	THEODORE ROOSEVELT N.M.P. NORTH UNIT ROADWAY SITE LOCATION MAP DEC. 1980	Figur 1

FIELD INVESTIGATIONS

Field investigations were conducted during the period of October 15 through 22, 1980. Pavement, base and subgrade representative of roadway conditions were sampled and returned to the FHWA Central Direct Federal Division Materials laboratory in Denver for analysis.

A total of seven shallow power auger borings were drilled through the existing roadway. Two additional borings were drilled along the proposed realignment section (station 725 to 748±) and one hand excavated subgrade sample was obtained in the proposed cut realignment (station 675 to 695±). Four additional hand excavated samples were taken in the proposed line change areas in June of 1981. All four samples showed the material to be clay A-7-6. Results of laboratory tests on these materials are presented in Appendix 1.

Two test borings were conducted to 61 feet at the Squaw Creek Bridge site utilizing a CME 55 truck mounted drill rig and 3¼ inch hollow stem auger. Samples were obtained by split spoon and thin wall tube sampling techniques in accordance with AASHTO T-206 and T-207, respectively. All samples were transported to FHWA-CDFD Materials Division for analysis. Logs of the test borings and the results of subsurface soil tests are presented in Appendix 2.

SUBGRADE SOILS SURVEY AND RECOMMENDATIONS

The proposed roadway alignment passes through Paleocene and Eocene deposits of poorly cemented silts, clays and sand. These deposits are principally soft shales, siltstones and claystones with minor layers of sandstone and occasional lignite seams. The strata contain substantial amounts of bentonite.

The proposed alignment generally follows the existing roadway and grade, with two proposed line changes, stations 675 to 695± and 730 to 750±. The proposed line changes were reviewed by members of the Design and Materials Divisions and the National Park Service on May 29, 1981. It was felt by all concerned that there were no major problems with the proposed new alignments, except for some noted wet spots in the area between station 735 to 740. The water noted in this area is believed to be surface water. The grade should be raised as much as possible and proper ditching done to keep surface water away from the toe of fills.

At station 520 to 523± silt deposits build up at the culvert inlet which requires repeated cleaning by maintenance forces. Recommend raising grade and improving culvert gradient.

All cut and fill slopes should be designed on 1½:1 or flatter.

It was noted that several old fills along the existing project have settled and have been continually patched. The pavement thickness in these areas could be quite thick and it is recommended that all old pavement be removed, and the top foot of the existing road scarified and compacted with proper moisture density control before additional fill material is placed.

During the field review of May 29, 1981 there was some discussion about the possibility of using filter cloth on the subgrade in the new alignment areas and also along the existing road where there has been fill settlement. We do not feel that a filter cloth would be effective or economically justifiable.

TABLE I

Pavement, Base and Subgrade Sample Locations

Pavement and base thicknesses were measured and sampled along with the subgrade at the following locations.

Test Location	Station	Offset	Pavement	Base	Subgrade Sampled
1	498+80	13' R	1"	7"	to 3'
2	529+00	6' R	4"	4"	to 3'
3	563+12	2' R	1½"	4"	to 4.5'
4	602+80	2' R	1½"	3½"	to 3'
4A	602+70	20'R	expansive soil in cutbank		
5	654+00	9' R	1½"	3"	to 3'
6	681+40	20' L	new alignment, expansive subgrade		
7	712+50	9' R	3/4"	5"	to 3'
8	730+00	℄	8" topsoil	subgrade to 4'	
9	740+50	℄	8" topsoil	subgrade to 4'	
10	756+00	℄	1½"	7"	to 4' and 4' to 5'

FLEXIBLE PAVEMENT DESIGN

The existing roadway is constructed of 3/4" to 1½" of poor quality pavement (chip seals), 20 feet in width over ±3½ inches of dirty gravel, placed on the natural subgrade which in general consists of A-6 and A-7 clays, with very poor R-Values ranging from less than 5 to a high of 20.

We do not feel that it would be cost effective to recycle the existing pavement and base. This material could be utilized for finishing if the pavement were broken up to a workable size and the pavement and base utilized for finishing the top of the subgrade. It would depend on where the final grade line is set as to the economics of trying to utilize this material.

Using an R-Value of 5 for structural design a required structural number of 2.50 is needed, which would require a heavy structural section such as 3" asphalt pavement and 11" of crushed aggregate base.

By treating the top 8 inches of the subgrade with a maximum of 4% lime we can increase the R-Value to at least 40, thus reducing the required structural section and also helping prevent the intrusion of plastic fines into the base and subbase.

We suggest that the lime stabilization be used and handled as follows:

(1) Samples (40 lbs.) shall be taken of all material that will make up the top 8 inches of the finished subgrade (with a station to station summary of where the material will be on the roadway), and submitted to the Materials Lab for analysis three weeks prior to beginning of stabilization operations.

(2) After analysis is complete the percentages of lime for each type of material will be submitted to the project engineer.

(3) For quantity computations a maximum of 4% lime should be used. The amount will vary depending on soil type.

(4) During testing the percentage of lime to be added will be that which will bring the R-Value of the material up to 40.

Using an R-Value of 40 for the entire project the following structural section could be used.

Structural number required - 1.50

Alternates	#1	#2	#3	#4
Plant mix surfacing	2"	2"	1½"	1½"
Crushed aggregate base	3"	6"	7½"	4"
Subbase	4"	0	0	4"
Total structural number	1.56	1.52	1.50	1.48

See next page for work sheet for flexible pavement design.

FHWA 8-417
Rev. 7/19/73

U. S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Region 8, Denver, Colorado

DESIGN
FLEXIBLE PAVEMENT STRUCTURE

Date June 1981

Project TRNMP - North Dakota Route 14, North Unit

By Folkman

Regional Factor

Precipitation 14 " = 0.5

Avg. Elevation 2000 ' = 0

Drainage poor = 1.0

Total R.F. 1.5

Traffic Factor

1980 2000

58 + 58 x 0.6 = 34.8 Avg. V.P.D. one way, 20 yr. project.
2

34.8 x 0.05 = 1.7 18^k single axle loads/day.

(34.8 - 1.7) x .0002 = 0.01 Eq. 18^k single axle loads/day.

Total 1.71 Use 5

Soil Class	R Value	Soil Support Value G.I.	Soil Support Value R	Wt. Structural Number G.I.	Wt. Structural Number R	Inches G.I.	Inches Subbase R
	5		2.53		2.50		
	25		4.42				
	40		5.84		1.50		
	60		7.73		1.50		

RECOMMENDED ULTIMATE DESIGN

Pavement Component	Structural Coef. Range	Depth	Cost Coef. Range	Coef. for CN	Coef. for SN	Cost No.	Structural Number
Seal Coat							
Plant Mix Seal	.25 - .30		4.00 - 6.00				
Plant Mix Surf.	.35 - .45		3.75 - 5.75				
Road Mix Surf.	.20 - .25		3.25 - 5.25				
Stab. Base P.M.	.25 - .30		3.50 - 5.50				
Stab. Base R.M.	.15 - .20		3.25 - 5.25				
Stab. Base, SS-1	.12 - .17		1.90 - 2.80				
Cement T-Base	.12 - .17		2.10 - 3.00				
Ca $(OH)_2$ T-Base	.12 - .17		2.10 - 3.00				
Crushed Agg. Base	.10 - .15		1.10 - 2.00				
Gravel Base	.07 - .12		1.10 - 2.00				
Subbase	.07 - .12		1.00				
Select Borrow	.05 - .10		0.5 - 1.00				

Total Depth _____ Total SN _____

MATERIALS SOURCES

Possible materials sources were not sampled for this project. It shall be the contractor's responsibility to produce specification material from sources of his choice.

SOIL TEST DATA

Two samples of the silty clay loam topsoil along the project were sent to Colorado State University for testing of fertilizer needed with the same seeding requirements as project TRNP 1-D(3). See test results in Appendix 1.

SQUAW CREEK BRIDGE INVESTIGATION

SUBSURFACE CONDITIONS

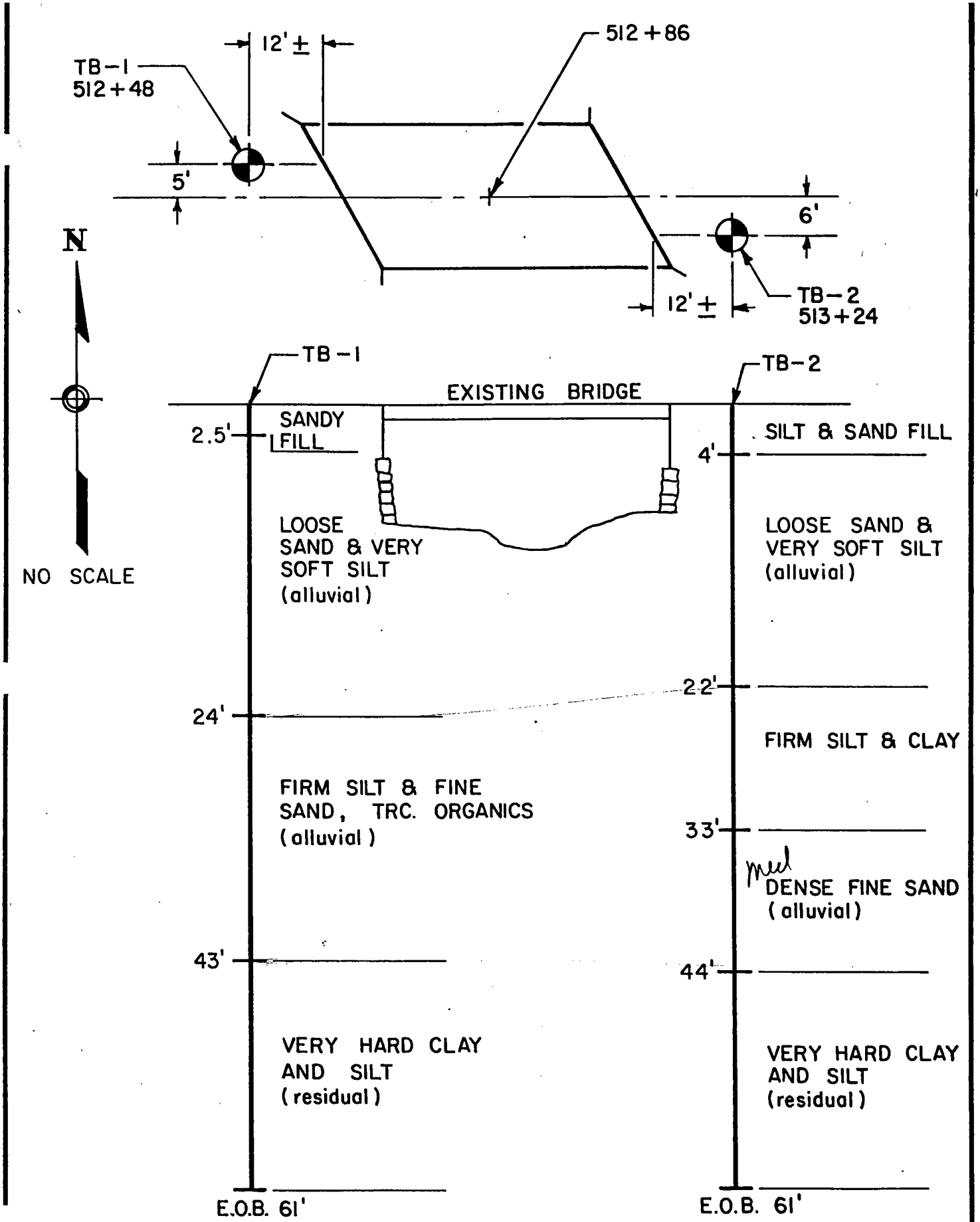
The two test borings conducted at the site encountered up to four feet of silty sand fill overlying very soft compressible alluvial silt and sand deposits to depths on the order of 24 feet. Below 24 feet firm to stiff silt and sand with some clay was encountered and contained carbonized road fragments. At approximately 44 feet hard to very hard laminated clay and silt was encountered. These lowermost deposits are weathered shale and claystone residuum and grade downward into rock strata. A generalized soils profile is shown in figure 2 and detailed boring logs are included in Appendix 2.

RECOMMENDATIONS

The extremely soft compressible soils between 4 and 24 feet necessitate the use of a deep foundation system for the bridge structure. If the existing approaches are raised above the existing ground level substantial settlements could occur resulting in the development of down drag forces on the piles.

Steel H-piles or cast-in-place displacement piles are suitable for use at this site.

Based on insitu soils data an allowable pile load of 50 tons for HP10X42 or 12-inch CIP pile can be obtained with an embedment of approximately 12 feet into the hard silty clay. Additional load carrying capacity can be obtained with increased penetration. The soils conditions do not require reinforced pile tips.



FEDERAL HIGHWAY ADMINISTRATION CENTRAL DIRECT FEDERAL DIVISION MATERIALS DIVISION Date: JAN. 1981	THEODORE ROOSEVELT NAT'L MEM. PARK NORTH UNIT – ROUTE 14 SQUAW CREEK BRIDGE BORING LOCATION AND PROFILE	FIG. 2

Soils and Foundation Investigation

Route 14 - North Unit

Theodore Roosevelt National Memorial Park
North Dakota

Prepared by Wayne C. Folkman
Wayne C. Folkman, Field Exploration Supervisor

Approved for distribution by Scott Rustay
Scott Rustay, Acting Chief, Materials Division

August 12, 1981

APPENDIX 1

Lab Tests

and

Soil Test Report

Form-8-226-A
Rev. 4-76

U. EPARTMENT OF TRANSPORTATION - REG: 8

DATE

SUMMARY OF SOIL OR AGGREGATE TESTS

SHEET 1 OF 1

PROJECT: NORTH DAKOTA - THEODORE ROOSEVELT MEMORIAL NAT'L PK. NORTH UNIT ROUTE 14

SUBMITTED BY: S. Hanson TESTED BY: DH,KW,KR REPORTED BY: Alan Held

DISTRIBUTION: Project Engineer -1, CDED Region -1, Materials Lab. -2

SAMPLE NUMBER								
Field No.	SP-1	SP-3	SP-4	SP-5	SP-7	SP-10	SP-10
Hole No.	BASE						SUBGRADE
Lab No.	81-352-SB	81-356-SB	81-358-SB	81-360-SB	81-362-SB	81-366-SB	81-367-SB

SAMPLE LOCATION							
Station or Location	498+80	563+12	602+80	654+00	712+50	756+00	756+00
Offset	13' Rt	2' Rt	2' Rt	7' Rt	9' Rt	℄	
Depth	1" - 8"	1½" -5"	1½"-5"	1½"-4½"	3/4"-5-3/4	1½"-8½"	4' - 5'

AASHTO T-11, 27 & 88								
	3"+							
	3"							
	1-1/2"	100	100	100		100	100	
	3/4"	96	93	97	100	99	99	
	1/2"	93	89	95	98	97	92	
	3/8"	90	85	93	95	93	89	
	#4	82	77	86	87	85	75	
	#8	73	68	79	78	76	61	
	#10	71	66	75	75	73	57	100
	#16							99
	#30	42	38	51	41	35	31	
	#40	36	32	46	36	29	26	99
	#50	31	26	42	32	25	22	
	#100							97
	#200	18.1	14.4	31.3	21.3	15.6	10.3	94.8
	0.05 mm							
	0.02 mm							
	0.002mm							
	0.001mm							
% Moist.								

AASHTO T-99, 90 & 92								
	SL							
	LL	21	21	28	24	23	NV	62
	PI	4	1	12	6	6	NP	16

AASHTO M-145								
	Class	A-1-b	A-1-b	A-2-6	A-1-b	A-1-b	A-1-b	A-7-5
	GI			(0)				(23)

AASHTO T-190								
	R							
	W(%)							
	γ_d(pcf)							

AASHTO T-99,180								
	W(%)							
	γ_d(pcf)							

REMARKS

All the base course samples contained varying traces of asphalt pavement.

Rev 4-76

SUMMARY OF SOIL OR AGGREGATE TESTS

SHEET 1 of 2

PROJECT NORTH DAKOTA-THEODORE ROOSEVELT MEMORIAL NAT'L PARK - NORTH UNIT

SUBMITTED BY S. HANSON TESTED BY RB, KW, KR REPORTED BY ALAN HELD

DISTRIBUTION Project Engineer -1, ~~XXXXXXX~~, Materials Lab -3

SAMPLE NUMBER								
	Field No.	SP-1	SP-2	SP-3	SP-4	SP-4A	SP-5	SP-6
	Hole No.							
	Lab No.	81-340-S	81-341-S	81-342-S	81-343-S	81-344-S	81-345-S	81-346-S
SAMPLE LOCATION	Station or Location	498+80 Subgrade	529+00 Subgrade	563+12 Subgrade	602+80 Subgrade	602+20 Cutslope	654+00 Subgrade	681+40 Subgrade
	Offset	13' R	6'R	2'R	2'R	20'R	7'R	20'L
	Depth	8"-3'	8"-3'	6"-4.5'	5"-3'	--	5"-3'	--
AASHTO T-11, 27 & 88	3"+							
	3"							
	1-1/2"	100						
	3/4"	99						
	1/2"	98						
	3/8"	98	100	100			100	
	#4	92	99	99			99	
	#8							
	#10	86	97	99		100	97	
	#16	82	96	98	100	99	96	
	#30							
	#40	78	94	97	99	99	94	
	#50							
	#100	70	92	96	99	99	92	100
	#200	63.2	90.9	93.2	98.3	98.7	80.9	99.6
	0.05 mm							
	0.02 mm							
	0.002mm							
	0.001mm							
% Moist.								
AASHTO T-89, 90 & 92	SL	13	12	13	14	2	8	17
	LL	36	96	36	70	144	40	218
	PI	18	77	9	49	114	21	183
AASHTO M-145	Class	A-6	A-7-6	A-4	A-7-6	A-7-5	A-6	A-7-5
	GI	(9)	(78)	(10)	(55)	(133)	(16)	(212)
AASHTO T-190	R	16	L.T.5	20	L.T.5	L.T.5	18	L.T.5
	W(%)	16.9	NV	25.3	NV	NV	20.5	NV
	γ_d(pcf)	114.8	NV	100.5	NV	NV	103.8	NV
AASHTO T-99,180	W(%)							
	γ_d(pcf)							

REMARKS

Rev 4-76

SUMMARY OF SOIL OR AGGREGATE TESTS

SHEET 2 OF 2

PROJECT NORTH DAKOTA-THEODORE ROOSEVELT MEMORIAL NATIONAL PARK NORTH UNIT

SUBMITTED BY S. Hanson TESTED BY RB, KW, KR REPORTED BY A. Held

DISTRIBUTION: Project Engineer -1, CDFD -1, Materials Lab 3²

SAMPLE NUMBER								
Field No.	SP-7	SP-8	SP-9	Sp-10				
Hole No.								
Lab No.	81-347-S	81-348-S	81-349-S	81-350-S				

SAMPLE LOCATION								
Station or Location	712+50 Subgrade	730+00 Subgrade	740+50 Subgrade	756+00 Subgrade				
Offset	9' Rt	Centerline	Centerline	Centerline				
Depth	6"-3'	8"-4'	5"-4'	8"-4'				

AASHTO T-11, 27 & 88								
3+								
3"								
1-1/2"								
3/4"								
1/2"								
3/8"								
#4	100			100				
#8								
#10	99			98				
#16	98			97				
#30								
#40	97			96				
#50								
#100	94	100	100	89				
#200	88.3	97.6	99.1	80.7				
0.05 mm								
0.02 mm								
0.002mm								
0.001mm								
% Moist.								

AASHTO T-89, 90 & 92								
SL	6	12	12	12				
LL	40	47	82	42				
PI	21	26	56	24				
		19	26	18				

AASHTO M-145								
Class	A-6	A-7-6	A-7-6	A-7-6				
GI	(19)	(28)	(55)	(19)				

AASHTO T-190								
R	17	11	L.T.5	10				
W(%)	19.3	23.9	NV	22.5				
γ_d (pcf)	105.6	100.4	NV	101.2				

AASHTO T-99,180								
W(%)								
γ_d (pcf)								

REMARKS

Form-8-226-A
Rev 4-76

U.S. DEPARTMENT OF TRANSPORTATION - REGION 8

SUMMARY OF SOIL OR AGGREGATE TESTS

DATE: 6/12/81
SHEET 1 of 1

PROJECT: NORTH DAKOTA - Theodore Roosevelt National Memorial Park-North Unit
SUBMITTED BY: R. BLENK TESTED BY: RB, KR, KW REPORTED BY: A. Hold
DISTRIBUTION: Project Engineer -1, Region -1, Materials Lab. -2 CDFD

SAMPLE NUMBER	Field No.	1	2	3	4			
	Hole No.							
	Lab. No.	81-879-S	81-880-S	81-881-S	81-882-S			
SAMPLE LOCATION	Station or Location	682+10	686+00	733+00	743+00			
	Offset	G	G	G	G			
	Depth							
AASHTO T-11, 27 & 88	3"+							
	3"							
	1-1/2"							
	3/4"							
	1/2"							
	3/8"							
	#4							
	#8							
	#10							
	#16							
	#30							
	#40	100						
	#50							
	#100	98	100	100	100			
	#200	92.9	99.1	99.3	99.4			
	0.05 mm							
	0.02 mm							
	0.002mm							
	0.001mm							
% Moist.								
AASHTO T-89, 90 & 92	SL							
	LL	112	133	94	132			
	PI	84	110	71	99			
AASHTO M-145	Class	A-7-6	A-7-6	A-7-6	A-7-6			
	GI	(90)	(127)	(82)	(118)			
AASHTO T-190	R							
	W(%)							
	γ_d (pcf)							
AASHTO T-99,180	W(%)							
	γ_d (pcf)							

REMARKS: Stations are from proposed new alignment

GPO 835-478

GROWER'S COPY

US DEPT OF TRANSPORTATION
PO BOX 25246 T. ROOSEVELT
DENVER CO 80225

COOPERATIVE EXTENSION SERVICE AND EXPERIMENT STATION

SOIL TESTING LABORATORY
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO 80521

SOIL TEST REPORT

NUMBER OF SAMPLES 2
DATE RECEIVED 01/21/81
DATE REPORTED 2/04/81
COUNTY

IDENTIFICATION		ROUTINE SOIL TEST RESULTS										ADDITIONAL RESULTS			
LAB. NO.	FIELD NUMBER	pH	SALTS mmhos/cm	ORGANIC MATTER %	NITRATE N ppm	PHOSPHORUS P ppm	POTASSIUM K ppm	ZINC Zn ppm	IRON Fe ppm	LIME %	TEXTURE	MANGANESE Mn ppm	COPPER Cu ppm	SAR	GYPSUM meq/100g
40A	363	7.0	.5	3.4	18	1.0	221	1.0	17.0	LOW	SILTY CLAY LOAM	1.2	1.4		
41B	364	7.6	.5	3.2	9	1.0	135	.5	18.3	HIG	SILTY CLAY LOAM	1.5	3.7		

DENT.	FIELD INFORMATION					RECOMMENDED FERTILIZER LBS./A							OTHER		
LAB. NO.	ACRES	IRRIGATION	LAST CROP	YIELD-LAST CROP	MANURE T/A	PROPOSED CROP	YIELD GOAL	N	P_2O_5	K_2O	Zn	FE (IRON)	Mn lbs/A	Cu lbs/A	GYPSUM T/A
40A		No			0			0	30	0	0	0	0	0	
41B		No			0			0	30	0	0	0	0	0	

Field NO 363 = station 730+00
Field NO 364 = station 740+50

ORTANT INFORMATION PRINTED ON REVERSE SIDE

APPROVED P. Soltanpour
TITLE Prof.

OPERATING WITH U.S.D.A.

APPENDIX G

GEOTECHNICAL REPORT 93-13

NORTH DAKOTA, PRA THO 10-1(1)
THEODORE ROOSEVELT NATIONAL PARK

GEOTECHNICAL REPORT
NOVEMBER 1993
REPORT 93-13

Report by:
T. Samuel Holder, P.E., Geotechnical Engineer

Investigation by:
T. Samuel Holder, P.E., Geotechnical Engineer
Charles Martinez, Engineering Geologist

Materials Branch
Central Federal Lands Highway Division
Federal Highway Administration
Denver, Colorado

Distribution:

Project Development (2)
Project Engineer (through Project Development)
Construction Engineer
National Park Service, Regional Office, Mr. Tim Windel
National Park Service, Service Center, Mr. Howard Wagner
CFLHD Central Files
Materials (2)
Keith Butler, NPS, North Dakota (4/30)

NORTH DAKOTA, PRA THO 10-1(1)
THEODORE ROOSEVELT NATIONAL PARK

GEOTECHNICAL REPORT
NOVEMBER 1993
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Report by:
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Materials (2)
Keith Butler, NPS, North Dakota (4/50)

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APPENDIX:
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- B - BORING LOGS
- C - LABORATORY TEST RESULTS
- D - INCLINOMETER DATA
- E - PAVEMENT INVESTIGATION NOTES
- F - PHOTOGRAPHS

INTRODUCTION

During the week of September 28 through October 2, 1992, the Materials Branch of Central Federal Lands Highway Division (CFLHD) conducted a pavement evaluation of the main Park roads in the south (MP 0-28.5) and north (MP 6.5-14.4) units. In addition, a fill area with tension cracks at Boicourt Area 1, MP 19, was investigated; selected metal pipes were inspected, and three were sampled.

The pavement evaluation consisted of augering through the pavement to a depth of 5 feet. Representative samples of pavement, base, subbase, and subgrade materials were taken. These samples were sent to the Central Laboratory for appropriate testing.

At Mile Post 19, Boicourt Area 1, a fill has settled and moved outward a small amount since reconstruction a few years ago. Because of concerns that the movement (tension cracks across the pavement) may be an indication of renewed large scale landslide activity, the site was instrumented with two inclinometers, one placed just behind the guardrail, and the other in the inside ditch.

A culvert survey was begun on the South Unit. Twelve culverts were inspected. Samples were taken from three culverts and tested for weight of zinc coating.

GEOLOGY

The North Dakota Geological Survey's geologic highway map of North Dakota indicates that the roadway system of Theodore Roosevelt National Park is within the Sentinel Butte formation. This Paleocene formation is described as dull gray layers of silt, clay, and sand, with interbedded sandstone, lignite, baked clay, and limestone. Delta, lake and river sediment, forms rolling topography over broad areas, and has been eroded to badlands near rivers as thick as 640 feet.

