U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **Geotechnical Recommendations for Damage Repair**
South Unit Scenic Loop Drive and North Unit Scenic Drive
Theodore Roosevelt National Park
ND ERFO 10(1)

Date: March 13, 2012

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Through: Matt DeMarco, CFLHD Geotechnical Team Lead

INTRODUCTION

This technical memorandum presents the investigation results, design analyses, and geotechnical recommendations for the repair of various embankment failures observed in the North and South Units of Theodore Roosevelt National Park (Park). A Project Vicinity Map of the South and North Units is presented on Figure 1.

The Park experienced an exceptionally wet 2010/2011 winter and spring that resulted in slope failures, pavement distress, and flooding conditions along the Little Missouri River. According to NOAA annual precipitation data, North Dakota as a whole has been abnormally wet as shown in Table 1, North Dakota Recent Annual Precipitation Data.

Table 1:- North Dakota Recent Annual Precipitation Data

Avg. (from 1895)	North Dakota Yearly Annual Precipitation (inches)									
	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
17.31	21.05	24.25	19.49	20.05	19.26	14.21	21.31	18.94	16.53	16.41

Debris from native slope and cut failures filled ditches and encroached on the roadway throughout the park. Embankment failures damaged the roadway causing rough road conditions and road closure. Flooding of campground facilities in both the North and South Units were reported. Thirteen damage sites in the South Unit and eight damage sites in the North Unit were identified as eligible for Emergency Relief for Federally Owned Roads (ERFO) program funds. The Park maintenance crews had already repaired the majority of the cut slope failures and damage from flooding; therefore, these sites are not included in this ERFO project. Table 2 lists the sites currently submitted for repair consideration under the ND ERFO 10(1) project and identifies the major failure mechanism. Site Maps showing the damage locations in the South and North Units are presented on Figures 2 and 3, respectively.

Of the 21 damage sites, a total of four sites were selected for geotechnical design. These sites are located at Station 200+40 in the South Unit and Stations 374+50, 500+00, and 600+00 in the North Unit. The remainder of this memo discusses the geology, seismic design parameters, investigation, analysis, and recommendations of these four damage sites. Photos of the four damage locations selected for geotechnical design can be found in Appendix A.

Table 2:- ND ERFO 10(2) Repair Sites

Location		Failure Mechanism
Park Unit	**Station (ft)**	
South	93+75	Embankment failure consistent with shallow rotational failures was observed in a two-sided embankment. The pavement is in good condition with no major cracking and no evidence of seeps were observed in the embankment. The failure is likely due to saturation of the embankment from surface water infiltration.
	103+00	Pavement distress such as rutting and cracking were observed, as well as crack sealing from previous maintenance operations. The embankment below the road in this area did not show obvious signs of distress. Pavement distress is likely due to soft, saturated subgrade.
	173+00	A cut slope failure that encroached into the travel way was observed in this area. The toe of the debris was removed to the face of curb by the park. The remaining debris is unstable.
	200+40*	Embankment failure consistent with shallow rotational failures was observed in the shoulder of the roadway and bank below the road.
	444+00	A cut slope failure that encroached into the travel way was observed in this area. The toe of the debris was removed and the ditch was reestablished by the park. The drop inlet and culvert in this are half full of sediment. Embankment failure/erosion exposing the southern end of the bin wall was observed. No notable distress was observed in the bin wall and the pavement is in good condition at this location. The embankment failure/erosion is likely due to the flooding of the adjacent Paddock Creek.
	1150+33	Sporadic cut slope failures encroached into the travel way in this area. Ditch cleaning and regrading behind the curb is recommended in this area to remove debris.
	1235+22	Cracks and depressions in the asphalt consistent with rotational failures formed in the outboard lane of the roadway for a distance of approximately 75 feet in length. Tension cracks were observed in the embankment below the road. The park has placed a blade patch that continues to show distress with reflective cracks.
	1242+46	A pavement depression formed and a blade patch was placed by the park staff that appears to be performing satisfactorily. Large voids were observed behind the curb of the inboard lane, and the embankment below the road shows signs of seeps. A geophysical investigation should be performed to determine extent and size of voids below the roadway. Voids can be backfilled with flow-fill concrete.
	1249+07	Cracks and depressions in the asphalt consistent with rotational failures formed in the outboard lane of the roadway for a length of approximately 105 feet. The embankment below the road in this area did not show obvious signs of distress. The park has placed a blade patch that appears to be performing satisfactorily.
	1297+23	A pavement depression formed and a blade patch was placed by the park staff that appears to be performing satisfactorily. Evidence of ponded water in the existing ditch was observed and the embankment below the road shows signs of seeps. The ditch and natural basin adjacent to the roadway should be graded to drain, thus reducing the moisture content of subgrade soils during periods of high precipitation.

Location		Failure Mechanism
Park Unit	**Station (ft)**	
South	1307+42	Cracks and depressions in the asphalt consistent with rotational failures formed in the outboard lane of the roadway for a length of approximately 25 feet. Tension cracks were observed in the embankment below the road. The park has placed a blade patch that continues to show distress with reflective cracks.
	Buck Hill	Embankment failure consistent with shallow rotational failures was observed approximately 4 feet in front of the guardrail and within the bank below the road. Seeps were not observed in the embankment failure; however, embankment materials showed evidence of saturation. The immediate failure was estimated at 20 feet in height; debris from this failure flowed over an existing, much larger head scarp that descends at approximately 50 degrees for another 30 feet in height. The failure occurred in embankment fill and soft grey clay containing lignite seams that has a slope angle of approximately 38 degrees. In addition to the immediate embankment failure, tension cracks were observed above the much larger, existing head scarp. This head scarp is estimated at 225 feet in length, containing the immediate failure, and is approximately 60 feet in height below the road to a natural bench that is approximately 40 feet in width. Tension cracks were observed between the roadway and natural head scarp adjacent to the embankment failure to the north. The tension cracks are encroaching on the roadway and indicate significant movement and slope instability.
	141+75	Longitudinal en echelon cracks and depression of the pavement developed in both lanes. Pavement was removed and replaced with aggregate to maintain traffic. This area recently received new pavement enhancements. The ditch and embankment did not show signs of distress and appeared to be in good working order. The source of increased moisture was not obvious but is assumed to be from water infiltrating the cut side ditch.
North	**374+50***	Embankment failure and damage to a stone culvert headwall was observed. The embankment failure is likely due to undercutting of the slope from flooding of the adjacent creek.
	378+00	Embankment failure consistent with shallow rotational failures was observed in the shoulder of the roadway and bank below the road. Surface water channels were observed in the shoulder above the failure. The failure was estimated at 16 feet in height, contains mature vegetation, and occurred in soft grey clay. The remaining embankment is estimated at 34 degrees and the bottom of the failure is consistent with a bench in the slope. Embankment failure at this location is likely caused by surface water flow from the roadway. To reduce the discharge of surface water at this location, it is recommended to install a V-ditch at the end of curb at station 379+00.
	380+00 to 385+00	Upheaval and collapse of the existing roadway was observed for a distance of approximately 350 feet in both lanes. The upheaval is primarily the first 30 feet of the damaged roadway and is likely the result of heaving bedrock. Heaving bedrock occurs when the moisture content of an expansive bedrock unit changes. The source of increased moisture was not obvious but is assumed to be from water infiltrating the cut side ditch. Mitigation is typically removal of expansive bedrock above seasonal moisture change zones and replacement with non-expansive material. Identification of heaving bedrock limits is performed by trenching, possibly at time of repair, by a trained Geologist.
	500+00*	Embankment failure consistent with rotational failures was observed in the shoulder of the roadway and bank below the road.
	600+00*	Sever embankment failure and loss of road width was observed.
	605+00	Cracks and depressions in the asphalt, up to 18 inches, consistent with rotational failures formed across both lane of the roadway for a distance of approximately 105 feet in length. The heavily vegetated embankment below the road in this area did not show obvious signs of distress.

Location		Failure Mechanism
Park Unit	**Station (ft)**	
North	700+00	Cracks and depressions in the asphalt consistent with rotational failures were observed across both lanes of the roadway. This area recently received new pavement improvements. These cracks appear to be increasing in number, length, aperture, and offset with respect to crack sealing reported to have taken place the previous spring. These cracks are located above the steepest part of the embankment below the roadway and encompass an area of approximately 50 feet in length. The pavement distress occurred at a recently constructed RSS embankment repair site. The cracks are likely due to creep of embankment materials due to increased moisture content. A catastrophic embankment failure is unlikely without warning signs due to previous installation of geosynthetics in the embankment.

***** Damage Sites Selected for Geotechnical Design

REGIONAL GEOLOGY

The roadways within the North and South Units lie primarily within the Sentinel Butte geologic formation. This formation generally consists of gray to brown colored, poorly lithified claystones, mudstones, and siltstones with subordinate amounts of fine-grained sandstones and lignite. A gray sandstone layer, that may attain a thickness of 100 feet, is present at the base of the Sentinel Butte Formation. The Sentinel Butte Formation can be over 600 feet thick in the project sites. A widespread ash/bentonite clay deposit called Sentinel Butte ash, at times 25 feet thick, occurs within the Sentinel Butte Formation. Also, the Sentinel Butte Formation generally forms fairly steep weathering slopes.

Several areas within the park have experienced fill failures, fill settlement, and/or severe erosion problems. The cause of the problems is attributed to dispersive clays. Dispersive soils are fine-grained with a high content of pore-water sodium. The individual clay particles go into suspension in slow moving water (colloidal erosion) and form deep gullies and tunnels. This phenomenon can be seen throughout the park. Many deep gullies have formed at the outlet of culverts and rundowns. Sinkholes have also formed where pipe sections have separated or corrosion has deteriorated culvert sections.

SEISMIC DESIGN PARAMETERS

Recommended seismic response parameters for the damaged sites design are based on the (AASHTO) LRFD Bridge Design Specifications, 5th edition, 2010, and represents horizontal peak ground acceleration (PGA) with 7 percent probability of exceedance in 75 years (approximate 1000-year return period). The 1000-year return period uniform hazard spectrum for the South Unit damage site at Station 200+40 located at 46.93794º N latitude and -103.53266º W longitudinal and the North Unit damage site at Station 600+00 located at 47.61097º N latitude and -103.37542º W longitudinal was obtained in accordance with the AASHTO ground motion maps for the probabilistic horizontal acceleration values corresponding to specific peak ground acceleration (PGA) and the spectral coefficients, namely the short- and long- period ground acceleration (S_s and S_1 respectively) and corrected for the soil profile at the damage sites.

Based on the subsurface profile at the damage sites, the average time-weighted shear wave velocity for the top 100 feet (V_{S100}) of subsurface materials was estimated to be less than 600 feet per second. Therefore, the site soils are classified as *Class E* according to the site class definitions specified in Table 3.10.3.1-1 of AASHTO.

A seismic hazard analysis to establish ground motions for seismic design was conducted. The recommended spectral acceleration coefficient values for probabilistic design with a return period of 1000 years were calculated using the program provided with the AASHTO LRFD Bridge Design Specifications Manual developed by the USGS (2008) entitled "Seismic Design Parameters", version 2.10 and are summarized in Table 3, Summary of Seismic Parameters Corrected for Class E Soils.

TABLE 3:- Summary of Seismic Parameters Corrected for Class E Soil

Seismic Design Parameter	South Unit Station 200+40	North Unit Station 600+00
Peak Seismic Ground Acceleration Coefficient, (A_s)	0.047g	0.055g
Horizontal Response Spectral Acceleration at Period of 0.2 sec, (SD_s)	0.115g	0.129g
Horizontal Response Spectral Acceleration at Period of 1.0 sec, (SD_1)	0.059g	0.055g
Site Factor at Zero-Period of Acceleration Spectrum, (F_{pga})	2.50	2.50
Site Factor at Short-Period Range of Acceleration Spectrum, (F_a)	2.50	2.50
Site Factor at Long-Period Range of Acceleration Spectrum, (F_v)	3.50	3.50

Based on the long acceleration coefficient SD_1 values of 0.059g and 0.055g for the South and North Units, respectively, the damage sites are assigned to seismic hazard ***Zone 1*** according to Table 3.10.6-1 in AASHTO. While the soil class, seismic parameters and hazard zone was developed for Station 600+00 in the North Unit, these values are appropriate for design of the other damage sites in the North Unit.

INVESTIGATION

The geotechnical investigation consisted of an office study, visual site investigations, and laboratory testing of exposed samples collected during the visual site investigations. No comprehensive subsurface investigation program was conducted.

Office Study:

The office study consisted of review of historical roadway work and geology publications. Historic geotechnical reports prepared by Central Federal Lands Highway Division(CFLHD) geotechnical staff were reviewed for consistency with observations made during the visual site investigation. Boring logs and laboratory testing data presented in a March 2002 report at the reoccurring slide at Site 600+00 were used in the analysis and are contained in Appendix B. Historic geological reports reviewed are as follows:

- CFLHD, 2002, "Memoradum, ND PRA-THRO10(2), Recommendations for Embankment Reconstruction, Theodore Rooselvelt National memorial Park," dated March 26, 2002.
- CFLHD, 2008, "Final Geotechnical Design Report, ND PRA THRO 10(3) & 10(4), Theodore Rooselvelt National Park – North Unit," dated January, 2008.
- CFLHD, 2010, "Inspection Report, Theodore Roosevelt National Park, North Unit, North Dakota," dated June 1, 2010.

In general, subsurface materials described in the above reports are consistent with the Sentinel Butte Formation. These materials consist of thin interbeded layers of yellow brown to brown to grey, moist, medium stiff to stiff, clays and silts with occasional sand and lignite layers. Groundwater is anticipated to be relatively shallow and slow moving due to the low permeability of the clayey soils encountered during and/or after drilling at select boring locations. Perched groundwater conditions should be anticipated close to the ground surface during seasonal snowmelt and heavy rain events.

Visual Site Investigation:

CFLHD geotechnical staff conducted a site visit on May 25, 2011 to observe reported damage sites (9 total). In October 2011, the CFLHD geotechnical staff participated in a cross-functional scoping review of the damage sites including the nine sites previously observed and twelve new sites. Observations, conclusions, and recommendations from these site visits are contained in the following reports:

- CFLHD, 2011, "Site Visit Report, Pavement Distress and Embankment Failures, North Unit Scenic Drive – MP 0 to MP 7.7, South Unit Loop Drive – MP0 to MP 17.0, Buck Hill Road – MP 0.5," dated July 14, 2011.
- CFLHD, 2011, " Inspection Report, ND ERFO 10(1), Theodore Roosevelt National Park Scoping," dated November 28,2011.

Relevant findings for the geotechnical design of the four selected damage sites by approximate station are as follows: Additional photos of the damage locations can be found in Appendix A.

South Unit

- 200+40 (Skyline Vista) - Embankment failure consistent with shallow rotational failures was observed in the shoulder of the roadway and bank below the road. Evidence of seeps were observed in the embankment failure approximately 6.5 to 12 feet below the roadway. Sediment carried by surface water flow was observed on both sides of the curb above the failure area. The failure was estimated at 45 feet in height and 75 feet wide and occurred in embankment fill and soft, mottled clay. The remaining embankment is estimated at 34 to 36 degrees. The pavement is in good condition with no major cracking. Asphalt curb above the failure is in poor condition and a rundown was damaged in the slide.

  The pavement section exposed in the slide scarp consisted of approximately 3 inches of asphalt, 4 inches of road base and 12 inches of red baked clay scoria. The pavement section overlays a grey, clayey sand fill to a depth of 8 to 12 feet below the road surface.

Sample 1 was collected at a depth of 11 feet below the road surface in the slide scarp. Pocket penetrometer and field vane shear tests were conducted in this material with approximate values of 1.5 ton/ft^2. The remaining exposed embankment material below the clayey sand consisted of lean to fat mottled clay with pocket penetrometer and field vane shear results of 1.0 to 1.5 ton/ft^2, and 4 to 6 ton/ft^2, respectively. Samples 2 and 3 were collected in this material at depths of 13 and 18 feet, respectively.

The slide plane appeared to be approximately 2 to 3 feet in depth and parallel to the embankment slope. Material in this zone was observed to be highly plastic when overlaying the mottled clay and likely corresponds to the depth of seasonal variation. Sample 4 was collected in the slide plane material. Laboratory test results of samples collected are shown in Table 3, Summary of Classification Index Tests for Use in Design.

North Unit

The damage areas from Station 374+50 through 700+00 occur within the Cedar Canyon area where the roadway gains considerable elevation. As the roadway gains elevation it crosses several distinct clay layers, including a dark gray, bentonitic, expansive clay layer. Roadway distress in this area ranges from dips and heaving pavement to large slope failures.

- Site 374+50 - Embankment failure and damage to a stone culvert headwall was observed. The embankment failure is likely due to undercutting of the slope from flooding of the adjacent creek. Seeps were observed in the embankment failure approximately 5 feet above the creek bed where a silty clay layer overlies a clayey sand layer. The failure was estimated at 20 feet in height and approximately 30 feet long. One sample was collected in the silty clay exposed in the slide scarp at a depth of approximately 14 feet below the road surface.

- Site 500+00 - Embankment failure consistent with rotational failures was observed in the shoulder of the roadway and bank below the road. The heavily forested failure area was extensive with a headscarp exceeding 8 feet in height and extending to the bottom of the adjacent drainage. The width of the failure is estimated at 150 feet wide and occurred in primarily natural slopes. The failure is likely due to a combination of groundwater and surface water infiltration.

- Site 600+00 - This site contains two failures, one from station 600+00 to 603+00 designated as Site 601+00 and another from Stations 603+40 to 604+40 designated as Site 603+80.

    - Site 601+00 - Severe embankment failure, loss of road width, and tension cracks with offset were observed. The failure was estimated at 32 feet in height and occurred in embankment fill and soft gray clay. The embankment ranges from 34 to 38 degrees. This area experienced embankment failures in 2002 and 2009. The Embankment failure is likely due to a combination of seeps from groundwater and surface water infiltration.

      The 2002 slide occurred from approximate Station 600+90 to Station 601+30. Survey, boring logs, and laboratory testing from the 2002 slide geotechnical investigation are presented in Appendix B. The embankment was repaired with

granular import material. A sample of the imported embankment material was collected at approximately Station 601+00 in the slide scarp at a depth of approximately 4 feet below the road surface. Laboratory test results of samples collected during this investigation and the 2002 investigation are shown in Table 3, Summary of Classification Index Tests for Use in Design.

The 2009 slide occurred from approximate station 600+40 to 600+90. Embankment drains were installed and the embankment was repaired with local clayey soils. Water was observed flowing from embankment drains and seeps were observed in the embankment failure location.

- Site 604+40 - Embankment failure consistent with shallow rotational failures less than 5 feet in depth was observed in the shoulder of the roadway and bank below the road. Seeps were observed in the embankment failure within 9 feet of the road surface. The meadow above the roadway contains standing water in the spring and after rain events. The failure was estimated at 24 feet in height and occurred in embankment fill and soft gray clay. The remaining embankment is estimated at 34 degrees. The pavement is in good condition with no major cracking. Asphalt curb above the failure is damaged from snow plows.

  The embankment fill exposed in the slide scarp appears to be soft grey clay. Samples 1 and 2 was collected at depths of 7 and 15 feet, respectively, at approximate Station 604+00. Pocket penetrometer and field vane shear test results were 0.15 to 0.2 ton/ft^2, and 1.5 ton/ft^2, respectively, within 9 feet of the road surface and are considered to represent the saturated condition. Pocket penetrometer and field vane shear tests conducted between depths of 9 feet and 20 feet below the road surface resulted in 0.05 to 1.0 ton/ft^2, and 2.5 ton/ft^2, respectively, representing the moist condition. Laboratory test results of samples collected are shown in Table 3, Summary of Classification Index Tests for Use in Design.

Laboratory Testing:

In addition to laboratory test results from the CFLHD (March 2002) report,[(1)] testing was conducted on select soil samples obtained during the visual investigation to determine material properties for use in design. Relevant soil classification index tests from the March 2002 report and from supplemental testing of samples collected during the visual investigation are shown in Table 4, Summary of Classification Index Tests for Use in Design, and in Appendix B and C, respectively. Soil samples were tested for moisture in accordance with AASHTO T 255, gradation and classification in accordance with ASTM D 2487 and AASHTO M 145, and Atterberg limits in accordance with AASHTO T 89 and T 90.

(1) CFLHD, 2002, "Memoradum, ND PRA-THRO10(2), Recommendations for Embankment Reconstruction, Theodore Rooselvelt National memorial Park," dated March 26, 2002.

Table 4:- Summary of Soil Classification Index Tests for Use in Design

Location			Field Sample Number	Sample Depth	Percent Moisture (%)	Percent Passing 200	LL	PI	USCS	AAASHTO
Unit	**Damage Location**	**Approximate Sample Location(1)**								
South Unit	200+40, Skyline Vista	201+50	1	Exposed Surface	26.9	40	33	16	SC	A-6 (2)
			2	Exposed Surface	25.5	83	37	21	CL	A-6 (16)
			3	Exposed Surface	26.4	83	50	31	CH	A-7-6 (26)
			4	Exposed Surface	36.7	81	88	67	CH	A-7-6 (57)
North Unit	374+50	375+00	1	Exposed Surface	28.5	65	24	5	CL-ML	A-4(1)
	600+00	601+00 Original Slide, 2002	Upper Slide, HA-1	0.30 m	NV	91.2	49.9	30.7	CL	A-7-6
				0.9 m	36.6	NV	NV	NV	NV	NV
				1.5 m	NV	96.7	86.2	68.4	CH	A-7-6
				2.1 m	NV	98.2	86.8	69.2	CH	A-7-6
			Lower Slide, HA-2	3.0 m	30.7	98.8	75.5	51.7	CH	A-7-6
			Existing Cut Slope HA-3	Exposed Surface	NV	99.38	54.6	38.7	CH	A-7-6
		601+00, 2002 Slide Backfill	1	Exposed Surface	7.7	18	19	5	SC-SM	A-1-b (0)
		604+00	1	Exposed Surface	42.4	93	51	31	CH	A-7-6 (31)
			2	Exposed Surface	34.6	94	50	31	CH	A-7-6 (31)

Notes: (1) See Visual Site Investigation Section for Sample Location Description
(2) NV = No Value

A compaction test was conducted on the HA-3 sample collected in the existing road cut during the 2002 investigation at approximate station 601+00 to determine optimum moisture and maximum dry density. The USCS classification for this material is a CH and the AASHTO classification is an A-7-6 material as shown above. This material is typical of sub-soils encountered on the site. Due to the fine grained nature of the soil sample, the Standard Proctor test, in accordance with ASTM D 698 A, was conducted. This test consists of a 5.5 pound hammer falling 12 inches, with 25 blows on each of three lifts in a 4 inch mould, for a compactive effort of about 12,400 ft-lbf/ft^3. Results are presented in Table 5, Compaction Test Results.

Table 5:- Compaction Test Results

Location			Station	Sample Depth	Class. (AASHTO) (USCS)	Maximum Dry Density (psf)	Optimum Moisture Content (%)
Unit	Damage Location	Approx. Sample Location(1)					
North Unit	600+00	601+00 Original Slide, 2002	Existing Cut Slope HA-3	Exposed Surface	A-2-6 CH	102.4	20.4

Notes: (1) See Visual Site Investigation Section for Sample Location Description

A Triaxial Stress Test was also conducted, in accordance with ASTM D 4767, on the HA-3 sample collected in the existing road cut during the 2002 investigation at approximate station 601+00 to determine the relationship between of shear strength to consolidation stress. The disturbed sample was remolded into three cylinders and subjected to a consolidated-undrained (CU) test with three constant confining pressures of 418 psf, 835 psf, and 1670 psf and increasing axial stress until 20% strain. Results of the test are presented in Appendix B

Analytical tests were conducted on a blended sample of samples 1 through 3 collected at the South Unit 200+40 damage site to determine if soils may have detrimental effects on concrete and buried metals. The minimum resistivity result, in accordance with AASHTO T 288, was 1,000 ohm-cm. The pH result, in accordance with AASHTO T 289, was 6.9. Tests for sulfate and chloride content were performed because the resistivity result was less than 5000 ohm-centimeters. The sulfate content, according to AASHTO T 290, was 0.472%/ 4720 ppm, and the chloride content; according to AASHTO T 291, was 0.0008%/ 8 ppm.

The electrical resistivity measurement value is within the range of 500 to 3,000 ohm-centimeters indicating that corrosive restrictions are necessary for the proposed type of pipe culverts used on the project. Pipe culverts types should be limited to Type II aluminized steel, aluminum alloy, polymer coated, reinforced concrete, and plastic.

The concentration of water soluble sulfates represents a severe degree of sulfate attack on concrete exposed to these materials. The degree of attack is based on a range of negligible, moderate, severe, and very severe as presented in the American Concrete Institute (ACI, 2010) *Building Code Requirements for Structural Concrete*. Based on this information, Type V special sulfate resistant cement will be required for concrete exposed to the on-site soils. Geochemical tests were not conducted in the North Unit; however, a similar degree of soil aggressiveness is anticipated.

ANALYSIS

Reinforced soil slopes (RSS) were evaluated as potential repair solutions for the damage sites at Station 200+40 in the South Unit and Stations 374+50, 500+00, and 600+00 in the North Unit. The potential for retreating the roadway alignment into the cut slopes is not considered feasible because of existing horizontal alignment and curvature at the sites. Traditional embankment reconstruction methods are not considered feasible at these sites because of the environmental impacts and quantity of material required to construct the embankment at stable slope ratios. The reinforced slopes will provide sufficient strength to the embankments to slow or even stop continued movement at the sites.

Analysis of the reinforced slopes was performed using RESSA, a two dimensional, limit equilibrium computer program from ADAMA Engineering. The Simplified Bishop method of slices was used with isotropic soil parameters. The analysis evaluated global stability in accordance with AASHTO "LRFD Bridge Design Specifications" (5th edition), and FHWA Publication NHI-10-024 and NHI-10-025, Volumes 1 and 2, respectively, entitled "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes" dated November 2009. Sliding, bearing resistance and settlement were not calculated as damage site repairs do not change significantly from the existing geometry and were not the mode of failure.

Proposed RSS repair options were evaluated based on the existing site conditions and available subsurface information. Cross sections were evaluated where the slope height was at its maximum and/or where the slope in front of damage site was the steepest. A traffic surcharge of 250 psf was modeled in the analyses. For the purpose of the analysis, the foundation and retained native material was assumed to be fat Clay (CH) soils and the embankment materials to meet the unclassified borrow (FP-03 704.06) specification. Estimated material properties for native soil consistent with the Triaxial Stress Test Data and reinforced zone backfill are shown in Table 6, Estimated Material Properties for Design.

Table 6:- Estimated Material Properties for Design

Description	Total Unit Weight, γ pcf.	Friction Angle, ϕ (deg)	Cohesion Intercept, c psf
Native Clay Soil (CH/A-7-6)	115	14	480
Unclassified Borrow	125	30	0

On-site clayey soil is highly plastic and exhibits significant cohesion; however, the friction angle is estimated to be relatively low. Because of the characteristics of the clay, the material shows significant strength when dry, but becomes unstable and susceptible to shear failure when wet. This material is likely to creep even at optimum moisture.

Groundwater levels were not determined from the visual site investigation; however, evidence of springs and seeps were observed in the embankment failures and in cut slopes above the road indicating that perched groundwater conditions exist. A water table at the base of the wall was included in the analyses as fully saturated slopes would yield an extremely costly design. Perched groundwater that enters the reinforced zone is anticipated to migrate horizontally to the

free face of the RSS as the permeability of backfill material is significantly greater in the horizontal direction than the vertical direction. To mitigate free water at the embankment surface, geosynthetic spacing at the slope face was designed to not exceed 1 foot. In addition, extensive erosion control measures are included in the recommendation section of the memo.

Analyses were performed for each site to determine embedment length, spacing, and tensile strength required of the primary geogrid reinforcement for a desired minimum static factor of safety of 1.30 and a seismic factor of safety of 1.1. However, a static factor of safety greater than 1.2 is considered acceptable considering the low traffic volumes at this site. Recommended designs are included in the recommendations section. Factors of safety of recommended designs are shown in Table 7, Summary of Stability Analysis. Static design calculations are available upon request as Appendix D.

Table 7:- Summary of Stability Analysis

Location			Slope Height (ft)	Cross Section Case	Calculated F.S.(1)
Unit	**Damage Location**	**Critical Section Station**			
South Unit	200+40 Skyline Vista	201+50	37	Static	1.26(2)
				Seismic (7% in 75)	1.20
North Unit	374+50	375+00	18	Static	1.49
				Seismic (7% in 75)	1.42
	500+00	501+00	12	Static	1.33
				Seismic (7% in 75)	1.26
		501+50	9	Static	1.30
				Seismic (7% in 75)	1.24
	600+00	600+70	28	Static	1.36
				Seismic (7% in 75)	1.29
		601+00	34	Static	1.30
				Seismic (7% in 75)	1.23
		603+80	26	Static	1.35
				Seismic (7% in 75)	1.28

Notes: (1) F.S. = Factor of Safety
(2) Calculated FS is less than 1.3 but is considered acceptable for site conditions

RECOMMENDATIONS

Recommendations for mitigation of the four damage sites selected for geotechnical design include removal of failed/creeping material, replacement with RSS using granular materials, and improved drainage. Previous embankment mitigation techniques observed during the site visit (North Unit 600+00 and 700+00) have had limited success. Recommended designs apply more conservative mitigation techniques, such as closer reinforcement spacing, improved backfill material, enhanced drainage components, and expanded embankment mitigation areas.

RSS backfill should be unclassified borrow and meet the requirements of Subsection 704.06 of the FP-03. Riprap protection below culvert outlets is recommended. Based on laboratory testing results, ***on-site, native soils will generally not meet the requirements for unclassified borrow due to the high percent fines and high plasticity index.*** Backfill from the 2002 slide repair classified as A-1-b, which meets the unclassified borrow specification. This backfill can be salvaged provided that it is excavated free of deleterious material.

RSS reinforcement should consist of primary and secondary reinforcement in accordance with SCR Section 714.03. Primary reinforcement should consist of uniaxial geogrid with a minimum long term design strength (allowable tensile strength) of 2200 lbs/ft. Secondary reinforcement should consist of biaxial geogrid with a minimum long term design strength of 900 lbs/ft. The secondary reinforcement should be centered between the primary reinforcement with a 4 foot minimum geogrid embedment length. Primary and secondary reinforcement should terminate at the slope face. Primary reinforcement lengths, vertical spacing, and special construction requirements are discussed in the damage site specific recommendations below.

It is acknowledged that successful drainage of groundwater contained in dispersive fat clays (CH) has limited success; however, drainage components should still be incorporated in mitigation measures to provide new embankments reasonable time to consolidate prior to an influx of groundwater. Groundwater filter design was not conducted due to the lack of laboratory test data available of soil particles less than 0.075 mm. Recommended filter geotextiles should consist of Type I- F for sheet drain geotextile and Type I - C for all other drainage applications, such as the underdrain system.

For repair and reconstruction recommendations to function properly and remain stable, it is required that ditches and culvert inlets in the area of the failure sites be cleaned and reconditioned to prevent future roadway damage from large storm events. Replacement culverts should be adequately sized to meet the hydraulic demands during storm events per recommendations from the CFLHD Hydraulics group. Adequately sized curb and gutter should be maintained above failure areas.

Erosion control for RSS should consist of an approved seed mix protected by an erosion control blanket. The blanket should be anchored at the top and bottom of the slope with a continuous trench. In addition, the blanket should be stapled to the slope in accordance with the manufacturers' recommendations. Utilize sediment log waddles and check dams wherever concentrated flow is anticipated.

Damage site specific recommendations are as follows:

South Unit

- Site 200+40 – Combination of a shear key and RSS with a height of approximately 37 feet and a maximum slope of 1V:1.5H is recommended to mitigate the embankment failure. Primary reinforcement should be placed at 2 foot maximum vertical spacing with a minimum design geogrid embedment length of 12 feet. In addition, the plans should reflect that the top two lifts of primary reinforcement should extend to centerline of the roadway and to within 1 foot of the back of excavation when in excess of 12 feet.
  A shear key is recommended below the RSS between Stations 201+30 and 201+70. The shear key should extend to a depth of 5 feet below the bottom of the RSS and have a minimum base width of 8 feet. Shear key backfill should consist of mechanically placed special rock embankment in accordance with SCR Section 705.04. Type IV - B geotextile separator fabric, in accordance with SCR Section 714.01, should completely enclose shear key backfill.

  Geocomposite sheet drains, in accordance with SCR Section 714.02, should be installed from 3 feet to 11 feet below the existing roadway and the bottom two embankment benches of the RSS. Perforated drain pipe should be included at the bottom of the shear key. Daylight collector pipes every 25 feet to limit large volumes of concentrated water from being released on the slope.

North Unit

- Site 374+50 – Combination of rock embankment and RSS with a total height of approximately 18 feet and a maximum slope of 1V:1.5H is recommended to mitigate the embankment failure. Mechanically placed special rock embankment, in accordance with SCR Section 705.04, should constitute the bottom 6 feet of the slope and be embedded a minimum of 4 feet below the existing drainage channel with a minimum base width of 8 feet. Type IV - B geotextile separator fabric, in accordance with SCR Section 714.01, should be placed where the rock embankment is in contact with native soils or backfill.

  The RSS should be constructed above the rock embankment, approximately 12 feet in height, with a primary reinforcement minimum embedment length of 12 feet with a 2 foot maximum vertical spacing. The top two lifts of primary reinforcement should extend to centerline of the roadway.

  Geocomposite sheet drains, in accordance with SCR Section 714.02, should be installed in the bottom two embankment benches of the RSS. Daylight collector pipes every 25 feet to limit large volumes of concentrated water from being released on the slope.

- Site 500+00 – RSS with a height of approximately 12 feet and a maximum slope of 1V:1.5H is recommended to mitigate the embankment failure. Primary reinforcement should be placed at 2 foot maximum vertical spacing with a minimum geogrid embedment length of 10 feet. When the total height of the RSS is less than 9 feet, the minimum primary reinforcement embedment length is 8 feet. The top two lifts of primary reinforcement should extend to centerline of the roadway.

Geocomposite sheet drains, in accordance with SCR Section 714.02, should be installed in the bottom two embankment benches of the RSS. Daylight collector pipes every 25 feet to limit large volumes of concentrated water from being released on the slope.

- Site 600+00 – This site contains two failures requiring different RSS recommendations. Recommendations for Site 601+00 should be followed from Stations 600+00 to 603+00 and recommendations for Site 603+80 should be followed from Stations 603+40 to 604+40.

    - Site 601+00 – RSS with a maximum height of 34 feet and a maximum slope of 1V:1.5H is recommended to mitigate the embankment failure. Primary reinforcement should be placed at 2 foot maximum vertical spacing with a minimum geogrid embedment length ratio of 0.7 times the height of the slope (0.7H). When the total height of the RSS is less than 11 feet, the minimum primary reinforcement embedment length is 8 feet. The top two lifts of primary reinforcement should extend the entire width of the roadway to the white line of the inside lane.

      Standard Underdrain should be installed to a depth of 5 feet below the excavation of the top two lifts of reinforcement for a total depth of about 9 feet below the white line of the inside lane. Geocomposite sheet drains, in accordance with SCR Section 714.02, should be installed in each embankment bench of the RSS. Daylight collector pipes every 25 feet to limit large volumes of concentrated water from being released on the slope.

    - Site 603+80 – RSS with a height of approximately 26 feet and a maximum slope of 1V:1.5H is recommended to mitigate the embankment failure. Primary reinforcement should be placed at 2 foot maximum vertical spacing with a minimum geogrid embedment length of 8 feet. The top two lifts of primary reinforcement should extend to centerline of the roadway.

      Regrade the ditch of the inside lane to reduce ponding of water in the meadow above the roadway. Geocomposite sheet drains, in accordance with SCR Section 714.02, should be installed 3 feet to 7 feet below the existing roadway and the bottom two embankment benches of the RSS. Daylight collector pipes every 25 feet to limit large volumes of concentrated water from being released on the slope.

CONSTRUCTION CONSIDERATIONS

Specifications:

Special provisions were developed to be consistent with geotechnical recommendations stated above and should be incorporated into the special contract requirements (SCR) to amend the FHWA Standard Specification for Construction of Roads and Bridges on Federal Highway Projects; known as FP-03. SCR sections provided are Section 207 – Earthwork Geosynthetics,

Section 272- Reinforced Soil Slopes, Section 704- Soil, and Section 714 –Geosynthetic Materials.

Borrow Sources:

On-site soils are not suitable for use as borrow because of their high plasticity and high fines content. It is estimated that such soils will have a shrink percentage of 15 percent if placed as compacted embankment, corresponding to a shrink/swell factor of 0.87. Most likely, sources outside of the Park boundaries will have to be located for suitable borrow materials.

Site Access:

Access plans for each site should be developed by the contractor and submitted to the CO for approval.

LIMITATIONS

The recommendations in this memorandum are based on the data obtained from visual field investigation and the laboratory test results. The results of these observations and tests represent conditions at the specific locations indicated. Subsurface variations across the site are likely and may not become evident until excavation is performed. The analysis and recommendations include interpretations developed by the Government in the process of preparing the design. These interpretations are not intended as a substitute for the personal investigation, independent interpretation, and judgment of the Contractor.

Date 3/13/2012

Braden Peters, P.E.
Geotechnical Engineer, CFLHD

FIGURES

Figure 1 - Vicinity Map
Figure 2 - South Unit Site Map
Figure 3 - North Unit Site Map

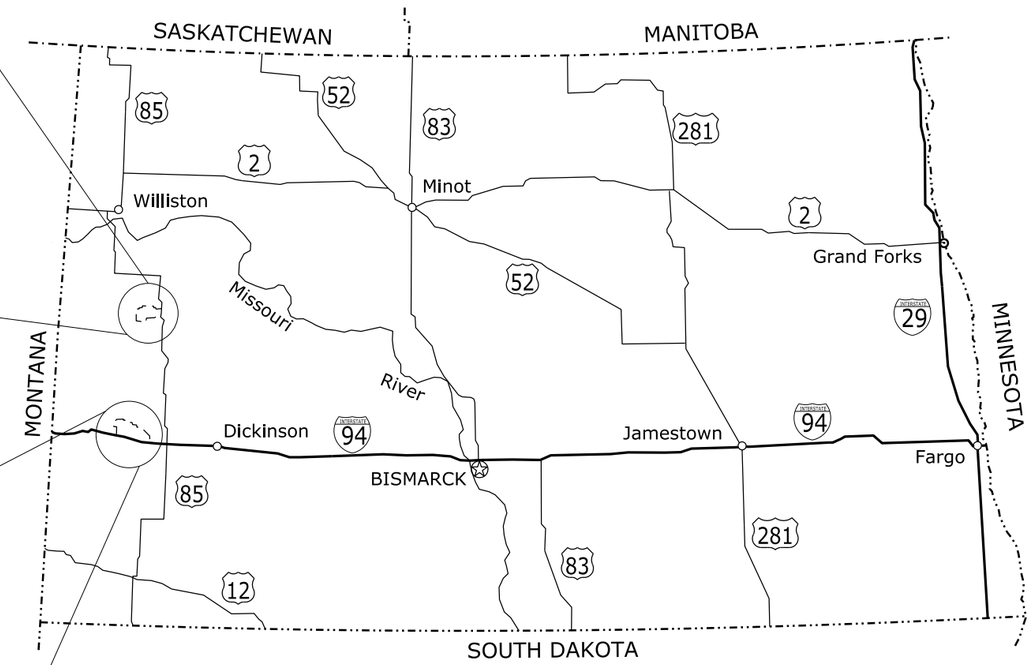
APPENDICIES

Appendix A – Photos
Appendix B – 2002 Geotechnical Report Laboratory Results
Appendix C – Supplemental Laboratory Results
Appendix D – Analysis (available upon request)

REG	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
MW	ND	ND ERFO 10(1) Theodore Roosevelt	1	3

NORTH UNIT SCENIC DRIVE

SOUTH UNIT SCENIC LOOP DRIVE



MAP OF THEODORE ROOSEVELT NATIONAL PARK, NORTH DAKOTA

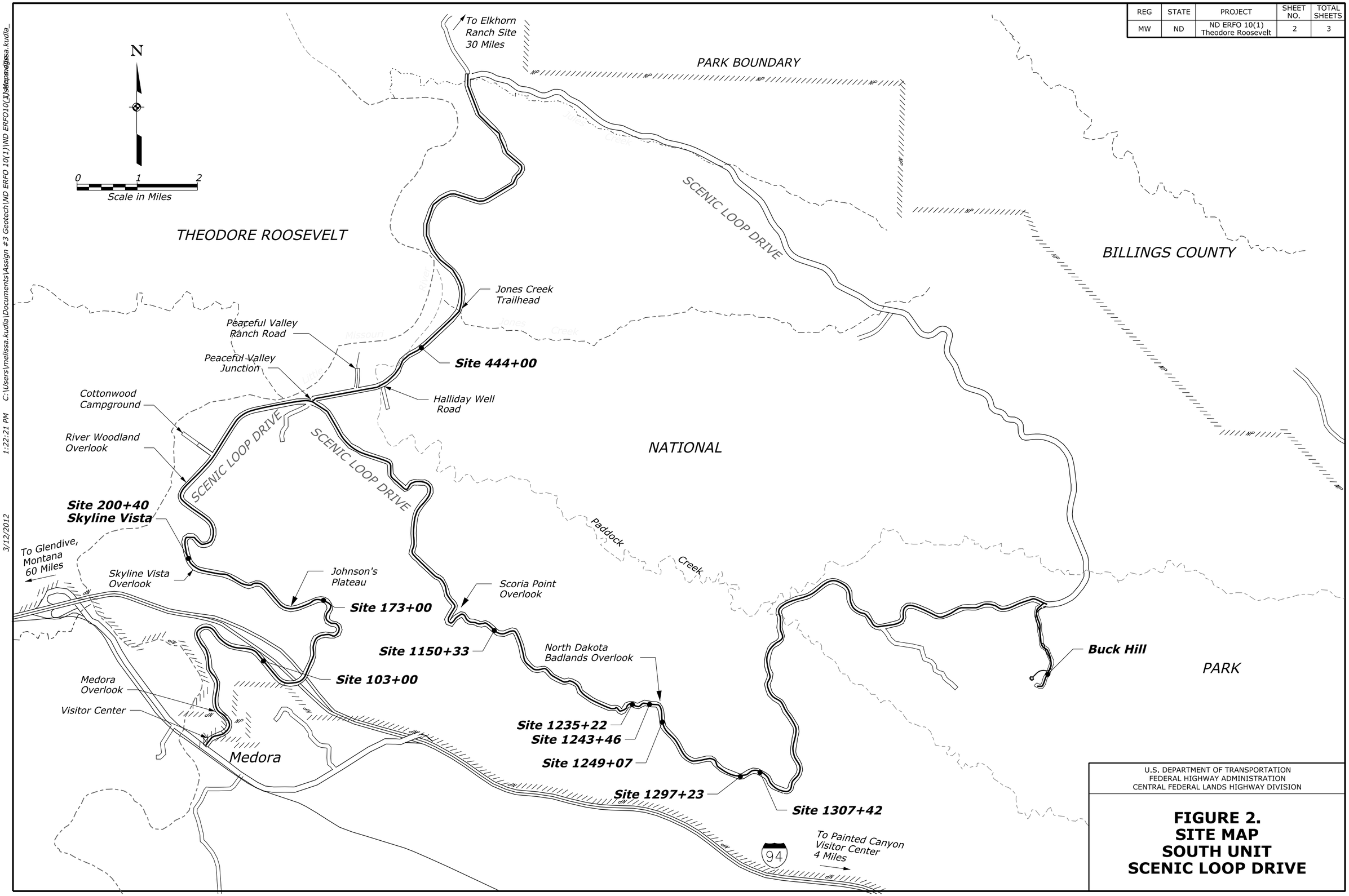
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

FIGURE 1.
VICINITY MAP
NORTH & SOUTH UNITS

NPS PMIS NO.: XXXXX DRAWING NO.: XXX-XXXXX

User: melissa.kudla
2/28/2012 3:57:48 PM C:\Users\melissa.kudla\Documents\Assign #3 Geotech\ND ERFO 10(1)\Fig 1_ERFO10(1).dgn

REG	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
MW	ND	ND ERFO 10(1) Theodore Roosevelt	2	3



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

FIGURE 2.
SITE MAP
SOUTH UNIT
SCENIC LOOP DRIVE

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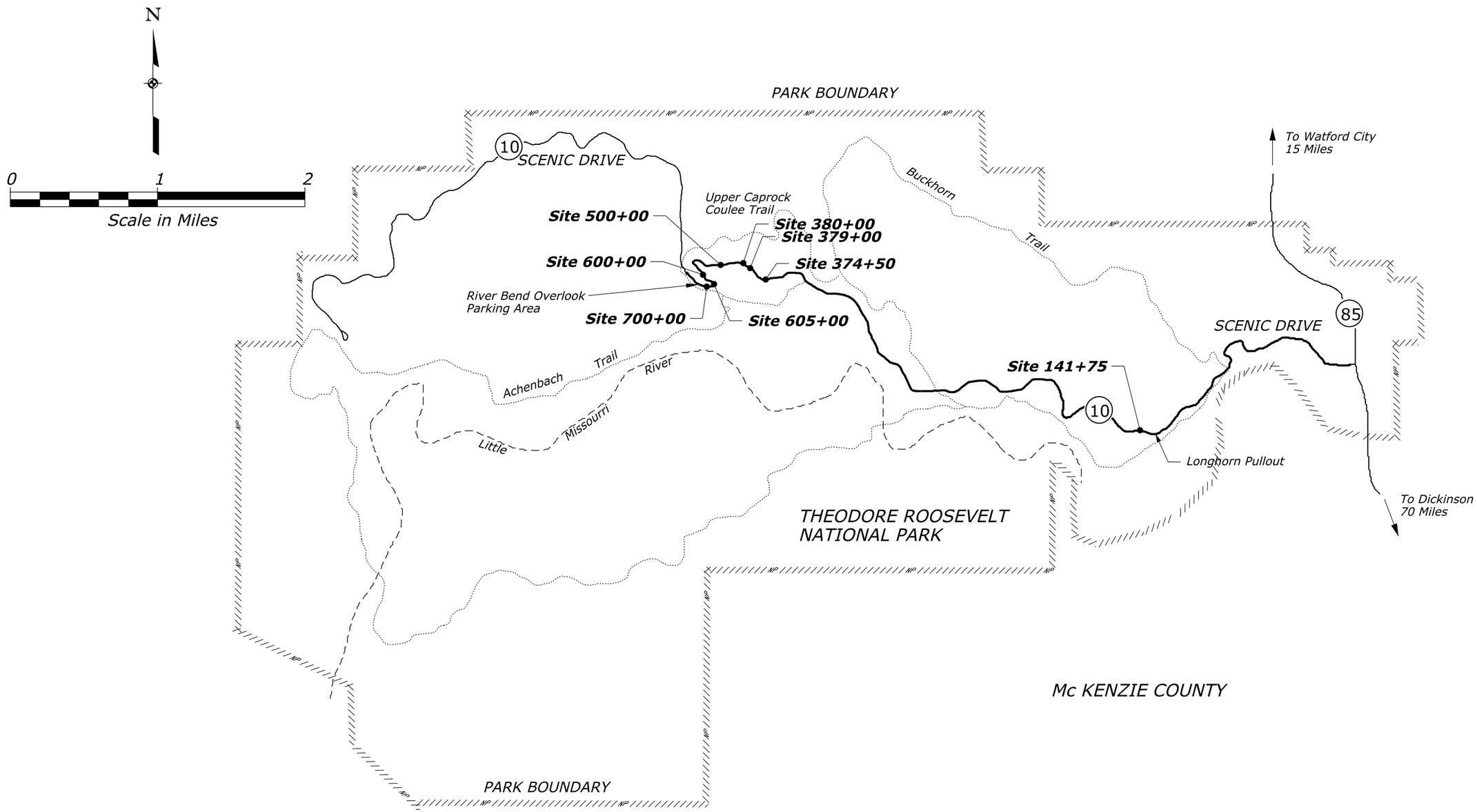
3/12/2012