DISPERSIVE SOILS

Several areas within the park have had fill failures, fill settlement, and/or severe erosion problems at culvert outlets. The cause of the problems seem to be dispersive clays. Dispersive clays are defined in the "Foundation Engineering Handbook", edited by Hsai-Yang Fang, and published by Van Nostrand Reinhold, as the following:

> "Some fine-grained soils, called dispersive soils, with a higher content of dissolved pore-water sodium than ordinary soils, rapidly erode, forming tunnels and deep gullies by a process in which the individual clay particles go into suspension in slow-moving water (colloidal erosion), damaging earth dams, canals, and other structures. In general, dispersive clays have a preponderance of dissolved sodium cations in the pore water, whereas ordinary, erosion-resistant clays have a preponderance of dissolved calcium and magnesium cations."

In the Medora Overlook area (Mile Post 0.5), the problem has manifested itself in the form of settlement along the axis of two culverts, and severe erosion at culvert outlets. Twenty to 30 feet (vertically) of erosion has occurred at the outlet of one culvert (Photos #47 and #50).

In the Boicourt area (Mile Post 21), these problem soils are reported to have eroded large size cavities under the roadway, causing the pavement to collapse (Photo #44). The high erodibility of these soils is shown on Photo #45. Photo #46 shows a large size cavern in the slope across the drainage from the roadway. This photo shows that dispersive soils erosion is a naturally occurring phenomenon in the Park.

In the North Unit in a fill repair area at about Mile Post 7, signs of drainage water disappearing into the ground and reappearing several hundred feet lower was noted.

FINDINGS

South Unit

The information from the pavement investigation is summarized for the South Unit in the following tables:

THEODORE ROOSEVELT NATIONAL PARK - NORTH DAKOTA
SOIL SURVEY - SOUTH UNIT

BORING	LOC(M.P.)	ASPHALT PAVEMENT	CHIP SEAL & ASPHALT PAV.	FABRIC	BASE COURSE	SUBBASE	SUBGRADE SOILS	FT. WIDTH
SECTION 1								
B- 1	0.5,RT	4-1/2"			4-1/2"	9 "	Clayey Silt	
B- 2	1.0,RT	5"			4 "	8 "	Clayey Silt	
B- 3	1.5,RT	9"			3 "	11 "	Silty Clay	
B- 4	2.0,RT	6-1/2"			1-1/2"	14 "	Clayey Silt	
B- 5	2.5,RT	6"			3 "	8 "	Silty Clay	
B- 6	3.0,RT	9"			0	11 "	Silty Clay	
B- 7	3.5,RT	5-1/2"			2-1/2"	12 "	Clayey Silt	
B- 8	4.0,RT	7"			-	13 "	Silty Sand	
B- 9	4.5,RT	7-1/2"			3 "	6-1/2"	Silty Clay	
B-10	5.0,RT	7"			1-1/2"	11-1/2"	Silty Clay	
B-11	5.5,RT	5-1/2"			4-1/2"	12 "	Silty Clay	
B-12	6.0,RT	7-1/2"			1-1/2"	11 "	Clay	
B-13	6.5,RT	6-1/2"			2-1/2"	16 "	Silty Clay	21'
B-14	28.5,LT	2"			8-1/2"	-	Silty Clay	20.5'
B-15	28.0,LT	5"			6-1/2"	-	Silty Clay	20.5'
B-16	27.5,LT	7-1/2"			7 "	-	Sandy Silt	21'
B-17	27.0,LT	5-1/2"		Yes	5 "	-	Clay	20.5'
B-18	26.5,LT	4-1/2"		Yes	5-1/4"	-	Silty Clay	20.5'
B-19	26.0,LT	4-1/2"		Yes	5-1/2"	-	Silty Clay	21'
B-20	25.5,LT	1'			2-1/2"	-	Clay	20.5'
SECTION 6								
B-21	25.0,LT	4"			15-1/2"	-	Silty Sand	21'
B-22	24.5,LT		6-1/2"		4-3/4"	7-1/2"	Silty Clay	21'
B-23	24.0,LT		3"		5 "	11 "	Clayey Silt	
B-24	23.5,LT		4-1/2"		3-1/2"	12 "	Silty Clay	20'
B-25	23.0,LT		2-1/2"		4-1/2"	12 "	Silty Clay	
B-26	22.5,LT		5"		2 "	12 "	Clayey Silt	
B-27	22.0,LT		3"		8-1/2"	10-1/2"	Sandy Clay	21.6'
B-28	21.5,LT		4"		5 "	8 "	Silty Clay	21.1'
B-29	21.0,LT		4"		10 "	6 "	Clay	
B-30	20.5,LT		5"		11 "	-	Clay	22'

THEODORE ROOSEVELT NATIONAL PARK - NORTH DAKOTA (continued)
SOIL SURVEY - SOUTH UNIT

BORING	LOC(M.P.)	ASPHALT PAVEMENT	CHIP SEAL & ASPHALT PAV.	FABRIC	BASE COURSE	SUBBASE	SUBGRADE SOILS	FT. WIDTH
(SECTION 6 continued:)								
B-31	20.0,LT		4"		13 "	-	Silty Sand	
B-32	19.5,LT		3"		8 "	4 "	Silty Sand	
B-33	19.0,LT		6"		10 "	4 "	Clayey Silt	
SECTION 5								
B-34	18.5,LT		2-1/2"		12-1/2"	3 "	Silty Clay	
B-35	18.0,LT		2-1/2"		4-1/2"	12-1/2"	Silty Clay	
B-36	17.5,LT		2-1/2"		5 "	9-1/2"	Silty Sand	
SECTION 4								
B-37	17.0,LT		6"		3 "	2 "	Silty Sand	
B-38	16.5,LT		6-1/2"		-	5 "	Silty Sand	
B-39	16.0,LT		6"		-	?	Silty Sand	
SECTION 3								
B-40	15.5,RT		3-1/4"		2-3/4"	6 "	Silty Clay	21.7'
B-41	15.0,RT		2-1/2"		3-1/2"	11-3/4"	Clay	
B-42	14.5,RT		3-3/4"		3-1/4"	14-1/2"	Silty Clay	23.1'
B-43	14.0,RT		3"		2-1/4"	14-1/4"	Silty Sand	
B-44	13.5,RT		2"		4-1/2"	14 "	Clay	19.4'
B-45	13.0,RT		3"		2-3/4"	10"	Clay	
SECTION 2								
B-46	12.5,RT		3-1/4"		6-3/4"	-	Clay	20.3'
B-47	12.0,RT		4-1/4"		5-3/4"	-	Clay	
B-48	11.5,RT		2"		6-3/4"	-	Silty Clay	20.5'
B-49	11.0,RT		1' 1"		6-1/2"	-	Clay	
B-50	10.5,RT		3"		6-1/2"	-	Clay/Lignite	20.8'

THEODORE ROOSEVELT NATIONAL PARK - NORTH DAKOTA (continued)
SOIL SURVEY - SOUTH UNIT

BORING	LOC(M.P.)	ASPHALT PAVEMENT	CHIP SEAL & ASPHALT PAV.	FABRIC	BASE COURSE	SUBBASE	SUBGRADE SOILS	FT. WIDTH
(SECTION 2 continued:)								
B-51	10.0,RT		2-3/4"		4-1/2"	-	Clay	
B-52	9.5,RT		2-3/4"		5-1/4"	-	Clay	20.9'
B-53	9.0,RT		1-1/2"		9-1/2"	-	Sandy Silt	
B-54	8.5,RT		2-3/4"		4-1/4"	-	Silty Sand	21'
B-55	8.0,RT		3"		6 "	-	Coal/Clay	20.1'
B-56	7.5,RT		3-1/2"		6 "	-	Silty Clay	
B-57	7.0,RT		3-1/2"		1-1/2"	-		20.8'

Photographs of the pavement at areas where samples were taken are included in Appendix F. As can be determined from the tables, there are considerable variations in the structural sections for the South Unit. Based on pavement depth, pavement type, and the presences of a subbase, it is possible to group the roadway into six sections as follows:

1. Recent Overlay (1989 and 1990), Mile Posts 0.0 to 6.55 and 25.0 to 28.5 (B-1 to B-21). This section of roadway was overlain with 2 inches of hot asphaltic pavement in 1989 and 1990. The only distress noted in this section is transverse cracking. This reflective thermal cracking is coming through the overlay from the old pavement. The amount of cracking seemed to be the same for the areas with and without a pavement fabric. The average pavement thickness for this section is 6.25 inches.

2. Mile Posts 6.55 to 12.5 (B-46 to B-57). We understand that this is the oldest section of roadway. Hand-laid masonry headwalls from the CCC era are present in this section. The pavement averages 3.75 inches. It varies from 1.5 inches at Mile Post 9, to 13 inches at Mile Post 11. The base averages about 5.23 inches. The wearing course is a chip seal. Observed distresses consist of transverse cracking (thermal cracking) and longitudinal distortion. Pavement rutting varies from less than 1/8 inch to 1 inch in depth. This section seems to be in the poorest condition. There is no subbase present in this section.

3. Mile Posts 12.5 to 15.5 (B-40 to B-45). The pavement wearing course is a chip seal. The pavement's thickness averages 2.9 inches; the base, 3.2 inches; and the subbase, 11.75 inches. Block cracking is present in varying dimensions. Some wheel path rutting is present in this section. The surface is distorted longitudinally.

4. Mile Posts 15.5 to 17.0 (B-37 to B-39). The wearing course for this section is a recycled pavement with a bleeding surface. The pavement averages 6.2 inches; base 1 inch; and subbase 2.33 inches. However, two of the borings did not encounter any base (Mile Posts 16 and 16.5), and the subbase is not present at Mile Post 16.

5. Mile Posts 17 to 18.5 (B-34 to B-36). The wearing course is a chip seal. The pavement averaged 2.5 inches; the base 7.33 inches; and the subbase 8.33 inches. However, there is considerable variation in the base and subbase. This section is experiencing similar distress as in Sections 2 and 3, consisting of block cracking and longitudinal distortions.

6. Mile Posts 18.5 to 24.5 (B-22 to B-35). The wearing coarse is a chip seal. The pavement averages 4.0 inches; the base 7.3 inches; and subbase 7.3 inches. However, at Mile Posts 20 and 20.5, no subbase was encountered. This is in similar condition as Sections 2, 3, and 5.

North Unit

The results from the North Unit pavement investigation are summarized in the following table:

THEODORE ROOSEVELT NATIONAL PARK - NORTH DAKOTA
SOIL SURVEY - NORTH UNIT

BORING	LOC.(M.P.)	CHIP SEAL AND ASPHALT PAVEMENT	BASE COURSE	SUBGRADE SOILS (VISUAL)	FT. WIDTH
B- 1	13.0,LT	3-1/2"	5-1/2"	Silty Sand	25.8'
B- 2	12.5,LT	3-3/4"	6-1/2"	Silty Clay	
B- 3	12.0,LT	3-1/2"	6-1/2"	Silty Clay	26.2'
B- 4	11.5,LT	2-3/4"	6-3/4"	Sandy Clay	
B- 5	11.0,LT	3-1/2"	7-3/4"	Sandy Clay	25.8'
B- 6	10.5,LT	3"	7 "	Silty Clay	
B- 7	10.0,LT	3"	7 "	Clay	25.6'
B- 8	9.5,LT	3-1/2"	8-1/2"	Silty Clay	
B- 9	9.0,LT	3"	7 "	Silty Clay	26.3'
B-10	8.5,LT	3-1/2"	6 "	Clay	
B-11	8.0,LT	3"	6-1/2"	Sandy Clay	26.1'
B-12	7.5,LT	7"	12 "	Sandy Clay	
B-13	7.0,LT	3-3/4"	6-3/4"	Clay	26.6'
B-14	6.5,LT	3-1/2"	7 "	Silt	
		Average - 3.6"	Average - 7.2"		

The National Park Service was concerned that when a chip seal was milled off this section of the North Unit, some of the pavement (up to 2 inches) was also removed.

The distress most noted on this section was several large patches. From Mile Posts 6.5 to 8.0, the roadway is mostly patched. Photographs of the pavement is included in Appendix F. Pavement investigation notes are included in Appendix E.

As the table shows, the North Unit's pavement from Mile Posts 6.5 to 14.4 are similar. They consist of 3.6 inches of pavement, 7.2 inches of base, and no subbase. No areas with reduced thickness of pavement were found.

CULVERT SURVEY

A culvert survey was conducted in the South Unit. Three culverts were sampled. Two-inch diameter disks were removed for laboratory evaluation. The culverts were located at Mile Posts 1.5, 2.3, and 8.6. Because the culverts where visibly in good condition, no additional samples were taken.

Several additional culverts were inspected. The following notes were made:

MILEPOST	COMMENTS
1.5	48-inch corrugated metal pipe bituminous coated; no headwall. Looks very good. Sampled for laboratory testing.
2.3	36" corrugated metal pipe, some rust stains on inside, no coatings, no headwalls, sampled.
4.5	Bituminous coated 36 inch corrugated metal pipe. No headwall. Good condition.
4.6	48-inch bituminous-coated. Bituminous coating worn off inside invert. Very good condition.
4.8	36-inch bituminous-coated with metal end sections. Good condition.
5.0	Metal end section, bituminous-coated, looks very good.
5.7	Squash pipes (2), metal end sections, bituminous coated. Looks very good.
6.6	48-inch cmp, missing some bituminous coating from invert. Otherwise, very good.
7.45	36-inch, replaced in 1961, metal end section, looks new.

8.6	36-inch cmp, sandstone headwall, very good condition, took sample.
9.5	36-inch cmp, rusty in bottom, perforated in upper 1/4 inlet side, no headwall.
11.5	24-inch cmp, perforated, in a through fill.

In the area generally known as Boicourt 2, Mile Post 20.4, the 5-foot diameter culvert installed in the bottom of the drainage below the roadway is very rusty at the outlet. This culvert should be sampled to determine the rate of corrosion and the remaining service life before the culvert perforates. Perforation of the culvert may cause piping of the soil around the pipe which could adversely affect the stabilization measures previous completed for the area.

BOICOURT AREA 1 INVESTIGATION:

Inclinometers installed in this area were read during November 1992. A second set of readings were scheduled to be taken in 1993. However, because of probe problems, the readings have to be retaken.

South Unit

The only work currently being considered for the recently overlaid section of the South Unit is a friction coarse. The other sections will need to be rehabilitated. Currently, the following alternatives are being considered:

1. Overlay: As was done previously, the roadway could be restored by overlaying the existing pavement with hot asphalt concrete pavement. Before overlaying, the existing roadway will require considerable leveling to restore the roadway template. This alternative does not provide any additional width.

   The existing pavement cracking will reflect through the overlay as it has in the other overlaid sections.

2. Recycle: The existing pavement could be recycled by pulverizing the pavement and adding an emulsion. The recycled mix could then be relayed as a black base. This will require an overlay of hot asphalt concrete pavement. The roadway template could be partially restored when the black base is relaid. Some additional width might be obtained.

3. Recycle: By breaking up the existing pavement and mixing the material with the aggregate base, the roadway could be rehabilitated and the template restored. This option would require an overlay with hot asphalt concrete pavement. This method would result in the best restored roadway template of any alternative considered. Some additional width could be obtained also.

4. Light Reconstruction: Because the section from Mile Posts 6.55 to 12.5 has the poorest condition (roadway template and pavement), horizontal alignment and width, consideration is being given to reconstructing this section.

There are some operational problems with the current geometries on the loop road. Because of the limited amount of funds available, overlaying the existing roadway would rehabilitate the most miles of roadway but would not correct the operational problems.

RECOMMENDATIONS

Procedures

The pavement, base, and subbase thickness varied considerably, even through the six identified sections. Because several outliers are present in each section, the average thickness was not used in the pavement analysis. The determination of the appropriate thickness for analysis was a two-step process as follows:

1. The thickness versus mile post was graphed.

2. The thickness that best represented the section was visually picked off each graph.

Using the traffic data supplied in the Park Roads Needs Study, and from the information obtained during the pavement evaluation, the following structural sections will be required for overlaying the various sections of the South Unit:

Recent Overlay, Mile Posts 0.0 to 6.55 and 25.0 to 28.5

This section is in good condition with some transverse (reflective) cracking. The section is structurally adequate. In the near future (two to five years), the cracking should be sealed with a chip seal.

Overlay Option

If the overlay option is selected, the following overlay thicknesses are required:

Section	Mile Post	Thickness
2	6.55 to 12.5	4.5 inches
3	12.5 to 15.5	2.25 inches
4	15.5 to 17.0	2.75 inches
5	17.0 to 18.5	2.75 inches
6	18.5 to 25	2.75 inches

The overlaid sections should perform similarly to Section 1. Transverse cracks will reflect through in a few years, but otherwise should perform adequately.

Reconstruction Option

We understand that the selected alternative is to reconstruct Section 2. The reconstruction will include widening the roadway from 20 to 22 feet, and some horizontal and vertical profile changes.

The selected structural section will be dependent on how close the new profile grade matches the existing pavement. If the profile grade matches within an inch or so, then breaking up the pavement, mixing it with base, and spreading it out to the new width is a viable alternative. We estimate 5 inches of pavement and base is available for this alternative. This would leave 2 inches of base in place for equipment support, driving surface, and prevention of base contamination. The required structural section for this option is as follows:

Materials		
4.5 inches recycled base and asphalt concrete		4.5" x .10 = 0.45
6.0 inches aggregate base course		6.0" x .12 = 0.72
4 inches hot asphalt concrete pavement		4.0" x .40 = 1.60
Required structural number, 2.7		
	Total	2.77

If the profile does not closely match the existing, then removing the existing structural section, stabilizing the subgrade with lime or lime-fly ash, should be considered. After stabilizing the subgrade, the salvaged pulverized base and asphalt material could be used as a granular base under the new structural section. The structural section required will depend upon the appropriate coefficient for the lime stabilized base. If this option is selected, additional subgrade samples will have to be obtained for testing. Using an assumed value of 0.08, the following structural section was obtained:

LIME STABILIZED SUBGRADE

Materials		
8 inches stabilized subgrade		8" x .08 = 0.88
4.5 inches recycled base		4.5" x .10 = 0.45
2 inches crushed aggregate base		2" x .12 = 0.24
3 inches hot asphalt concrete pavement		3" x .40 = 1.20
	Total	2.77

An additional advantage of stabilizing the subgrade is that it prevents the base from becoming contaminated by intrusion of the clay into the granular base.

This analysis is based on salvaging 5 inches of the base and asphalt concrete. The average thickness of the existing base and asphalt concrete is 9.5 inches. Even taking into consideration that some of this material is contaminated or will become contaminated during the removal process, there probably will be more than 5 inches of recycled base available for use.

North Unit

No work is currently proposed for the north unit. If an overlay is to be considered for the section, Mile Post 6.5 to 14, the following is required:

Mile Post	Asphalt Overlay Thickness
6.5 to 14	2 inches

Boicourt Area 1

Dispersive Soils Area

In the Medora Overlook area, the repairs should consist of repairing the two culverts with settlement along their axis by slip lining the culverts. Erosion protection (rip rap or an energy dissipator) should be provided at all the drainage outlets. The flat area across from the Medora Overlook should be regraded so that water does not pond.

In the Boicourt area, Mile Post 21, the rusted culvert shown in Photo #43 should be removed and replaced. All areas between the cutslope and the roadway should be graded to drain (Photo #50A).

FUTURE WORK

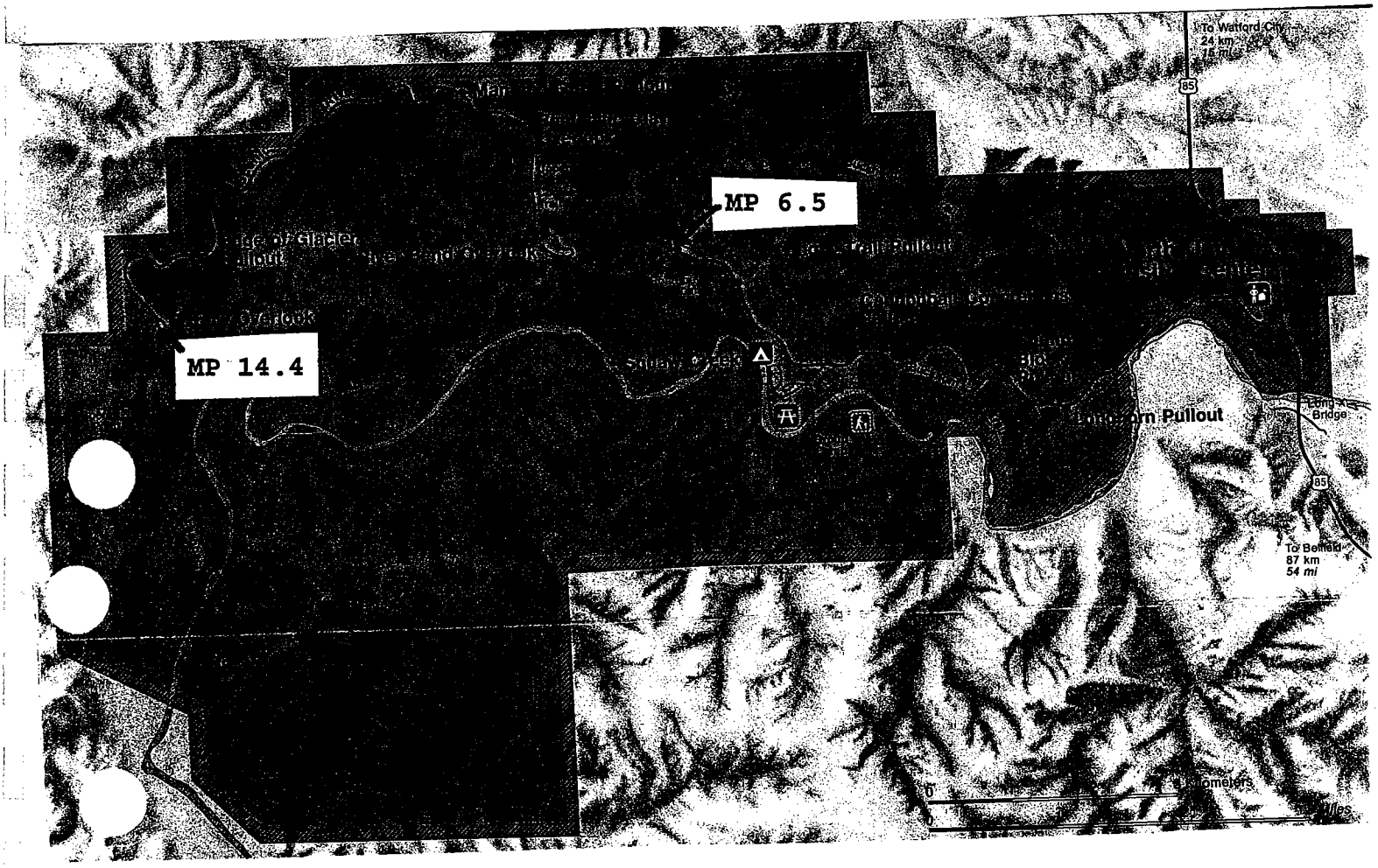
Because the dispersive soils problem is compounded with corrosive soils, all the culverts from Mile Posts 11.5 to 21.5 (south unit) need to be investigated. Considering that the Park has a history of fill failures caused by perforated culverts, the condition of all culverts in the Park needs to be closely monitored.

North Unit, Mile Posts 7 to 8

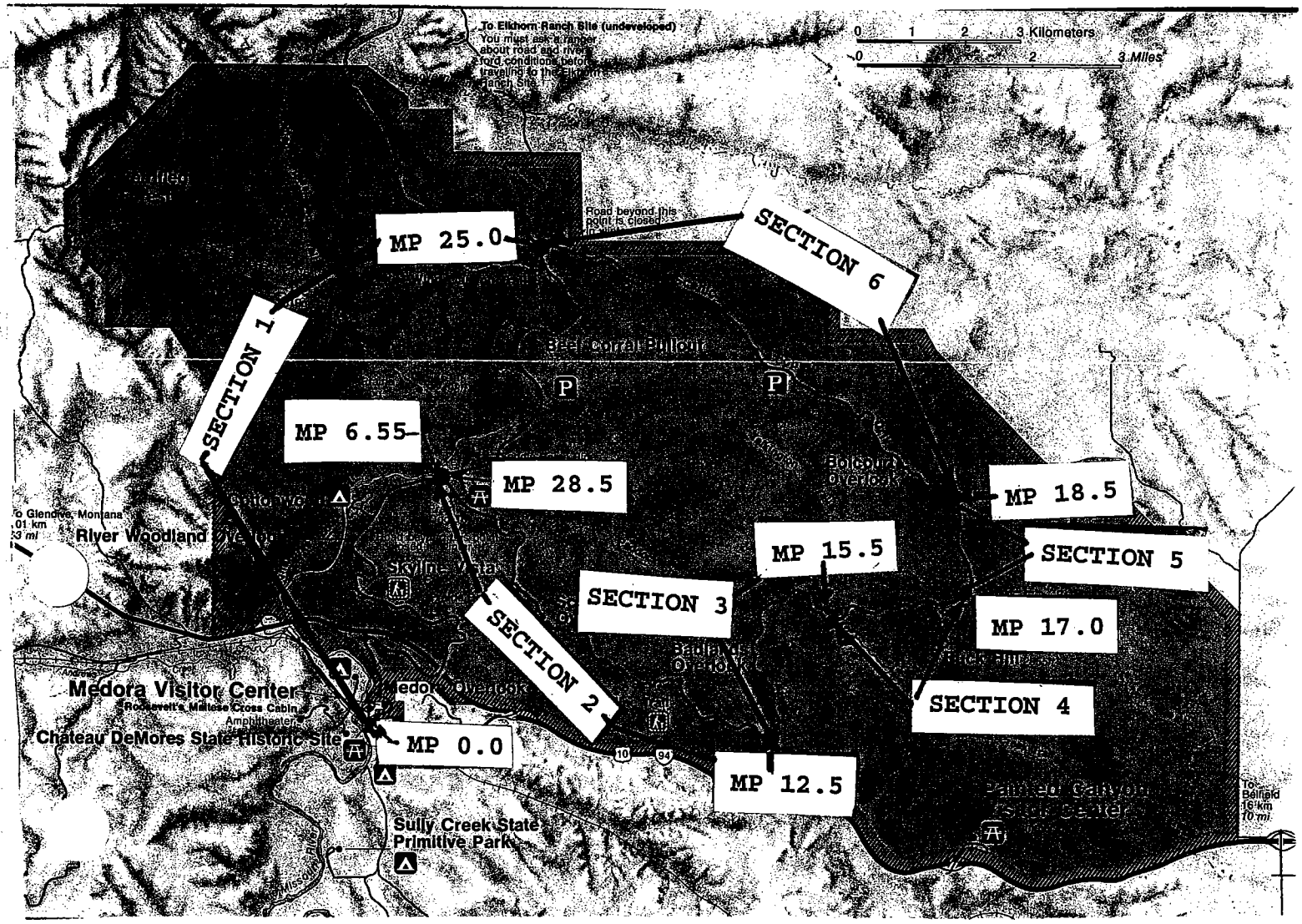
At this location in the north unit, tension cracks were observed in the roadway. One crack extended completely across the roadway with a 2-inch wide and about 4-inch deep crack. This area has the features of an impending fill failure. We recommended continued monitoring of this site. If it continues to move, the site should be drilled and instrumented with inclinometers as done at Boicourt Area 1.

APPENDIX A

LOCATION MAP



THEODORE ROOSEVELT NATIONAL PARK
North Unit MP 6.5 to 14.4
LOCATION MAP



THEODORE ROOSEVELT NATIONAL PARK
South Unit MP 0.0 to 28.5
LOCATION MAP

APPENDIX B

BORING LOGS

BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

Project Name: So. Unit, Theodore Roosevelt Nat'l Park		Boring No. SI-1	Date: 12/10/92	Sheet 1 of 2
Boring Location: MP 19, 16.9' RT (Boicourt Slide Area)		Type of Boring: Auger		
Drill: CME 55	Driller: Braun Intertech	Casing Used: HSA		Size: 3.25"ID
Field Logged By: C. Martinez		Boring Began: 9/30/92	Completed: 9/30/92	
Revisions/Final By: C. Martinez		Ground Elev: ft. MSL	Weather: sunny	
		Water Depth:		
		Date:		
		Time:		

Run/Samp No.	Depth Elevation (feet)	Graphic Log	U.S.C.S.	Length Recov. ----- % Rec.	RQD ----- Fract. Spacing	SPT Blows per 6 inches	Adjust SPT (N') per ft.	Description: (Density, Color, Type, Moisture, Other)
AR #1								0-14.2' Brown to dark brown FILL - SILTY SAND AND SANDY CLAY Auger Run #1 Brown loose silty sand, sl. gravelly, dry.
SPT #1				1.1' 73%		7/10/14		SPT #1 @ 3.5-5' Rec. 1.1' of brown silty sand, dry.
	5							
AR #2								Auger Run #2 Brown silty sand changing to dark brown sandy clay, moist at 5.5'.
SPT #2				0.75 50%		4/4/5		SPT #2 @ 8.5-10' Rec. 0.75' of brown silty sand, moist.
	10							
AR #3								AR #3 Brown silty sand, moist, easy drilling.
SPT3	-14.2			0.7' 100%		3/4-2"		SPT #3 @ 13.5-14.2' Rec. 0.7' of brown silty sand, moist.
	15							
AR #4	-15.5							14.2'-15.5' CLAYSTONE 15.5'-19' Brown SANDY CLAY Auger Run #4 Claystone changing to brown sandy clay.
SPT #4	-19			1.3 87%		2/4/3		SPT #4 @ 18.5-20' Rec. 0.3' of sandy clay, moist, and 1.0' of brownish gray clay, disturbed at 19'-19.5'.
	20							
AR #5								19'-28.8' Brownish gray CLAY Auger Run #5 Brownish gray clay, stiffer with depth.
SPT #5				1.2 80%		2/2/5		SPT #5 @ 23.5-25' Rec. 1.2' of brownish gray clay, moist.
	25							

BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

Project Name: So. Unit, Theodore Roosevelt Nat'l Park		Boring No. SI-1	Date: 12/10/92	Sheet 2 of 2
Boring Location: MP 19, 16.9' RT (Boicourt Slide Area)		Type of Boring: Auger		
Drill: CME 55	Driller: Braun Intertech	Casing Used: HSA		Size: 3.25"ID
Field Logged By: C. Martinez		Boring Began: 9/30/92		Completed: 9/30/92
Revisions/Final By: C. Martinez		Ground Elev: ft. MSL		Weather: sunny
		Water Depth:		
		Date:		
		Time:		

Run/Samp No.	Depth / Elevation (feet)	Graphic Log	U.S.C.S.	Length Recov. / % Rec.	RQD / Fract. Spacing	SPT Blows per 6 inches	Adjust SPT (N') per ft.	Description: (Density, Color, Type, Moisture, Other)
AR #6								Auger Run #6 Brownish gray clay, moist. **28.8'-38.5'** Yellowish brown to brownish gray **CLAYSTONE**
SPT #6	-28.8			1.5 100%		5/12/13		SPT #6 @ 28.5-30' Rec. 0.3' of brownish gray clay, and 1.2' of yellowish brown to brownish gray claystone.
AR #7	30							Auger Run #7 Claystone
SPT #7				1.5 100%		10/15/21		SPT #7 @ 33.5-35' Rec. 1.5' of brownish gray claystone.
AR #8	35							Auger Run #8 Claystone, stiffer with depth. **38.5'-48'** Bluish gray **CLAYSTONE**
SPT #8				1.5 100%		17/44/44		SPT #8 @ 38.5-40' Rec. 1.5' of bluish gray claystone
AR #9	40							Auger Run #9 Bluish gray claystone
AR #10	45							Auger Run #10 Bluish gray claystone changing to bluish gray shale at 48'.
	-48							**48'-49'** Bluish gray **SHALE**
	-49							
	50							BHT @ 49' (Slope Inclonometer Installed)

BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

Project Name: So. Unit, Theodore Roosevelt Nat'l Park		Boring No. SI-2	Date: 12/10/92	Sheet 1 of 2
Boring Location: MP 19, 15.8' LT (Boicourt Slide Area)		Type of Boring: Auger		
Drill: CME 55	Driller: Braun Intertech	Casing Used: HSA		Size: 3.25"ID
Field Logged By: C. Martinez		Boring Began: 10/1/92		Completed: 10/1/92
Revisions/Final By: C. Martinez		Ground Elev: ft. MSL		Weather: sunny
		Water Depth:		
		Date:		
		Time:		

Run/Samp No.	Depth Elevation (feet)	Graphic Log	U.S.C.S.	Length Recov. ----- % Rec.	RQD ----- Fract. Spacing	SPT Blows per 6 inches	Adjust SPT (N') per ft.	Description: (Density, Color, Type, Moisture, Other)
AR #1								0-16.5' Lt. brown to dark brown FILL - SILTY SAND AND SANDY CLAY Auger Run #1 Lt. brown silty sand, gravelly, dry.
AR #2	5							Auger Run #2 Lt. brown silty sand changing to dark brown sandy clay moist at 5.5'.
AR #3	10							Auger Run #3 Brown sandy clay, moist.
AR #4	15 -16.5							Auger Run #4 Brown sandy clay changing to gray clay at 16.5' 16.5'-29.5' Gray CLAY
AR #5	20							Auger Run #5 Gray clay, sl. moist.
	25							Auger Run #6 Gray clay, stiffer with depth.

BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

Project Name: So. Unit, Theodore Roosevelt Nat'l Park		Boring No. SI-2	Date: 12/10/92	Sheet 2 of 2
Boring Location: MP 19, 15.8' LT (Boicourt Slide Area)		Type of Boring: Auger	
Drill: CME 55	Driller: Braun Intertech	Casing Used: HSA	Size: 3.25"ID
Field Logged By: C. Martinez		Boring Began: 10/1/92	Completed: 10/1/92
Revisions/Final By: C. Martinez		Ground Elev: ft. MSL	Weather: sunny
		Water Depth:	
		Date:	
		Time:	

Run/Samp No.	Depth *Elevation* (feet)	Graphic Log	U.S.C.S.	Length Recov. ----- % Rec.	RQD ----- Fract. Spacing	SPT Blows per 6 inches	Adjust SPT (N') per ft.	Description: (Density, Color, Type, Moisture, Other)
AR #6								Auger Run #6 Gray clay, stiffer with depth.
	-29.5							
AR #7	30							29.5'-47.5' Gray CLAYSTONE Auger Run #7 Gray claystone.
AR #8	35							Auger Run #8 Gray claystone with coal layer.
AR #9	40							Auger Run #9 Gray claystone.
AR #10	45							Auger Run #10 Gray claystone changing to bluish gray shale at 47.5'.
	-47.5							47.5'-49.5' Bluish gray SHALE
	-49.5							
	50							BHT @ 49.5' (Slope Inclonometer Installed)

APPENDIX C

LABORATORY TEST RESULTS

FEDERAL HIGHWAY ADMINISTRATION
Central Federal Lands Highway Division

REPORT ON SOIL OR AGGREGATE TESTS

Project: NORTH DAKOTA PRA THO 10-1(1) THEODORE ROOSEVELT NATIONAL PARK
Submitted By: CHARLIE MARTINEZ
Date Reported: 2/22/93

Sample Number	Lab Number	92-1351-RV	92-1353-RV	92-1355-RV	92-1358-RV	92-1359-RV
	Hole Number	—	—	—	—	—
	Field Number	B-22	B-24	B-26	B-29	B-30
Sample Location	Station or Location	SOUTH UNIT M.P. 24.5	M.P. 23.5	M.P. 22.5	M.P. 21.0	M.P. 20.5
	Offset	LT	LT	LT	LT	LT
	Depth	1'7" - 5'	1'8" - 5'	1'7" - 5'	1'8" - 5'	1'6" - 5'
AASHTO T 11, 27 & 88 (% Passing)	3" 75.0 mm					
	1 1/2" 37.5 mm					
	1" 25.0 mm					
	3/4" 19.0 mm				100	
	1/2" 12.5 mm				99	
	3/8" 9.5 mm	100	100	100	98	100
	#4 4.75 mm	99	98	99	95	98
	#8 2.36 mm					
	#10 2.00 mm	97	95	98	91	94
	#16 1.18 mm	96	94	97	88	91
	#30 600 µm					
	#40 425 µm	94	92	96	84	87
	#50 300 µm					
	#100 150 µm	92	91	95	82	70
	#200 75 µm	87.5	84.5	83.8	79.7	59.5
	2 µm					
	0.2 µm					
	0.1 µm					
	Moisture (%)					
AASHTO T 89 & 90	Liquid Limit	35	31	26	36	44
	Plasticity Index	16	12	11	12	28
Soil Classification	AASHTO M 145	A-6 (14)	A-6 (9)	A-6 (7)	A-6 (9)	A-7-6 (14)
	ASTM D 2487	CL	CL	CL	CL	CL
AASHTO T 190	R-Value	<5	7	11	<5	<5
AASHTO T 288	Min. Resistivity (ohm-cm)					
AASHTO T 289	pH					
AASHTO T Method:	Optimum Moisture (%)					
	Max. Dry Density (pcf)					

Distribution:
Materials 3 Copies

Geotechnical
CHARLIE MARTINEZ

Remarks:

Reported by:
Alan M. Held
Materials Specialist

Bob H. Welch, P. E.
Materials Engineer

FHWA 16-228
REV. PFZ.1 04/22/92

FEDERAL HIGHWAY ADMINISTRATION
Central Federal Lands Highway Division

REPORT ON SOIL OR AGGREGATE TESTS

Project: NORTH DAKOTA PRA THO 10-1(1) THEODORE ROOSEVELT NATIONAL PARK
Submitted By: CHARLIE MARTINEZ
Date Reported: 2/22/93

Sample Number	Lab Number	92-1361-RV	92-1363-RV	92-1365-RV	92-1369-RV	92-1370-RV
	Hole Number	—	—	—	—	—
	Field Number	B-32	B-34	B-36	B-40	B-41
Sample Location	Station or Location	SOUTH UNIT M.P. 19.5	M.P. 18.5	M.P. 17.5	M.P. 15.5	M.P. 15.0
	Offset	LT	LT	LT	LT	LT
	Depth	1'3"-5'	1'6"-5'	1'5"-5'	1'5"-5'	1'5 3/4"-5'
SHTO T 1, 27 & 88 (% Passing)	3" 75.0 mm					
	1 1/2" 37.5 mm					
	1" 25.0 mm					
	3/4" 19.0 mm					
	1/2" 12.5 mm					100
	3/8" 9.5 mm		100	100	100	99
	#4 4.75 mm	100	99	99	99	97
	#8 2.36 mm					
	#10 2.00 mm	99	97	98	98	95
	#16 1.18 mm	99	95	97	97	93
	#30 600 µm					
	#40 425 µm	98	93	96	95	92
	#50 300 µm					
	#100 150 µm	90	89	95	95	91
	#200 75 µm	48.6	81.5	94.7	91.2	89.6
	2 µm					
	0.2 µm					
	0.1 µm					
	Moisture (%)					
AASHTO T 89 & 90	Liquid Limit	NV	34	36	34	36
	Plasticity Index	NP	4	13	15	19
Soil Classification	AASHTO M 145	A-4 (0)	A-4 (4)	A-6 (13)	A-6 (13)	A-6 (11)
	ASTM D 2487	SM	ML	CL	CL	CL
AASHTO T 190	R-Value	66	19	<5	<5	<5
AASHTO T 288	Min. Resistivity (ohm-cm)					
AASHTO T 289	pH					
AASHTO T Method:	Optimum Moisture (%)					
	Max. Dry Density (pcf)					

Distribution:
Materials 3 Copies

Geotechnical
CHARLIE MARTINEZ

Remarks:

Reported by:
Alan M. Held
Materials Specialist

Bob H. Welch, P. E.
Materials Engineer

FHWA 16-228
REV. PFZ.1 3/1/2?

FEDERAL HIGHWAY ADMINISTRATION
Central Federal Lands Highway Division

REPORT ON SOIL OR AGGREGATE TESTS

Project: NORTH DAKOTA PRA THO 10-1(1) THEODORE ROOSEVELT NATIONAL PARK
Submitted By: CHARLIE MARTINEZ
Date Reported: 2/22/93

Sample Number	Lab Number	92-1373-RV	92-1375-RV	92-1376-RV	92-1378-RV	92-1387-RV
	Hole Number	—	—	—	—	—
	Field Number	B-44	B-46	B-47	B-49	B-52
Sample Location	Station or Location	SOUTH UNIT M.P. 13.5	M.P. 12.5	M.P. 12.0	M.P. 11.0	M.P. 9.5
	Offset	LT	LT	LT	LT	LT
	Depth	1'8½"-5'	10"-5'	1'-5'	1'7½"-5'	8"-5'
AASHTO T 11, 27 & 88 (% Passing)	3" 75.0 mm					
	1 1/2" 37.5 mm					
	1" 25.0 mm					
	3/4" 19.0 mm	100	100			
	1/2" 12.5 mm	99	99			
	3/8" 9.5 mm	99	99	100	100	100
	#4 4.75 mm	97	98	99	98	98
	#8 2.36 mm					
	#10 2.00 mm	94	96	99	95	95
	#16 1.18 mm	93	95	98	94	94
	#30 600 µm					
	#40 425 µm	90	92	97	89	92
	#50 300 µm					
	#100 150 µm	88	90	95	81	90
	#200 75 µm	85.3	89.8	89.4	67.3	88.9
	2 µm					
	0.2 µm					
	0.1 µm					
	Moisture (%)					
AASHTO T 89 & 90	Liquid Limit	38	68	55	37	73
	Plasticity Index	16	40	32	20	51
Soil Classification	AASHTO M 145	A-6(14)	A-7-6(41)	A-7-6(31)	A-6(11)	A-7-6(50)
	ASTM D 2487	CL	CH	CH	CL	CH
AASHTO T 190	R-Value	<5	<5	<5	<6	<5
AASHTO T 288	Min. Resistivity (ohm-cm)					
AASHTO T 289	pH					
AASHTO T Method:	Optimum Moisture (%)					
	Max. Dry Density (pcf)					

Distribution:
Materials 3 Copies

Geotechnical
CHARLIE MARTINEZ

Remarks:

Reported by:
Alan M. Held
Alan M. Held
Materials Specialist

Bob H. Welch, P. E.
Materials Engineer

FHWA 16-228
REV. PF2.1 3/92

FEDERAL HIGHWAY ADMINISTRATION
Central Federal Lands Highway Division

REPORT ON SOIL OR AGGREGATE TESTS

Project: NORTH DAKOTA PRA THO 10-1(1) THEODORE ROOSEVELT NATIONAL PARK
Submitted By: CHARLIE MARTINEZ
Date Reported: 2/22/93

Sample Number	Lab Number	92-1383-RV	92-1385-RV	92-1387-RV	92-1389-RV	92-1391-RV
	Hole Number	—	—	—	—	—
	Field Number	B-54	B-56	B-1	B-3	B-5
Sample Location	Station or Location	SOUTH UNIT M.P. 8.5	→ M.P. 7.5	NORTH UNIT M.P. 13.0	M.P. 12.0	→ M.P. 11.0
	Offset	LT	LT	LT	LT	LT
	Depth	7"-5'	9 1/2"-5'	9"-5'	10"-5'	11 1/4"-5'
AASHTO 1, 27 & 88 (% Passing)	3" 75.0 mm					
	1 1/2" 37.5 mm					
	1" 25.0 mm					
	3/4" 19.0 mm	100				
	1/2" 12.5 mm	99		100		100
	3/8" 9.5 mm	97		99	100	99
	#4 4.75 mm	92	100	99	98	98
	#8 2.36 mm					94
	#10 2.00 mm	85	99	97	96	91
	#16 1.18 mm	82	99	96	95	87
	#30 600 µm					
	#40 425 µm	76	98	93	94	82
	#50 300 µm					
	#100 150 µm	72	97	80	93	78
	#200 75 µm	66.6	97.0	74.5	92.6	75.9
	2 µm					
	0.2 µm					
	0.1 µm					
	Moisture (%)					
AASHTO T 89 & 90	Liquid Limit	34	54	26	28	38
	Plasticity Index	18	32	10	6	20
Soil Classification	AASHTO M 145	A-6(10)	A-7-6(35)	A-4(5)	A-4(5)	A-6(14)
	ASTM D 2487	CL	CH	CL	CL-ML	CL
AASHTO T 190	R-Value	<5	<5	18	21	<5
AASHTO T 288	Min. Resistivity (ohm-cm)					
AASHTO T 289	pH					
AASHTO T Method:	Optimum Moisture (%)					
	Max. Dry Density (pcf)					

Distribution:
Materials 3 Copies

Geotechnical
CHARLIE MARTINEZ

Remarks:

Reported by:
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FHWA 16-228
REV. PF2.1 04/2232

FEDERAL HIGHWAY ADMINISTRATION
Central Federal Lands Highway Division

REPORT ON SOIL OR AGGREGATE TESTS

Project: NORTH DAKOTA PRA THO 10-1(1) THEODORE ROOSEVELT NATIONAL PARK
Submitted By: CHARLIE MARTINEZ
Date Reported: 2/22/93

Sample Number	Lab Number		92-1393-RV	92-1394-RV	92-1396-RV	92-1397-RV	92-1398-RV
	Hole Number		—	—	—	—	—
	Field Number		B-7	B-8	B-11	B-13	B-14
Sample Location	Station or Location		NORTH UNIT M.P. 10.0	M.P. 9.5	M.P. 8.0	M.P. 7.0	M.P. 6.5
	Offset		LT	LT	LT	LT	LT
	Depth		10"-5'	1'-5'	9½"-5'	10½"-5'	10½"-5'
SHTO 1, 27 & 88 (% Passing)	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm					
	3/4"	19.0 mm					
	1/2"	12.5 mm	100			100	
	3/8"	9.5 mm	99	100		99	100
	#4	4.75 mm	98	99	100	97	99
	#8	2.36 mm					
	#10	2.00 mm	96	98	98	94	98
	#16	1.18 mm	94	97	97	92	97
	#30	600 µm					
	#40	425 µm	92	94	94	88	96
	#50	300 µm					
	#100	150 µm	89	90	93	86	95
	#200	75 µm	83.5	84.4	92.7	84.9	94.8
		2 µm					
		0.2 µm					
		0.1 µm					
	Moisture (%)						
AASHTO T 89 & 90	Liquid Limit		49	36	24	91	31
	Plasticity Index		27	17	1	67	7
Soil Classification	AASHTO M 145		A-7-6(24)	A-6(14)	A-4(0)	A-7-6(63)	A-4(7)
	ASTM D 2487		CL	CL	ML	CH	ML
AASHTO T 190	R-Value		7	7	28	<5	47
AASHTO T 288	Min. Resistivity (ohm-cm)						
AASHTO T 289	pH						
AASHTO T Method:	Optimum Moisture (%)						
	Max. Dry Density (pcf)						

Distribution:
Materials 3 Copies

Geotechnical
CHARLIE MARTINEZ

Remarks:

Reported by:
Alan M. Held
Materials Specialist

Bob H. Welch, P. E.
Materials Engineer

RAWA 16-228
REV. PFZ.1 04/22/92

FEDERAL HIGHWAY ADMINISTRATION
Central Federal Lands Highway Division

REPORT OF MISCELLANEOUS TESTS

Laboratory Number: 92-(1170-1172)-0 **Date Reported:** 1/5/93

Project: North Dakota PRA THO 10-1(1) Theodore Roosevelt National Park (South Unit)

Submitted By: Sam Holder **Material Type:** Culvert Pipe

Material Source: Various

Tested For: Weight of Coating on Zinc - Coated (Galvanized) Culvert Pipe

TEST RESULTS

Lab Number	Mile Post	Size of CMP (Inches)	Zinc Coating * (Oz/Sq Ft)
92-1170-O	1.5	48	1.38
92-1171-O	2.3	36	.59
92-1172-O	8.6	36	.73

Remarks: * Calculated using both sides for area determination

Distribution:
Geotechnical: Sam Holder
Laboratory: 3 Copies

Reported By: Alan Held

Bob H. Welch, P.E.
Materials Engineer

FHWA 16-202
REV. 9/25/89

FEDERAL HIGHWAY ADMINISTRATION
Central Federal Lands Highway Division

REPORT ON SOIL OR AGGREGATE TESTS

Project: NORTH DAKOTA PRA THO 10-1(1) THEODORE ROOSEVELT N.P.
Submitted By: SAM HOLDER
Date Reported: 8-16-93

Sample Number	Lab Number		93-951-RV	93-952-RV	93-953-RV	93-954-RV	93-955-RV
	Hole Number		—	—	—	—	—
	Field Number		B-1	B-4	B-7	B-10	B-13
Sample Location	Station or Location		SOUTH UNIT M.P. 0.5	M.P. 2.0	M.P. 3.5	M.P. 5.0	M.P. 6.5
	Offset		RIGHT				
	Depth		9"-1'6"	8"-1'10"	8"-1'8"	8½"-1'8"	9"-2'1"
AASHTO T 11, 27 & 88 (% Passing)	3"	75.0 mm					
	1 1/2"	37.5 mm		100			
	1"	25.0 mm	100	99	100		100
	3/4"	19.0 mm	98	97	99	100	99
	1/2"	12.5 mm	88	90	92	95	95
	3/8"	9.5 mm	80	85	86	91	91
	#4	4.75 mm	63	68	69	74	75
	#8	2.36 mm					
	#10	2.00 mm	51	54	55	63	63
	#16	1.18 mm	45	48	48	56	56
	#30	600 µm					
	#40	425 µm	36	41	39	46	46
	#50	300 µm					
	#100	150 µm	29	36	29	36	38
	#200	75 µm	26.0	33.5	21.9	30.9	34.2
		2 µm					
		0.2 µm					
		0.1 µm					
	Moisture (%)						
AASHTO T 89 & 90	Liquid Limit		NV	32	NV	32	33
	Plasticity Index		NP	6	NP	6	7
Soil Classification	AASHTO M 145		A-2-4(0)	A-2-4(0)	A-1-b (0)	A-2-4(0)	A-2-4(0)
	ASTM D 2487		GM	SM	SM	SM	SM
AASHTO T 190	R-Value		79	65	76	69	60
AASHTO T 288	Min. Resistivity (ohm-cm)						
AASHTO T 289	pH						
AASHTO T Method:	Optimum Moisture (%)						
	Max. Dry Density (pcf)						

Distribution:
Materials 3 Copies

Geotechnical SAM HOLDER

Remarks:
THIS MATERIAL IS SUBBASE.

Reported by:
Alan M. Held
Alan M. Held
Materials Specialist

Bob H. Welch, P. E.
Materials Engineer

FHWA 18-226
REV. PF2.1 04/22

FEDERAL HIGHWAY ADMINISTRATION
Central Federal Lands Highway Division

REPORT ON SOIL OR AGGREGATE TESTS

Project: NORTH DAKOTA PRA THO 10-1(1) THEODORE ROOSEVELT N.P.
Submitted By: SAM HOLDER
Date Reported: 8-16-93

Sample Number	Lab Number	93-959-RV	93-963-RV			
	Hole Number	—	—			
	Field Number	B-25	B-1 THROUGH B-14			
Sample Location	Station or Location	SOUTH UNIT M.P. 23.0	NORTH UNIT. M.P. 6.5-13.0			
	Offset	LEFT	—			
	Depth	7"-1'7"	VARIOUS DEPTHS			

AASHTO T 11, 27 & 88 (% Passing)	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm	100				
	3/4"	19.0 mm	99	100			
	1/2"	12.5 mm	91	93			
	3/8"	9.5 mm	85	86			
	#4	4.75 mm	67	65			
	#8	2.36 mm					
	#10	2.00 mm	51	42			
	#16	1.18 mm	45	29			
	#30	600 µm					
	#40	425 µm	38	19			
	#50	300 µm					
	#100	150 µm	34	13			
	#200	75 µm	29.9	10.3			
		2 µm					
		0.2 µm					
		0.1 µm					
	Moisture (%)						
AASHTO T 89 & 90	Liquid Limit		NV	NV			
	Plasticity Index		NP	NP			
Soil Classification	AASHTO M 145		A-2-4(0)	A-1-a(0)			
	ASTM D 2487		SM	SW-SM			
AASHTO T 190	R-Value		71	72			
AASHTO T 288	Min. Resistivity (ohm-cm)						
AASHTO T 289	pH						
AASHTO T Method:	Optimum Moisture (%)						
	Max. Dry Density (pcf)						

Distribution:
Materials 3 Copies

Geotechnical SAM HOLDER

Remarks:
93-959-RV IS COMPOSED OF SUBBASE.
93-963-RV IS BASE COURSE.