REG	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
MW	ND	ND ERFO 10(1) Theodore Roosevelt	3	3



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

FIGURE 3.
SITE MAP
NORTH UNIT
SCENIC DRIVE

Appendix A

Figure 1: South Unit 240+00 (Skyline Vista) Damage Site

Figure 2: North Unit 374+50 Damage Site

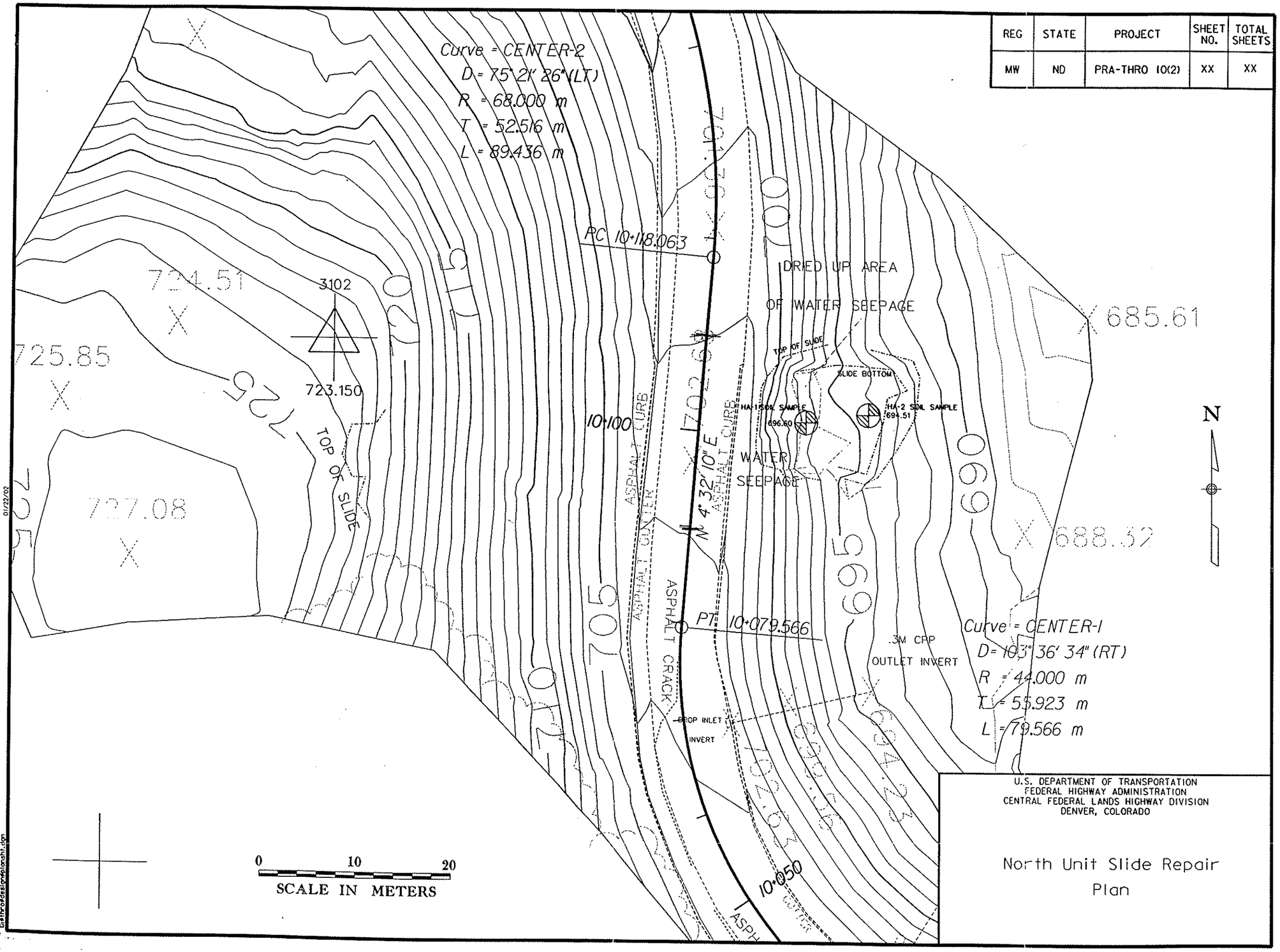
Figure 3: North Unit 500+00 Damage Site

Figure 4: North Unit 600+00 Damage Site at Approximate Station 601+00

Figure 5: North Unit 600+00 Damage Site at Approximate Station 603+80

Appendix B

REG	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
MW	ND	PRA-THRO 10(2)	XX	XX



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

North Unit Slide Repair
Plan

FIGURE 1

Theodore Roosevelt National Park Landslide

Figure 2. Area of landslide within embankment fill.

Figure 3. Area of landslide within embankment fill.

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division

Project Name: Theodore Roosevelt National Park Landslide		Boring No. HA-1	Date: 11/4/01	Sheet: 1 of 1
Boring Location:		Type of Boring: Hand Auger		
Coordinates:		Casing Used:		
Drill:	Driller:	Boring Started:	Boring Completed:	
Field Logged By : Charlie Martinez		Elevation: 696 m	Weather:	
Revisions By: Khamis Haramy		Water Depth:		

Depth Elevation (m)	Run No.	Graphic Log	Length Rec. m / % Rec.	RQD	SPT Blows	Depth, m	Description: (Density, Color, Type, Moisture, Other)
		Unit I				-0.5	0-0.3 m Loose, Tan-Gray, Fine, Sandy, Silty CLAY, Dry 0.3-0.6 m Soft, Tan, Fine, Sandy, Silty CLAY, Moist to Wet 0.6-0.9 m Soft, Tan, Fine, Sandy, Silty CLAY, Wet
695.0						-1.0	0.9-1.1 m Soft, Tan-Gray, Fine, Sandy, Silty CLAY w/ grass material, Wet
		Unit II				-1.5	1.1-1.2 m Soft, Tan-Gray, Silty CLAY w/ fine sand, Wet
694.0						-2.0	1.2-2.1 m Firm to Stiff, Tan-Gray, Silty CLAY w/ fine sand, Wet to Moist
						-2.5	**BHT=2.1 m**
693.0						-3.0	
						-3.5	
692.0						-4.0	
						-4.5	
691.0						-5.0	
						-5.5	
						-6.0	

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division

Project Name: Theodore Roosevelt National Park Landslide		Boring No. HA-2	Date: 11/4/01	Sheet: 1 of 1
Boring Location:		Type of Boring: Hand Auger	
Coordinates:		Casing Used:	
Drill:	Driller:	Boring Started:	Boring Completed:
Field Logged By : Charlie Martinez		Elevation: 694.5 m	Weather:
Revisions By: Khamis Haramy		Water Depth:	

Depth Elevation (m)	Run No.	Graphic Log	Length Rec. m / % Rec.	RQD	SPT Blows	Depth, m	Description: (Density, Color, Type, Moisture, Other)
		Unit I					0-0.45 m Loose, Tan-Gray, Fine, Sandy, Silty CLAY, Dry
						-0.5	0.45-0.9 m Soft, Tan, Fine, Sandy, Silty CLAY, Moist
693.5						-1.0	0.9-1.5 m Soft, Tan, Fine, Sandy, Silty CLAY w/ apparent weathered coal, Wet
						-1.5	1.5-1.8 m Firm, Gray, Fine, Silty CLAY w/ apparent weathered coal, Wet to Moist
692.5		Unit II				-2.0	1.8-2.4 m Firm, Tan-Gray, Silty CLAY w/ small cherty or dry clay fragments, Moist
						-2.5	2.4-2.9 m Apparent weathered COAL, Wet
691.5						-3.0	2.9-3.1 m Stiff, Gray, Clay with apparent weathered coal, Dry to Moist
							BHT=3.1 m
						-3.5	
690.5						-4.0	
						-4.5	
689.5						-5.0	
						-5.5	
						-6.0	

LABORATORY TEST REPORT ON SELECTED SOIL SAMPLES

MOISTURE CONTENT
ASTM D 2216

Moisture Content Determinations
ASTM D 2216

CLIENT: Federal Highway Administration JOB NO.: 2135-15
LOCATION: N. Unit Slide Repair, Proj # ND PRA THRO 10(2)

BORING	Upper Silde	Lower Silde
SAMPLE DEPTH	0.90 - 0.91 m	2.1 - 2.2 m
SAMPLE NO.	HA-1	HA-2
DATE SAMPLED		
DATE TESTED	12/6/01 KF	12/6/01 KF

MOISTURE DETERMINATIONS		
Wt. of Wet Soil & Dish (gms)	398.73	359.18
Wt. of Dry Soil & Dish (gms)	293.99	276.83
Net Loss of Moisture (gms)	104.74	82.35
Wt. of Dish (gms)	8.20	8.43
Wt. of Dry Soil (gms)	285.79	268.40
Moisture Content (%)	36.6	30.7

Data entered by: MC Date: 12/11/2001
Data checked by: SR Date: 12-11-01
FileName: FHN0HA12 ADVANCED TERRA TESTING, INC.

ATTERBERG LIMITS TEST
ASTM D 4318

ATTERBERG LIMITS TEST
ASTM D 4318

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Lower Side	DATE SAMPLED	
DEPTH	3.0 m - 3.1 m	DATE TESTED	12/28/01 SR/CJW
SAMPLE NO.	HA-2		
SOIL DESCR.	Proj # ND-PRA THRO 10(2)		
LOCATION	N. Unit Slide Repair		

Plastic Limit Determination

	1	2	3
Wt Dish & Wet Soil	4.56	4.43	4.39
Wt Dish & Dry Soil	3.83	3.71	3.69
Wt of Moisture	0.73	0.72	0.70
Wt of Dish	0.74	0.74	0.74
Wt of Dry Soil	3.09	2.97	2.95
Moisture Content	23.62	24.24	23.73

Liquid Limit Determination — Device Number 0258

	1	2	3
Number of Blows	30	20	16
Wt Dish & Wet Soil	11.45	11.19	11.37
Wt Dish & Dry Soil	6.88	6.66	6.73
Wt of Moisture	4.57	4.53	4.64
Wt of Dish	0.76	0.74	0.76
Wt of Dry Soil	6.12	5.92	5.97
Moisture Content	74.67	76.52	77.72

Liquid Limit	75.5
Plastic Limit	23.9
Plasticity Index	51.7

Atterberg Classification CH

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Checked by: CJ Date: 01/03/02
FileName: FHG0LS32

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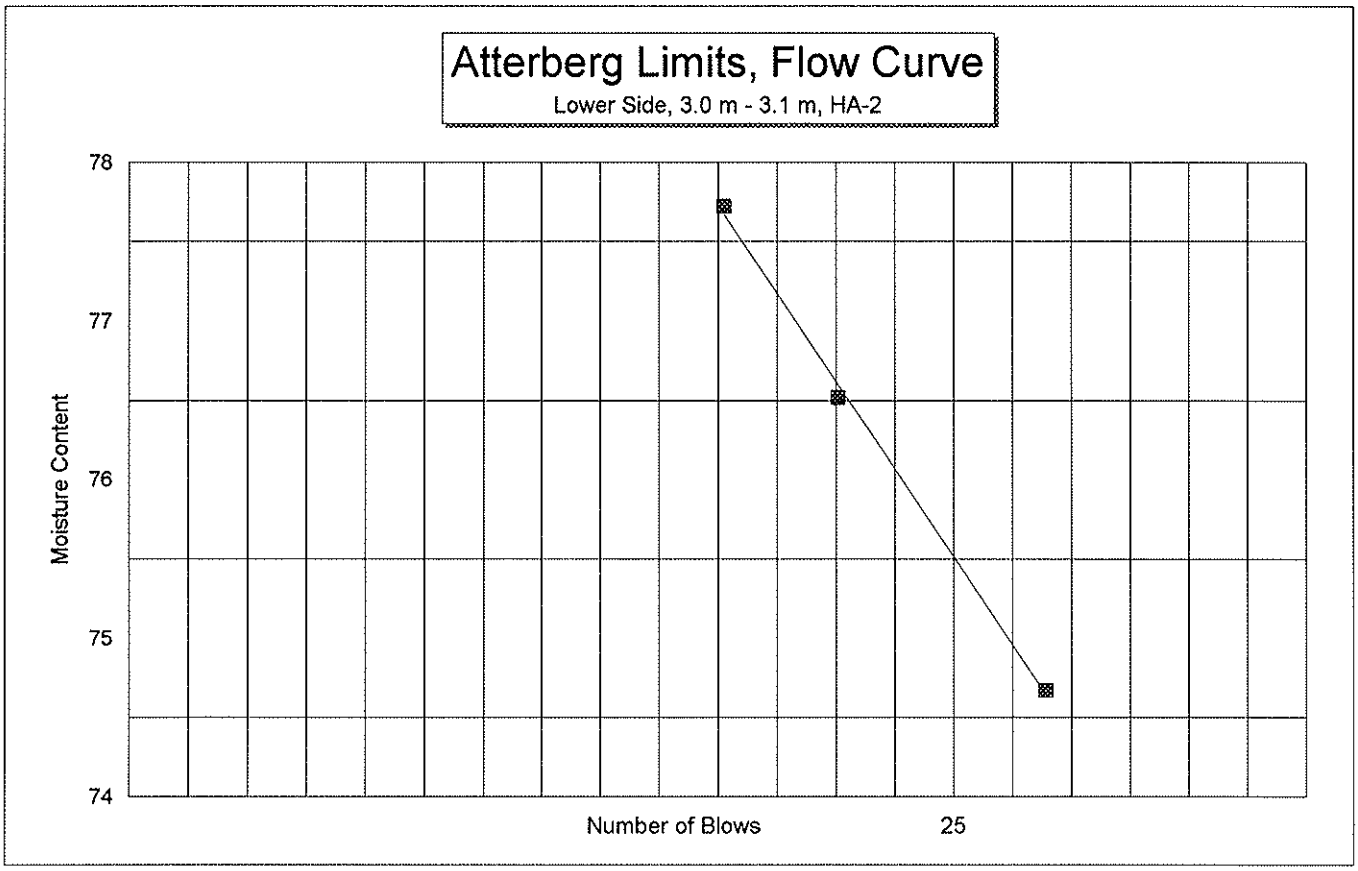
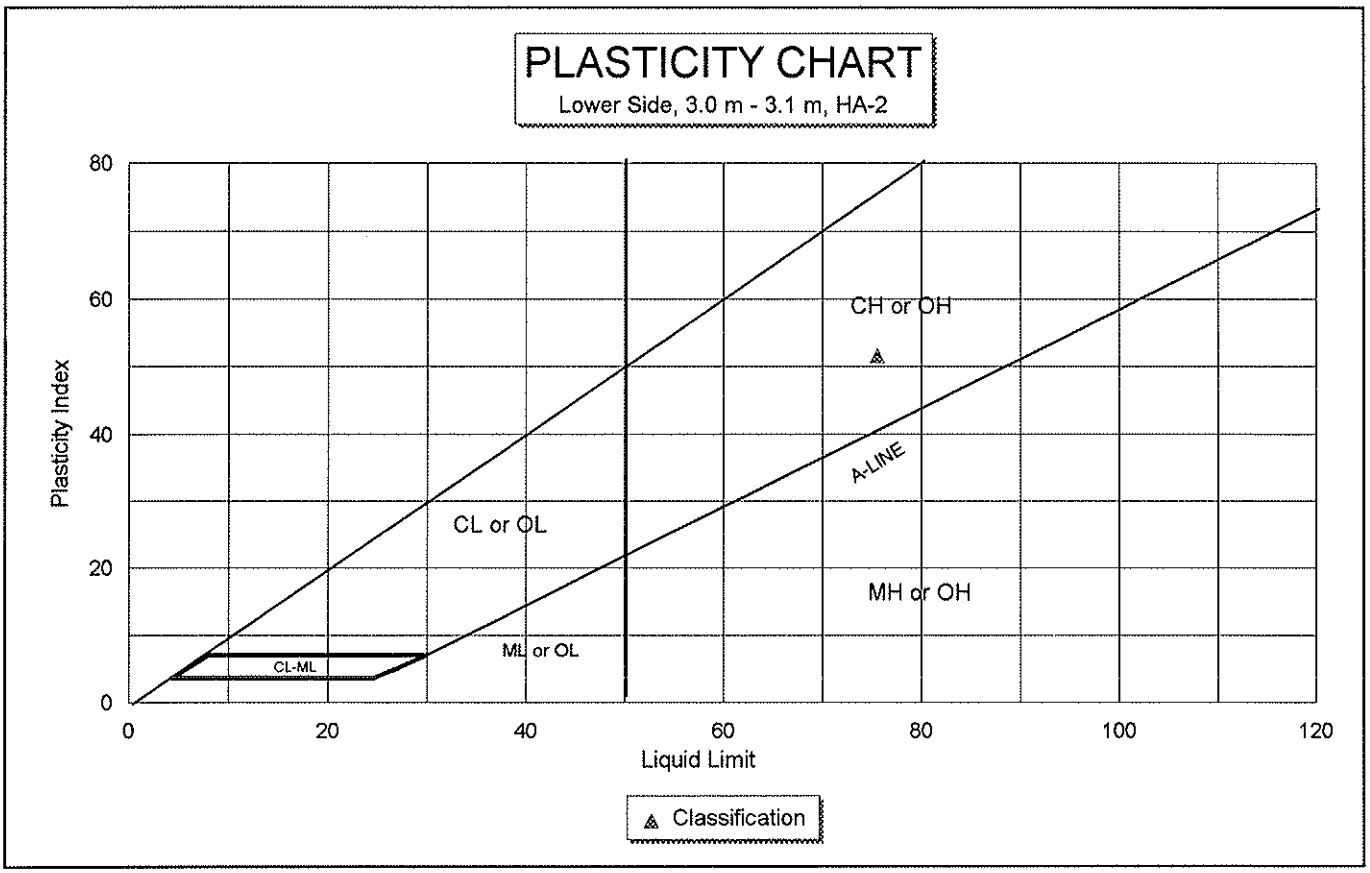

Atterberg Limits, Flow Curve
Lower Side, 3.0 m - 3.1 m, HA-2
Moisture Content
78
77
76
75
74
Number of Blows
25


PLASTICITY CHART
Lower Side, 3.0 m - 3.1 m, HA-2
Plasticity Index
80
60
40
20
0
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
Classification

ATTERBERG LIMITS TEST
ASTM D 4318

CLIENT	FHA	JOB NO.	2135-15
BORING NO.	Upper Slide	DATE SAMPLED	
DEPTH	0.30m - 0.31m	DATE TESTED	12/24/01 CJW
SAMPLE NO.	HA-1		
SOIL DESCR.	Proj # ND PRA THRO 10(2)		
LOCATION	N. Unit Slide Repair		

Plastic Limit Determination

	1	2	3
Wt Dish & Wet Soil	5.46	4.42	4.08
Wt Dish & Dry Soil	4.67	3.83	3.56
Wt of Moisture	0.79	0.59	0.52
Wt of Dish	0.73	0.74	0.74
Wt of Dry Soil	3.94	3.09	2.82
Moisture Content	20.05	19.09	18.44

Liquid Limit Determination — Device Number 0860

	1	2	3	4	5
Number of Blows	31	22	27	21	17
Wt Dish & Wet Soil	8.46	8.65	8.55	8.30	8.68
Wt Dish & Dry Soil	5.93	6.01	5.96	5.76	5.95
Wt of Moisture	2.53	2.64	2.59	2.54	2.73
Wt of Dish	0.73	0.77	0.74	0.76	0.76
Wt of Dry Soil	5.20	5.24	5.22	5.00	5.19
Moisture Content	48.65	50.38	49.62	50.80	52.60

Liquid Limit	49.9
Plastic Limit	19.2
Plasticity Index	30.7

Atterberg Classification CL

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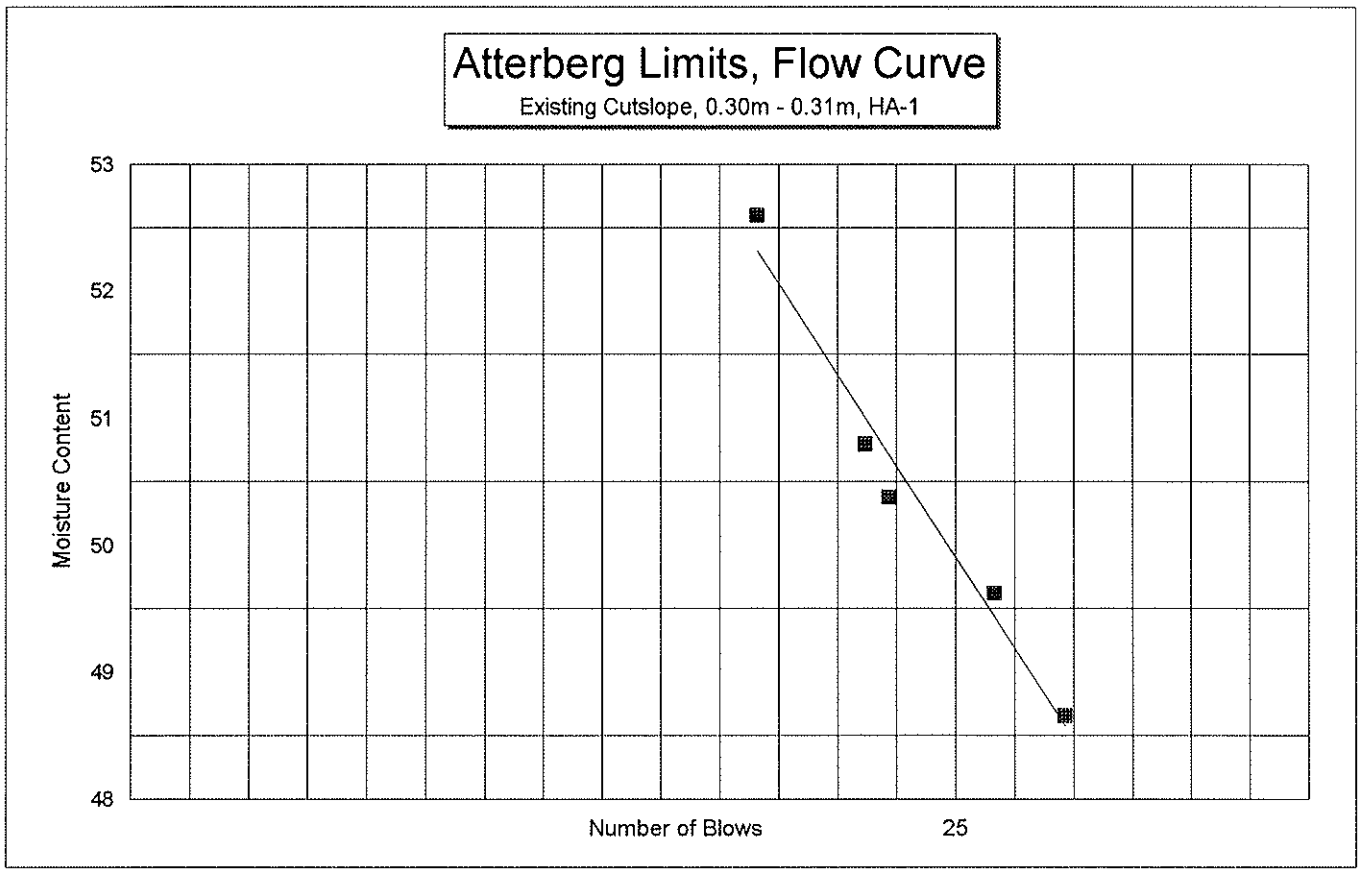
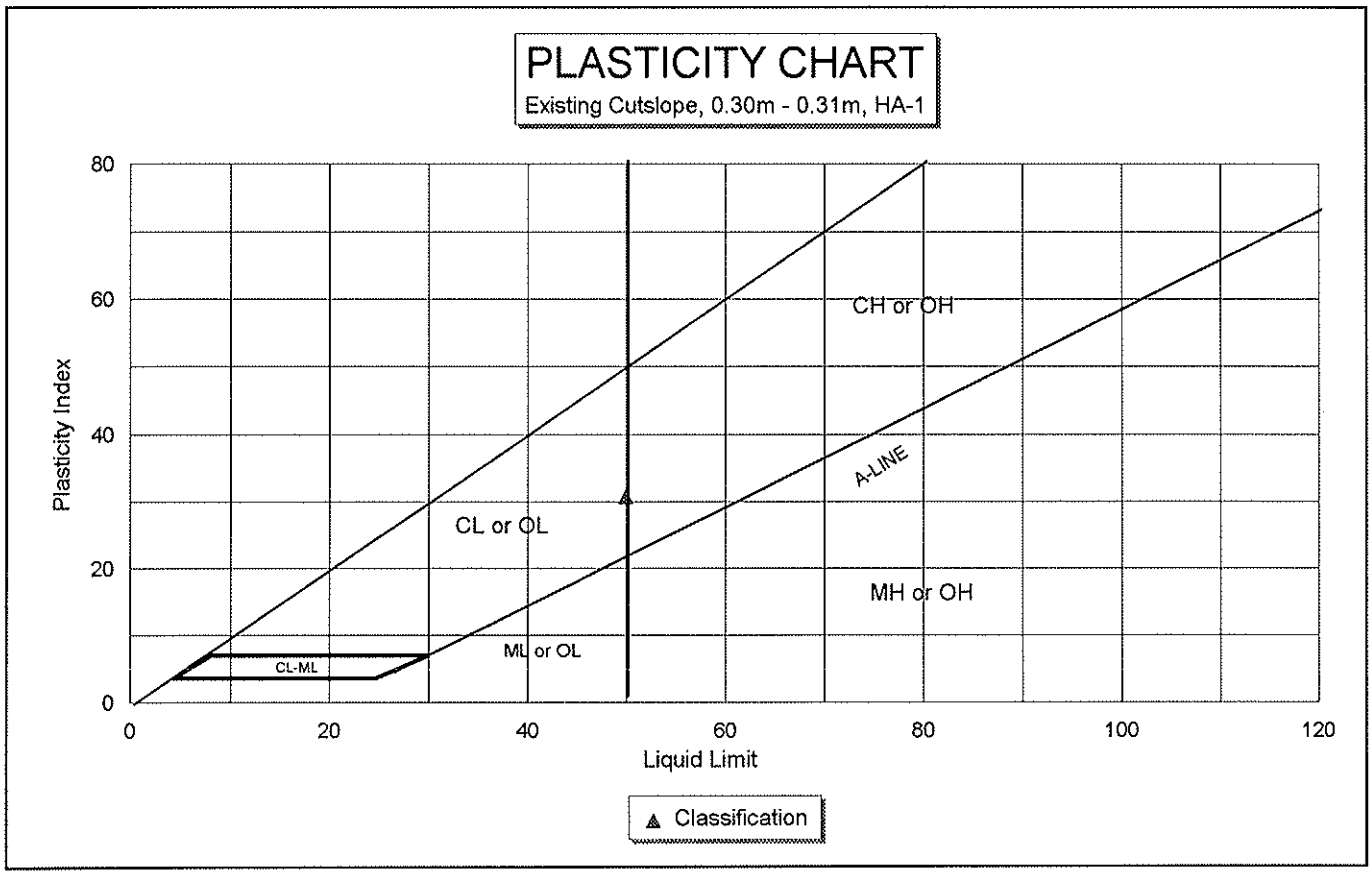
Checked by: CJ Date: 01/03/02
FileName: FHG00HA1

ADVANCED TERRA TESTING, INC.