Reported by:
Alan M. Held
Alan M. Held
Materials Specialist

Bob H. Welch, P. E.
Materials Engineer

FHWA 16-226
REV. PF2.1 04

APPENDIX E

PAVEMENT INVESTIGATION NOTES

Pavement Structure Layer Thickness Worksheet

Project: THEODORE ROOSEVELT N.P. **Prepared By:** JIM POWELL
Section: NORTH UNIT **From:** 6.5 **To:** 13.0 **Date:** _____

Traffic Analysis

AADT X DY X 365 X DDF X LDF X LF = Total 18Kip ESAL Design

3 X 20 X 365 X 0.55 X 1.0 X 1.0 = 12045 Use 12,100

AADT = (Present ADT + Future ADT)/2
DY = Number of Design Years (Typ. 20)
DDF = Directional Factor (Typ. .5)
LDF = Lane Distribution Factor (Typ. 1.0)

Load Factor (LF) = 18 Kip Equivalent Load Factor Per Vehicle

Regional Factor (RF)

Percipitation (inches/yr) _____ P_r _____
Average Elev. (Ft.) _____ E_f _____
Drainage _____ D_r _____
Total RF 1.5

Existing Pavement Structure

	Material Type	Thickness Range	Strength Range
Surface	AC	2.75-7.0	
Base	GRAN.	5.5-12	
Subbase			

Soil Support Value

Description: _____ Classification: _____
No. Samples Taken: 8 Range of Test Values: 45 - 47
Type of Tests: R VALUE No. of Tests: 8 Design Test Value: 8

Design Soil Support Value 2.7

Design Terminal Serviceability (P_t) = 2.0

Required Structural Number (SN) = 2.1

Pavement Structure Alternatives

Pavement Component	Typical Range of Structural Coefficient (SC)	Alternative #1 Design			Alternative #2 Design			Alternative #3 Design		
		SC	Thick.	SN	SC	Thick.	SN	SC	Thick.	SN
Seal Coat	.0 - .05									
Plant Mix Seal	.25 - .50									
Plant Mix Surfacing	.35 - .45	0.40	2.0	0.80						
Road Mix Surfacing	.20 - .25									
Stab. Base Plant Mix	.25 - .30									
Stab. Base Road Mix	.15 - .20									
Stab. Base Emulsion	.12 - .28									
Stab. Base Cement	.12 - .24									
Stab. Base Lime	.12 - .24									
Crushed Agg. Base	.10 - .15	0.11	6.2	0.68						
Gravel Base	.07 - .14									
Select Borrow	.05 - .10									
Exist. Roadway		0.20	2.9	0.58						
Totals				2.06						

Thickness Worksheet

Section 2

Pavement Structure Layer Thickness Worksheet

Project: PRA THO 10-1(1) THEODORE ROOSEVELT N.P. **Prepared By:** JIM POWELL
Section: SOUTH UNIT **From:** 6.55 **To:** 12.5 **Date:** _____

Traffic Analysis

AADT X DY X 365 X DDF X LDF X LF = Total 18Kip ESAL Design

10 X 20 X 365 X 0.55 X 1.0 X 1.0 = 40,150 Use **40,500**

AADT = (Present ADT + Future ADT)/2
DY = Number of Design Years (Typ. 20)
DDF = Directional Factor (Typ. .5)
LDF = Lane Distribution Factor (Typ. 1.0)

Load Factor (LF) = 18 Kip Equivalent Load Factor Per Vehicle

Regional Factor (RF)

Percipitation (inches/yr) 16 P_f 0.5
Average Elev. (Ft.) < 6500' E_f 0
Drainage POOR D_f 1.0
Total RF **1.5**

Existing Pavement Structure

	Material Type	Thickness Range	Strength Range
Surface	AC	1.5-4.25	
Base	GRAN.	1.5-9.5	
Subbase			

Soil Support Value

Description: _____
No. Samples Taken: 7
Type of Tests: R VALUE
Classification: A-6
Range of Test Values: <5 - 6
No. of Tests: 7 Design Test Value: <5
Design Soil Support Value **2.25**

Design Terminal Serviceability (P_t) = 2.0

Required Structural Number (SN) = 2.7

Pavement Structure Alternatives

Pavement Component	Typical Range of Structural Coefficient (SC)	Alternative #1 Design			Alternative #2 Design			Alternative #3 Design		
		SC	Thick.	SN	SC	Thick.	SN	SC	Thick.	SN
Seal Coat	.0 - .05									
Plant Mix Seal	.25 - .50									
Plant Mix Surfacing	.35 - .45	0.40	4.5	1.8	0.40	3.5	1.4			
Road Mix Surfacing	.20 - .25									
Stab. Base Plant Mix	.25 - .30									
Stab. Base Road Mix	.15 - .20									
Stab. Base Emulsion	.12 - .28									
Stab. Base Cement	.12 - .24									
Stab. Base Lime	.12 - .24									
Crushed Agg. Base	.10 - .15	0.11	4.5	0.50	0.11	6	0.66			
Gravel Base	.07 - .14				0.11	7	.77			
Select Borrow	.05 - .10									
Exist. Roadway		0.20	2.4	0.48						
Totals				2.78			2.83			

Thickness Worksheet

Section 3

Pavement Structure Layer Thickness Worksheet

Project: THEODORE ROOSEVELT N.P. **Prepared By:** _____

Section: SOUTH UNIT **From:** 12.5 **To:** 15.5 **Date:** _____

Traffic Analysis

AADT X DY X 365 X DDF X LDF X LF = Total 18Kip ESAL Design

_____ X _____ X 365 X _____ X _____ X _____ = _____ Use 40,500

AADT = (Present ADT + Future ADT)/2
DY = Number of Design Years (Typ. 20)
DDF = Directional Factor (Typ. .5)
LDF = Lane Distribution Factor (Typ. 1.0)

Load Factor (LF) = 18 Kip Equivalent Load Factor Per Vehicle

Regional Factor (RF)

Percipitation (inches/yr) _____ P_f _____
Average Elev. (Ft.) _____ E_f _____
Drainage _____ D_f _____
Total RF 1.5

Existing Pavement Structure

	Material Type	Thickness Range	Strength Range
Surface	AC	2.0-3.25	
Base	GRAN.	12.75-17.75	
Subbase			

Soil Support Value

Description: _____ Classification: _____
No. Samples Taken: _____ Range of Test Values: _____
Type of Tests: _____ No. of Tests: _____ Design Test Value: _____

Design Soil Support Value 2.25

Design Terminal Serviceability (P_t) = 2.0

Required Structural Number (SN) = 2.7

Pavement Structure Alternatives

Pavement Component	Typical Range of Structural Coefficient (SC)	Alternative #1 Design			Alternative #2 Design			Alternative #3 Design		
		SC	Thick.	SN	SC	Thick.	SN	SC	Thick.	SN
Seal Coat	.0 - .05									
Plant Mix Seal	.25 - .50									
Plant Mix Surfacing	.35 - .45	0.40	2.25	0.90						
Road Mix Surfacing	.20 - .25									
Stab. Base Plant Mix	.25 - .30									
Stab. Base Road Mix	.15 - .20									
Stab. Base Emulsion	.12 - .28									
Stab. Base Cement	.12 - .24									
Stab. Base Lime	.12 - .24									
Crushed Agg. Base	.10 - .15	0.11	12.5	1.38						
Gravel Base	.07 - .14									
Select Borrow	.05 - .10									
Exist. Roadway		0.20	2.4	0.48						
Totals				2.76						

Thickness Worksheet

Section 5

Pavement Structure Layer Thickness Worksheet

Project: THEODORE ROOSEVELT N.P. **Prepared By:** JIM DOWELL
Section: SOUTH UNIT **From:** 17.0 **To:** 18.5 **Date:** _____

Traffic Analysis

AADT X DY X 365 X DDF X LDF X LF = Total 18Kip ESAL Design

_____ X _____ X 365 X _____ X _____ X _____ = _____ Use 40,500

AADT = (Present ADT + Future ADT)/2
DY = Number of Design Years (Typ. 20)
DDF = Directional Factor (Typ. .5)
LDF = Lane Distribution Factor (Typ. 1.0)

Load Factor (LF) = 18 Kip Equivalent Load Factor Per Vehicle

Regional Factor (RF)

Percipitation (inches/yr) _____ P_f _____
Average Elev. (Ft.) _____ E_f _____
Drainage _____ D_f _____
Total RF 1.5

Existing Pavement Structure

	Material Type	Thickness Range	Strength Range
Surface	AC	2.5	
Base	GRAN.	14.5-17.0	
Subbase			

Soil Support Value

Description: _____ Classification: _____
No. Samples Taken: _____ Range of Test Values: _____
Type of Tests: _____ No. of Tests: _____ Design Test Value: _____

Design Soil Support Value 2.25

Design Terminal Serviceability (P_t) = 2.0

Required Structural Number (SN) = 2.7

Pavement Structure Alternatives

Pavement Component	Typical Range of Structural Coefficient (SC)	Alternative #1 Design			Alternative #2 Design			Alternative #3 Design		
		SC	Thick.	SN	SC	Thick.	SN	SC	Thick.	SN
Seal Coat	.0 - .05									
Plant Mix Seal	.25 - .50									
Plant Mix Surfacing	.35 - .45									
Road Mix Surfacing	.20 - .25	0.40	1.5	0.60						
Stab. Base Plant Mix	.25 - .30									
Stab. Base Road Mix	.15 - .20									
Stab. Base Emulsion	.12 - .28									
Stab. Base Cement	.12 - .24									
Stab. Base Lime	.12 - .24									
Crushed Agg. Base	.10 - .15	0.11	14.8	1.63						
Gravel Base	.07 - .14									
Select Borrow	.05 - .10									
Exist. Roadway		0.20	2.5	0.50						
Totals				2.73						

Thickness Worksheet

Section 6

Pavement Structure Layer Thickness Worksheet

Project: THEODORE ROOSEVELT N.P. **Prepared By:** JIM POWELL
Section: SOUTH UNIT **From:** 18.5 **To:** 25.0 **Date:** _____

Traffic Analysis

AADT X DY X 365 X DDF X LDF X LF = Total 18Kip ESAL Design

_____ X _____ X 365 X _____ X _____ X _____ = _____ Use 40,500

AADT = (Present ADT + Future ADT)/2
DY = Number of Design Years (Typ. 20)
DDF = Directional Factor (Typ. .5)
LDF = Lane Distribution Factor (Typ. 1.0)

Load Factor (LF) = 18 Kip Equivalent Load Factor Per Vehicle

Regional Factor (RF)

Percipitation (inches/yr) _____ P_f _____
Average Elev. (Ft.) _____ E_f _____
Drainage _____ D_f _____
Total RF 1.5

Existing Pavement Structure

	Material Type	Thickness Range	Strength Range
Surface	AC	2.5-6.5	
Base	GRAN	12.0-19.0	
Subbase			

Soil Support Value

Description: _____ Classification: _____
No. Samples Taken: _____ Range of Test Values: _____
Type of Tests: _____ No. of Tests: _____ Design Test Value: _____

Design Soil Support Value 2.25

Design Terminal Serviceability (P_t) = 2.0

Required Structural Number (SN) = 2.7

Pavement Structure Alternatives

Pavement Component	Typical Range of Structural Coefficient (SC)	Alternative #1 Design			Alternative #2 Design			Alternative #3 Design		
		SC	Thick.	SN	SC	Thick.	SN	SC	Thick.	SN
Seal Coat	.0 - .05									
Plant Mix Seal	.25 - .50									
Plant Mix Surfacing	.35 - .45	0.40	1.5	0.6						
Road Mix Surfacing	.20 - .25									
Stab. Base Plant Mix	.25 - .30									
Stab. Base Road Mix	.15 - .20									
Stab. Base Emulsion	.12 - .28									
Stab. Base Cement	.12 - .24									
Stab. Base Lime	.12 - .24									
Crushed Agg. Base	.10 - .15	0.11	12.8	1.41						
Gravel Base	.07 - .14									
Select Borrow	.05 - .10									
Exist. Roadway		0.20	3.4	0.68						
Totals				2.69						

Thickness Worksheet

SOUTH UNIT

BASE STRUCTURAL COEFFICIENT = 0.12

SUBBASE : $\bar{R} = 70$ $R_{75} = 65$

STRUCTURAL COEFF. $\approx$ 0.11

FOR DESIGN PURPOSES, COMBINE BASE AND SUBBASE THICKNESS AND USE 0.11 STRUCTURAL COEFFICIENT.

TRAFFIC: 1988 ADT = 360 GROWTH RATE = 2%

TRUCKS = 2%

DIRECTIONAL DIST. = 55%

$$1995\ ADT = (1+G)^n (360)$$

$$= (1+0.02)^7 (360) = 414$$

$$2015\ ADT = (1+0.02)^{20} (360) = 615$$

$$\text{CUMULATIVE} = \frac{(1+G)^n - 1}{G} (414)(365) = 3{,}671{,}576 \text{ VEHICLES}$$

TRUCK ESAL's = (3,671,576)(0.55)(0.02)(1.0) = 40387

CAR ESAL's = (3,631,189)(0.55)(0.0002) = 399

TOTAL DESIGN ESAL's = 40,786

ASSUME STRUCT. COEFF OF 0.20 FOR EXISTING A.C.

SOILS: $\therefore R_{75} < 5$, USE SOIL SUPPORT VALUE OF

2.25

REGIONAL FACTOR:

PRECIP.:	12-16	USE	R = 0.5
ELEV.:	< 6500'		R = 0
DRAIN.:	USE POOR		R = 1.0
			R = **1.5**

REQUIRED SN (AASHTO INTERIM) = 2.70 ✓

SOUTH UNIT

M.P. 6.55 - 12.5

AC : $\bar{D} = 2.9''$ $s = 0.7424$ $D_{75} = 2.4''$

BASE : $\bar{D} = 5.77''$ $s = 1.8933$ $D_{75} = 4.5''$

OVERLAY : $\dfrac{2.70 - [(2.4)(0.2) + (4.5)(0.11)]}{0.40} = \underline{4.3''}$ $4\frac{1}{4}''$

M.P. 12.5 - 15.5

AC: $\bar{D} = 2.85''$ $s = 0.6519$ $D_{75} = 2.4''$

BASE : $\bar{D} = 3.17''$ $s = 0.7853$ $D_{75} = 2.6''$

SUBBASE : $\underline{\bar{D} = 11.75''}$ $\underline{s = 3.3166''}$ $\underline{D_{75} = 9.5''}$

COMBINED : $\bar{D} = 14.92''$ $s = 3.6389$ $D_{75} = \underline{12.5''}$

$\dfrac{2.7 - [(2.4)(0.2) + (12.5)(0.11)]}{0.40} = \underline{2.1''}$ $2''$

M.P. 15.5 - 17.0

A.C. : $\bar{D} = 6.17''$ $s = 0.2887$ $D_{75} = 6.0''$

BASE : $\bar{D} = 1''$ $s =$ $D_{75} = 0''$

SUBBASE : $\underline{\bar{D} = 2.33}$ $\underline{s = 2.5166}$ $D_{75} = \underline{0.6''}$

COMBINED : $\bar{D} = 3.33$ $s = 2.8868$ $D_{75} = 1.4''$

ASSUME 5" BASE @ 16.0

COMBINED : $\bar{D} = 5''$ $D_{75} = \underline{5''}$

$\dfrac{2.7 - [(6.0)(0.2) + (5)(0.11)]}{.4} = \underline{2.4''}$ $2\frac{1}{2}''$

M.P. 17.0 - 18.5

AC.: $\bar{D}$ = 2.5" s = 0 D_{75} = 2.5"

BASE: $\bar{D}$ = 7.33" s = 4.4814" D_{75} = 4.3"

SUBBASE: $\bar{D}$ = s = D_{75} =

COMBINED: $\bar{D}$ = 15.67 s = 1.2583 D_{75} = 14.8"

$$2.7 - [2.5(0.2) + 14.8(0.11)] / 0.4 = \underline{\underline{1.4''}}$$

M.P. 18.5 - 25.0

A.C.: $\bar{D}$ = 4.21 s = 1.2515 D_{75} = 3.4"

BASE: $\bar{D}$ = 14.35" s = 2.2973 D_{75} = 12.8"

$$\frac{2.7 - [3.4(0.2) + 12.8(0.11)]}{0.4} = \underline{\underline{1.5''}}$$

NORTH UNIT

AC: $\bar{D}$ = 3.59 S = 1.0313 D_{75} = 2.9"

BASE: $\bar{D}$ = 7.20 S = 1.5541 D_{75} = 6.2"

SOIL: $\bar{R}$ = 17.37 S = 14.6671 R_{75} = 7

SUPPORT = 2.7

TRAFFIC: 105 ADT (1988)

1995 ADT = $105(1+0.02)^7$ = 121

2015 ADT = $121(1+0.02)^{20}$ = 180

CUMULATIVE = 1,073,093

TRUCK ESAL'S = (1,073,093)(0.55)(0.02)(1.0) = 11,804

CARS = (105 1631)(0.55)(0.0002) = 116

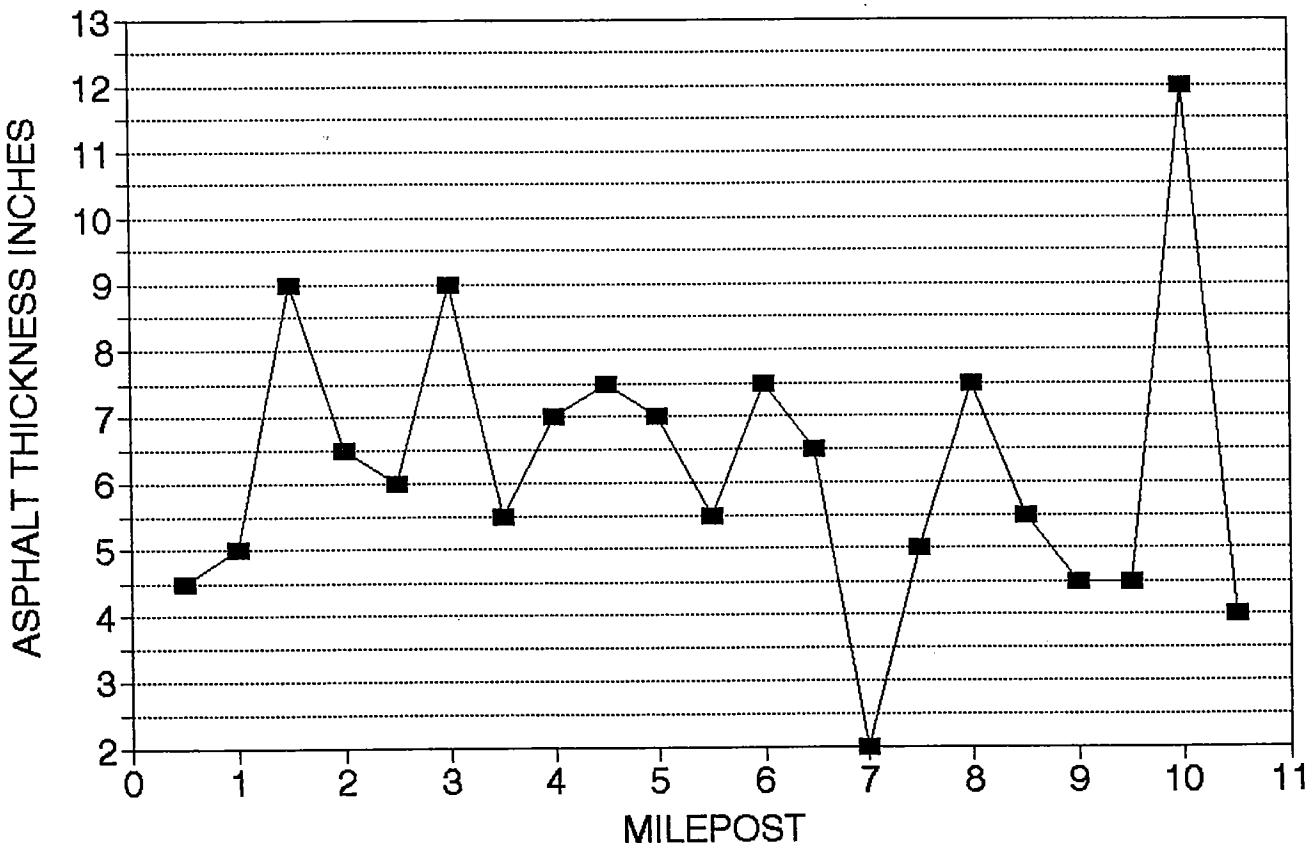
TOTAL = 11920 ESAL'S IN DESIGN LANE

SN_{REQ} = 2.09 − [(2.9)(0.2) + (6.2)(0.11)]/4 = 2.07"