Atterberg Limits, Flow Curve
Existing Cutslope, 0.30m - 0.31m, HA-1
Moisture Content
53
52
51
50
49
48
Number of Blows
25


PLASTICITY CHART
Existing Cutslope, 0.30m - 0.31m, HA-1
Plasticity Index
80
60
40
20
0
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
Classification

ATTERBERG LIMITS TEST
ASTM D 4318

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Upper Slide	DATE SAMPLED	
DEPTH	2.1m-2.2m	DATE TESTED	12/21/01
SAMPLE NO.	HA-1		
SOIL DESCR.	Proj# ND PRA THRO 10(2)		
LOCATION	N. Unit Slide Repair		

Plastic Limit Determination

	1	2	3
Wt Dish & Wet Soil	4.63	3.81	4.03
Wt Dish & Dry Soil	4.05	3.35	3.54
Wt of Moisture	0.58	0.46	0.49
Wt of Dish	0.74	0.76	0.75
Wt of Dry Soil	3.31	2.59	2.79
Moisture Content	17.52	17.76	17.56

Liquid Limit Determination — Device Number 0860

	1	2	3	4	5
Number of Blows	26	28	23	19	21
Wt Dish & Wet Soil	6.36	6.96	6.08	7.23	6.37
Wt Dish & Dry Soil	3.75	4.11	3.59	4.16	3.72
Wt of Moisture	2.61	2.85	2.49	3.07	2.65
Wt of Dish	0.75	0.75	0.76	0.76	0.73
Wt of Dry Soil	3.00	3.36	2.83	3.40	2.99
Moisture Content	87.00	84.82	87.99	90.29	88.63

Liquid Limit	86.8
Plastic Limit	17.6
Plasticity Index	69.2

Atterberg Classification CH

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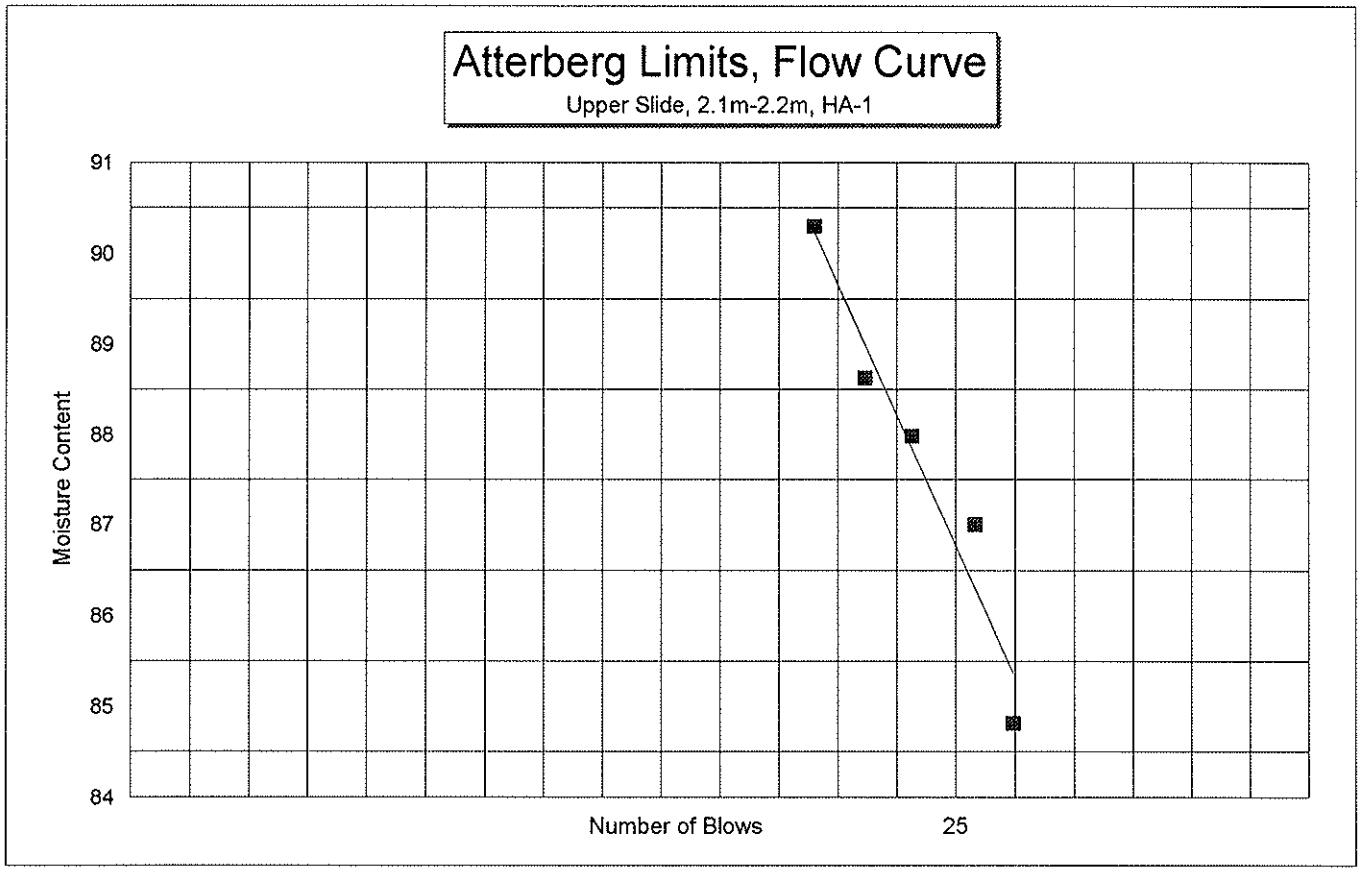
Checked by: CJ Date: 01/03/02
FileName: FHG0HA1

ADVANCED TERRA TESTING, INC.


Atterberg Limits, Flow Curve
Upper Slide, 2.1m-2.2m, HA-1
Moisture Content
91
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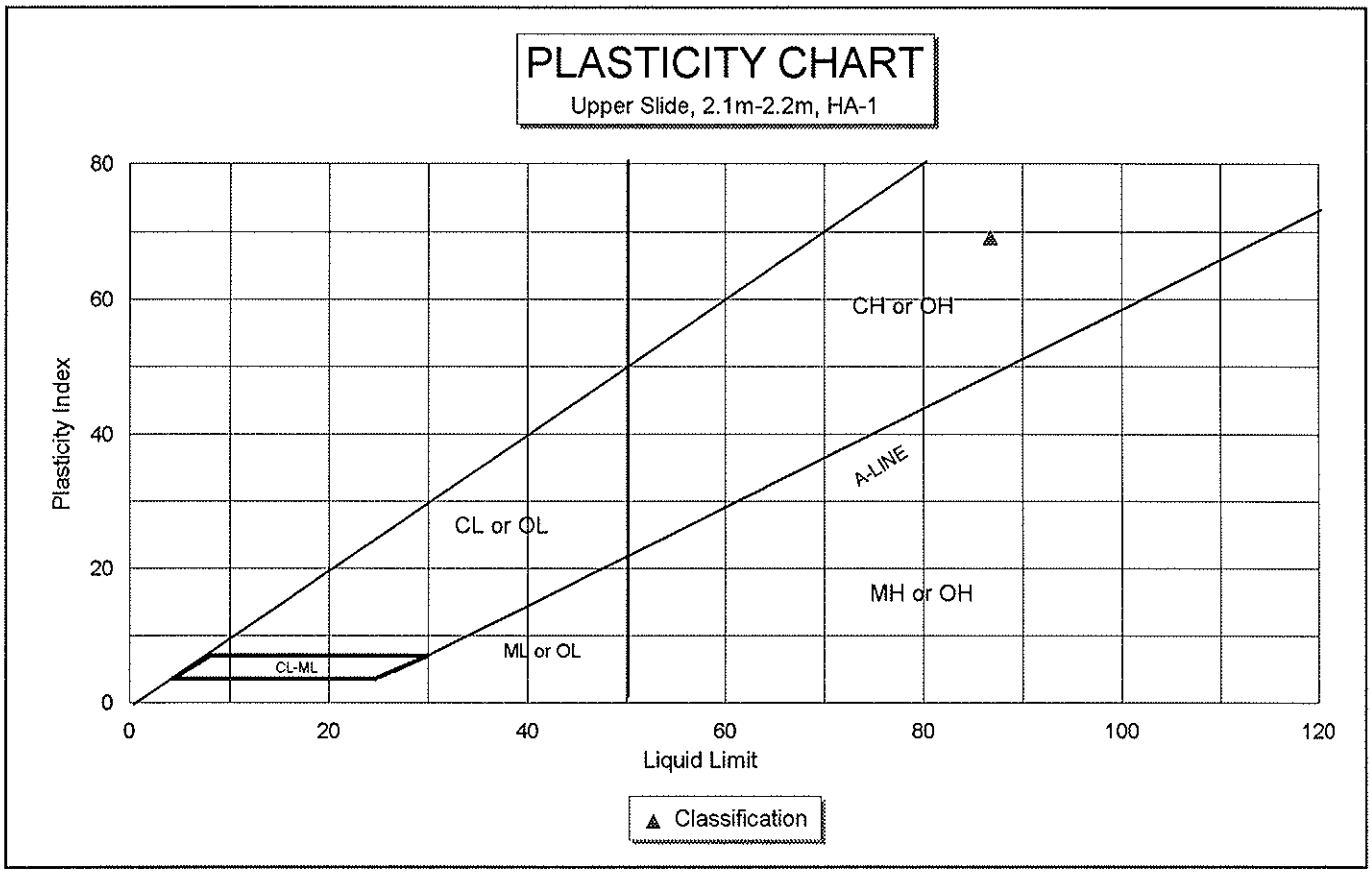
89
88
87
86
85
84
Number of Blows
25


PLASTICITY CHART
Upper Slide, 2.1m-2.2m, HA-1
Plasticity Index
80
60
40
20
0
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
Classification

ATTERBERG LIMITS TEST
ASTM D 4318

CLIENT	FHA	JOB NO.	2135-15
BORING NO.	Existing Cutslope	DATE SAMPLED	
DEPTH		DATE TESTED	12/24/01 CJ
SAMPLE NO.	HA-3		
SOIL DESCR.	Proj # ND PRA THRO 10(2)		
LOCATION	N. Unit Slide Repair		

Plastic Limit Determination

	1	2	3
Wt Dish & Wet Soil	5.93	4.40	4.85
Wt Dish & Dry Soil	5.23	3.90	4.28
Wt of Moisture	0.70	0.50	0.57
Wt of Dish	0.77	0.74	0.74
Wt of Dry Soil	4.46	3.16	3.54
Moisture Content	15.70	15.82	16.10

Liquid Limit Determination — Device Number 0860

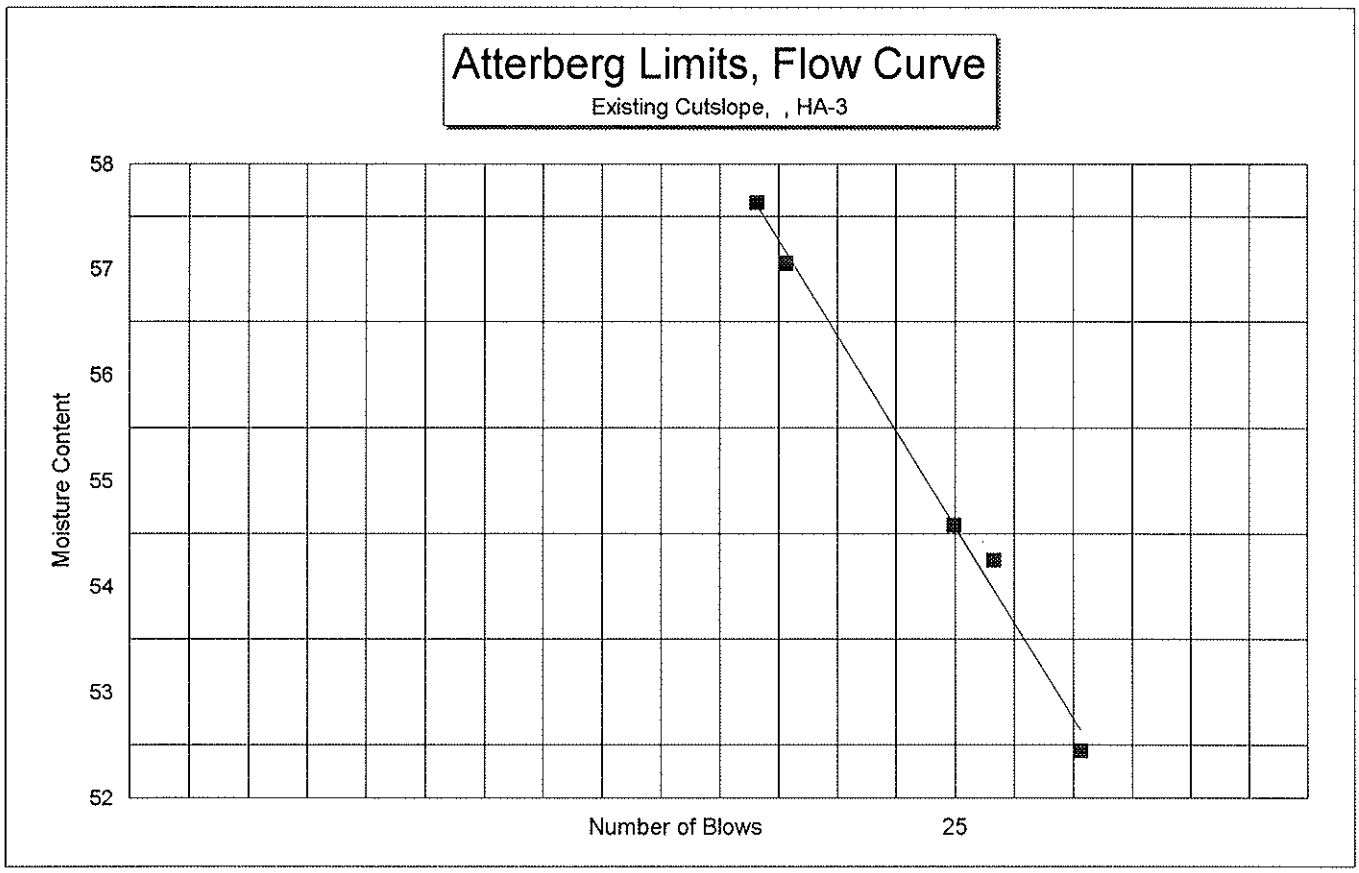
	1	2	3	4	5
Number of Blows	32	25	27	18	17
Wt Dish & Wet Soil	7.95	7.84	8.53	8.33	7.67
Wt Dish & Dry Soil	5.48	5.34	5.79	5.58	5.14
Wt of Moisture	2.47	2.50	2.74	2.75	2.53
Wt of Dish	0.77	0.76	0.74	0.76	0.75
Wt of Dry Soil	4.71	4.58	5.05	4.82	4.39
Moisture Content	52.44	54.59	54.26	57.05	57.63

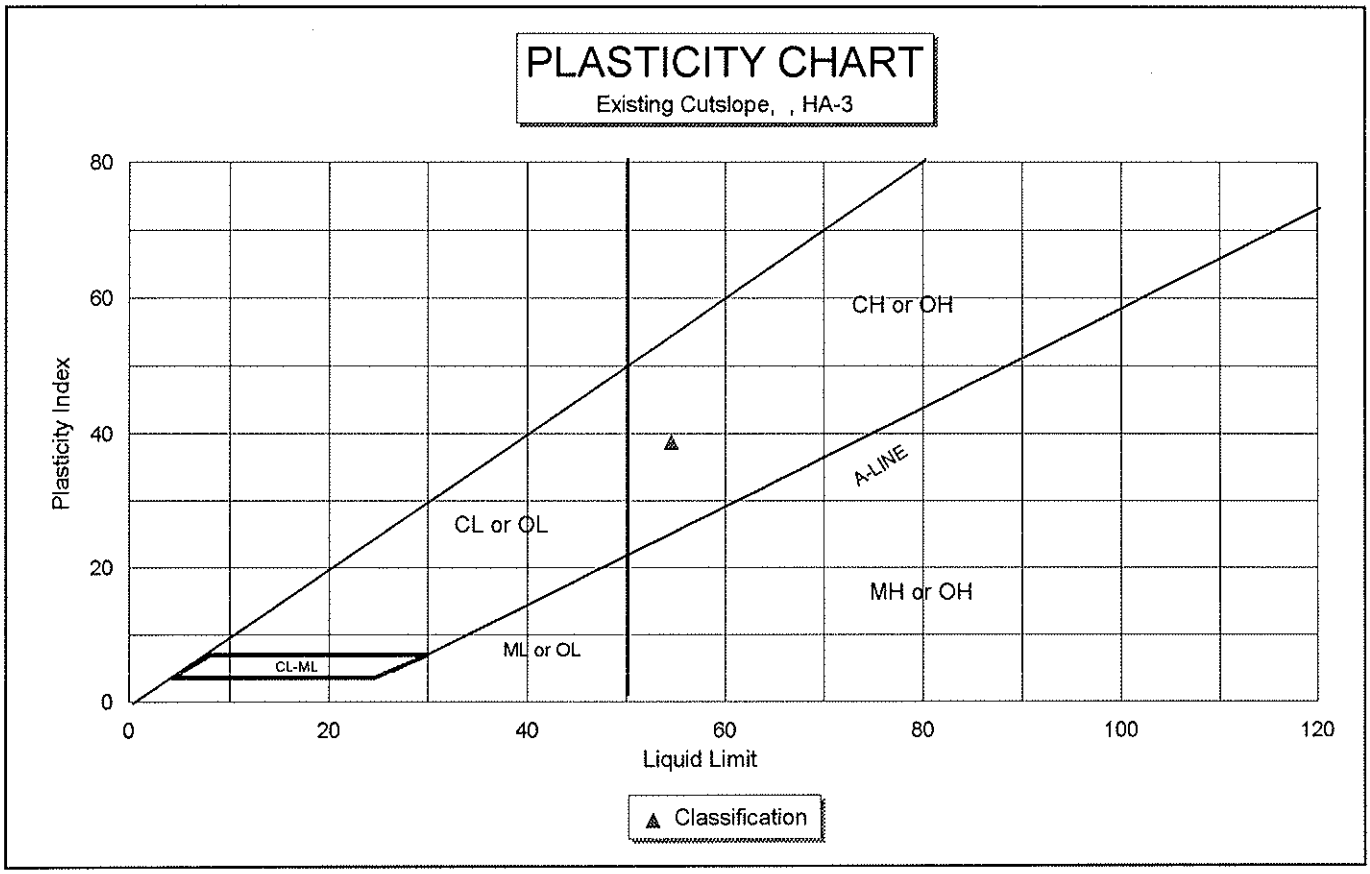
Liquid Limit	54.6
Plastic Limit	15.9
Plasticity Index	38.7

Atterberg Classification CH

Data entry by: MC Date: 12/26/2001
Checked by: CJ Date: 01/03/02
FileName: FHG0HA3

ADVANCED TERRA TESTING, INC.