2" REQUIRED

THEODORE ROOSEVELT NP SOUTH UNIT

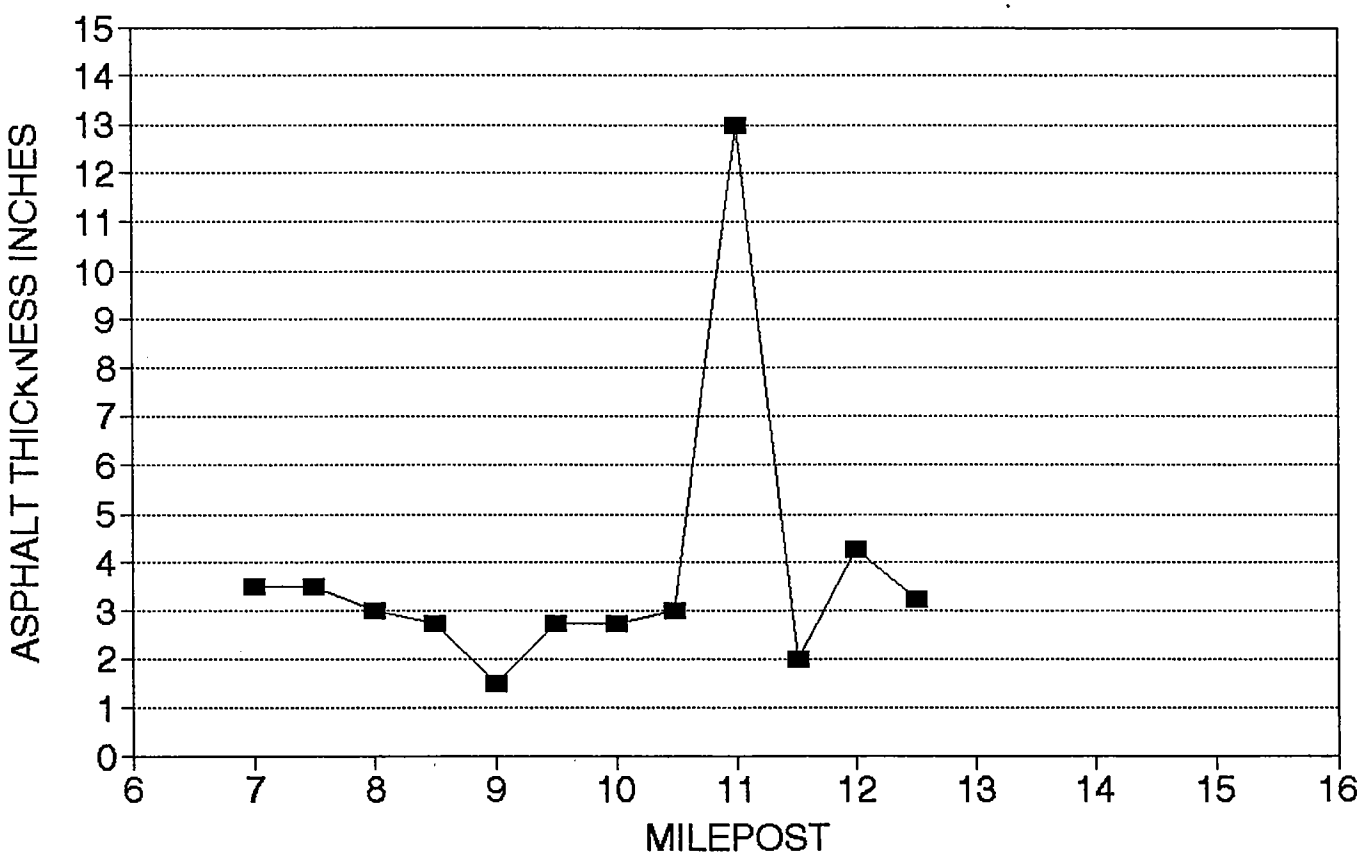
ASPHALT THICKNESS SECTION 1



Note MP 7 = MP 28.5 and MP 10.5 = MP 25.0

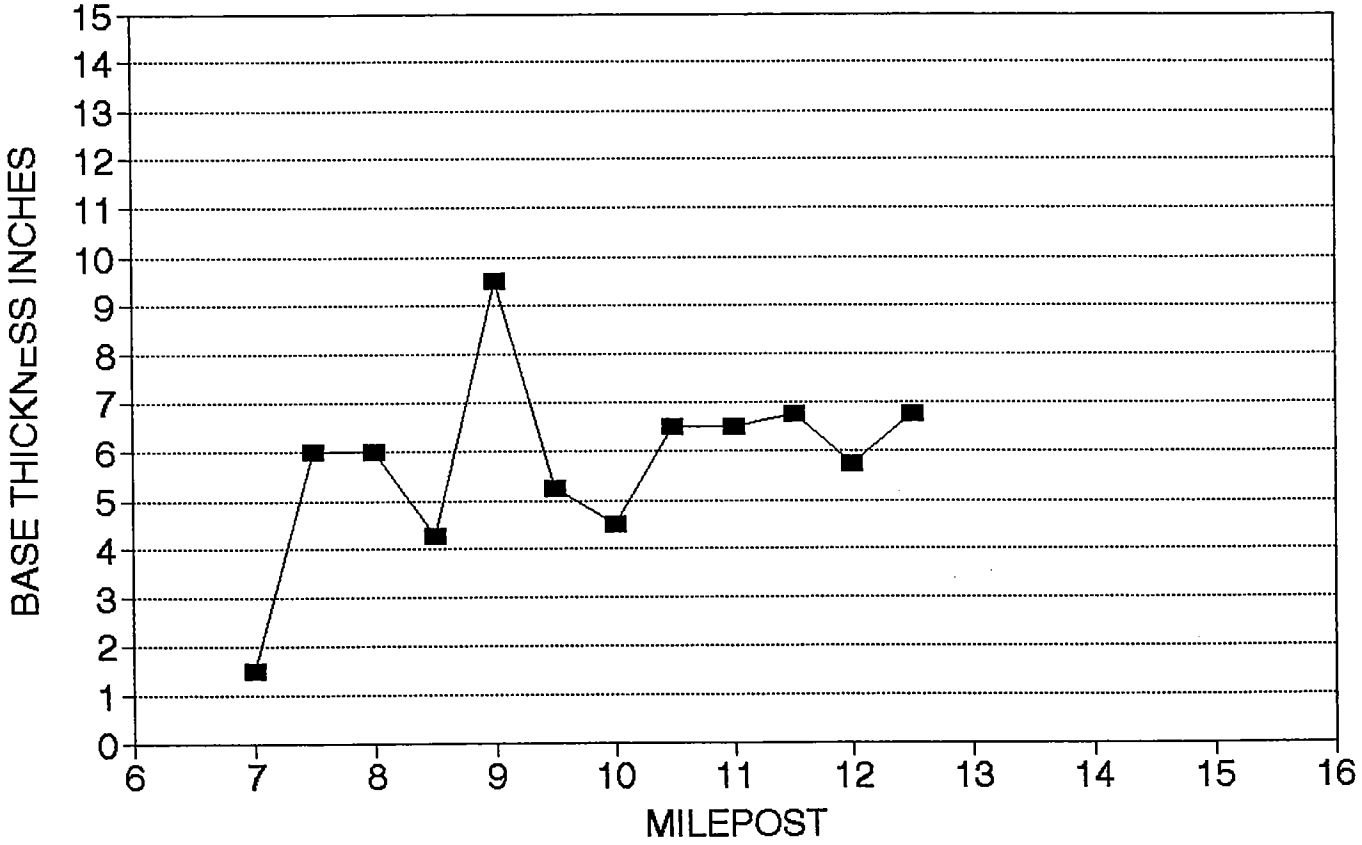
THEODORE ROOSEVELT NP SOUTH UNIT

ASPHALT THICKNESS SECTION 2



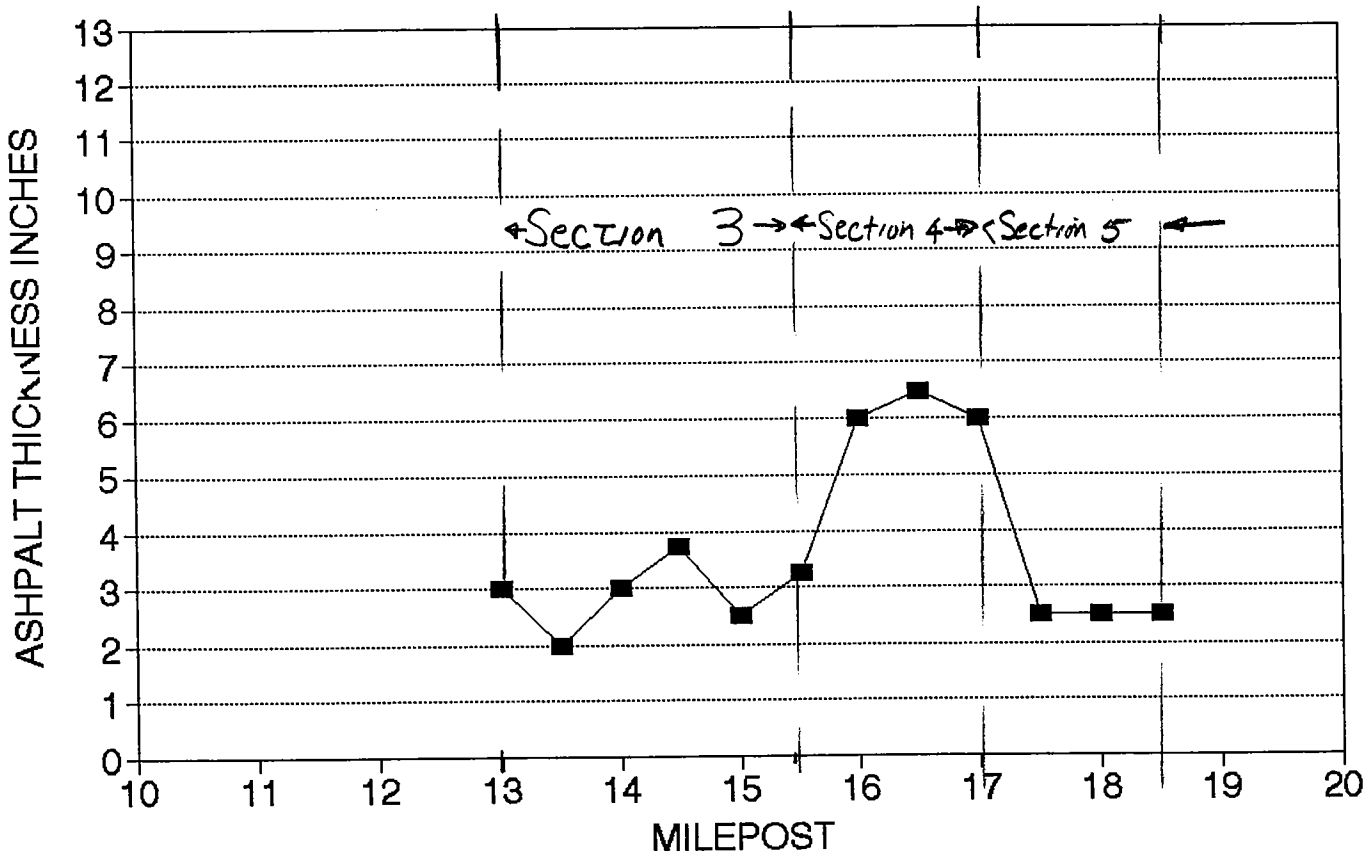
THEODORE ROOSEVELT NP SOUTH UNIT

BASE THICKNESS SECTION 2



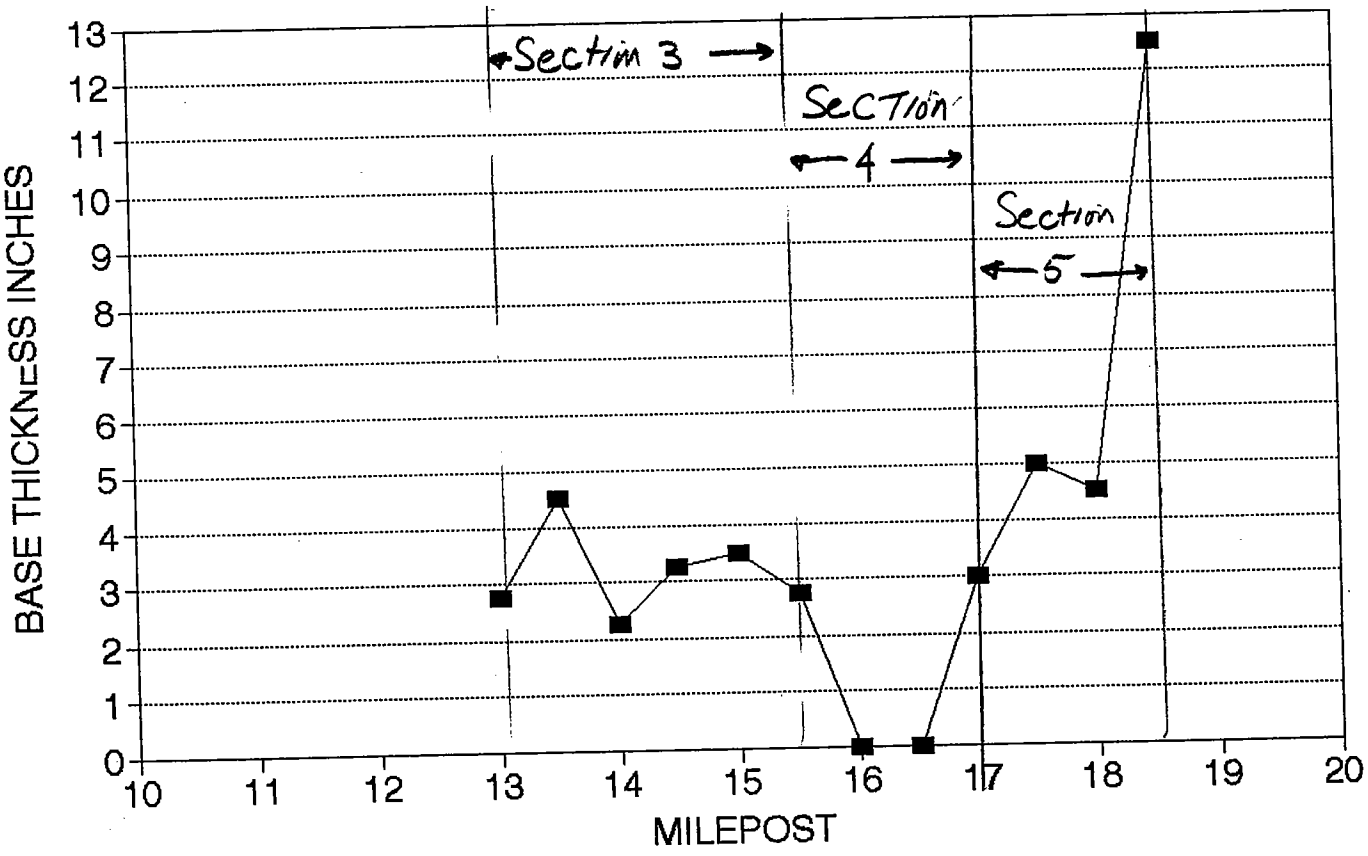
THEODORE ROOSEVELT NP SOUTH UNIT

ASPHALT THICKNESS SECTION 3 THROUGH 5



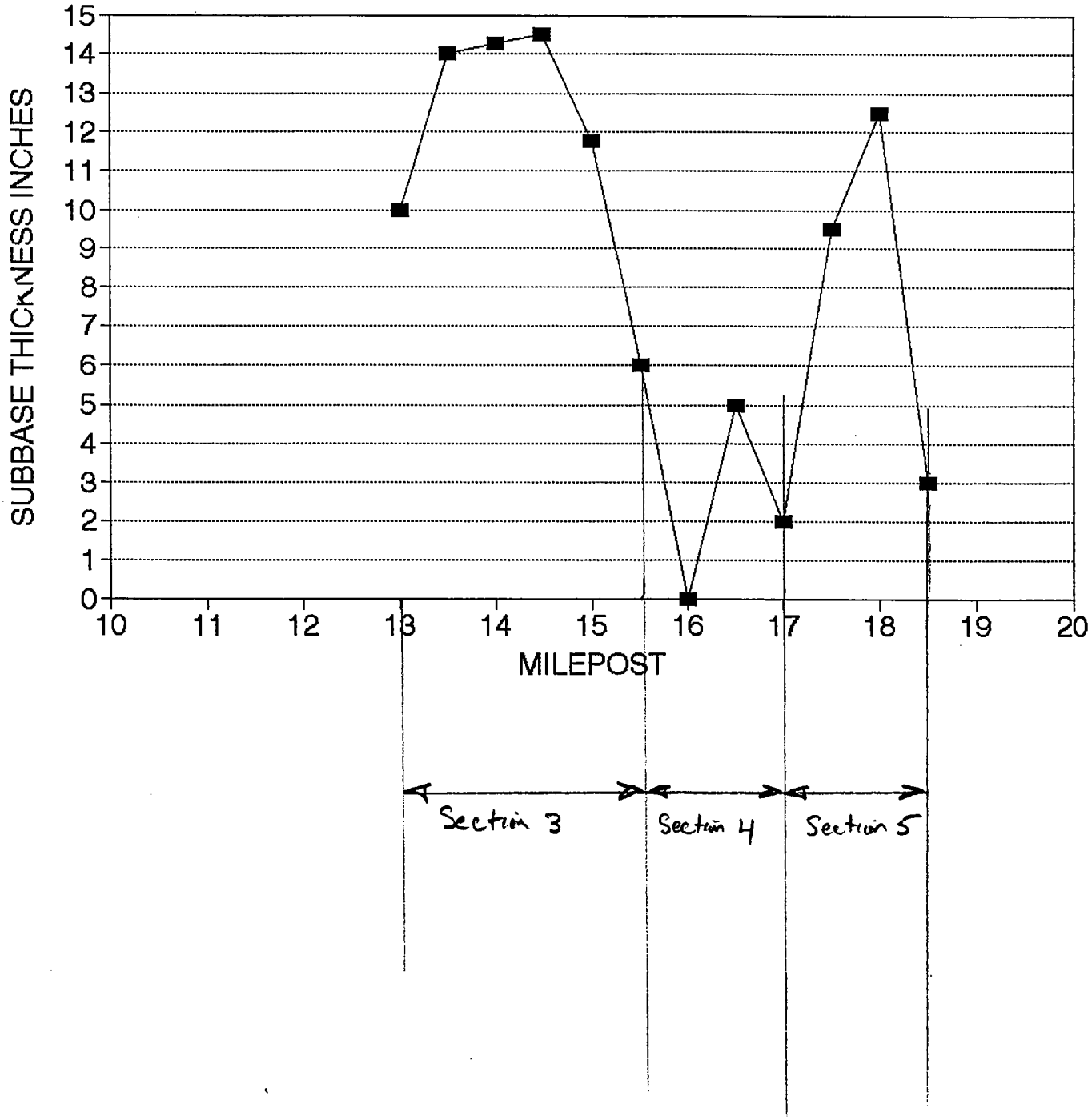
THEODORE ROOSEVELT NP SOUTH UNIT

BASE THICKNESS SECTIONS 3 THROUGH 5



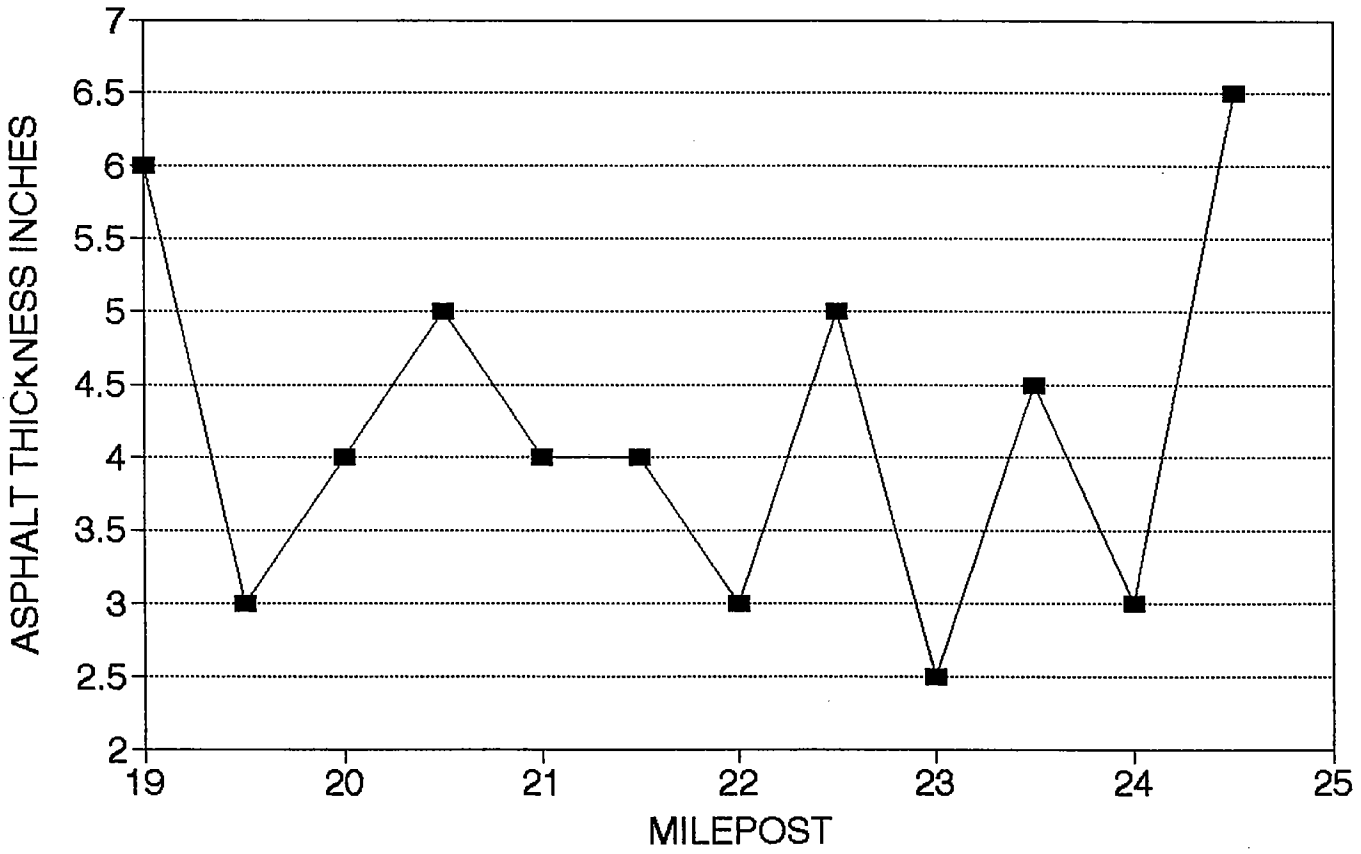
THEODORE ROOSEVELT NP SOUTH UNIT

SUBBASE THICKNESS SECTIONS 3 THROUGH 5



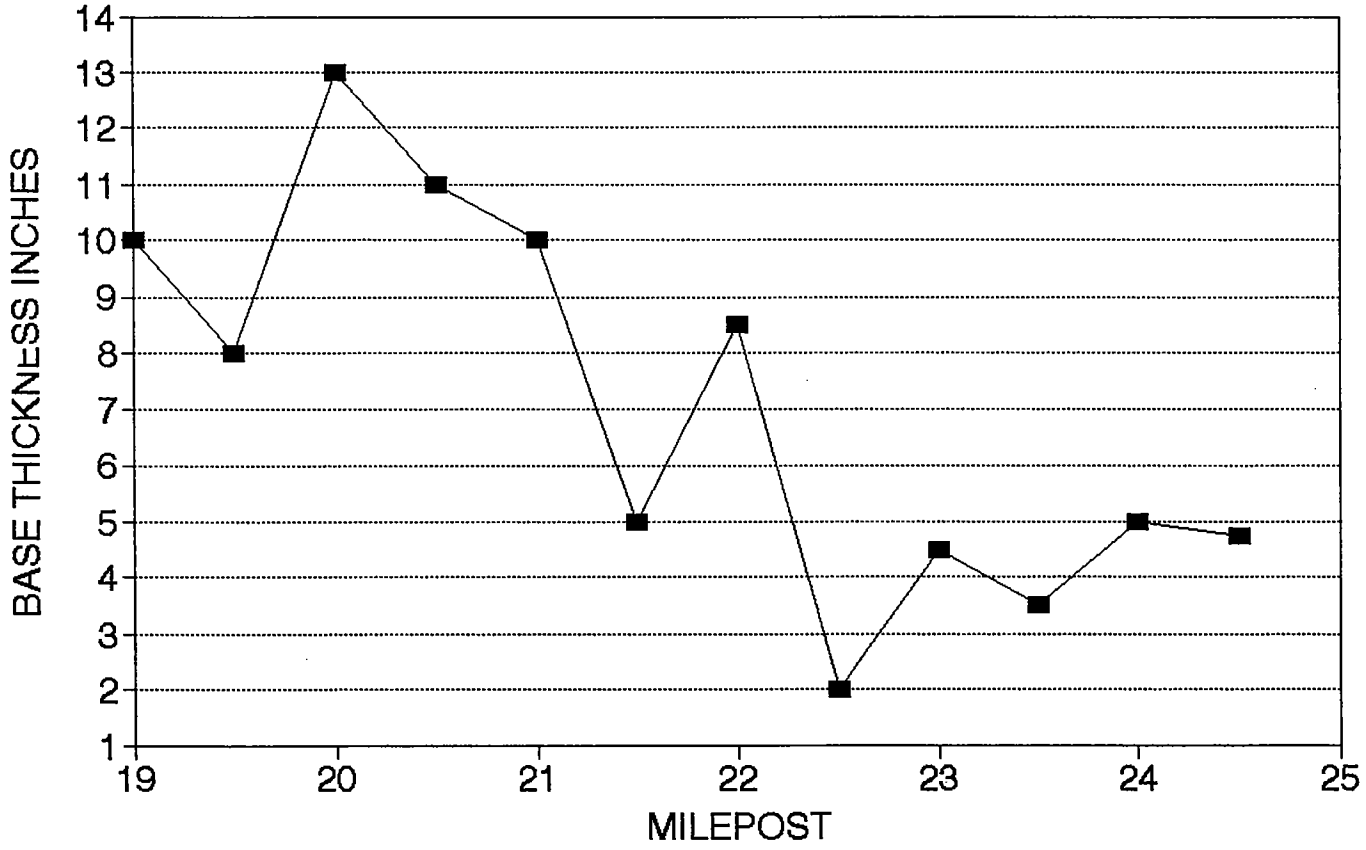
THEODORE ROOSEVELT NP SOUTH UNIT

ASPHALT THICKNESS SECTION 6



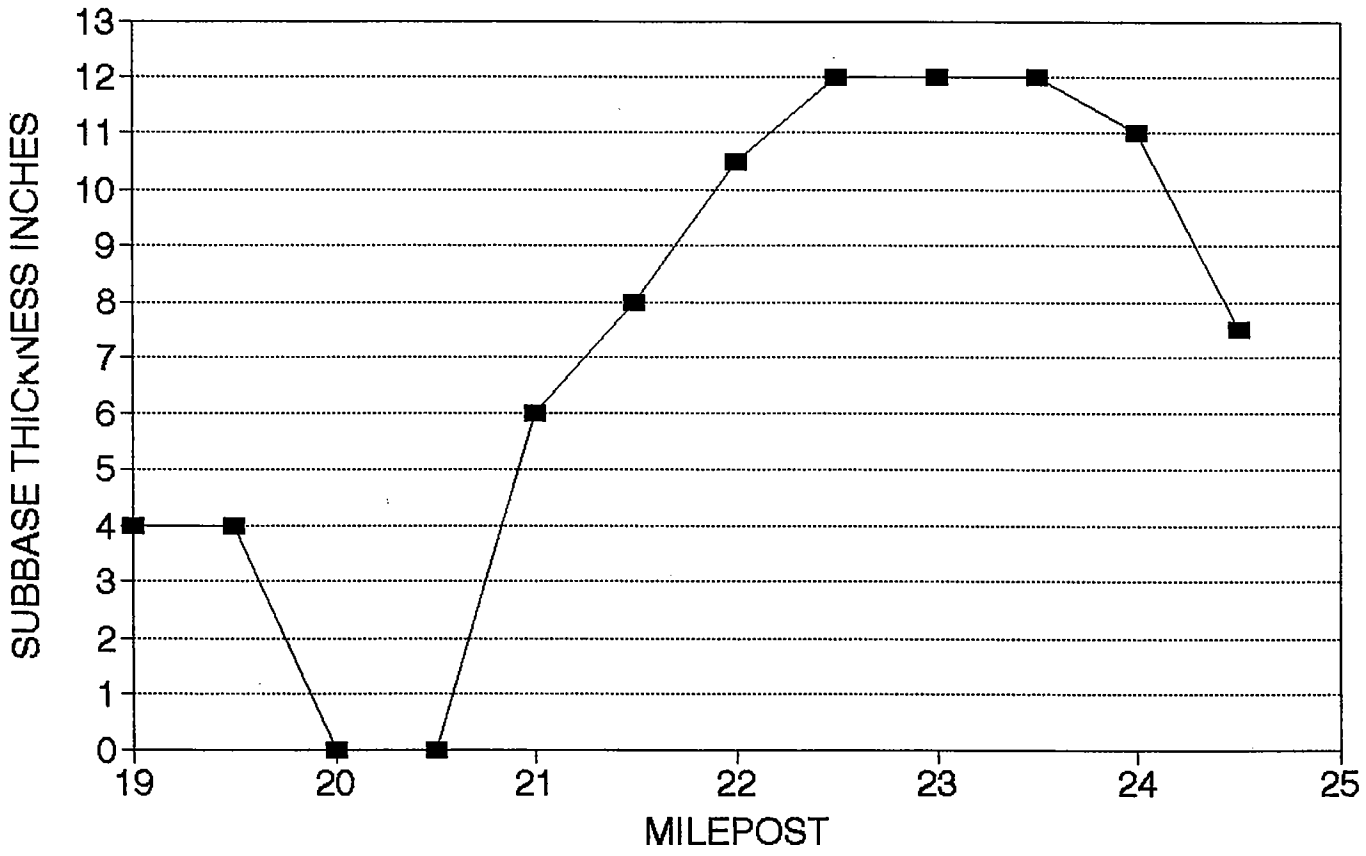
THEODORE ROOSEVELT NP SOUTH UNIT

BASE THICKNESS SECTION 6



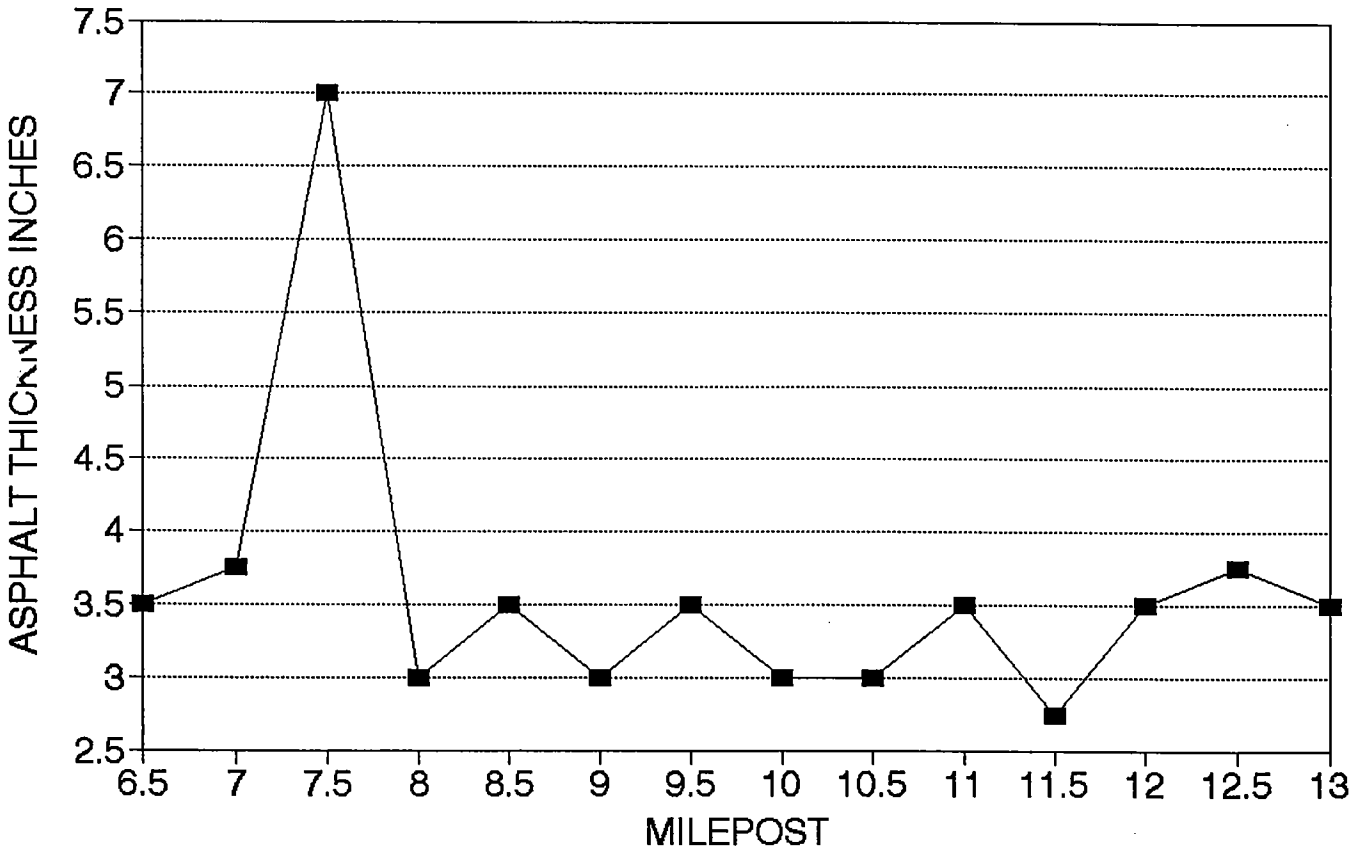
THEODORE ROOSEVELT NP SOUTH UNIT

SUBBASE THICKNESS SECTION 6



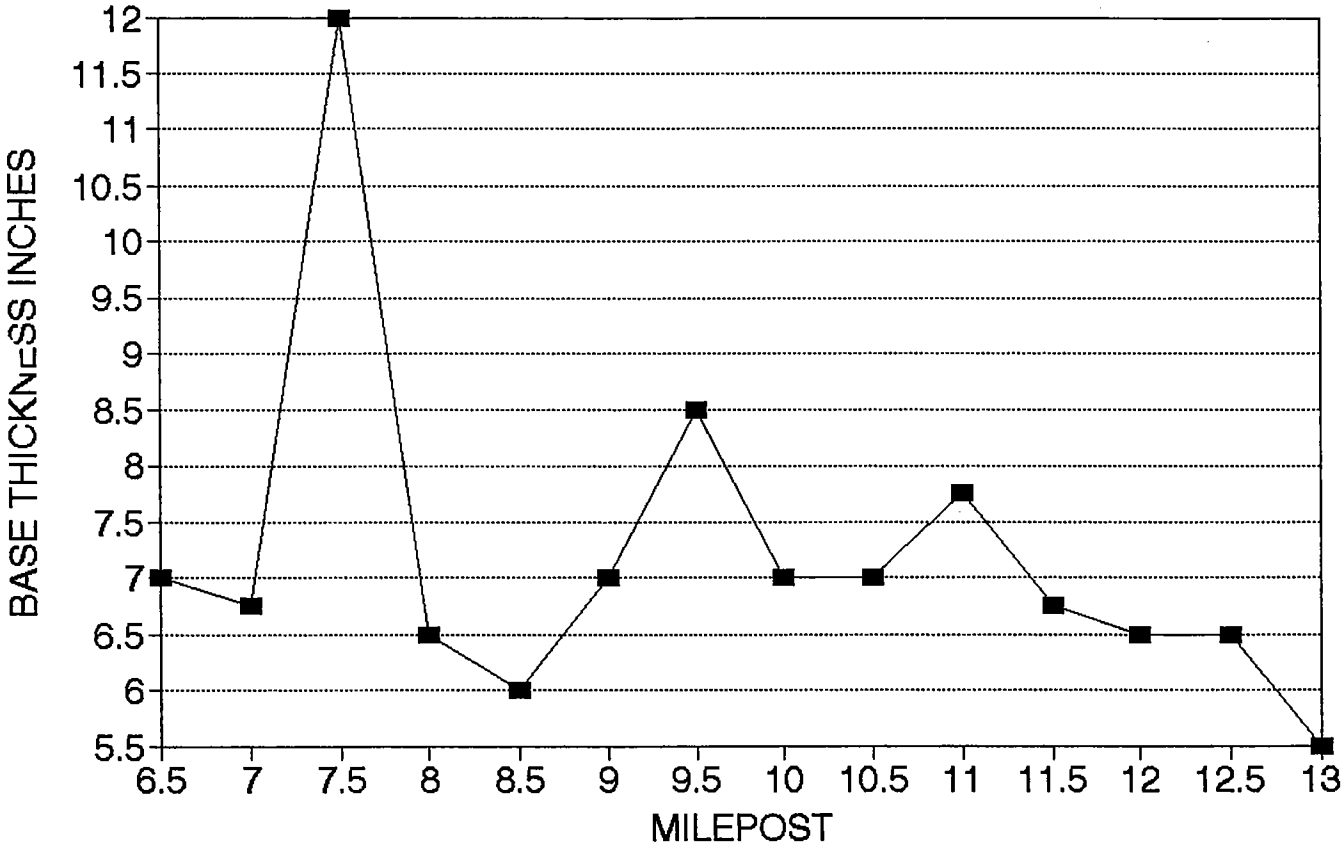
THEODORE ROOSEVELT NP NORTH UNIT

ASPHALT THICKNESS



THEODORE ROOSEVELT NP NORTH UNIT

BASE THICKNESS



PAVEMENT INVESTIGATION NOTES
9/29/92

SOUTH UNIT

LOCATION	BORING	PHOTO#	COMMENTS
PM 0.5	B- 1	1	Recent overlay, temperature cracking 18-foot centers.
PM 1.5	B- 3	2	Recent overlay, temperature cracking 50-foot centers.
PM 2.5	B- 5	3	Longitudinal crack in center of right lane. Temperature cracking 20 feet.
PM 3.5	B- 7	4	Recent overlay area, prairie dogs have dug in roadway.
PM 4.5	B- 9	5	Wheel path rutting <1/8 inch, temperature crack, 18-foot centers.
PM 5.5	B-11	6	Wheel path rutting 1/8 inch, both lanes.
PM 6.5	B-13	7	Temperature cracking, 25-foot centers.
PM 28.0	B-15	8	Temperature cracking on 20.5-foot centers.
PM 26.0	B-19	9	Temperature cracks 50 feet, fabric used in overlay.
PM 25.5	B-20	10	62-foot c-c temperature cracking; culvert outlet sever erosion.
PM 25	B-21	11	Wind Canyon Nature Trail Parking Area. Fabric, temperature cracking. End of overlay section.
PM 24.5	B-22	12	On Loop Road. Minor wheel path cracking, left lane. Chip sealed.
PM 23.5	B-24	13	Temperature cracking, 15-foot centers; minor wheel path rutting.
PM 22.5	B-26	14	Note paved ditch. Minor wheel path rutting.
PM 21.5	B-28	15	Some distortion in right lane.
PM 20.5	B-30	16	Boicourt area, roadway is badly distorted, settlement in roadway.
PM 19.5	B-32	17	30-foot block cracks.

LOCATION	BORING	PHOTO#	COMMENTS
PM 18.5	B-34	18	Chip seal, temperature cracking.
PM 17.5	B-36	19	Note temperature cracking, chip seal.
PM 16.5	B-38	20	Bleeding in wheel paths.
PM 16.0	B-39	21	Bleeding pavement.
PM 7.0	B-57	22	Note wheel path rutting 1 inch, and bleeding in wheel path.
PM 8.0	B-55	23	Rough pavement, temperature cracking.
PM 9.0	B-53	24	Horizontal and vertical roughness, rutting, temperature cracking.
PM 10.0	B-51	25	Wheel path rutting, temperature cracking.
PM 11.0	B-49	26	Half-moon crack in pavement.
PM 11.5		27	24-inch CMP corroded through, in a through fill.
PM 12	B-47	28	Temperature cracking, distorted.
PM 13	B-45	29	Wheel path rutting 1 inch, temperature cracking.
PM 14.0	B-43	30	Temperature cracking, wheel path rutting 1/2 inch, widened section, newer, paved ditch.
PM 15.0	B-41	31	Block cracking 30 feet x 20 feet.
			NORTH UNIT
PM 13.0	B- 1	32	Recent chip seal. 25.8 feet wide. Temperature cracks 25-foot on centers.
PM 12.5			200-foot patch both lanes, temperature cracking 15 - 50 feet.
PM 12.2			300-foot patch, both lanes.
PM 12.0	B- 3	33	Temperature cracking 50 feet. Some block cracking. Note left edge where chip seal was rotor milled off.
PM 11.5			Temperature cracking, some long cracking along shoulder 300 feet.

LOCATION	BORING	PHOTO#	COMMENTS
PM 11.0	B- 5	34	Temperature cracking, 50 feet.
PM 10.5			300-foot patch in outbound lane.
PM 10.25			500-foot patch, both lanes.
PM 10.0	B- 7	35	Temperature cracking, 75 feet.
PM 9.5	B- 8		Temperature cracks vary from 15 - 75 feet apart.
PM 9.0-9.5		35A	Two patches about 300 feet each, 1/@ lane width.
PM 9.0	B- 9	36	Outbound lane patched 500 feet, temperature cracking, inbound lane cracked along edge.
PM 8.5-9.0			Some wheel path rutting 1/8 inch.
PM 8.0-8.5			3 - 300-foot patches, both lanes.
PM 8.0	B-11	37	Temperature cracking varies 25 - 50 feet apart.
PM 7.5	B-12	38	Fill distress area, half-moon crack completely across roadway. Cracks about 2 inches wide and 4 inches deep.
PM 7.5-7.0			Mostly patches, worst section of pavement.
PM 7.0	B-13	39	Cold patch across roadway with some long tension cracks, 1/8-inch to hairline.
PM 7-6.5			Almost continuous patch, both lanes (80%).

APPENDIX H

ND PRA THRO 10(3) NORTH UNIT SLIDE REPAIR
Subexcavation Recommendations for Route 10
Dated 11/4/2008

U.S. Department of Transportation
Federal Highway Administration

MEMORANDUM

Central Federal Lands
November 4, 2008

12300 West Dakota Avenue
Suite 210A
Lakewood, CO 80228

Subject: ND PRA THRO 10(4) NORTH UNIT SLIDE REPAIR
Subexcavation Recommendations for Route 10

To: Mark Meng, Project Manager
Leo De Paula, Construction Operations Engineer
Danny Johnson, Project Engineer

From: Steve Deppmeier, Pavements Engineer

During construction of the subject project the haul route and future ND PRA THRO 10(3) NORTH UNIT SCENIC DRIVE was severely damaged (rutting) by construction vehicles to the point that the road was impassable to passenger vehicles. The result of the failure was due to poor subgrade soils. Over 8 locations with a cumulative length of approximately 1.5 mile roadway, covering both lanes will require subexcavation. Based on the SprectaPave 2 analysis software the following is recommended for most subexcavation areas:

1. Subexcavate a minimum of 24 inches.
2. Shape a crown for the subgrade to drain and ensure that subsurface water can exit to the foreslopes, avoiding trapping subsurface water in a confined bathtub effect.
3. Place a geotextile fabric, non-woven for filtration purposes, Type 1-C, and a minimum of 6 oz weight meeting the requirements of Table 714-1 with the added restriction of a maximum of apparent opening size (AOS) of 0.15 mm.
4. Place immediately on the geotextile fabric a GeoGrid BX1200.
5. Backfill 24 inches with granular material meeting subsection 704.07 Select Borrow or 308 Minor Crushed Aggregate. End-dump the material onto the geogrid and spread with a D6 dozer or smaller equipment. Do not operate equipment directly on the geogrid, push 6 to 12 inch lift of borrow out in front of the equipment. See the attached installation guide and specifications.
6. In the spring of 2009, remove 1.5 inches of gravel and place 1.5 inches of subsection 404 minor hot asphalt concrete pavement.

The parameters for the above include the following: Subgrade CBR = 0.8, M_r subgrade = 1000 psi, subgrade PI < 60, M_r borrow = 30,000 psi, allowable ESALs prior to paving = 1200, and allowable ESALs after paving = 42,000.

At the approach to Squaw Creek Bridge, MP 4.75, high groundwater and high PI (>60) results are expected based on the *Soil and Foundation Investigation 1981 Report.* These conditions are possible at other locations as denoted by asterisk in Table 1 below. To minimize the amount of subexcavation depth, an additional layer of geogrid is recommended as outlined below:

- Proceed as above from Steps 1 through 4.
- Backfill 12 inches with granular material meeting subsection 704.07 Select Borrow or 308 Minor Crushed Aggregate.
- Place a second layer of GeoGrid BX1200 at this depth on the Select Borrow or Minor Crushed Aggregate.
- Backfill 12 inches with the Select Borrow or Minor Crushed Aggregate.
- Continue with Step 6 from above.

Below is the table summary of the various lab results from 3 investigations that will appear in the forthcoming ND PRA 10(3) Pavements Report 09-03. The soil characteristics are highly variable even within the same soil classifications as the plasticity index (PI) & liquid limit (LL) in the first 5 laboratory results were classified as A-7-6, but the ranges were 24 to 99 & 42 to132 for PI & LL respectfully, all within ½ mile of each other.

For the Table 1 below:

A - Black ink is data from the May 2006 investigation
B- Blue ink is data from 1981 Report
Italicize blue ink is proposed new alignment (built in 1983) from 1981 Report
C- Red ink is data from Report 93-13

Table 1: Scenic Drive Subgrade Summary for MP 0.0 to 7.0

Report Designation	MP	AASHTO M 145	R-Value	PI	LL	- #4	- #200
B	0.27	A-7-6	10	24	42	100	81
**B*	*0.50*	*A-7-6*	-	**99*	**132*	*100*	*99*
*B	0.56	A-7-6	<5	*56	*82	100	99
**B*	*0.70*	*A-7-6*	-	**71*	**94*	*100*	*99*
B	0.76	A-7-6	11	26	47	100	98
A	1.00	A-6	-	23	40	97	70
B	1.09	A-6	17	21	40	100	88
**B*	*1.60*	*A-7-6*	-	**110*	**133*	*100*	*99*
**B*	*1.67*	*A-7-6*	-	**84*	**112*	*100*	*93*
*B	1.68	A-7-5	<5	*183	*218	100	100
A	2.00	A-6	23	14	35	92	45
B	2.20	A-6	18	21	40	99	81
A	3.00	A-6	-	15	39	95	59
B	3.17	A-7-6	<5	49	70	100	98
*B	3.18	A-7-5	<5	*114	*144	100	99
A	3.50	A-7-6	8	23	42	99	69
B	3.92	A-4	20	9	36	99	93
*B	4.57	A-7-6	<5	*77	*96	99	91
B	5.14	A-6	16	18	36	92	63
A	6.00	A-7-6	3	23	42	97	73
C	6.50	A-4	47	7	31	99	95
*C	7.00	A-7-6	<5	*67	*91	97	85

*Denotes locations that may require a second layer of GeoGrid BX1200 per the 5 bullets above.

Table 2 is the subexcavation guidance from Chapter 11 of the PDDM. It is provided here for informational purposes only; use the guidance as stated above.

Table 2: Subexcavation Guidelines

Plasticity Index (PI)	Liquid Limit (LL)	Depth of Subexcavation *
15 – 25	< 50	2 feet
25 – 35	50 – 60	2 – 4 feet
> 35	> 60	4 – 6 feet

* Traffic volume, project significance, and results of AASHTO T 258 and T 92 should influence subexcavation depth.

Note: the 10(4) construction on-site geotextile fabric R1 is not acceptable due to low permittivity and too large of AOS. The North Dakota Department of Transportation S2 geotextile fabric would be acceptable.

If you have any questions call me at, 720-963-3504.

CC: Mike Voth, Pavements & Materials FDL
Marilyn Dodson, Geotechnical Engineer
Richard Duval, QA Engineer
Project Files

Attachment: Spectra Roadway Improvement System worksheets
Section 207 – Earthwork Geotextile
Section 714 – Geotextile and Geocomposite Drain Material

Roadway
Improvement System

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1-800-TENSAR-1

ND PRA THRO 10(4) North Unit Slide Repair

McKenzie Count, North Dakota, United States

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(FAX)
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10-16-08

CLIENT

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(FAX)

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Design Methodology

The aggregate fill thicknesses determined in the Results section below are based on the methodology prescribed in Giroud and Han (2004). The design method is intended for the calculation of the required unbound aggregate layer thickness for unpaved roads constructed on weak subgrades.

Validation of the thicknesses achieved for pavement sections reinforced with Tensar biaxial geogrids using this method were achieved through calibration with several sets of test data including the results obtained from work undertaken in the pavement test facility at North Carolina State University (Gabr, 2001).

Design Parameters

a) Trafficking Requirements

Property	Value
Axle Load (kips)	20
Tire Pressure (psi)	100
Axial Passes (Each)	1200
Maximum Rut Depth (in)	1.5

b) Pavement Soil Properties

Property	Value
Aggregate Fill CBR (%)	30
Field Subgrade CBR (%)	0.4

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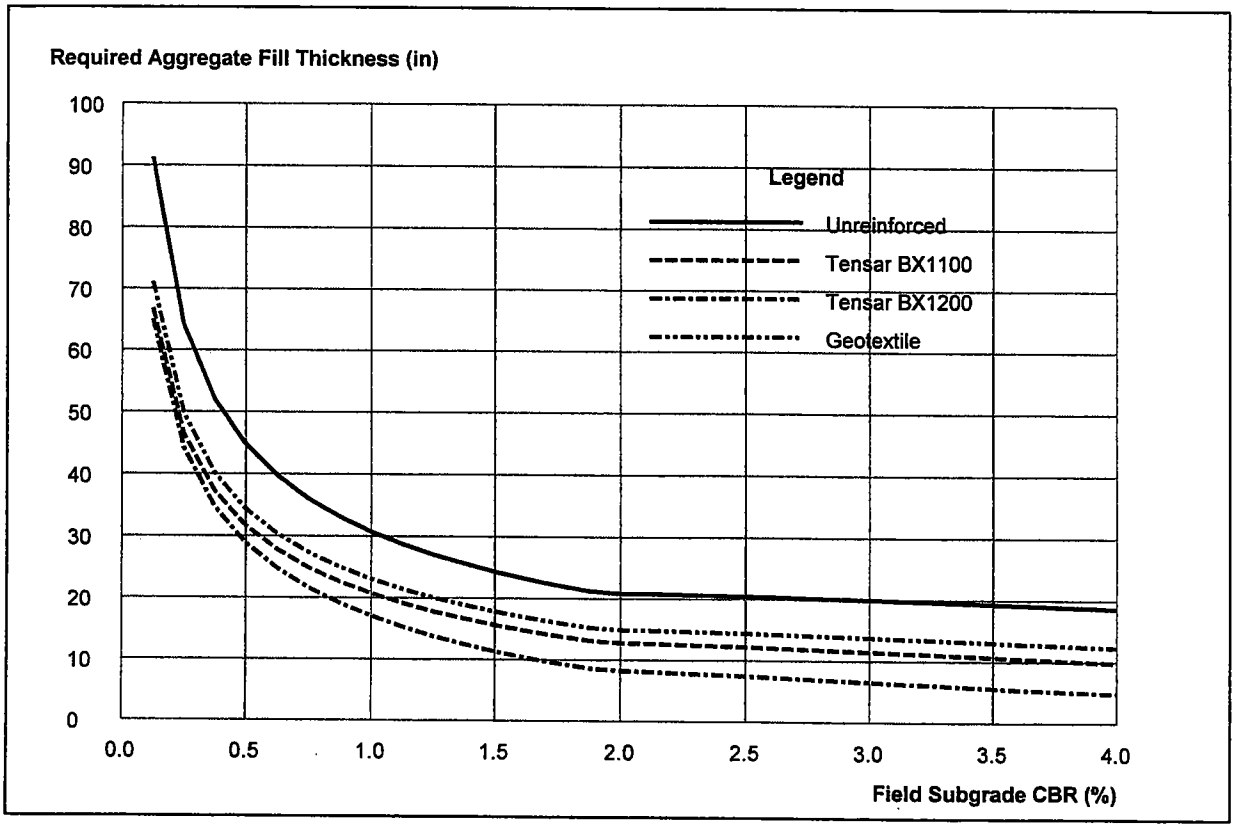
c) Geosynthetic Properties

Parameter	BX1100	BX1200
Geogrid type	Integrally formed, single layer	Integrally formed, single layer
Rib shape	Rectangular/ square	Rectangular/ square
Rib thickness (in)	0.03	0.05
Aperture stability modulus (m-N/degree)	0.32	0.65
Junction efficiency (%)	90	90
Aperture dimensions (in) - Machine direction - Cross machine	 1.0 1.3	 1.0 1.3
Thickness adjustment factor	1.0	1.0

Results



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Aggregate Fill Thickness Savings

Geosynthetic	Aggregate Fill Thickness (in)		Aggregate Fill Thickness Savings (in)	
	Calculated	Required	(in)	(%)
Unreinforced	50.35	51	N/A	N/A
Tensar BX1100	35.93	36	15	29
Tensar BX1200	33.34	34	17	33
Geotextile	38.8	39	12	24

References

1. Gabr M. (2001)
   Cyclic plate loading tests on geogrid reinforced roads.
   Research report to Tensar Earth Technologies Inc., N.C. State University

2. Giroud, J.P., and Han, J. (2004)
   Design method for geogrid-reinforced unpaved roads:
   Part 1 – Development of design method
   ASCE Journal of Geotechnical and Geoenvironmental Engineering

3. Giroud, J.P., and Han, J. (2004)
   Design method for geogrid-reinforced unpaved roads:
   Part II – Calibration and applications
   ASCE Journal of Geotechnical and Geoenvironmental Engineering

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ND PRA THRO 10(4) North Unit Slide Repair

McKenzie Count, North Dakota, United States

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The aggregate fill thicknesses determined in the Results section below are based on the methodology prescribed in Giroud and Han (2004). The design method is intended for the calculation of the required unbound aggregate layer thickness for unpaved roads constructed on weak subgrades.

Validation of the thicknesses achieved for pavement sections reinforced with Tensar biaxial geogrids using this method were achieved through calibration with several sets of test data including the results obtained from work undertaken in the pavement test facility at North Carolina State University (Gabr, 2001).