Atterberg Limits, Flow Curve
Existing Cutslope, , HA-3
Moisture Content
58
57
56
55
54
53
52
Number of Blows
25


PLASTICITY CHART
Existing Cutslope, , HA-3
Plasticity Index
80
60
40
20
0
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
Classification

ATTERBERG LIMITS TEST
ASTM D 4318

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Upper Slide	DATE SAMPLED	
DEPTH	1.5m-1.51m	DATE TESTED	12/21/01CJW
SAMPLE NO.	HA-1		
SOIL DESCR.	Proj# ND PRA THRO 10(2)		
LOCATION	N. Unit Slide Repair		

Plastic Limit Determination

	1	2	3
Wt Dish & Wet Soil	4.82	5.42	4.59
Wt Dish & Dry Soil	4.19	4.73	4.01
Wt of Moisture	0.63	0.69	0.58
Wt of Dish	0.76	0.74	0.77
Wt of Dry Soil	3.43	3.99	3.24
Moisture Content	18.37	17.29	17.90

Liquid Limit Determination — Device Number 0860

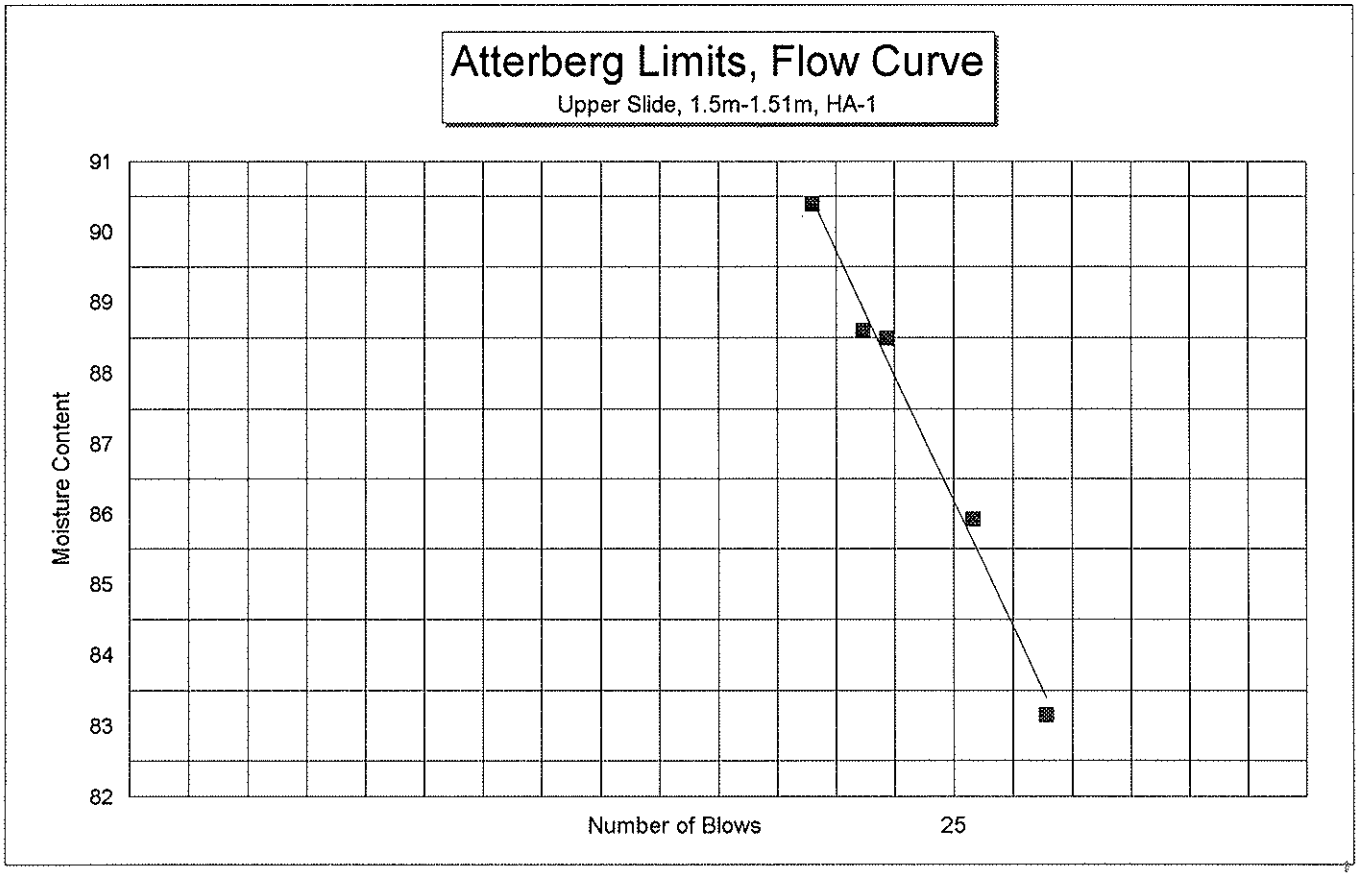
	1	2	3	4	5
Number of Blows	30	26	21	22	19
Wt Dish & Wet Soil	7.48	7.08	7.38	7.13	7.68
Wt Dish & Dry Soil	4.42	4.15	4.27	4.13	4.39
Wt of Moisture	3.06	2.93	3.11	3.00	3.29
Wt of Dish	0.74	0.74	0.76	0.74	0.75
Wt of Dry Soil	3.68	3.41	3.51	3.39	3.64
Moisture Content	83.15	85.92	88.60	88.50	90.38

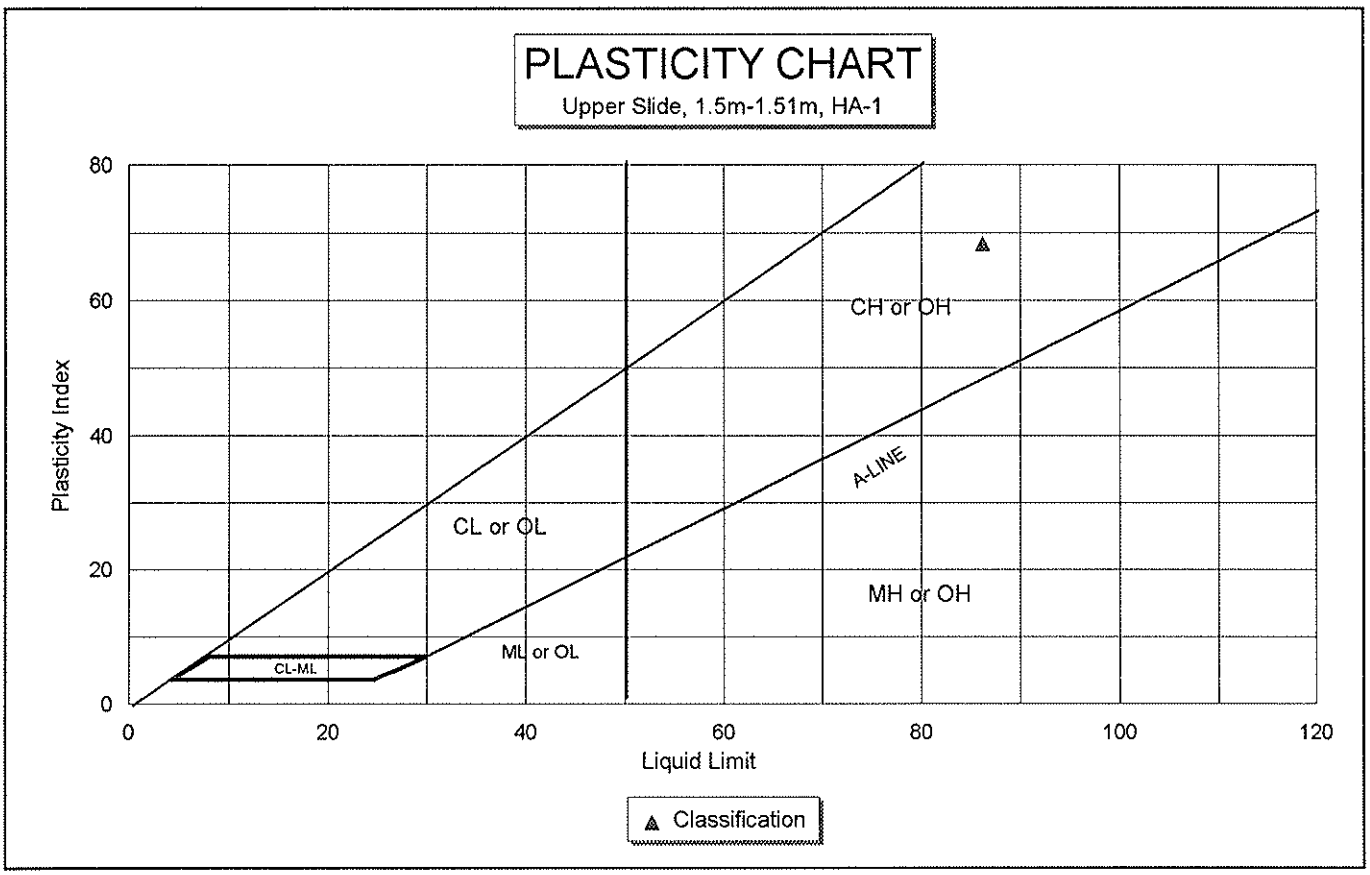
Liquid Limit	86.2
Plastic Limit	17.9
Plasticity Index	68.4

Atterberg Classification CH

Data entry by: CJW Date: 01/04/2002
Checked by: CJ Date: 01/04/02
FileName: FHG0HA15

ADVANCED TERRA TESTING, INC.


Atterberg Limits, Flow Curve
Upper Slide, 1.5m-1.51m, HA-1
Moisture Content
91
90
89
88
87
86
85
84
83
82
Number of Blows
25


PLASTICITY CHART
Upper Slide, 1.5m-1.51m, HA-1
Plasticity Index
80
60
40
20
0
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
Classification

GRAIN SIZE ANALYSIS, MECHANICAL
ASTM D 422

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT Federal Highway Administration

JOB NO. 2135-15

BORING NO.	Lower Slide	SAMPLED	
DEPTH	3.0-3.1m	DATE TESTED	12/27/01 SR
SAMPLE NO.	HA-2	WASH SIEVE	Yes
SOIL DESCR.	Proj# ND PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No

Wt. Wet Soil & Pan (g)	223.78
Wt. Dry Soil & Pan (g)	220.84
Wt. Lost Moisture (g)	2.94
Wt. of Pan Only (g)	88.09
Wt. of Dry Soil (g)	132.75
Moisture Content %	2.2
Wt. Hydrom. Sample Wet (g)	135.69
Wt. Hydrom. Sample Dry (g)	132.75

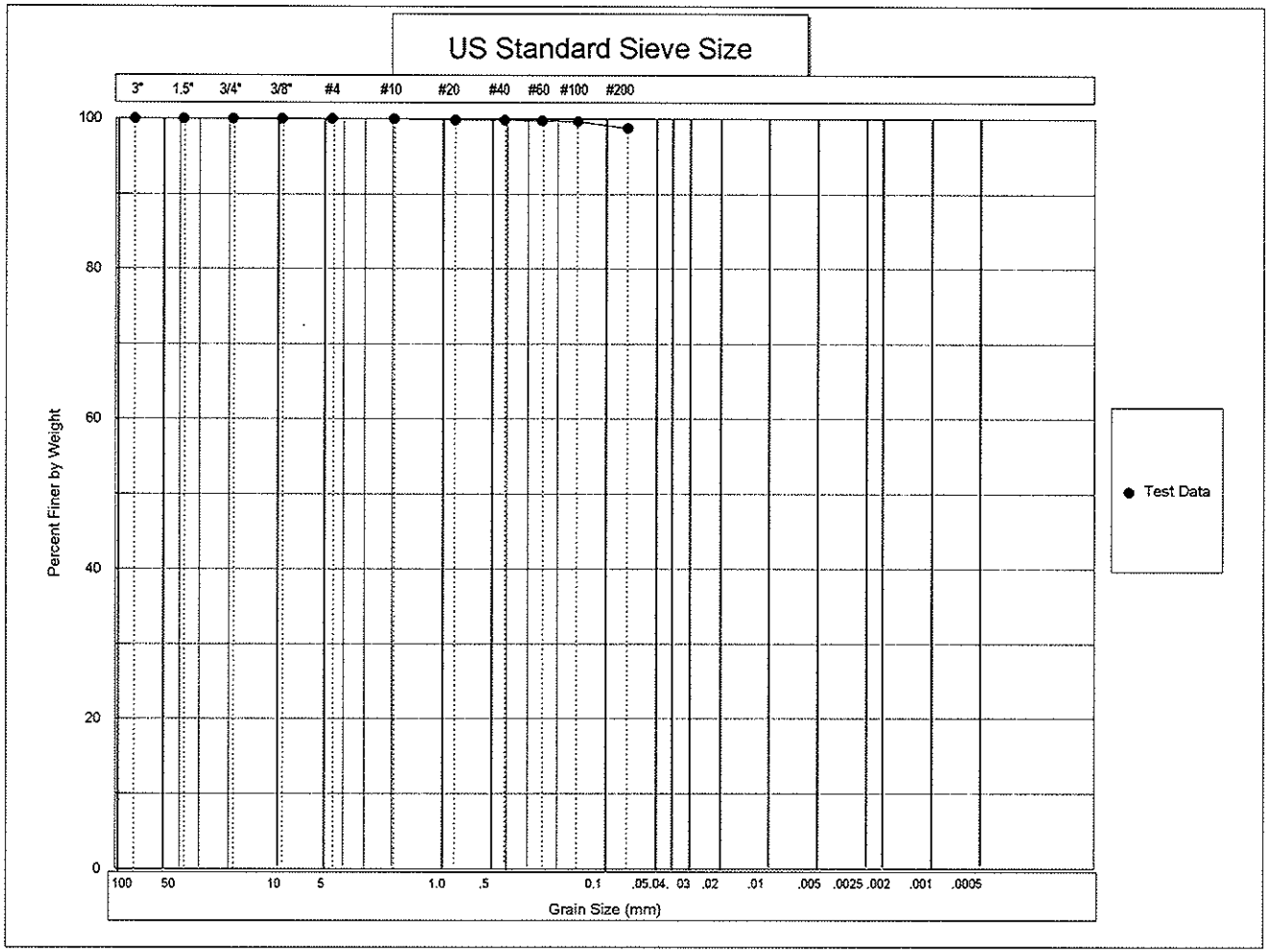
WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	135.69
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	135.69
Weight of - #10 Dry (g)	132.75
Wt. Total Sample Dry (g)	132.75
Calc. Wt. "W" (g)	132.75
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.64	3.80	0.16	0.16	0.1	99.9
#40	3.59	3.66	0.07	0.23	0.2	99.8
#60	3.57	3.64	0.07	0.30	0.2	99.8
#100	3.68	3.79	0.11	0.41	0.3	99.7
#200	3.71	4.90	1.19	1.60	1.2	98.8

Data entered by: CJW Date: 01/03/2002
Data checked by: CJ Date: 01/03/02
FileName: FHMULS30

ADVANCED TERRA TESTING, INC.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	CRS	MEDIUM	FINE	

USCS

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE		

WENTWORTH

Client: Federal Highway Admini Boring No.: Lower Slide Sample No.: HA-2
Job Number: 2135-15 Depth: 3.0-3.1m
Classification: **CH, Fat clay**

Advanced Terra Testing, Inc.

USCS Classification
D 2487

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Lower Slide	SAMPLED	
DEPTH	3.0-3.1m	DATE TESTED	12/27/01 SR
SAMPLE NO.	HA-2	WASH SIEVE	Yes
SOIL DESCR.	Proj# ND PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

ATTERBERG CLASSIFICATION: CH

% Gravel =	0.00
% Sand =	1.21
% Fines =	98.79

D60 =	N/A
D30 =	N/A
D10 =	N/A

Cu =	N/A
Cc =	N/A

Classification = CH, Fat clay

Data entered by: CJW
Data checked by: CJ
FileName: FHMULS30

Date: 01/03/2002
Date: 01/03/02
ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT Federal Highway Administration

JOB NO. 2135-15

BORING NO.	Upper Slide	SAMPLED	
DEPTH	0.30 m - 0.31 m	DATE TESTED	12/15/01 SR
SAMPLE NO.	HA-1	WASH SIEVE	Yes
SOIL DESCR.	Proj # PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No

Wt. Wet Soil & Pan (g)	52.43
Wt. Dry Soil & Pan (g)	51.50
Wt. Lost Moisture (g)	0.93
Wt. of Pan Only (g)	3.67
Wt. of Dry Soil (g)	47.83
Moisture Content %	1.9
Wt. Hydrom. Sample Wet (g)	174.19
Wt. Hydrom. Sample Dry (g)	170.87

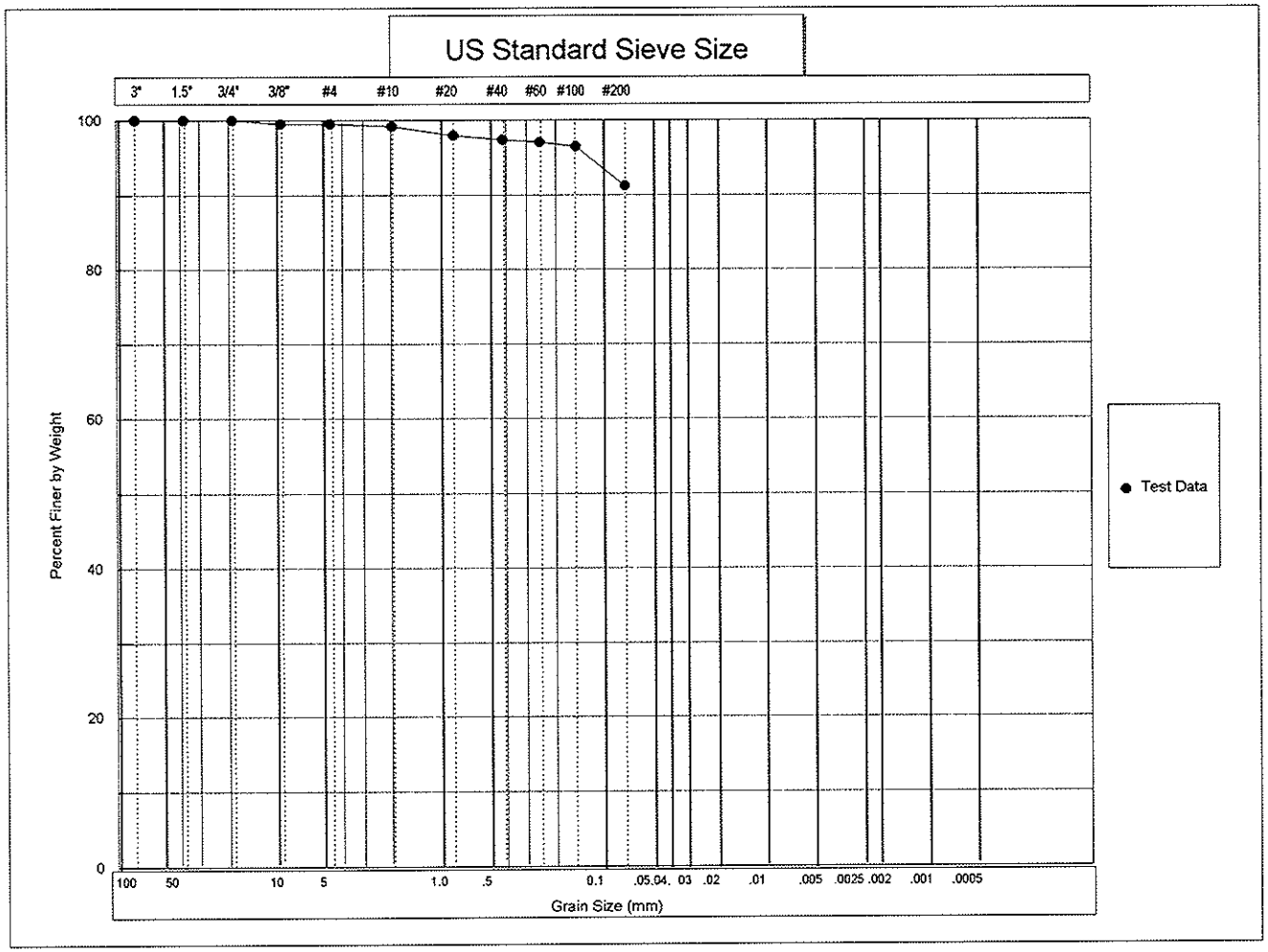
WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	526.70
Weight of + #10 Before Washing (g)	7.91
Weight of + #10 After Washing (g)	4.27
Weight of - #10 Wet (g)	518.79
Weight of - #10 Dry (g)	512.47
Wt. Total Sample Dry (g)	516.74
Calc. Wt. "W" (g)	172.29
Calc. Mass + #10	1.42

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	2.33	2.33	2.33	0.5	99.5
#4	0.00	0.00	0.00	2.33	0.5	99.5
#10	0.00	1.94	1.94	4.27	0.8	99.2
#20	3.67	5.73	2.06	2.06	2.0	98.0
#40	3.58	4.65	1.07	3.13	2.6	97.4
#60	3.61	4.19	0.58	3.71	3.0	97.0
#100	3.62	4.59	0.97	4.68	3.5	96.5
#200	3.61	12.62	9.01	13.69	8.8	91.2

Data entered by: MC Date: 01/03/2002
Data checked by: CJ Date: 01/03/02
FileName: FHMU0HA1

ADVANCED TERRA TESTING, INC.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	CRS	MEDIUM	FINE	

USCS

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE		

WENTWORTH

Client: Federal Highway Admini Boring No.: Upper Slide Sample No.: HA-1
Job Number: 2135-15 Depth: 0.30 m - 0.31 m
Classification: **CL, Lean Clay**

Advanced Terra Testing, Inc.

USCS Classification
D 2487

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Upper Slide	SAMPLED	
DEPTH	0.30 m - 0.31 m	DATE TESTED	12/15/01 SR
SAMPLE NO.	HA-1	WASH SIEVE	Yes
SOIL DESCR.	Proj # PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

ATTERBERG CLASSIFICATION: CL

% Gravel =	0.45
% Sand =	8.32
% Fines =	91.23

D60 =	N/A
D30 =	N/A
D10 =	N/A

Cu =	N/A
Cc =	N/A

Classification = CL, Lean Clay

Data entered by: MC
Data checked by: CO
FileName: FHMU0HA1

Date: 01/03/2002
Date: 01/03/02
ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT Federal Highway Administration

JOB NO. 2135-15

BORING NO.	Upper Slide	SAMPLED	
DEPTH	2.10 m - 2.20 m	DATE TESTED	12/15/01 SR
SAMPLE NO.	HA-1	WASH SIEVE	Yes
SOIL DESCR.	Proj # PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No

Wt. Wet Soil & Pan (g)	59.89
Wt. Dry Soil & Pan (g)	59.05
Wt. Lost Moisture (g)	0.84
Wt. of Pan Only (g)	3.60
Wt. of Dry Soil (g)	55.45
Moisture Content %	1.5

Wt. Hydrom. Sample Wet (g)	216.43
Wt. Hydrom. Sample Dry (g)	213.20

WASH SIEVE ANALYSIS

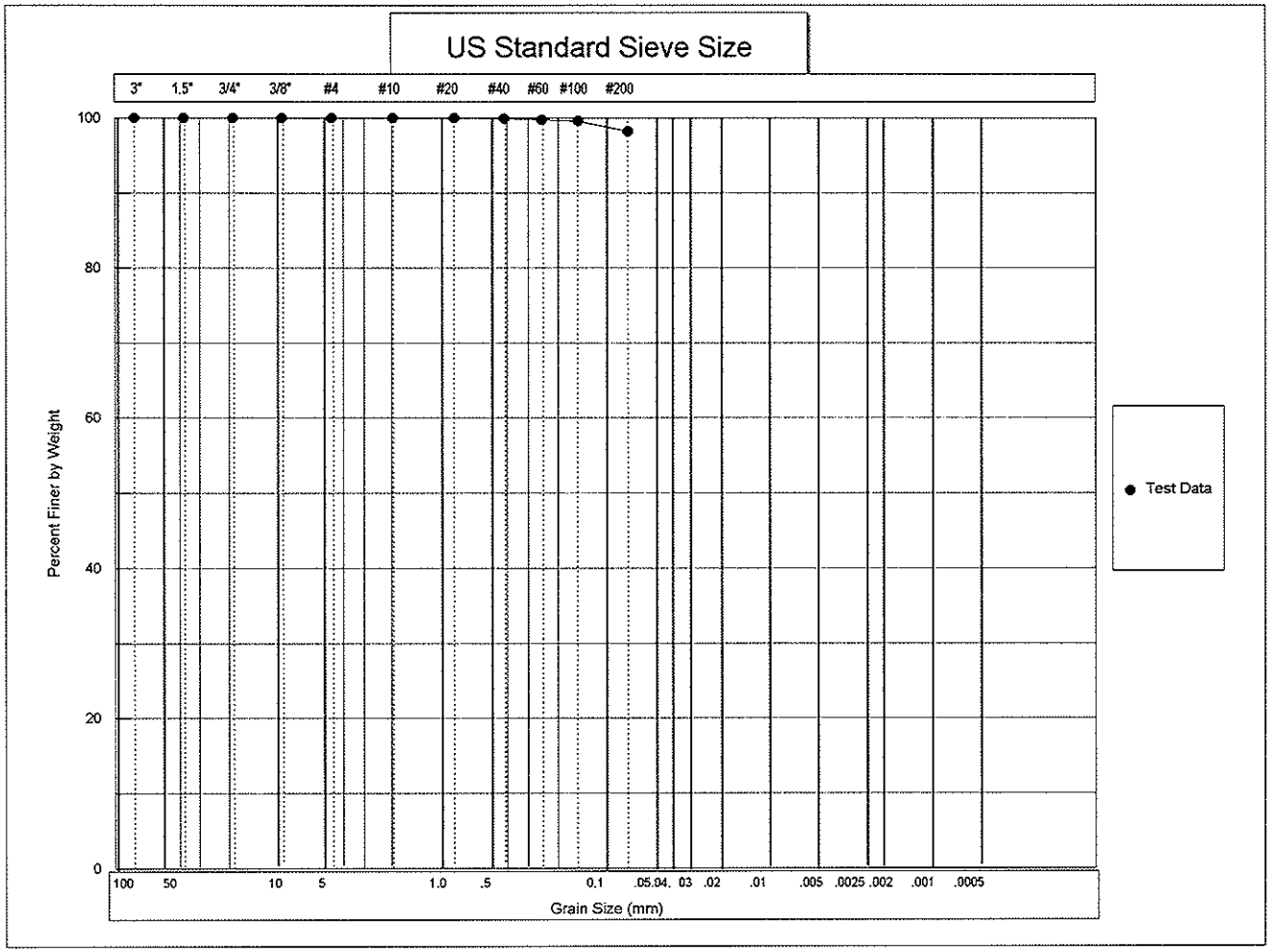
Wt. Total Sample Wet (g)	996.62
Weight of + #10 Before Washing (g)	0.00
Weight of + #10 After Washing (g)	0.00
Weight of - #10 Wet (g)	996.62
Weight of - #10 Dry (g)	981.75
Wt. Total Sample Dry (g)	981.75

Calc. Wt. "W" (g)	213.20
Calc. Mass + #10	0.00

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.00	0.00	0.00	0.0	100.0
#10	0.00	0.00	0.00	0.00	0.0	100.0
#20	3.58	3.61	0.03	0.03	0.0	100.0
#40	3.59	3.71	0.12	0.15	0.1	99.9
#60	3.64	3.89	0.25	0.40	0.2	99.8
#100	3.58	3.90	0.32	0.72	0.3	99.7
#200	3.64	6.79	3.15	3.87	1.8	98.2

Data entered by: MC Date: 12/26/2001
Data checked by: W Date: 01/03/02
FileName: FHMUHA12

ADVANCED TERRA TESTING, INC.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	CRS	MEDIUM	FINE	

USCS

COBBLES TO BOULDERS	PEBBLE GRAVEL				SAND			SILT	CLAY
	COARSE	MED	FINE	GRAN	COARSE	MED	FINE		

WENTWORTH

Client: Federal Highway Admini Boring No.: Upper Slide Sample No.: HA-1
Job Number: 2135-15 Depth: 2.10 m - 2.20 m
Classification: **CH, Fat clay**

Advanced Terra Testing, Inc.