Design Parameters

a) Trafficking Requirements

Property	Value
Axle Load (kips)	20
Tire Pressure (psi)	100
Axial Passes (Each)	1200
Maximum Rut Depth (in)	3.0

b) Pavement Soil Properties

Property	Value
Aggregate Fill CBR (%)	30
Field Subgrade CBR (%)	0.4

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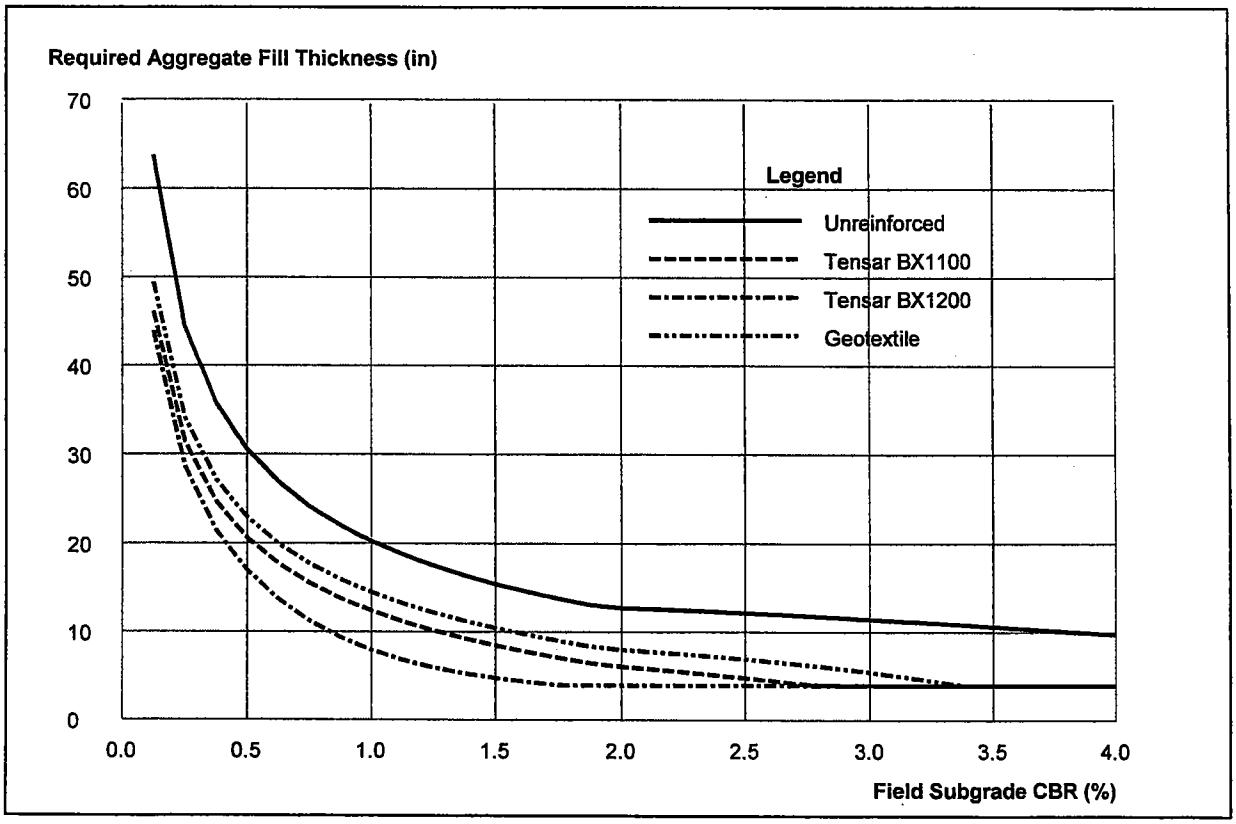
c) Geosynthetic Properties

Parameter	BX1100	BX1200
Geogrid type	Integrally formed, single layer	Integrally formed, single layer
Rib shape	Rectangular/ square	Rectangular/ square
Rib thickness (in)	0.03	0.05
Aperture stability modulus (m-N/degree)	0.32	0.65
Junction efficiency (%)	90	90
Aperture dimensions (in) - Machine direction - Cross machine	 1.0 1.3	 1.0 1.3
Thickness adjustment factor	1.0	1.0

Results



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Aggregate Fill Thickness Savings

Geosynthetic	Aggregate Fill Thickness (in)		Aggregate Fill Thickness Savings (in)	
	Calculated	Required	(in)	(%)
Unreinforced	34.81	35	N/A	N/A
Tensar BX1100	23.94	24	11	31
Tensar BX1200	20.59	21	14	40
Geotextile	26.37	27	8	23

References

1. Gabr M. (2001)
   Cyclic plate loading tests on geogrid reinforced roads.
   Research report to Tensar Earth Technologies Inc., N.C. State University

2. Giroud, J.P., and Han, J. (2004)
   Design method for geogrid-reinforced unpaved roads:
   Part 1 – Development of design method
   ASCE Journal of Geotechnical and Geoenvironmental Engineering

3. Giroud, J.P., and Han, J. (2004)
   Design method for geogrid-reinforced unpaved roads:
   Part II – Calibration and applications
   ASCE Journal of Geotechnical and Geoenvironmental Engineering

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Roadway
Improvement System

SPECTRA®

TENSAR EARTH TECHNOLOGIES, INC.
www.tensarcorp.com
1-800-TENSAR-1

ND PRA THRO 10(4) North Unit Slide Repair

McKenzie Count, North Dakota, United States

DESIGNER

CFLHD
12300 W. Dakota Avenue
Lakewood, Colorado 80228, United States
ATTN: Steve Deppmeier
303-963-3504 (TEL)
(FAX)
steve.deppmeier@dot.gov
10-16-08

CLIENT

National Park Service
Theodore Roosevelt N.P.
Medora, North Dakota , United States
ATTN:
(TEL)
(FAX)

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Design Methodology

The aggregate fill thicknesses determined in the Results section below are based on the methodology prescribed in Giroud and Han (2004). The design method is intended for the calculation of the required unbound aggregate layer thickness for unpaved roads constructed on weak subgrades.

Validation of the thicknesses achieved for pavement sections reinforced with Tensar biaxial geogrids using this method were achieved through calibration with several sets of test data including the results obtained from work undertaken in the pavement test facility at North Carolina State University (Gabr, 2001).

Design Parameters

a) Trafficking Requirements

Property	Value
Axle Load (kips)	20
Tire Pressure (psi)	100
Axial Passes (Each)	1200
Maximum Rut Depth (in)	1.5

b) Pavement Soil Properties

Property	Value
Aggregate Fill CBR (%)	30
Field Subgrade CBR (%)	0.8

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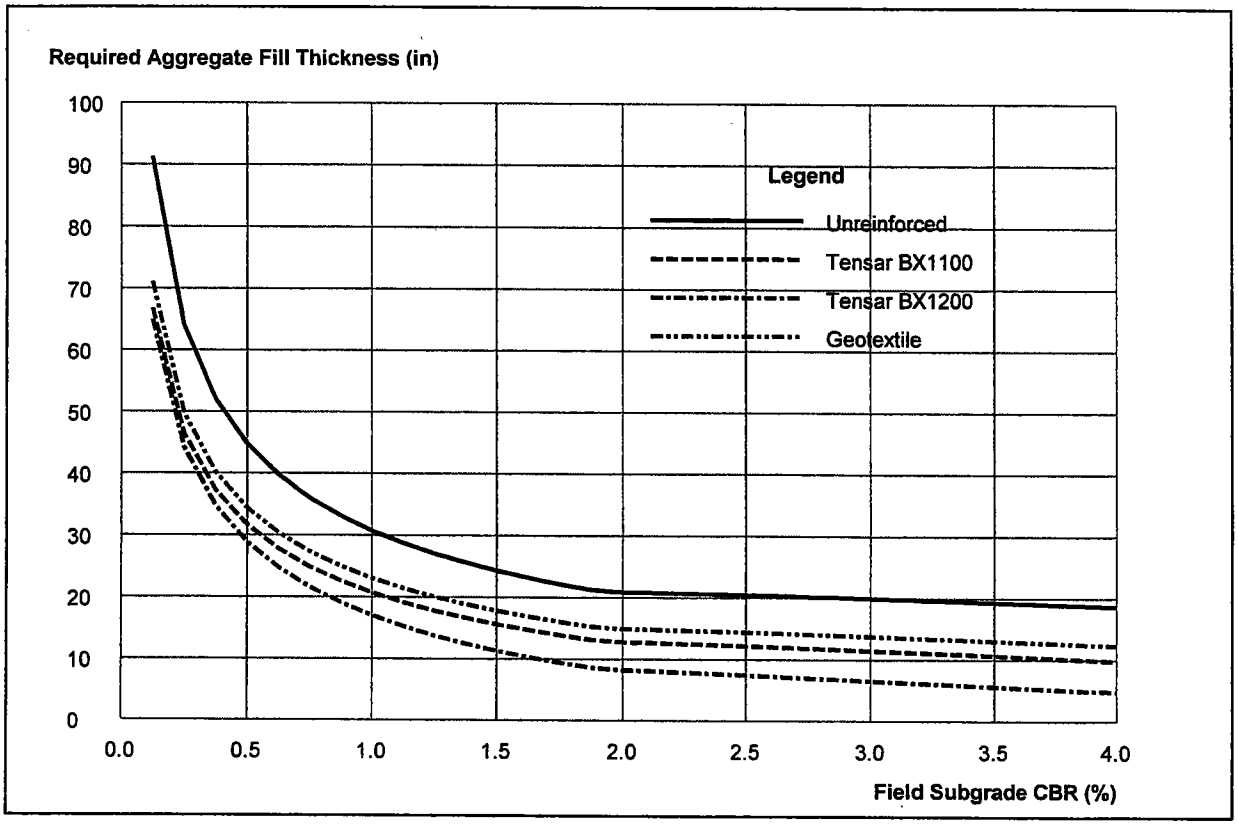
c) Geosynthetic Properties

Parameter	BX1100	BX1200
Geogrid type	Integrally formed, single layer	Integrally formed, single layer
Rib shape	Rectangular/ square	Rectangular/ square
Rib thickness (in)	0.03	0.05
Aperture stability modulus (m-N/degree)	0.32	0.65
Junction efficiency (%)	90	90
Aperture dimensions (in) - Machine direction - Cross machine	 1.0 1.3	 1.0 1.3
Thickness adjustment factor	1.0	1.0

Results



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Aggregate Fill Thickness Savings

Geosynthetic	Aggregate Fill Thickness (in)		Aggregate Fill Thickness Savings (in)	
	Calculated	Required	(in)	(%)
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Design Methodology

The calculations contained in this section are based on the methodology prescribed in the AASHTO (1993) guide. When reference is made to the 'AASHTO (1993) Equation', the equation concerned is that given at the top of Figure 3.1 on Page II-32 of the document.

In addition to ensuring that the overall Structural Number of the pavement is at least equal to that required to carry the intended traffic load, it is also recommended to ensure that individual layers are designed in accordance with the Layered Analysis approach prescribed in Section 3.1, Part II of the AASHTO (1993) docume

Design Parameters

a) Pavement Layer Properties

Layer	Description	Elastic modulus, E (psi)	Cost ($/CY)	Layer coefficient	Drainage factor
ACC2	Dense-graded Asphalt	400,000	118	0.44	N/A
ABC	Aggregate Base Course	30,000	43	0.14	1.0
ABC	Aggregate Base Course	30,000	43	0.14	1.0

b) Input Parameters for AASHTO (1993) Equation

Parameter	Value
Reliability (%)	75
Standard Normal Deviate	-0.674
Standard Deviation	0.49
Initial Serviceability	4.2
Terminal Serviceability	2.0
Change in Serviceability	-2.2
Subgrade Resilient Modulus (psi)	1,000

c) Input Parameters for Tensar Geogrid

Parameter	Value
Supply cost for Tensar BX1100 $/SY	4.00
Supply cost for Tensar BX1200 $/SY	6.00
TBR value for Tensar BX1100	3
TBR value for Tensar BX1200	6
Cost to install geogrid $/SY	0.75

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Results

Table 1 - Proposed Pavement Section

Layer	Thickness (in)	ai	mi	SN
ACC2	1.5	0.44	N/A	0.66
ABC	18.0	0.14	1.0	2.52
ABC	4.5	0.14	1.0	0.63
Overall Structural Number (SN)				**3.81**

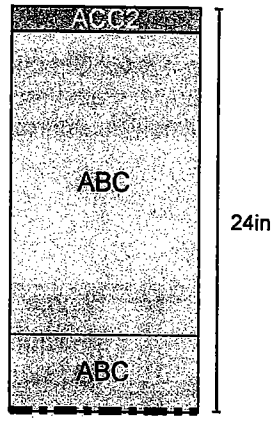

Table 2a - Calculated Trafficking Based on Overall Structural Number

Allowable traffic load (ESAL's)	Unreinforced	Reinforced	
		BX1100	BX1200
	42,000	126,000	252,000

Table 2b - Calculated Trafficking Based on a Layered Analysis

Layer	Underlying layer		SN of overlying layers	Allowable traffic (ESAL's)		
	Name	Modulus (psi)		Unreinforced	BX1100	BX1200
ACC2	ABC	30,000	0.66	7,000	21,000	42,000
ABC	ABC	30,000	3.18	32,842,000	98,526,000	197,052,000

A Layered Analysis ensures that individual layers within the pavement remain intact during its design life; full details are presented in Section 3.1.5, Part II of AASHTO (1993)

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Table 3 - Allowable Trafficking

	Allowable traffic (ESAL's)	Cost ($/SY)	Comparative Cost ($/SY/1000 ESAL's)
Unreinforced	7,000	31.79	4.541
BX1100	21,000	36.54	1.740
BX1200	42,000	38.54	0.918

The allowable trafficking for a specific pavement is the minimum value calculated using the Overall Structural Number approach (Table 2a) and the Layered Analysis (Table 2b); full details are presented in Section 3.1, Part II of AASHTO (1993).

Reference

1. AASHTO (1993). Guide for the design of pavement structures; The American Association of State Highway and Transportation Officials

2. AASHTO (2003). "Recommended Practice for Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures", American Association of State Highway and Transportation Officials, Publication PP46-01, Washington, D.C.

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The Spectra® System provides soil reinforcement and offers a predictable, cost-effective solution.

TENSAR® GEOGRIDS

The Spectra System owes its strength and durability to **Biaxial (BX)** Geogrids, Tensar's patented geosynthetic reinforcement grids. These geogrids stand the test of time, performing better than other commercially available geosynthetics due to their stiff interlocking capability. For more information, visit www.tensar-international.com.

Introduction

When weak subgrade, heavy loads, thick fill layers, high structural fill costs, contaminated subgrades or shallow utilities disrupt your construction schedule or budget, the Spectra® Roadway Improvement System can provide the best solution.

Not only does this system allow access and construction in less than ideal situations, it also offers a predictable engineered solution. This solution relies on Tensar® Biaxial (BX) Geogrids and crushed aggregate base acting together to create a stronger composite structure, which increases the performance of the underlying subgrade or aggregate base course.

Tensar BX Geogrids have proven their performance and cost-efficiency in thousands of applications. Over soft ground, BX Geogrids improve the soil's effective bearing capacity by distributing applied loads more widely, similar to the way a snowshoe supports a man's weight over soft snow (Figure 1). Over firmer ground, geogrids stiffen and interlock with fill materials by confining aggregate particles within its apertures, thus yielding a stronger component for increased serviceability and durability.

The subgrade improvement and base reinforcement applications, and their primary mechanisms, are predetermined by ground or foundation support. Proper geogrid installation is also based on subgrade strength. We use California Bearing Ratio (CBR) to quantify this important variable.

Tensar BX Geogrids are used to minimize aggregate fill requirements, reduce or eliminate undercut, improve compaction, serve as a construction platform and extend service life. These features depend upon proper installation as put forth in this guide.*

*This guide cannot account for every possible scenario, but it does cover most applications of the Spectra System. If you have questions regarding a specific project, call 800-TENSAR-1 or visit www.tensar-international.com.

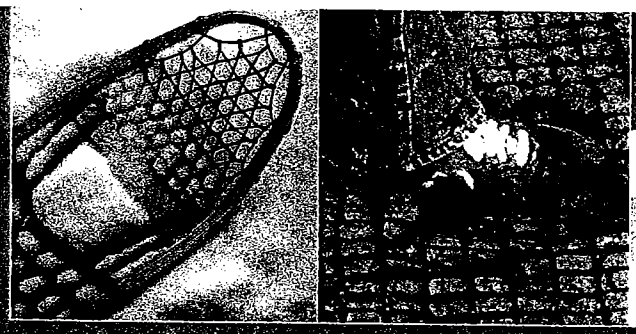
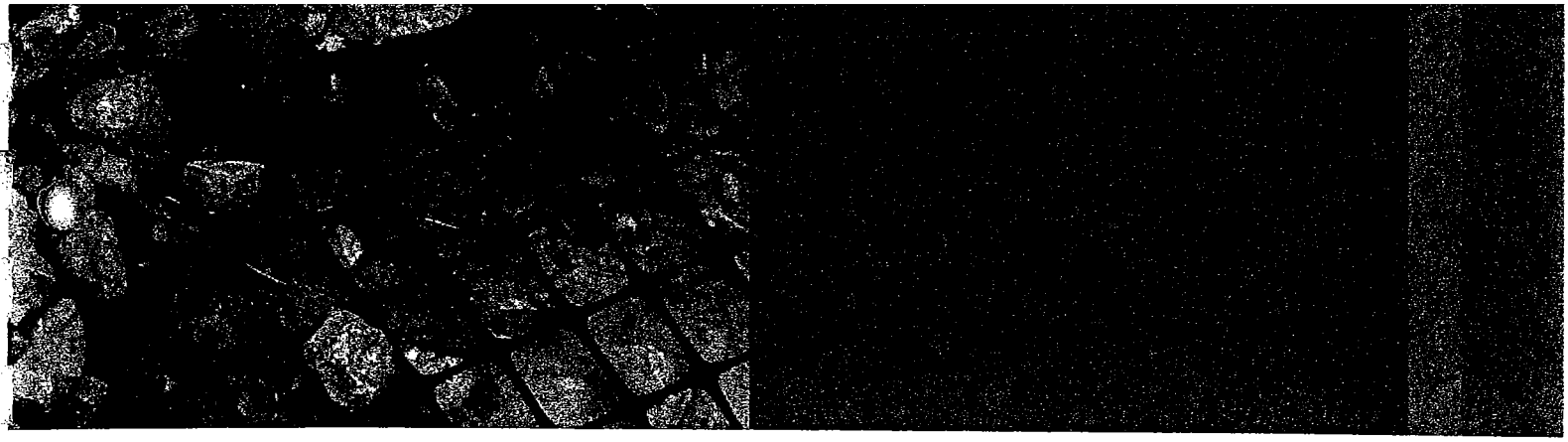


Figure 1: The Snowshoe Effect – Tensar BX Geogrids distribute heavy loads over soft soils just like a snowshoe supports the weight of a man over soft snow.

SPECTRA System Components

COMPONENT	FUNCTION
Tensar Biaxial Geogrids	Stiff geosynthetic reinforcement
Design	Roadway sections developed using SpectraPave3™ Software
Site Assistance	Reduce project costs and expedite the installation process



1. Getting Started

- When placing an order, communicate all pertinent project and/or application criteria, including certification requirements, if any, with your Tensar International Corporation (TIC) representative. It is normally advisable to schedule a pre-construction meeting with this representative and any other appropriate parties at this time.
- Upon delivery, check the BX Geogrid roll labels to verify that the intended product has been received. For instance, BX1100 and BX1200 Geogrids have a similar appearance, but different structural characteristics so their distinction is important. Inspect the geogrid to ensure it is free of any flaws or damage that may have occurred during shipping or handling. If variable roll widths are supplied, please confirm that the correct quantities have been delivered. Tensar BX Geogrid rolls are assigned distinct nomenclature to distinguish wide rolls from narrow rolls:*
    - BX110047 (9.8 ft.)
    - BX110075 (15.1 ft.)
    - BX120040 (9.8 ft.)
    - BX120060 (13.1 ft.)

*Additional roll characteristics can be found on page 8 of this guide under "Tensar BX Geogrid Roll Characteristics."

- Store Tensar BX Geogrids in a manner that prevents excessive mud, wet concrete, epoxy or other deleterious materials from coming in contact with and affixing to the geogrid. Store geogrids above -20°F (-29°C) and avoid handling below 14°F (-10°C) – the glass-transition temperature for polypropylene used in BX Geogrids. Tensar BX Geogrids may be stored uncovered for up to six months in direct exposure to sunlight without any loss in certifiable structural properties (contact TIC if longer exposure is anticipated). BX Geogrids may be stored vertically (rolls stood on end) or, typically, horizontally in stacks not exceeding five rolls high (Figure 2).
- Anticipate potential issues and resolve them with TIC prior to construction. To contact the local TIC representative for your area, call 800-TENSAR-1.

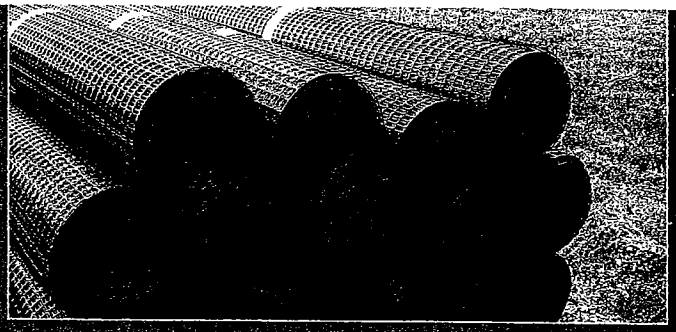


Figure 2: Storing the BX Geogrid rolls (horizontally).

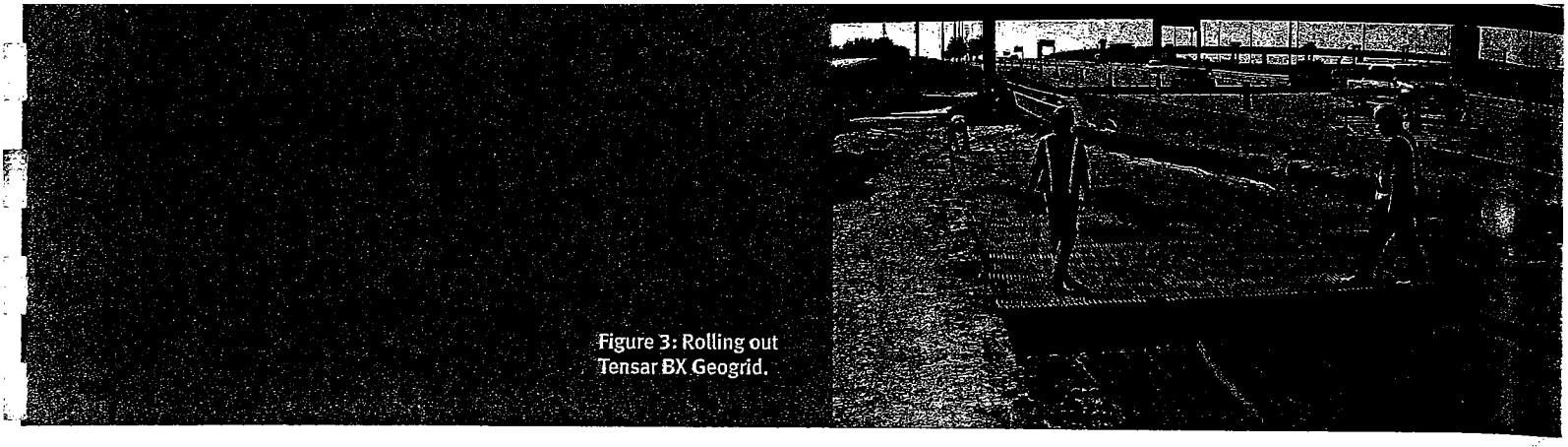


Figure 3: Rolling out Tensar BX Geogrid.

2. Site Preparation

- Clear, grub and excavate (if necessary) to the design subgrade elevation, stripping topsoil, deleterious debris and unsuitable material from the site. For very soft soils (CBR < 0.5), it may be beneficial to minimize subgrade disturbance and leave root mats in place, cutting stumps and other projecting vegetation as close and even to the ground surface as practical (Table 1). For moderately competent soils (CBR > 2), it may be prudent to lightly proof roll the subgrade to locate unsuitable materials. When possible, backdrag to smooth out any ruts.
- Smooth grade and compact the soils using appropriate compaction equipment. Swampland, peat, muskeg or marshes may be difficult to smooth grade and/or compact. In these situations, create a surface that is as uniformly smooth as possible. Grade or crown the surface for positive drainage away from the construction zone.

Note: Routine construction procedures are normally recommended for site preparation. Special measures are rarely required to accommodate Tensar BX Geogrids.

- Place the rolls of BX Geogrid* in position, cut the roll bands and manually unroll the material over the prepared surface (Figure 3). In subgrade improvement applications, this surface will always be the subgrade. In base reinforcement applications, it may be the subgrade, the subbase or at an elevation (ex., mid-depth) within the base course.
- Fine grained noncohesive soils such as silts present unique challenges, especially with the presence of excessive moisture. TIC recommends that a Tensar representative be contacted so that site conditions can be analyzed to ensure that geogrid performance is optimized.

*Tensar International Corporation manufactures several different types of BX Geogrids. Selection and optimization depends on structural performance requirements, subgrade and fill parameters, economic considerations and local availability.

Table 1: Summary of BX Geogrid Installation Parameters

Subgrade Strength	Clear All Vegetation?	BX Orientation[3]	BX Overlap[4]	Ties?[1,2]	Direct Traffic?[5]	Geotextile?[6]
CBR ≤ 0.5	N	T or L	3 ft.	Y	N	Analysis Req'd
0.5 ≤ CBR ≤ 2	Usually	L	2 – 3 ft.	N	N	Analysis Req'd
2 ≤ CBR ≤ 4	Y	L	1 – 2 ft.	N	Limited	Analysis Req'd
4 ≤ CBR	Y	L	1 ft.	N	Y	N

Notes:

1. Summary is a generalized presentation; see text for specifics.
2. Y = Yes, normally required; N = No, normally not required.
3. Geogrid Orientation (roll axis in relation to traffic): T = Transverse, L = Longitudinal.
4. General Geogrid Overlap Rule: Overlap = 3 ft. for CBR ≤ 1; Overlap = 1 ft. for CBR ≥ 3; interpolate between.
5. Direct Traffic pertains only to conventional rubber-tired equipment.
6. Analysis Req'd = Geotextile required only if filtration criteria not met by aggregate fill.

3. Placing Overlapping Geogrid

- Unroll the geogrid in the direction of travel so that the long axis of the roll is parallel with channelized traffic patterns. For very soft subgrades (CBR < 0.5), unrolling geogrid transversely or perpendicular to the roadway embankment alignment, may be preferred, particularly if lateral spreading and separation of overlaps is a concern (Table 1).
- Overlap adjacent rolls along their sides and ends in accordance with Table 1.
- Overlap ("shingle") geogrids in the direction the fill placement will be spread (Figure 4) to avoid "peeling" of geogrid at overlaps by the advancing fill. To expedite "shingling", consider placing rolls at the far end of the coverage area first, and work toward the near end from where the fill will be advanced. Weaker subgrades that are easily rutted with conventional construction traffic will require an "end-dumping" operation. Please refer to page 6 "Dumping and Spreading Aggregate Fill" for more information.
- Adjacent geogrid rolls are normally not connected to one another, particularly if fill is placed and spread as described herein (Table 1). A notable exception is over very soft subgrades (CBR < 0.5) where nylon cable ties (or "zip ties") can be effective in helping maintain overlap dimensions. These ties are not considered structural connections, but rather construction aids. In most applications their use is not required.
- Cut and overlap the geogrid to accommodate curves (Figure 5). Cutting may be done with sharp shears, a knife-like implement or handheld power (i.e., "cutoff") saws (Figure 6). (Wear appropriate safety equipment.) Cut grid to conform to manhole covers and other immovable protrusions.
- Place geogrids in daily work sections so that proper alignment is maintained.
- In some cases, especially on cooler days, Tensar BX Geogrid will exhibit "roll memory" where the product may roll back upon cutting or reaching the end of the roll. It is recommended that the installer take appropriate measures to ensure that the product lies flat during fill placement. This can be easily achieved by using sod staples, zip ties or simply adding a shovelful of fill to weigh down the product.

Figure 4: Geogrid should overlap in the direction of advancing fill.

Figure 5: Placing BX Geogrid to accommodate curves.

Figure 6: Using a handheld power saw to cut geogrid.

4. Tensioning and Pinning

Tensar BX Geogrids may be anchored in place to maintain overlaps and alignment over the coverage area.

- Before fully unrolling the geogrid, anchor the beginning of the roll, in the center and at the corners, to the underlying surface.
- Anchor the BX Geogrid with small piles of aggregate fill or a washer and pin (Figure 7a). Large, heavy-gauge staples (Figure 7b) may also be used by driving them into the subsoil through the apertures of the grid.
- Unroll the geogrid. Align it and pull it taut to remove wrinkles and laydown slack with hand tension, then secure in place. Because of the unique manufacturing process of Tensar BX Geogrid, maneuvering an unrolled sheet of geogrid is very easy.
- Additional shoveled piles of aggregate fill, pins or staples may be required to hold the geogrid in place prior to placement of the aggregate fill.