USCS Classification
D 2487

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Upper Slide	SAMPLED	
DEPTH	2.10 m - 2.20 m	DATE TESTED	12/15/01 SR
SAMPLE NO.	HA-1	WASH SIEVE	Yes
SOIL DESCR.	Proj # PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

ATTERBERG CLASSIFICATION: CH

% Gravel =	0.00
% Sand =	1.82
% Fines =	98.18

D60 =	N/A
D30 =	N/A
D10 =	N/A

Cu =	N/A
Cc =	N/A

Classification = CH, Fat clay

Data entered by: MC
Data checked by: CW
FileName: FHMUHA12

Date: 12/26/2001
Date: 01/03/02
ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT Federal Highway Administration

JOB NO. 2135-15

BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		DATE TESTED	12/27/01 SR
SAMPLE NO.	HA-3	WASH SIEVE	Yes
SOIL DESCR.	Proj # ND PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	66.07
Wt. Dry Soil & Pan (g)	64.84
Wt. Lost Moisture (g)	1.23
Wt. of Pan Only (g)	3.79
Wt. of Dry Soil (g)	61.05
Moisture Content %	2.0
Wt. Hydrom. Sample Wet (g)	219.81
Wt. Hydrom. Sample Dry (g)	215.47

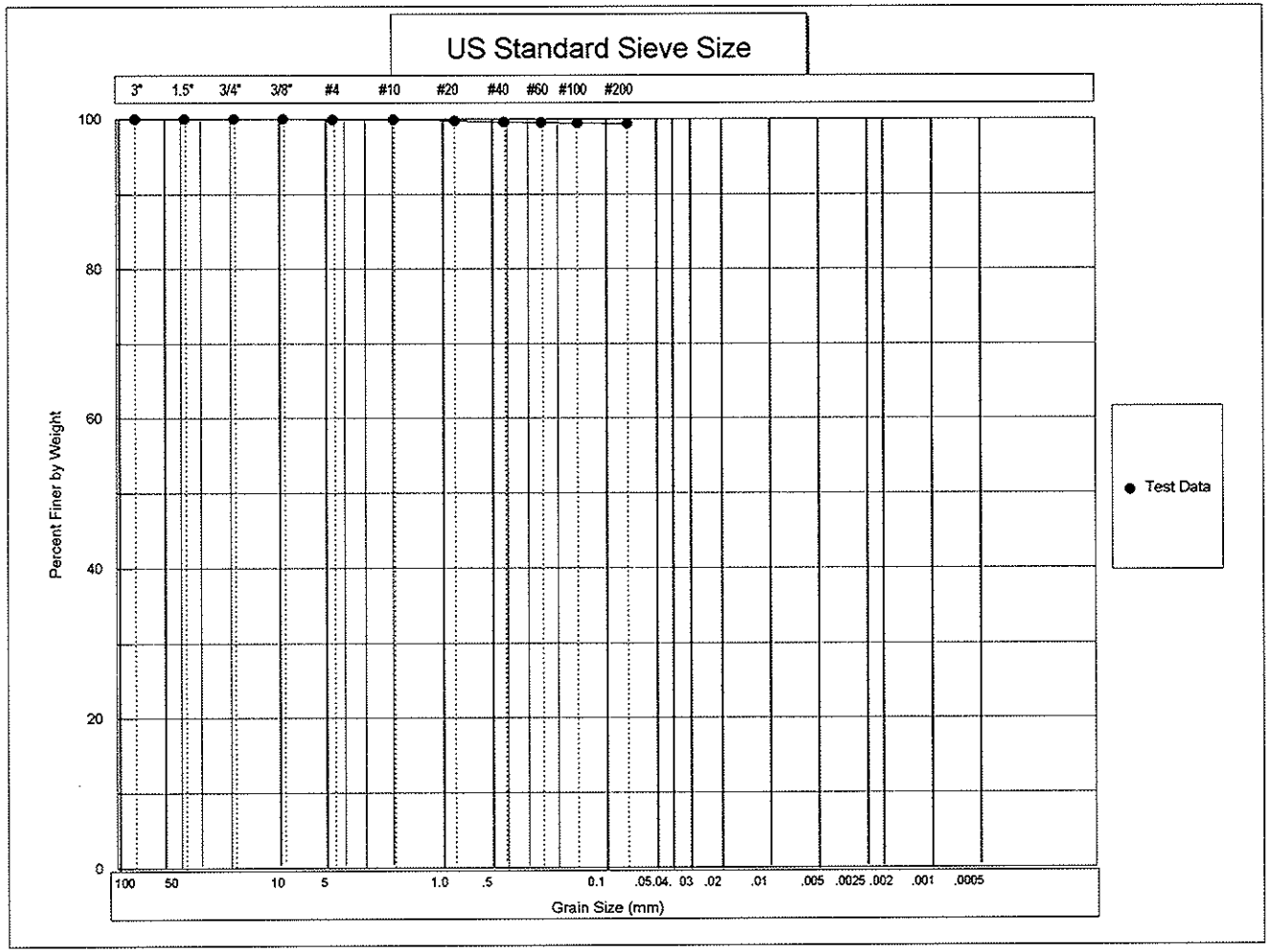
WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	846.44
Weight of + #10 Before Washing (g)	1.19
Weight of + #10 After Washing (g)	0.72
Weight of - #10 Wet (g)	845.25
Weight of - #10 Dry (g)	829.02
Wt. Total Sample Dry (g)	829.74
Calc. Wt. "W" (g)	215.66
Calc. Mass + #10	0.19

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	0.72	0.72	0.72	0.1	99.9
#10	0.00	0.00	0.00	0.72	0.1	99.9
#20	3.59	3.98	0.39	0.39	0.3	99.7
#40	3.58	3.80	0.22	0.61	0.4	99.6
#60	3.67	3.82	0.15	0.76	0.4	99.6
#100	3.67	3.86	0.19	0.95	0.5	99.5
#200	3.63	3.84	0.21	1.16	0.6	99.4

Data entered by: MC Date: 12/28/2001
Data checked by: [illegible] Date: 01/02/02
FileName: FHMUEC3

ADVANCED TERRA TESTING, INC.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	CRS	MEDIUM	FINE	

USCS

COBBLES TO BOULDERS	PEBBLE GRAVEL				SAND			SILT	CLAY
	COARSE	MED	FINE	GRAN	COARSE	MED	FINE		

WENTWORTH

Client: Federal Highway Admini Boring No.: Existing Cutslope Sample No.: HA-3

Job Number: 2135-15 Depth:

Classification: **CH, Fat clay**

Advanced Terra Testing, Inc.

USCS Classification
D 2487

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		DATE TESTED	12/27/01 SR
SAMPLE NO.	HA-3	WASH SIEVE	Yes
SOIL DESCR.	Proj # ND PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

ATTERBERG CLASSIFICATION: CH

% Gravel =	0.09
% Sand =	0.54
% Fines =	99.38

D60 =	N/A
D30 =	N/A
D10 =	N/A

Cu =	N/A
Cc =	N/A

Classification = CH, Fat clay

Data entered by: MC
Data checked by: a)
FileName: FHMUEC3

Date: 12/28/2001
Date: 01/03/02
ADVANCED TERRA TESTING, INC.

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT Federal Highway Administration

JOB NO. 2135-15

BORING NO.	Upper Slide	SAMPLED	
DEPTH	'1.50 m - 1.51 m	DATE TESTED	12/27/01 SR
SAMPLE NO.	HA-1	WASH SIEVE	Yes
SOIL DESCR.	Proj # ND PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No

Wt. Wet Soil & Pan (g)	47.58
Wt. Dry Soil & Pan (g)	47.07
Wt. Lost Moisture (g)	0.51
Wt. of Pan Only (g)	3.65
Wt. of Dry Soil (g)	43.42
Moisture Content %	1.2

Wt. Hydrom. Sample Wet (g)	203.42
Wt. Hydrom. Sample Dry (g)	201.06

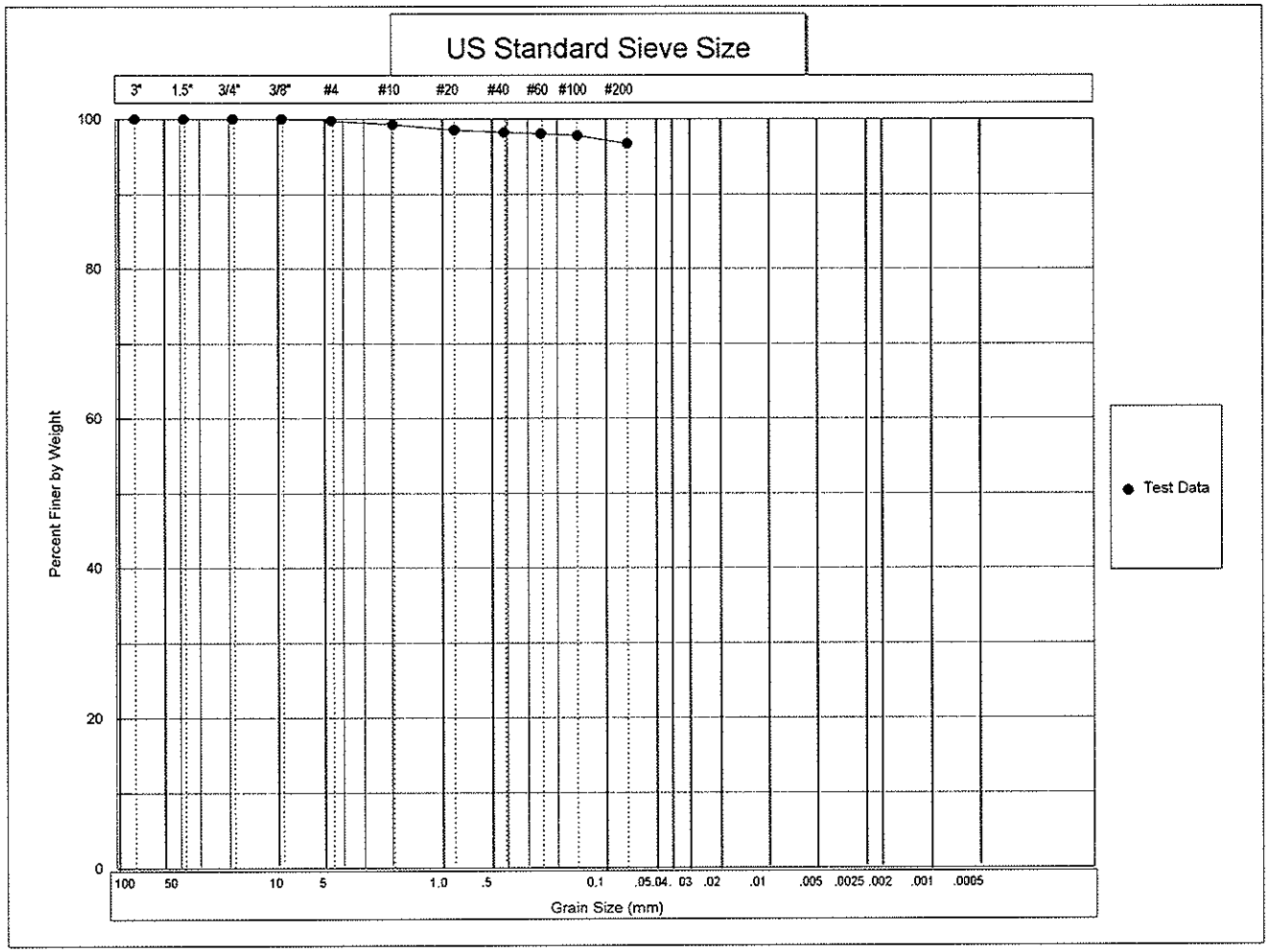
WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	1024.03
Weight of + #10 Before Washing (g)	13.96
Weight of + #10 After Washing (g)	6.95
Weight of - #10 Wet (g)	1010.07
Weight of - #10 Dry (g)	1005.27
Wt. Total Sample Dry (g)	1012.22
Calc. Wt. "W" (g)	202.45
Calc. Mass + #10	1.39

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	0.00	0.00	0.00	0.0	100.0
3/8"	0.00	0.00	0.00	0.00	0.0	100.0
#4	0.00	2.58	2.58	2.58	0.3	99.7
#10	0.00	4.37	4.37	6.95	0.7	99.3
#20	3.61	5.24	1.63	1.63	1.5	98.5
#40	3.59	4.23	0.64	2.27	1.8	98.2
#60	3.67	3.94	0.27	2.54	1.9	98.1
#100	3.65	4.13	0.48	3.02	2.2	97.8
#200	3.58	5.83	2.25	5.27	3.3	96.7

Data entered by: MC Date: 01/04/2002
Data checked by: Q Date: 1/04/02
FileName: FHMUUS12

ADVANCED TERRA TESTING, INC.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	CRS	MEDIUM	FINE	

USCS

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE		

WENTWORTH

Client: Federal Highway Admini Boring No.: Upper Slide Sample No.: HA-1
Job Number: 2135-15 Depth: '1.50 m - 1.51 m
Classification: **CH, Fat clay**

Advanced Terra Testing, Inc.

USCS Classification
D 2487

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Upper Slide	SAMPLED	
DEPTH	'1.50 m - 1.51 m	DATE TESTED	12/27/01 SR
SAMPLE NO.	HA-1	WASH SIEVE	Yes
SOIL DESCR.	Proj # ND PRA THRO 10(2)	DRY SIEVE	No
LOCATION	N. Unit Slide Repair		

ATTERBERG CLASSIFICATION: CH

% Gravel =	0.25
% Sand =	3.03
% Fines =	96.71

D60 =	N/A
D30 =	N/A
D10 =	N/A

Cu =	N/A
Cc =	N/A

Classification = CH, Fat clay

Data entered by: MC
Data checked by: CW
FileName: FHMUUS12

Date: 01/04/2002
Date: 01/04/02
ADVANCED TERRA TESTING, INC.

PROCTOR COMPACTION - STANDARD
ASTM D 698

COMPACTION TEST
ASTM D 698 A

CLIENT:	Federal Highway Administration	JOB NO.	2135-15

BORING NO.	Existing Cutslope	DATE SAMPLED	
DEPTH		DATE TESTED	12-19-01 KF
SAMPLE NO.	HA-3	LOCATION	N. Unit Slide Repair
SOIL DESCR.	Proj.# ND PRA THRO 10(2)		

Moisture Determination

	1	2	3	4	5
Wt of Moisture added (ml)	500.00	450.00	400.00	350.00	300.00
Wt. of soil & dish (g)	337.16	368.71	373.04	382.47	329.54
Dry wt. soil & dish (g)	271.71	303.45	312.76	327.89	286.82
Net loss of moisture (g)	65.45	65.26	60.28	54.58	42.72
Wt. of dish (g)	7.99	8.34	9.24	9.00	9.45
Net wt. of dry soil (g)	263.72	295.11	303.52	318.89	277.37
Moisture Content (%)	24.82	22.11	19.86	17.12	15.40
Corrected Moisture Content					

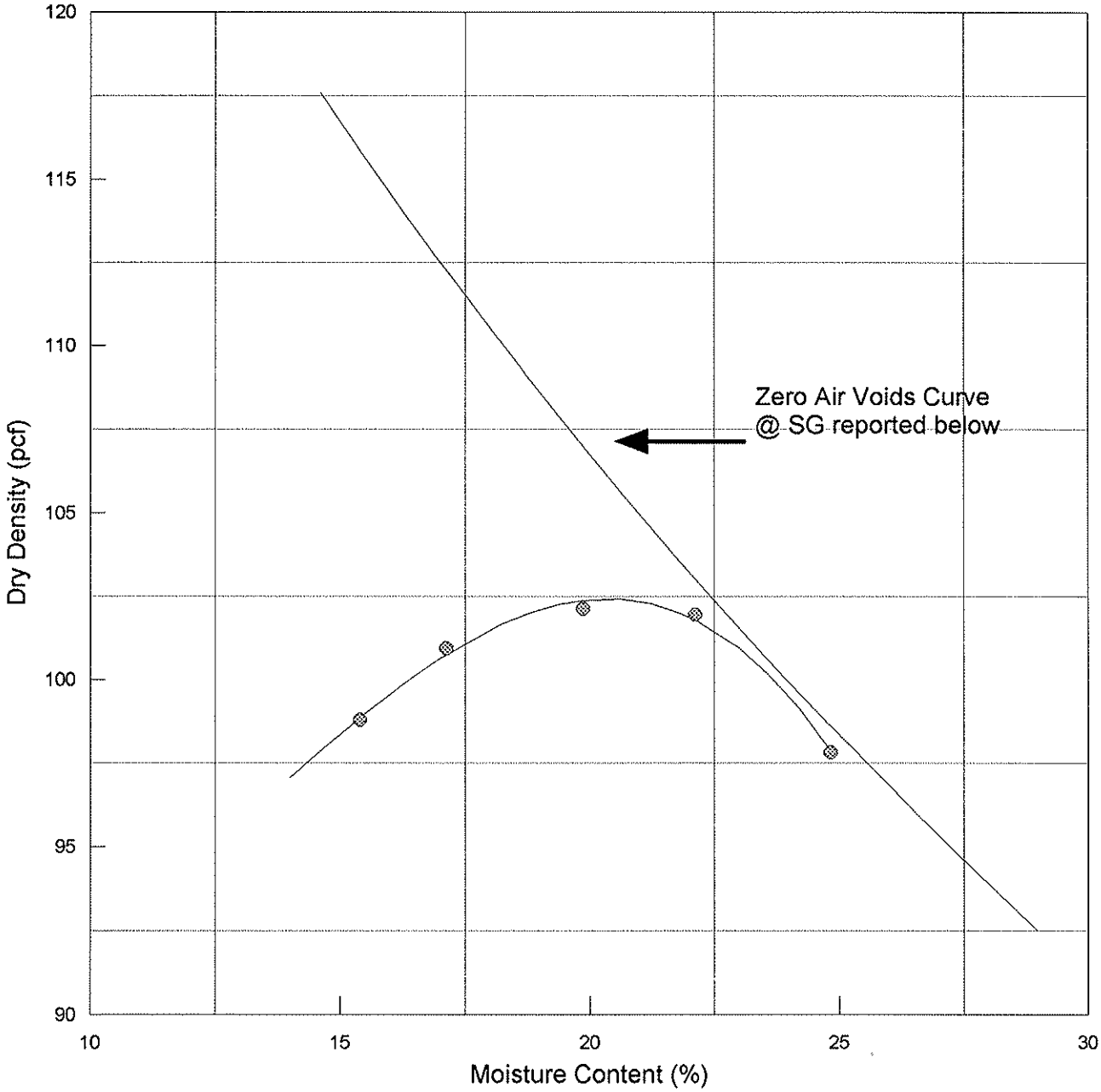
Density determination

Wt of soil & mold (lb)	14.39	14.47	14.39	14.26	14.12
Wt. of mold (lb)	10.32	10.32	10.32	10.32	10.32
Net wt. of wet soil (lb)	4.07	4.15	4.07	3.94	3.80
Net wt of dry soil (lb)	3.26	3.40	3.40	3.36	3.29
Dry Density, (pcf)	97.82	101.95	101.87	100.93	98.79
Corrected Dry Density (pcf)					
Volume Factor	30	30	30	30	30

Data entered by: KF Date: 12/20/2001
Data checked by: cc Date: 12/20/01
FileName: FHPRNUSR ADVANCED TERRA TESTING, INC

Proctor Compaction Test

Existing Cutslope, , HA-3



– Best Fit Curve ◍ Actual Data

– Zero Air VoidsCurve @ SG = 2.60

OPTIMUM MOISTURE CONTENT = 20.4 MAXIMUM DRY DENSITY = 102.4
ASTM D 698 A, Rock correction applied? N

ADVANCED TERRA TESTING, INC.