Note: When aggregate fill is spread by pushing it over the BX Geogrid with heavy equipment, such as bulldozers, the shoving action may create a "wave" in the sheet of geogrid ahead of the advancing fill. Shoveled fill or pins can trap this wave and force the geogrid up into the aggregate layer where it can be damaged by the spreading equipment. Pulling the geogrid taut will mitigate laydown slack, thereby removing "waving." If significant waving occurs, the pins or shoveled material should be removed to allow the waves to dissipate at the ends and edges of the roll.

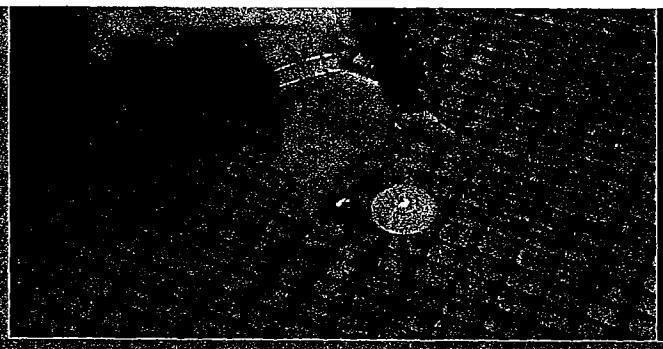


Figure 7a: Anchoring geogrid with a washer and pin.

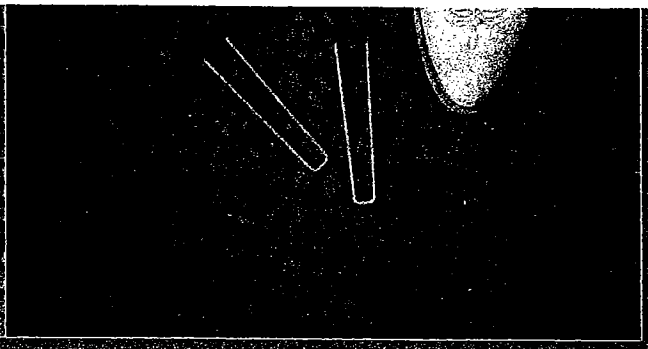


Figure 7b: Staples for anchoring BX Geogrid.

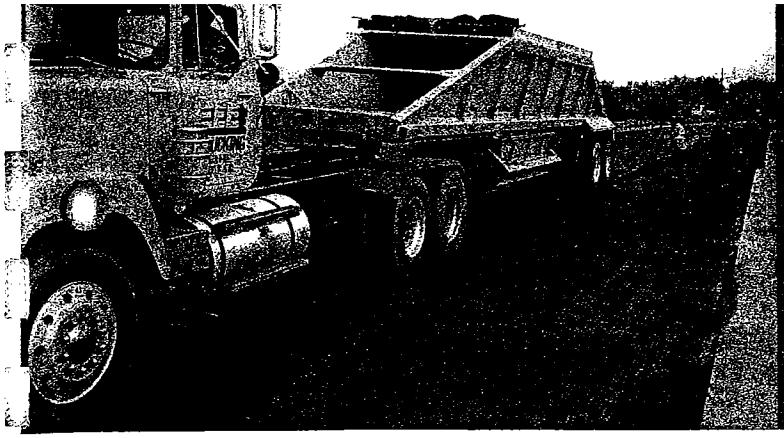


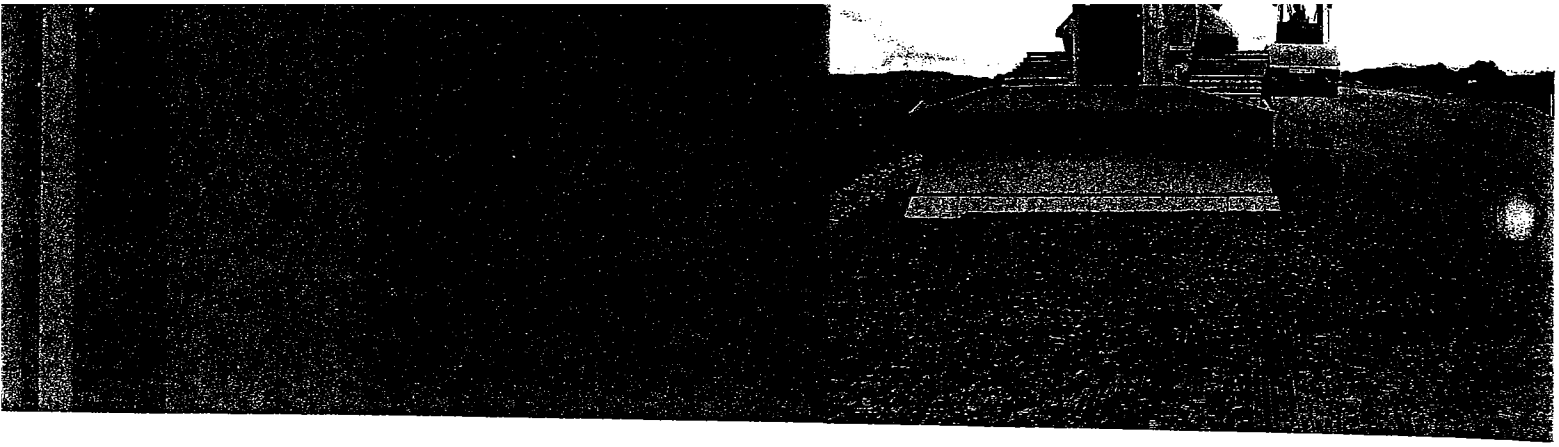
Figure 8: Dumping aggregate fill on top of BX Geogrid over competent subgrade.

5. Dumping and Spreading Aggregate Fill

- Generally, at least 6 inches is required for the initial lift thickness of aggregate fill over BX Geogrids. However, for very soft conditions, a significantly thicker fill layer will be required to prevent excessive rutting and/or bearing capacity failure of the underlying subgrade soils.
- Over relatively competent subgrades (CBR > 4, see Table 1), aggregate fill may be dumped directly onto the geogrid (Figure 8). Standard, highway-legal, rubber-tired trucks (end dumps and belly dumps) may drive over the geogrid at very slow speeds (less than 5 mph) and dump aggregate fill as they advance, provided this construction traffic will not cause significant rutting upon bare subgrade. Turns and sudden starts and stops should be avoided.
- Over softer subgrades, back trucks up and dump fill upon previously placed fill (Figure 9a). For very soft subgrades (CBR < 0.5), extreme caution should be taken to avoid overstressing the subgrade soil both during and after fill placement. Please contact a Tensar representative at 800-TENSAR-1 for guidance with constructing over extremely soft subgrade soils (CB < 0.5).
- Do not drive tracked equipment directly on the BX Geogrid. Ensure at least 6 inches of aggregate fill (or required minimum design fill thickness) is spread between the geogrid and tracked equipment (Figure 9b).
- Also, only operate rubber-tired equipment directly on the geogrid if the underlying subsoil is not prone to rutting under limited construction traffic.
- Over softer subgrades (CBR < 2), a lightweight, low ground pressure (LGP) dozer is recommended to evenly push out the fill over the exposed geogrid.
- Care should be taken not to catch the dozer blade or other equipment on the BX Geogrid. The dozer blade should be raised gradually as each lift is pushed out over the BX Geogrid. The desired effect is fill that cascades onto the geogrid, rather than being pushed into it.
- When building over a soft subgrade, it is desirable to work from stronger to weaker areas.
- Be aware of BX Geogrid overlaps and advance the aggregate fill with the shingle pattern.

Figure 9a: Dumping aggregate fill on top of BX Geogrid over soft subgrade.

Figure 9b: Spreading aggregate fill over BX Geogrid.



6. Compacting

- Standard compaction methods may be used unless the soils are very soft. In these cases, static instead of vibratory compaction is prudent, particularly over fine-grained, noncohesive soils such as silt. Compaction is then achieved using a light roller. Keeping the moisture content of the fill material near optimum will make compaction more efficient. Water spray is most effective with sand fill (see Figure 10). For construction over very soft soils, compaction requirements are normally reduced for the initial lift as the primary intent of the initial lift is to achieve a suitable working surface.
- If rutting or severe pumping occurs under truck or dozer traffic, fill should be added immediately to strengthen the section. Silty subgrades are particularly prone to pumping. In some cases, it may be prudent to cease operations for a period of time, allowing pore pressures to dissipate and the subgrade to stabilize. Otherwise, de-watering measures such as "bleeder ditches" should be considered to reduce the moisture content of the uppermost silty subgrade layer. Please contact a Tensar representative for more information.

Note: If the aggregate fill thickness is insufficient to support imposed load(s), deep rutting will result.

- Compact aggregate fill to project specifications, after it has been graded smooth and before it is subject to accumulated traffic (Figure 11). Inadequate compaction will result in surface rutting under wheel loads. This rutting reduces the total effective thickness of the fill and increases stress on the subgrade.

Note: Compaction equipment and methods should be appropriate for the type of fill being used, its thickness and the underlying subgrade conditions.

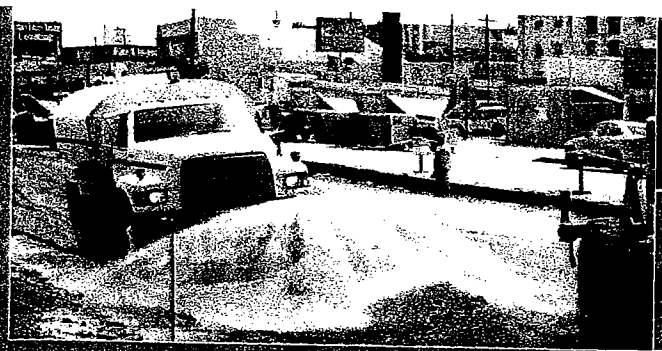


Figure 10: Moistening the fill before compaction.

Figure 11: Compacting the aggregate fill.

Tensar BX Geogrid Roll Characteristics

Product	Roll Width		Roll Length		Roll Weight		Roll Area	
	(m)	(ft)	(m)	(ft)	(kg)	(lbs)	(m2)	(sy)
BX110047	3	9.8	75	246	45.6	100.5	225	268
BX110075	4	13.1	75	246	61.2	135	300	358.6
BX120040	3	9.8	50	164	46.3	102	150	179.3
BX120060	4	13.1	50	164	62.6	138	200	239.1
BX130060	4	13.1	50	164	50.5	111.5	200	239.1

7. Special Considerations

Make Repairs

- If Tensar BX Geogrids become damaged during or after installation, repair them by patching the area with the following measures:
  1. Remove fill from the surface of the damaged geogrid and clear a 3 foot area around the damage.
  2. The geogrid patch should cover the damaged area and extend 3 feet beyond it in all directions.

Surface Rutting

- If deep rutting occurs beneath truck wheels, do not grade out the ruts. Rutting is normally indicative of fill that is too thin, too wet or inadequately compacted. Grading out the rut will reduce aggregate fill thickness between the wheel paths and may lead to geogrid exposure.
- Fill in the ruts with additional specified aggregate fill and compact. This places extra fill where it's needed and may prevent further rutting under channelized traffic.
- Crown the fill during the grading process to ensure rainfall runoff and to prevent fill saturation.

Cold Weather

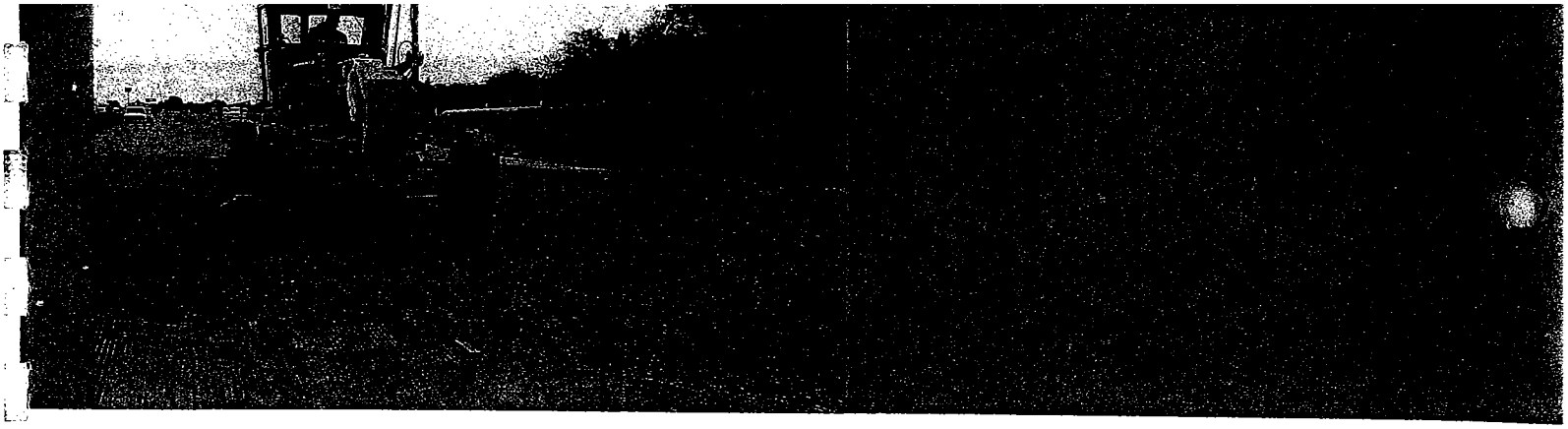
- At sub-freezing temperatures, BX Geogrid is less impact resistant and can be fractured with dynamic force (i.e., striking with a hammer). Other aspects of dynamic loading associated with very cold temperatures should be avoided. For example, direct trafficking by rubber-tired equipment atop geogrid is permissible when the subgrade is competent. However, it's not advisable at very cold temperatures.

Aggregate Fill Considerations

- The preferred gradation for base reinforcement applications is well-graded crushed aggregate fill with a maximum particle size of 1½ inches and less than 10% fines (passing #200 sieve). The gradations listed in Table 2 (below) provide good stability and low moisture susceptibility. **For subgrade improvement applications, any clean granular fill may be acceptable.**
- BX Geogrids will structurally enhance coarser or finer fill gradations, as long as the aggregate fill is compacted and placed at, or just below, optimum moisture content. For coarser fill, a graded filter analysis is recommended

Table 2: Preferred Fill Gradation

1½ in.	100
¾ in.	50 – 100
#4	25 – 50
#40	10 – 20
#100	5 – 15
#200	less than 10



to guard against potential contamination from the underlying subgrade (see Table 1 on pg. 3). If the aggregate fill does not meet the requirement(s) of a graded filter over soft and saturated clays and silts it is recommended that a sand filter layer be placed at a minimum depth of 6 in. on top of the geogrid layer. This sand fill may need to be increased in the event the design fill thickness requires a thicker initial lift. It is not recommended that a non-woven geotextile be used when constructing over saturated silts. However, non-woven geotextiles are recommended in conjunction with Tensar BX Geogrids when:

1. The filter criteria of the fill when compared to the subgrade soil does not pass the piping ratio requirement, and
2. Significant clay content is present that will limit the mobilization of fine particles with excessive stress and moisture.

- Do not use uniformly sized coarse fill as it does not compact well and will rut under wheel loading, despite the improved stability brought about by BX Geogrids.
- The moisture content of the fill should not exceed optimum. Wet fill is not easy to compact and will rut under wheel loading.

Preferred Equipment

- **Soft Ground** – the preferred equipment imposes low contact pressure on the ground surface. This may be done with smaller machinery, wide tires and/or LGP tracks. Equipment that concentrates heavy loads over relatively small contacts, such as front-end loaders, are not recommended. In all soft ground cases, fill must be sufficiently thick to avoid overstressing the underlying soils and BX Geogrid.
- **Competent Ground** – the preferred equipment maximizes productivity for specific construction requirements. Over competent ground, geogrids can be trafficked directly by rubber-tired equipment, making hauling equipment (i.e., dump trucks) and spreading equipment (i.e., motor graders) ideal (Figure 12). Spreader boxes are not recommended – wrinkling in the geogrid between the screed and wheels of the box and dump trucks can cause slack to become trapped, raising the geogrid up into the aggregate layer.

Excavating Through BX Geogrid

- When confined beneath and within compacted fill, the geogrid should pose no significant threat to post-construction activities like utility trenching or driving/auguring supports for rails, signs or standards. Conventional excavation equipment will shear directly through the geogrid leaving a clean cut as represented in Figure 13.

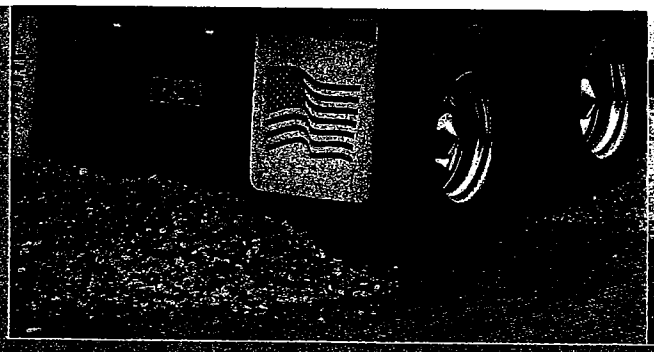


Figure 12: Geogrid can be trafficked directly by rubber-tired equipment.

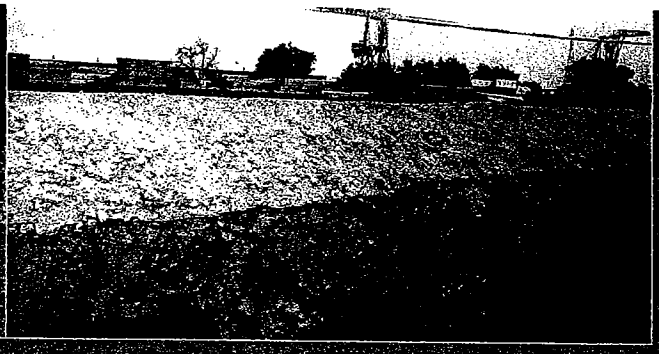


Figure 13: A backhoe excavation through BX Geogrid.

8. SpectraPave3™ Software for Subgrade Improvement and Base Course Reinforcement

Tensar International Corporation breaks new ground with the release of our industry-leading SpectraPave3™ Software. This new software allows the user to accurately predict the performance of geogrid reinforced and unreinforced conditions of both paved and unpaved surfaces. The software offers three distinct analyses modules and cost analyses tools to evaluate design options for paved roads, unpaved roads and working surfaces, which include:

- Subgrade Improvement
- Base Course Reinforcement – Standard Method
- Base Course Reinforcement – Advanced Method

Subgrade Improvement Module

Based on the Giroud-Han study, the subgrade improvement module incorporates a new design method, which supports the use of certain geosynthetics, to reduce aggregate thickness requirements and improve the subgrade performance. It indicates the required thickness for unreinforced aggregate fill layers and aggregate fill layers reinforced with BX Geogrids.

Base Course Reinforcement Modules

The base reinforcement module incorporates the design methodology prescribed by AASHTO in their Pavement Design Guide (1993) and also their Interim Standard PP46-01 (2003). BX Geogrids can be used in an AASHTO design to extend the design life of a flexible pavement and/or reduce the thickness of the pavement layers.

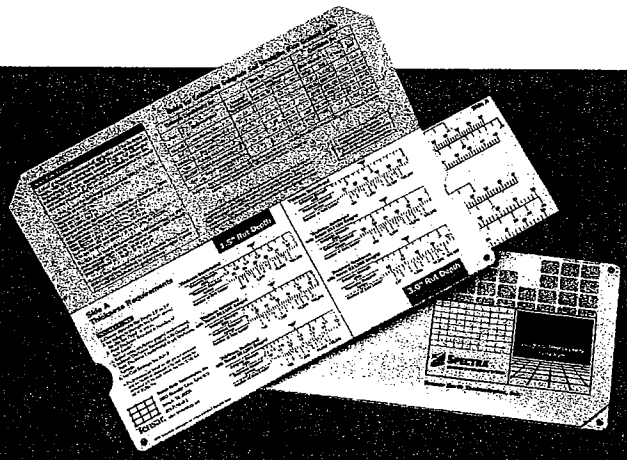
Cost Analysis Tools

The cost analysis tools provide total in-place costs (and savings) for each design option in dollars per unit area, giving you the flexibility to predict performance for a range of design scenarios.

Subgrade Improvement Slide Rule

You can't always have a computer at your fingertips, so TIC created a pocket-sized slide rule version of the subgrade improvement module from the SpectraPave3 Software for your convenience. It is versatile, accurate and handy – just right for making timely and informed decisions about building over soft soils with BX Geogrids. For more information and to obtain your own free slide rule, call 800-TENSAR-1 or contact your local Tensar representative.

Available in CD-ROM format supporting Windows® 95, 98, 2000, XP or NT, SpectraPave3 Software may also be downloaded at no charge from www.tensar-international.com. For more information or to request your free copy, call 800-TENSAR-1 or e-mail info@tensarcorp.com.



Include the following SCR when specifying **geogrid for subgrade stabilization**. This is NOT to be used to specify base reinforcement geogrid. The specification is intended for class 1 survivability conditions (high survivability). All property requirements specified and the initial lift thickness should be reviewed for each individual project. The minimum geogrid opening size should be greater than the D_{50} of the cover aggregate. The maximum geogrid opening size should be less than $2xD_{85}$ of the cover aggregate. A Type I a, b, or c nonwoven geotextile (check hydraulic and filtration requirements for subgrade soil) should be used in conjunction with the geogrid when the D_{85} of the aggregate above the geogrid is greater than $5xD_{85}$ of the subgrade soil.	**(WFL Specification 00/00/00)**

Section 207.— EARTHWORK GEOTEXTILE

Description

207.01 Add the following:

This work also consists of furnishing and placing geogrid between aggregate cover soil and soft subgrade soil as a stabilizer.

Material

207.02 Add the following to the materials list:

Subgrade Stabilization Geogrid	714.03

Construction Requirements

207.04A Geogrid. (Added Subsection.)

When placing a geogrid on native ground, cut the trees and shrubs flush with the ground surface. Do not remove the topsoil and vegetation mat. Remove all sharp objects and large rocks. Fill depressions or holes with suitable material to provide a firm foundation.

Replace or repair all geogrid that is torn or punctured. Remove the damaged area and place a patch of the same type of geogrid overlapping 3 feet beyond the damaged area. When placing a geogrid on a subgrade, prepare the subgrade according to Subsections 204.13(c) and (d).

Place geogrid directly over the subgrade as smoothly as possible. The Geogrid should be pulled taut to remove any wrinkles. Fold or cut the geogrid to conform to curves. Overlap in the direction of construction. Overlap the geogrid according to the manufacturer's recommendations but no less than 2 feet at the ends and sides of adjoining sheets. Do not place longitudinal overlaps below anticipated wheel loads. Pins or piles of cover material may be required to hold the geogrid in place.

End-dump the cover material onto the geogrid from the edge of the geogrid or from previously placed cover material. Do not operate equipment directly on the geogrid. Spread the end-dumped pile of cover material in a uniform layer thickness maintaining a minimum lift thickness of 12

inches. Compact the first lift of cover material with rubber-tired or nonvibratory smooth drum rollers. Do not use sheepsfoot or studded compaction equipment on the first lift placed over the geogrid. Avoid sudden stops, starts, or turns of the construction equipment. Fill all ruts from construction equipment with additional cover material. Do not blade material down to remove ruts. If rutting exceeds 3 inches on the first lift, decrease the construction equipment size and/or weight or increase the lift thickness.

Place subsequent lifts of cover material in the same manner. Vibratory compactors may be used for compacting subsequent lifts. If pumping or foundation failures occur, repair the damaged areas and revert to the use of nonvibratory compaction equipment.

207.06 Acceptance. Add the following:

Material for subgrade stabilization geogrid will be evaluated under Subsections 106.02, 106.03, and 714.03.

Geogrid installation will be evaluated under Subsections 106.02 and 106.04.

Section 714.— GEOTEXTILE AND GEOCOMPOSITE DRAIN MATERIAL

714.03 Subgrade Stabilization Geogrid. (Added Subsection.)

Furnish geogrid manufactured using long-chain synthetic polymers, composed of at least 95 percent by weight of polyolefins, polyesters, or polyamides. Fabricate the geogrid into a stable network such that the ribs, filaments, or yarns retain their dimensional stability relative to each other, including selvages.

(a) Physical requirements. Conform to Table 714-7 for subgrade stabilization geogrid.

All property values, with the exception of maximum opening size, in these specifications represent minimum average roll values (MARV) (i.e., average test results of any roll in a lot sampled for conformance or quality assurance testing shall meet or exceed the minimum specified values). The value for maximum opening size represents maximum average roll value. Acceptance will be based on ASTM D 4759.

Identify, store, and handle geogrids according to ASTM D 4873.

(b) Evaluation procedures. Geogrid will be evaluated under Subsection 106.03. Furnish a product certification including the name of the manufacturer, product name, style number, chemical composition of the geogrid product, physical properties applicable to this specification, and other pertinent information to fully describe the geogrid.

When samples are required, remove a 3-foot long, full-width sample from beyond the first outer wrap of the roll. Label the sample with the lot and batch number, date of sampling, project number, item number, manufacturer, and product name. If required, provide a sample of the aggregate cover layer.

Table 714-7
Physical Requirements for Subgrade Stabilization Geogrid

Property	Test Method	Units	Specifications[1][2]
Percent open area	CW-02215[3]	%	50
Minimum opening size	N/A[4]	in	0.5
Maximum opening size	N/A[4]	in	3
Ultimate tensile strength	ASTM D 6637	lb/ft	1230
Junction strength	GRI GG2[5]	lb	25
Ultraviolet stability (retained strength)	ASTM D 4355	% after 500 hours of exposure	50

(1) All values, except maximum opening size, are MARV values.
(2) Strength values are in the weaker principal direction.
(3) U.S. Army Corps of Engineers CW-00215 Test Method for Determining Percent Open Area (Modified for Geogrids).
(4) Direct measure with caliper.
(5) Geosynthetic Research Institute (Drexel University, Philadelphia, PA) GG2 Individual Geogrid Junction Strength.