TRIAXIAL SHEAR, CONSOLIDATED, UNDRAINED
WITH PORE PRESSURE MEASUREMENTS
TX/CUpp
ASTM D 4767

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	01-03-02 CAL
SAMPLE NO.	HA-3, Pt. C	TEST FINISHED	01-15-02 CAL
SOIL DESCR.		CELL NUMBER	13S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	418

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	706.3	747.6
Wt. Wet Soil & Pan (g)	721.5	762.8
Wt. Dry Soil & Pan (g)	593.7	593.7
Wt. Lost Moisture (g)	127.9	169.2
Wt. of Pan Only (g)	15.2	15.2
Wt. of Dry Soil (g)	578.5	578.5
Moisture Content %	22.1	29.2
Wet Density PCF	119.0	125.6
Dry Density PCF	97.5	97.2

Init. Diameter (in)	2.408
Init. Area (sq in)	4.554
Init. Height (in)	4.965
Vol. Bef. Consol. (cu ft)	0.01309
Vol. After Consol. (cu ft)	0.01312

Notes & Comments: Remolded Sample

Data entry by: SR Date: 01/18/2002
Data checked by: CM Date: 01/18/02
FileName: FHT0EC3C

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	01-03-02 CAL
SAMPLE NO.	HA-3, Pt. C	TEST FINISHED	01-15-02 CAL
SOIL DESCR.		CELL NUMBER	13S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	418

SATURATION DATA

Cell Pres. (PSI)	Back Pres. (PSI)	Burette Reading (CC)		Pore Pressure (PSI)		Change	B
		Close	Open	Close	Open		
40.0	38.0	2.5	20.2				
50.0	48.0	7.3	9.0	38.3	47.5	9.2	0.92
60.0	58.0	7.4	8.6	47.5	56.7	9.2	0.92
70.0	68.0	7.9	8.9	57.8	67.2	9.4	0.94
80.0		8.7	8.8	67.9	77.4	9.5	0.95

CONSOLIDATION DATA

Elapsed Time (Min)	SQRT TIME (Min)	Burette Reading (CC)	Vol. Defl. (CC)
0.00	0.0	8.6	0.00
0.25	0.5	8.8	-0.20
0.5	0.7	8.8	-0.20
1	1.0	8.8	-0.22
2	1.4	8.9	-0.30
4	2.0	8.9	-0.30
9	3.0	9.0	-0.40
16	4.0	9.0	-0.40
30	5.5	9.1	-0.50
60	7.7	9.2	-0.60
120	11.0	9.3	-0.70
240	15.5	9.3	-0.70
360	19.0	9.3	-0.70

Initial Height (in)	4.965	Init. Vol. (CC)	370.60
Height Change (in)	0.006	Vol. Change (CC)	8.00
Ht. After Cons. (in)	4.959	Cell Exp. (CC)	9.12
Initial Area (sq in)	4.554	Net Change (CC)	-1.12
Area After Cons. (sq in)	4.573	Cons. Vol. (CC)	371.71

Data entry by: SR Date: 01/17/2002
Data checked by: ar Date: 01/18/02
FileName: FHT0EC3C

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA

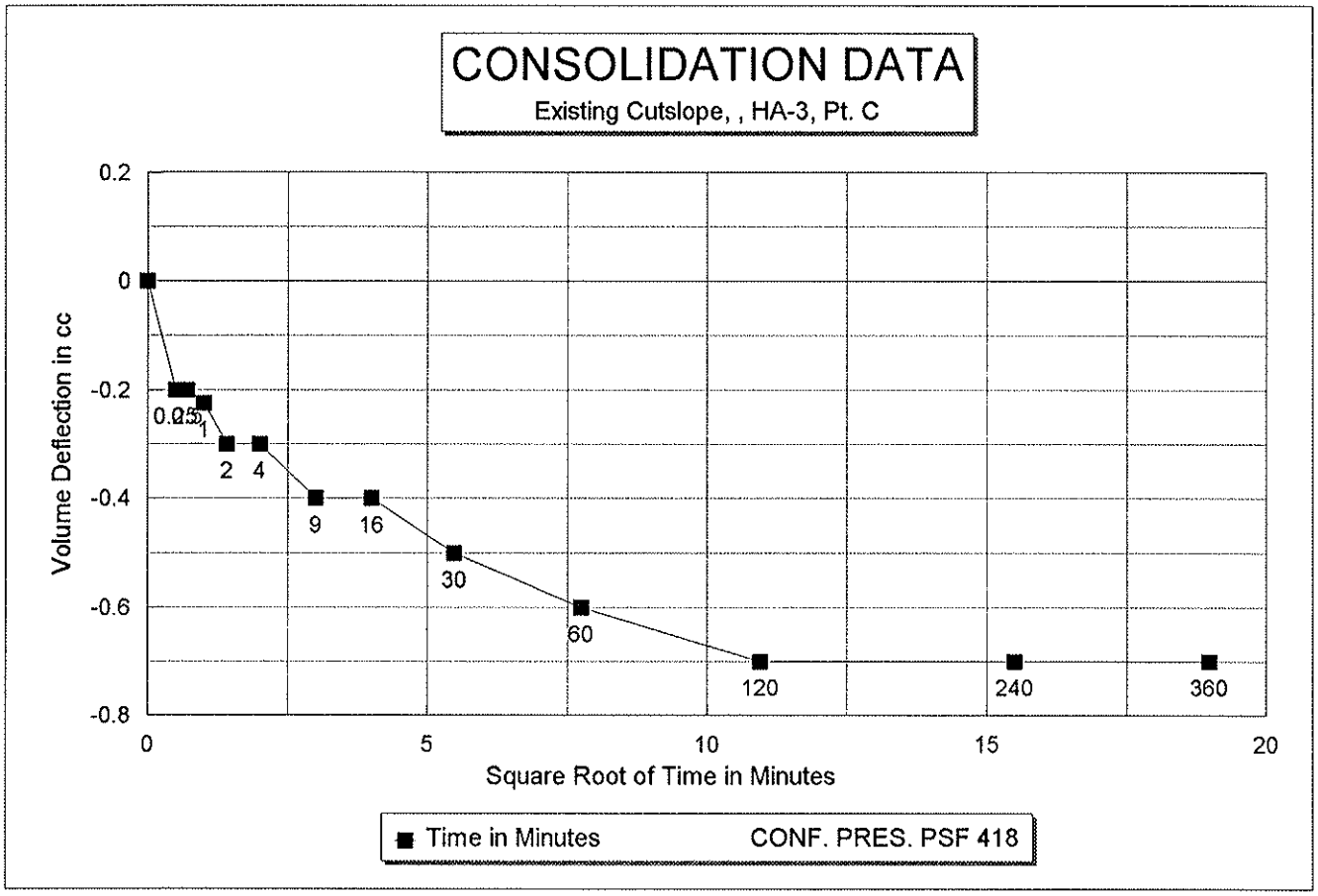
CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	01-03-02 CAL
SAMPLE NO.	HA-3, Pt. C	TEST FINISHED	01-15-02 CAL
SOIL DESCR.		CELL NUMBER	13S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	418

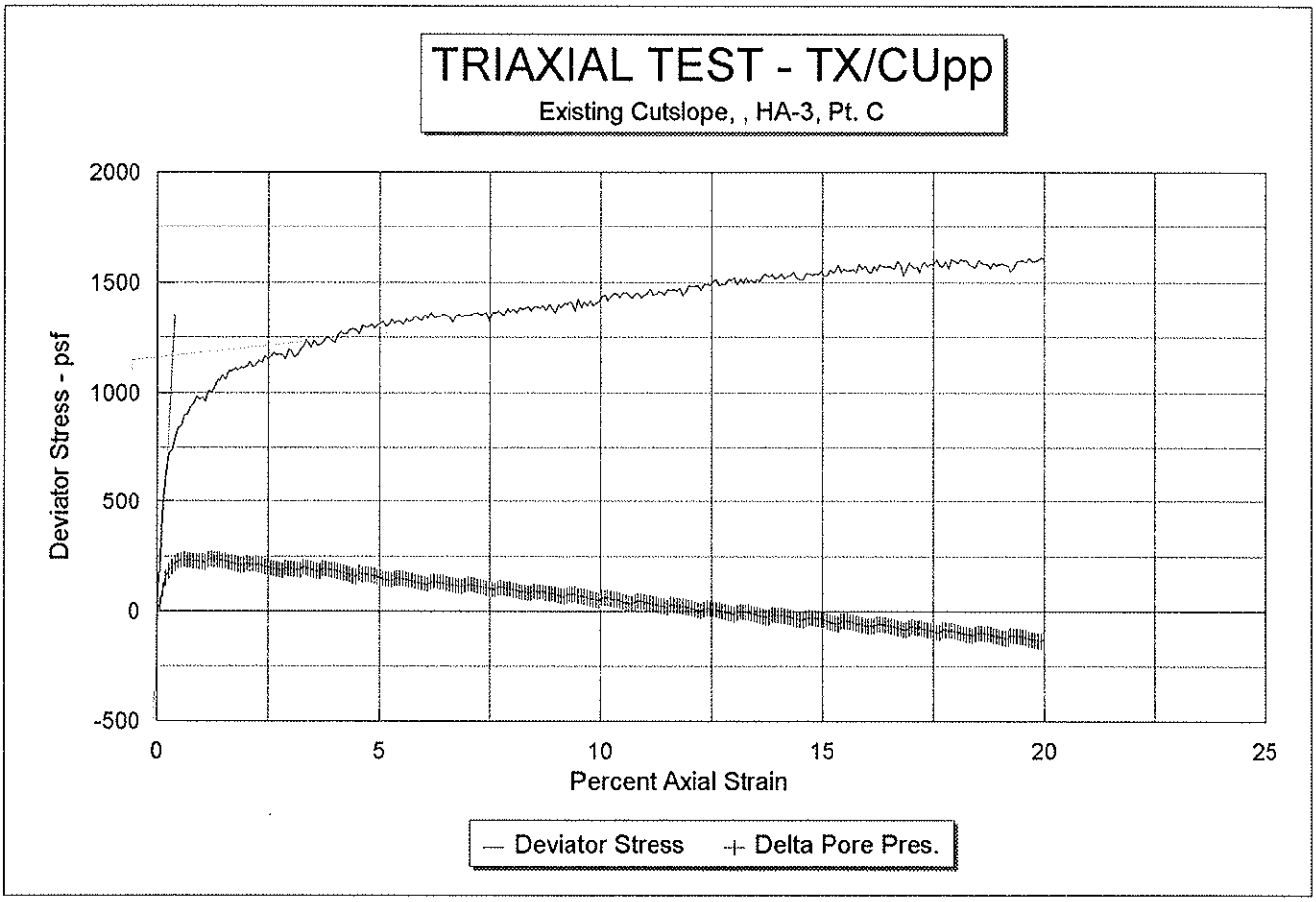
Init. Ht. (in)	4.965	Init. Area (sq in)	4.554
Consol. Ht. (in)	4.959	Consol. Area (sq in)	4.573
Back Pres. PSI	68.0	Strain Rate (in/min)	0.0008

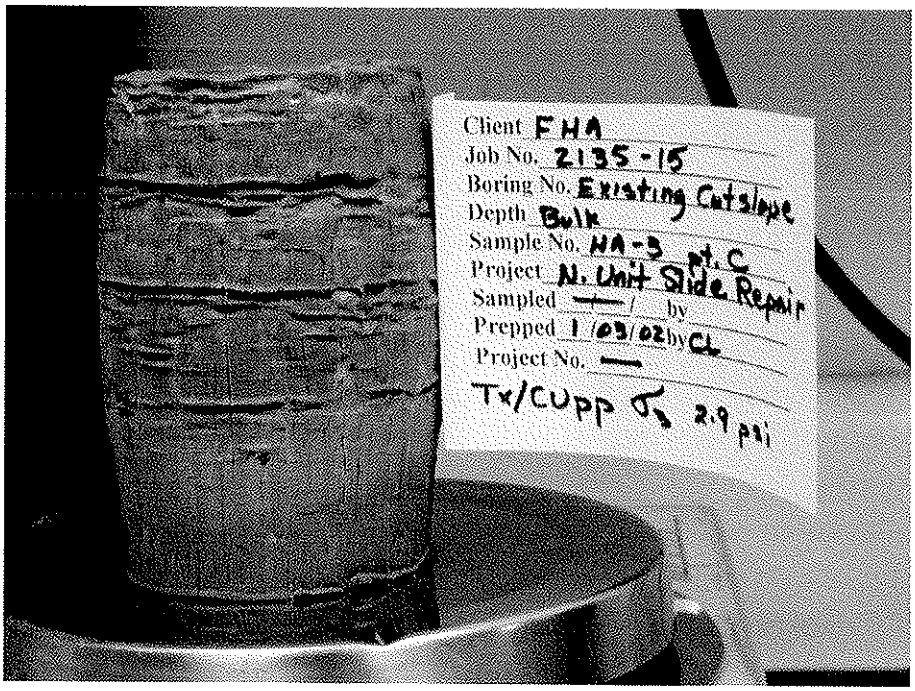
Axial Load Lbs.	Axial Load PSF	Delta Ht. In.	Axial % Strain	Area Final Sq In.	Dev. Stress PSF	Pore Pres. PSI	Delta Pres. PSF	Sigma 3 PSF	Sigma 1 PSF	Prin. Stress Ratio
0.0	0	0.000	0.00	4.573	0	68.0	0	418	418	1.00
28.7	903	0.030	0.60	4.601	898	69.7	237	181	1079	5.96
33.0	1038	0.063	1.27	4.632	1025	69.7	236	181	1206	6.65
36.1	1136	0.097	1.95	4.664	1114	69.5	208	209	1323	6.32
38.4	1210	0.130	2.62	4.696	1179	69.4	195	222	1401	6.30
39.7	1249	0.162	3.27	4.728	1208	69.4	204	214	1422	6.65
40.8	1286	0.195	3.93	4.761	1235	69.3	189	228	1463	6.41
43.4	1368	0.229	4.61	4.795	1305	69.2	170	248	1553	6.26
44.6	1405	0.262	5.28	4.828	1331	69.0	141	276	1608	5.82
44.9	1412	0.296	5.96	4.863	1328	68.9	128	289	1617	5.59
44.9	1413	0.330	6.65	4.899	1319	68.9	119	298	1618	5.42
46.6	1467	0.364	7.34	4.936	1359	68.8	109	309	1668	5.40
47.6	1500	0.398	8.02	4.972	1379	68.7	97	320	1700	5.31
48.6	1531	0.431	8.69	5.009	1398	68.6	88	330	1727	5.24
49.3	1553	0.464	9.36	5.046	1408	68.5	75	343	1751	5.10
50.7	1597	0.497	10.03	5.083	1436	68.4	60	357	1794	5.02
50.8	1600	0.530	10.70	5.121	1429	68.3	34	384	1813	4.72
52.1	1642	0.564	11.38	5.160	1455	68.2	23	395	1850	4.69
53.5	1686	0.598	12.06	5.201	1483	68.1	12	405	1888	4.66
54.3	1709	0.632	12.74	5.241	1491	68.0	-0	418	1909	4.57
55.4	1744	0.665	13.41	5.281	1511	68.0	-9	427	1937	4.54
56.9	1792	0.698	14.08	5.323	1540	67.9	-19	436	1976	4.53
57.2	1801	0.732	14.76	5.366	1535	67.8	-30	448	1983	4.43
58.1	1828	0.765	15.43	5.408	1546	67.7	-46	463	2009	4.34
58.3	1836	0.798	16.09	5.450	1541	67.5	-69	486	2027	4.17
60.2	1895	0.831	16.76	5.494	1577	67.5	-80	498	2075	4.17
60.4	1903	0.862	17.37	5.535	1572	67.4	-84	501	2073	4.14
61.4	1934	0.895	18.05	5.580	1585	67.4	-93	511	2096	4.10
61.7	1943	0.928	18.71	5.626	1580	67.3	-102	520	2100	4.04
62.8	1978	0.961	19.38	5.673	1595	67.2	-111	529	2124	4.01

Data entry by: SR Date: 01/17/2002
Data checked by: CAC Date: 01/18/02
FileName: FHT0EC3C

ADVANCED TERRA TESTING, INC.


CONSOLIDATION DATA
Existing Cutslope, , HA-3, Pt. C
Volume Deflection in cc
0.2
0
-0.2
-0.4
-0.6
-0.8
0.025
1
2
4
9
16
30
60
120
240
360
0
5
10
15
20
Square Root of Time in Minutes
Time in Minutes
CONF. PRES. PSF 418


TRIAXIAL TEST - TX/CUpp
Existing Cutslope, , HA-3, Pt. C
Deviator Stress - psf
2000
1500
1000
500
0
-500
0
5
10
15
20
25
Percent Axial Strain
Deviator Stress
Delta Pore Pres.



K:\FH2135\FHDPEC3C.PSP
01/17/02

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	01-03-02 CAL
SAMPLE NO.	HA-3, Pt. B	TEST FINISHED	01-16-02 CAL
SOIL DESCR.		CELL NUMBER	9S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	835

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	706.4	742.9
Wt. Wet Soil & Pan (g)	720.4	756.9
Wt. Dry Soil & Pan (g)	594.1	594.1
Wt. Lost Moisture (g)	126.3	162.9
Wt. of Pan Only (g)	14.0	14.0
Wt. of Dry Soil (g)	580.0	580.0
Moisture Content %	21.8	28.1
Wet Density PCF	118.4	125.4
Dry Density PCF	97.2	97.9

Init. Diameter (in)	2.408
Init. Area (sq in)	4.554
Init. Height (in)	4.992
Vol. Bef. Consol. (cu ft)	0.01316
Vol. After Consol. (cu ft)	0.01306

Notes & Comments: Remolded Sample

Data entry by: CL Date: 01/18/2002
Data checked by: DAM Date: 01/18/02
FileName: FHT0EC3B

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	01-03-02 CAL
SAMPLE NO.	HA-3, Pt. B	TEST FINISHED	01-16-02 CAL
SOIL DESCR.		CELL NUMBER	9S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	835

SATURATION DATA

Cell Pres. (PSI)	Back Pres. (PSI)	Burette Reading (CC)		Pore Pressure (PSI)		Change	B
		Close	Open	Close	Open		
40.0	38.0	2.0	20.8				
50.0	48.0	5.6	7.7	38.2	47.6	9.4	0.94
60.0		7.8	8.1	49.1	58.9	9.8	0.98

CONSOLIDATION DATA

Elapsed Time (Min)	SQRT TIME (Min)	Burette Reading (CC)	Vol. Defl. (CC)
0.00	0.0	8.1	0.00
0.25	0.5	9.0	-0.85
0.5	0.7	9.1	-1.00
1	1.0	9.3	-1.20
2	1.4	9.6	-1.50
4	2.0	9.9	-1.80
9	3.0	10.5	-2.40
16	4.0	11.1	-3.00
30	5.5	11.8	-3.70
60	7.7	12.8	-4.70
120	11.0	13.7	-5.60
240	15.5	14.5	-6.40
360	19.0	14.8	-6.70

Initial Height (in)	4.992	Init. Vol. (CC)	372.61
Height Change (in)	0.026	Vol. Change (CC)	15.00
Ht. After Cons. (in)	4.966	Cell Exp. (CC)	12.37
Initial Area (sq in)	4.554	Net Change (CC)	2.63
Area After Cons. (sq in)	4.546	Cons. Vol. (CC)	369.98

Data entry by: CL Date: 01/18/2002
Data checked by: DPM Date: 01/18/02
FileName: FHT0EC3B

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA

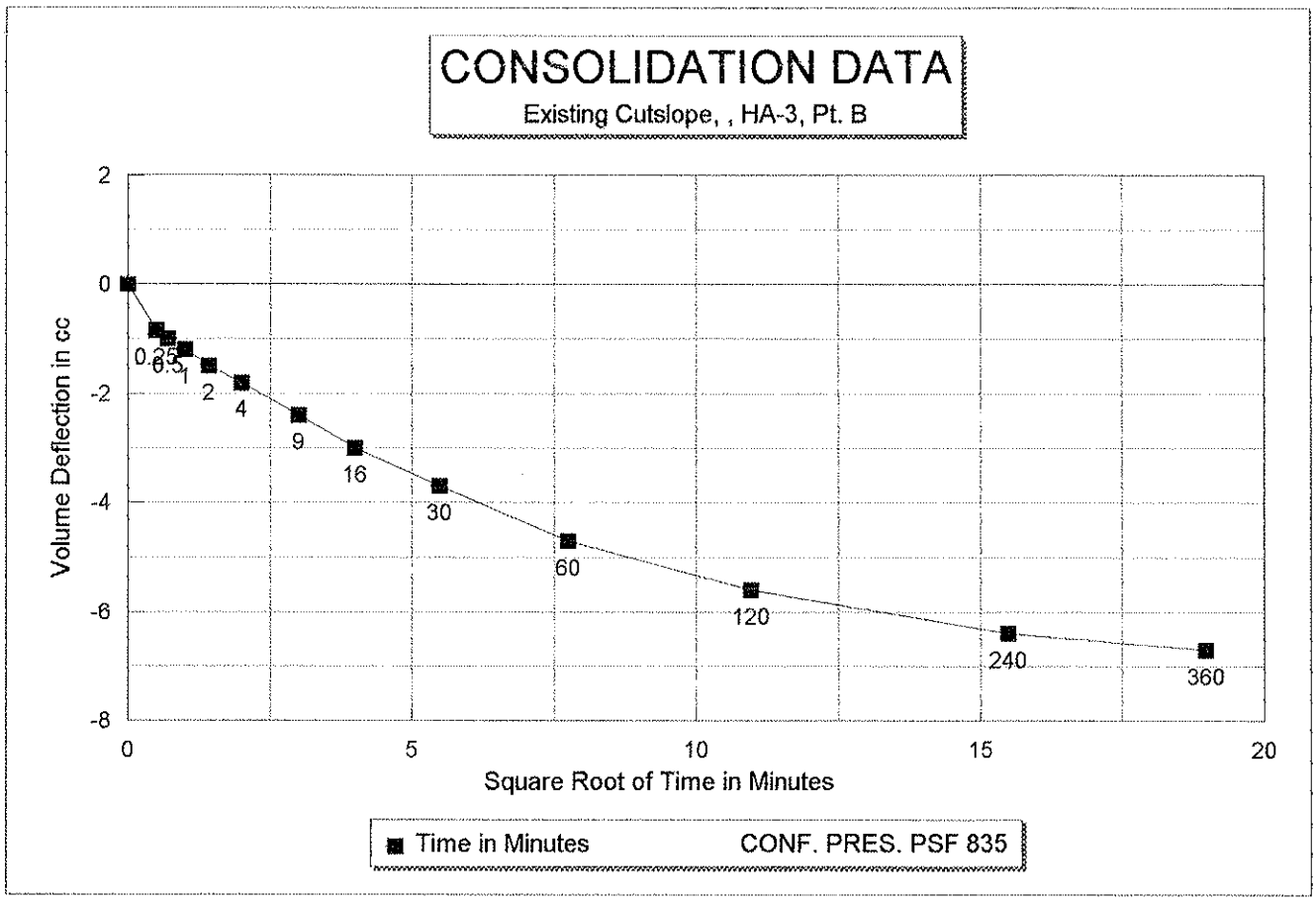
CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	01-03-02 CAL
SAMPLE NO.	HA-3, Pt. B	TEST FINISHED	01-16-02 CAL
SOIL DESCR.		CELL NUMBER	9S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	835

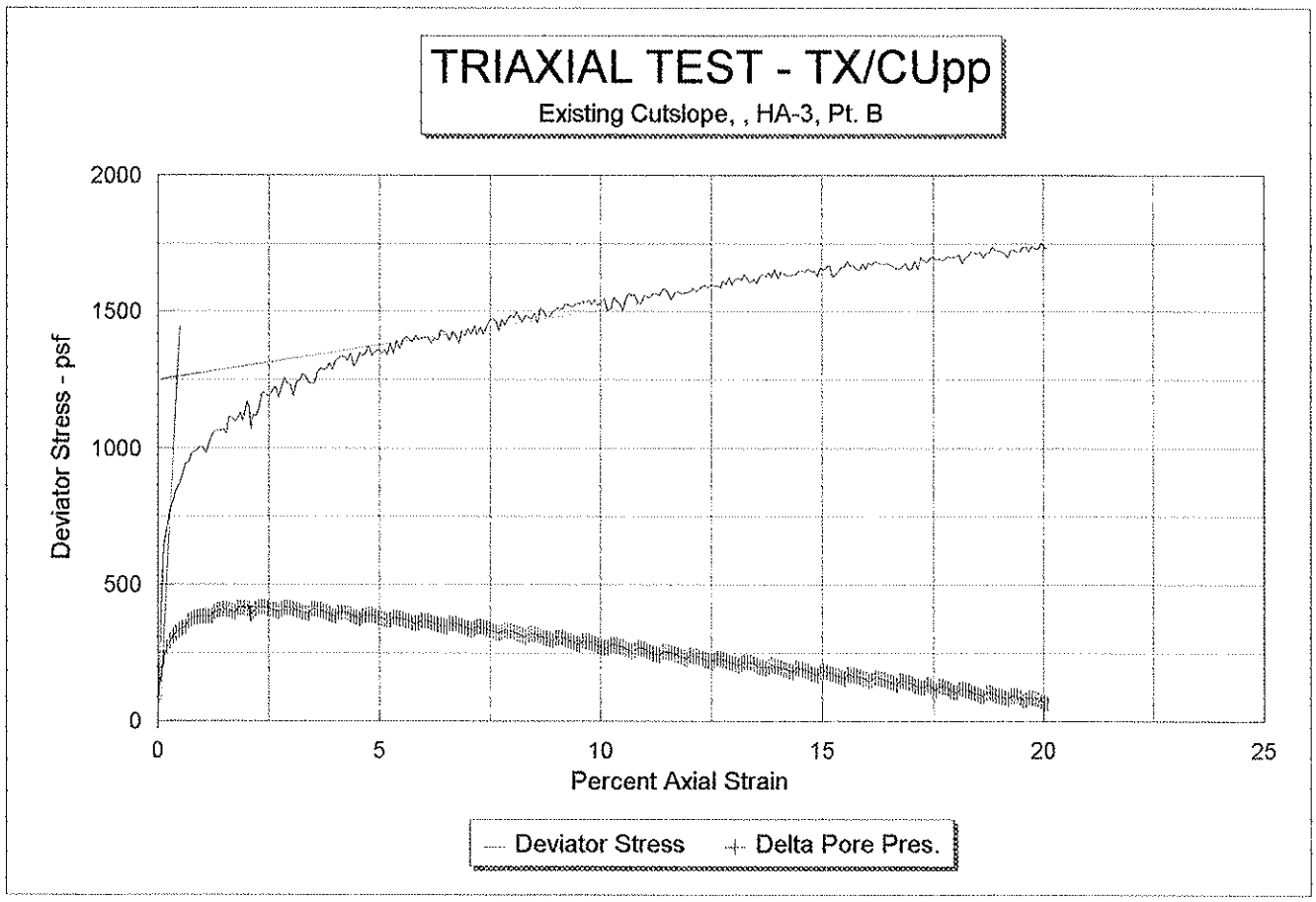
Init. Ht. (in)	4.992	Init. Area (sq in)	4.554
Consol. Ht. (in)	4.966	Consol. Area (sq in)	4.546
Back Pres. PSI	48.2	Strain Rate (in/min)	0.0006

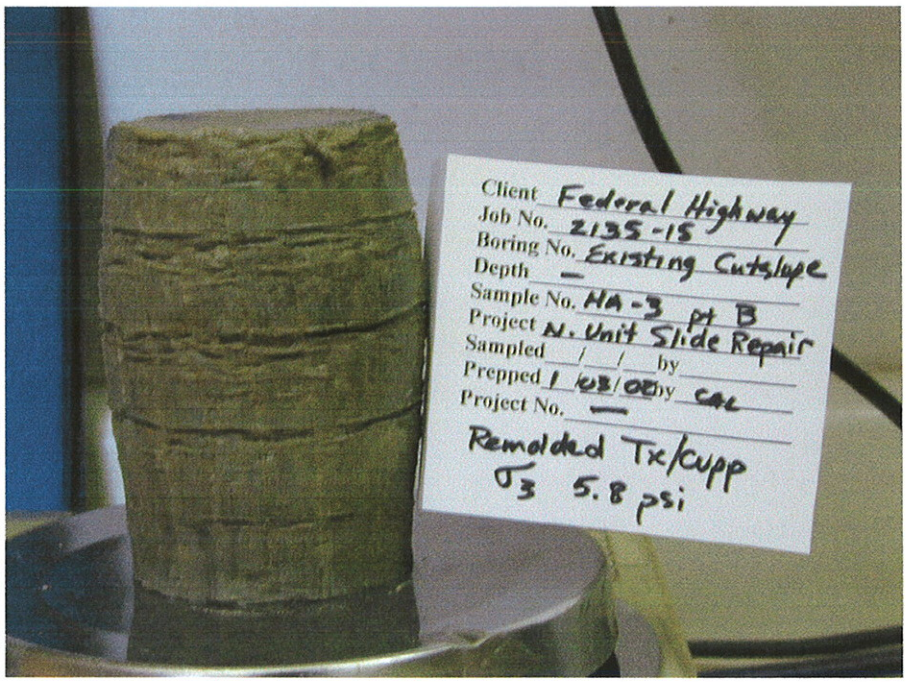
Axial Load Lbs.	Axial Load PSF	Delta Ht. In.	Axial % Strain	Area Final Sq In.	Dev. Stress PSF	Pore Pres. PSI	Delta Pres. PSF	Sigma 3 PSF	Sigma 1 PSF	Prin. Stress Ratio
0.0	0	0.000	0.00	4.546	0	48.2	0	835	835	1.00
28.7	909	0.027	0.55	4.571	904	50.5	340	495	1399	2.83
33.4	1059	0.060	1.20	4.601	1046	50.9	387	449	1495	3.33
36.3	1150	0.092	1.86	4.632	1129	51.1	416	419	1548	3.70
38.9	1231	0.116	2.33	4.654	1202	51.1	417	418	1620	3.88
40.2	1273	0.148	2.99	4.686	1235	51.1	415	421	1655	3.94
42.3	1341	0.182	3.67	4.719	1291	51.0	405	430	1721	4.00
44.4	1408	0.216	4.35	4.752	1347	50.9	390	446	1792	4.02
44.8	1419	0.250	5.04	4.787	1348	50.8	377	458	1806	3.94
46.5	1473	0.285	5.74	4.822	1389	50.7	360	475	1864	3.92
48.1	1525	0.320	6.45	4.859	1427	50.6	347	488	1915	3.92
49.2	1558	0.355	7.14	4.895	1446	50.5	340	496	1942	3.92
49.7	1575	0.389	7.82	4.931	1452	50.5	334	501	1953	3.90
51.6	1633	0.422	8.51	4.968	1494	50.4	319	516	2010	3.90
53.1	1683	0.456	9.19	5.006	1528	50.3	301	534	2062	3.86
54.1	1715	0.490	9.87	5.043	1545	50.1	283	552	2098	3.80
54.5	1726	0.524	10.56	5.082	1544	50.0	265	570	2114	3.71
55.6	1762	0.559	11.26	5.122	1564	49.9	247	588	2152	3.66
56.3	1782	0.593	11.95	5.162	1569	49.8	230	606	2175	3.59
57.5	1822	0.627	12.63	5.203	1592	49.8	231	604	2196	3.64
59.0	1870	0.661	13.30	5.243	1621	49.7	217	619	2240	3.62
59.5	1886	0.695	14.00	5.285	1622	49.6	200	635	2257	3.55
61.3	1942	0.729	14.68	5.328	1657	49.4	183	652	2309	3.54
61.5	1948	0.763	15.37	5.371	1649	49.3	166	669	2318	3.46
63.1	1998	0.797	16.04	5.414	1678	49.2	149	686	2364	3.44
62.8	1990	0.831	16.74	5.460	1657	49.2	150	686	2342	3.42
64.8	2053	0.865	17.42	5.505	1695	49.1	130	705	2401	3.40
65.9	2086	0.899	18.10	5.550	1709	49.0	118	717	2426	3.38
66.7	2111	0.932	18.77	5.596	1715	48.9	105	730	2445	3.35
67.4	2134	0.967	19.47	5.644	1719	48.8	89	746	2465	3.30

Data entry by: CL Date: 01/18/2002
Data checked by: DPM Date: 01/18/02
FileName: FHT0EC3B

ADVANCED TERRA TESTING, INC.


CONSOLIDATION DATA
Existing Cutslope, , HA-3, Pt. B
Volume Deflection in cc
Square Root of Time in Minutes
2
0
-2
-4
-6
-8
0
5
10
15
20
0.25
0.5
1
2
4
9
16
30
60
120
240
360
Time in Minutes
CONF. PRES. PSF 835


TRIAXIAL TEST - TX/CUpp
Existing Cutslope, , HA-3, Pt. B
Deviator Stress - psf
Percent Axial Strain
2000
1500
1000
500
0
0
5
10
15
20
25
Deviator Stress
Delta Pore Pres.



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01/17/02

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	1/03/02 CAL
SAMPLE NO.	HA-3 Pt.A	TEST FINISHED	1/17/02 CAL
SOIL DESCR.		CELL NUMBER	20S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	1670

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	709.3	735.8
Wt. Wet Soil & Pan (g)	724.8	751.4
Wt. Dry Soil & Pan (g)	595.3	595.3
Wt. Lost Moisture (g)	129.5	156.0
Wt. of Pan Only (g)	15.6	15.6
Wt. of Dry Soil (g)	579.8	579.8
Moisture Content %	22.3	26.9
Wet Density PCF	118.9	125.7
Dry Density PCF	97.2	99.1

Init. Diameter (in)	2.401
Init. Area (sq in)	4.528
Init. Height (in)	5.018
Vol. Bef. Consol. (cu ft)	0.01315
Vol. After Consol. (cu ft)	0.01290

Notes & Comments:

Data entry by: CL Date: 01/21/2002
Data checked by: DPM Date: 01/22/02
FileName: FHT0EC3A.WK4

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	1/03/02 CAL
SAMPLE NO.	HA-3 Pt.A	TEST FINISHED	1/17/02 CAL
SOIL DESCR.		CELL NUMBER	20S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	1670

SATURATION DATA

Cell Pres. (PSI)	Back Pres. (PSI)	Burette Reading (CC)		Pore Pressure (PSI)		Change	B
		Close	Open	Close	Open		
40.0	38.0	2.9	22.0				
50.0	48.0	10.3	11.9	38.6	47.2	8.6	0.86
60.0		11.1	11.2	49.1	58.6	9.5	0.95

CONSOLIDATION DATA

Elapsed Time (Min)	SQRT TIME (Min)	Burette Reading (CC)	Vol. Defl. (CC)
0.00	0.0	11.0	0.00
0.25	0.5	12.8	-1.80
0.5	0.7	13.0	-2.00
1	1.0	13.4	-2.40
2	1.4	14.0	-2.95
4	2.0	14.7	-3.70
9	3.0	16.0	-5.00
16	4.0	17.1	-6.10
30	5.5	18.8	-7.80
60	7.7	20.8	-9.80
120	11.0	22.7	-11.70
240	15.5	23.9	-12.90
360	19.0	24.3	-13.30

Initial Height (in)	5.018	Init. Vol. (CC)	372.38
Height Change (in)	0.054	Vol. Change (CC)	23.90
Ht. After Cons. (in)	4.964	Cell Exp. (CC)	16.93
Initial Area (sq in)	4.528	Net Change (CC)	6.97
Area After Cons. (sq in)	4.491	Cons. Vol. (CC)	365.40

Data entry by: CL Date: 01/21/2002
Data checked by: DPM Date: 01/22/02
FileName: FHT0EC3A.WK4

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA

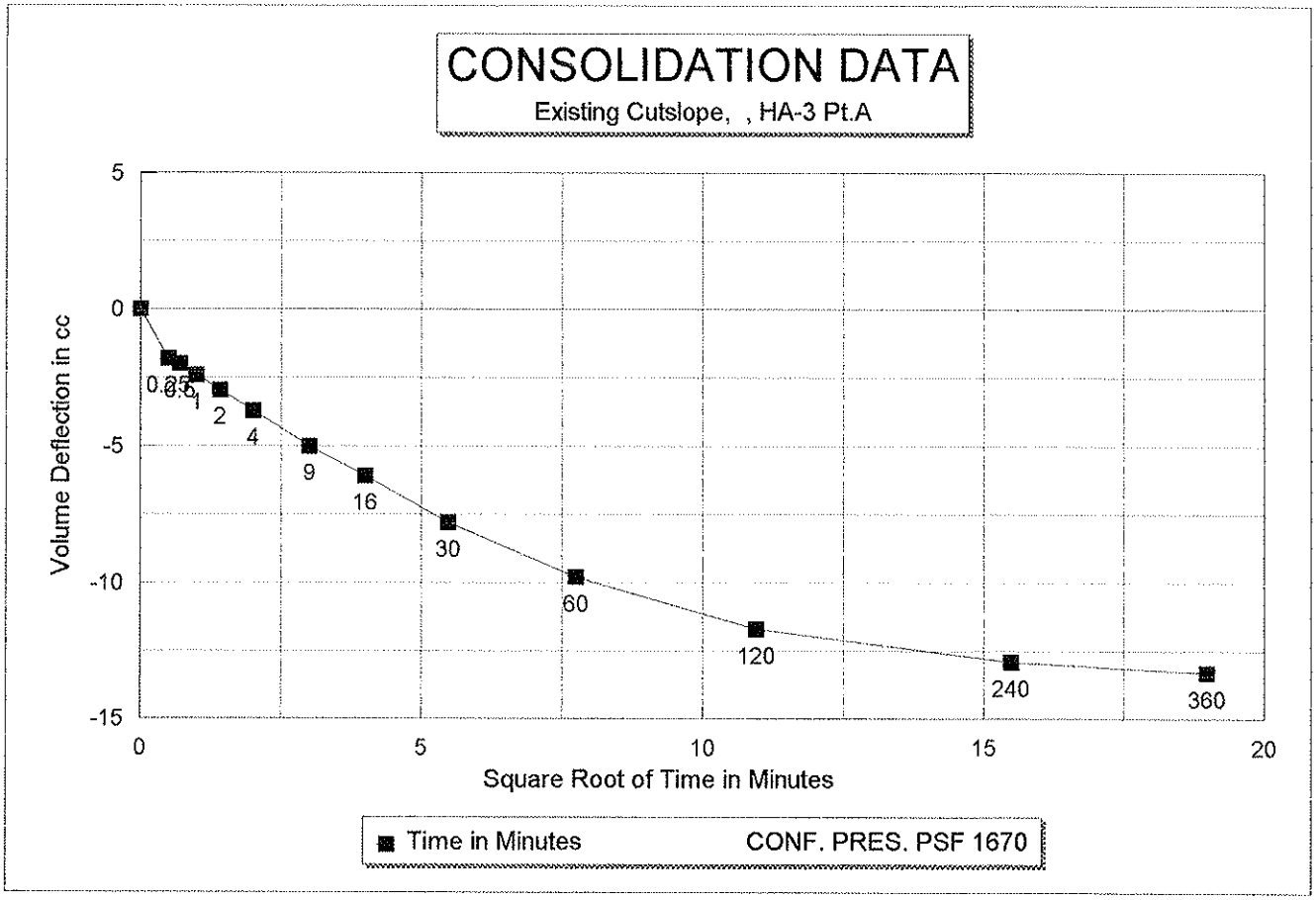
CLIENT	Federal Highway Administration	JOB NO.	2135-15
BORING NO.	Existing Cutslope	SAMPLED	
DEPTH		TEST STARTED	1/03/02 CAL
SAMPLE NO.	HA-3 Pt.A	TEST FINISHED	1/17/02 CAL
SOIL DESCR.		CELL NUMBER	20S
LOCATION:	N. Unit Slide Repair	SATURATED TEST	Yes
TEST TYPE	TX/CUpp	CONF. PRES. PSF	1670

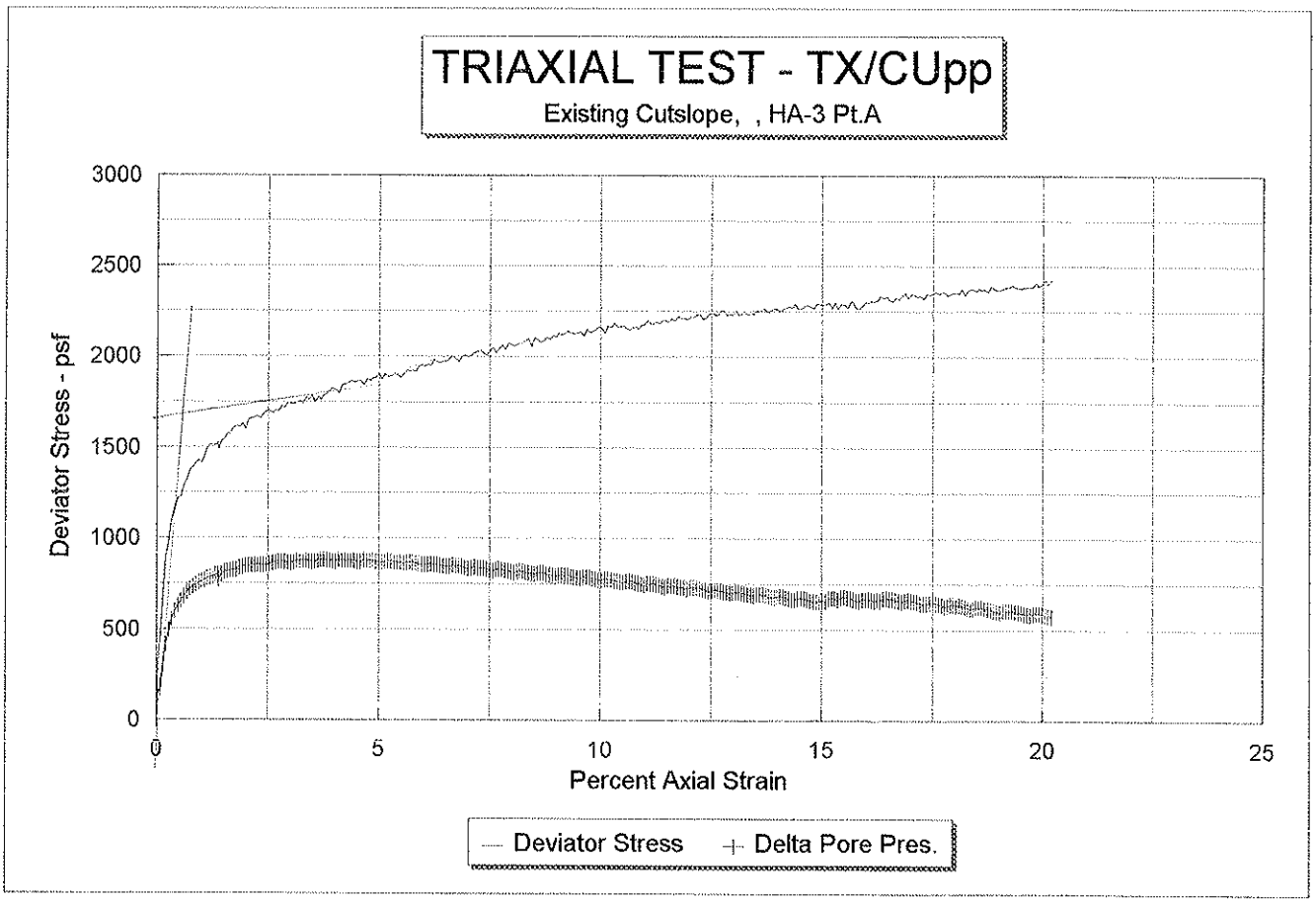
Init. Ht. (in)	5.018	Init. Area (sq in)	4.528
Consol. Ht. (in)	4.964	Consol. Area (sq in)	4.491
Back Pres. PSI	48.2	Strain Rate (in/min)	0.0007

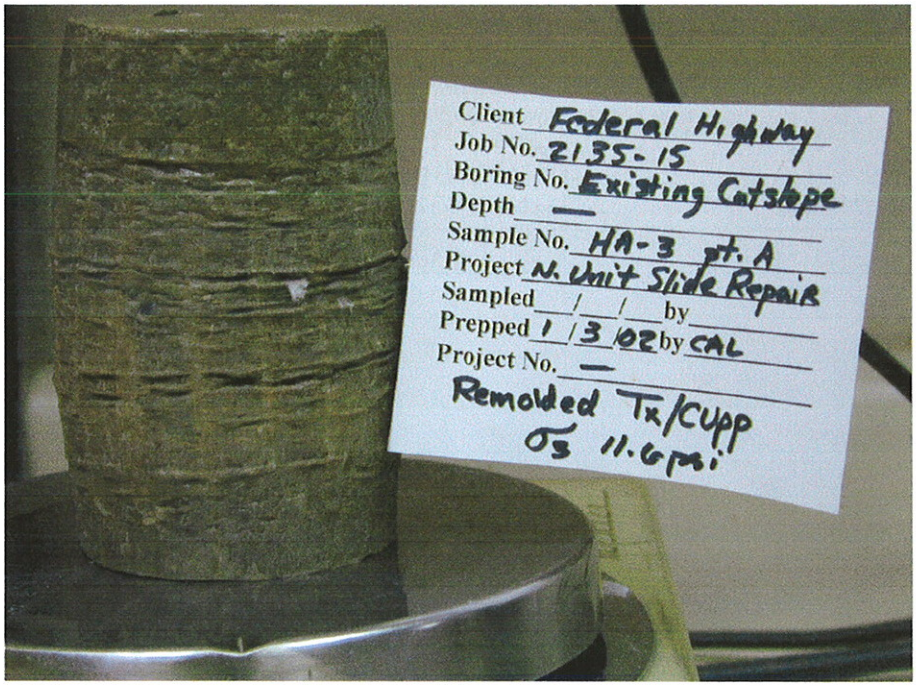
Axial Load Lbs.	Axial Load PSF	Delta Ht. In.	Axial % Strain	Area Final Sq In.	Dev. Stress PSF	Pore Pres. PSI	Delta Pres. PSF	Sigma 3 PSF	Sigma 1 PSF	Prin. Stress Ratio
0.0	0	0.000	0.00	4.491	0	48.2	0	1670	1670	1.00
38.3	1229	0.027	0.54	4.515	1223	52.8	658	1012	2235	2.21
47.8	1532	0.059	1.19	4.545	1514	53.7	781	889	2403	2.70
51.4	1646	0.088	1.78	4.573	1617	54.0	826	845	2462	2.91
54.2	1738	0.122	2.46	4.605	1695	54.1	853	817	2512	3.07
56.2	1803	0.156	3.15	4.637	1746	54.3	874	797	2543	3.19
58.2	1867	0.190	3.83	4.670	1795	54.3	879	792	2587	3.27
61.0	1956	0.224	4.52	4.704	1867	54.3	870	801	2668	3.33
62.2	1994	0.259	5.21	4.738	1890	54.3	874	797	2687	3.37
64.4	2064	0.293	5.91	4.773	1942	54.2	859	811	2753	3.39
66.4	2131	0.327	6.59	4.808	1990	54.1	846	825	2815	3.41
68.4	2192	0.362	7.30	4.845	2032	54.0	837	834	2865	3.44
70.1	2247	0.396	7.98	4.881	2067	53.9	816	855	2922	3.42
70.9	2272	0.429	8.64	4.916	2076	53.8	809	861	2937	3.41
73.2	2346	0.463	9.33	4.953	2127	53.7	791	880	3007	3.42
74.7	2394	0.497	10.02	4.991	2154	53.6	771	899	3053	3.40
75.3	2415	0.532	10.72	5.030	2156	53.5	763	907	3063	3.38
77.4	2480	0.566	11.40	5.069	2198	53.4	738	932	3130	3.36
78.8	2525	0.600	12.09	5.109	2220	53.3	730	941	3161	3.36
80.7	2587	0.635	12.78	5.149	2256	53.2	710	960	3216	3.35
80.5	2582	0.668	13.45	5.189	2234	53.0	688	982	3217	3.27
82.3	2638	0.701	14.12	5.230	2266	53.0	682	988	3254	3.29
83.0	2663	0.735	14.81	5.272	2268	52.8	657	1014	3282	3.24
84.4	2706	0.769	15.50	5.315	2287	52.9	680	991	3277	3.31
85.9	2753	0.803	16.18	5.358	2307	52.8	657	1013	3321	3.28
88.3	2830	0.838	16.87	5.403	2352	52.8	661	1009	3361	3.33
89.2	2859	0.872	17.57	5.448	2357	52.7	645	1025	3382	3.30
89.2	2860	0.905	18.23	5.493	2339	52.6	625	1045	3384	3.24
91.4	2932	0.937	18.88	5.537	2378	52.4	606	1064	3443	3.23
92.4	2961	0.972	19.57	5.584	2382	52.3	590	1080	3462	3.20

Data entry by: CL Date: 01/21/2002
Data checked by: DPM Date: 01/22/02
FileName: FHT0EC3A.WK4

ADVANCED TERRA TESTING, INC.


CONSOLIDATION DATA
Existing Cutslope, , HA-3 Pt.A
Volume Deflection in cc
5
0
-5
-10
-15
0.25
0.5
1
2
4
9
16
30
60
120
240
360
0
5
10
15
20
Square Root of Time in Minutes
Time in Minutes
CONF. PRES. PSF 1670


TRIAXIAL TEST - TX/CUpp
Existing Cutslope, , HA-3 Pt.A
Deviator Stress - psf
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
Percent Axial Strain
Deviator Stress
Delta Pore Pres.



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01/19/02

Appendix C

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 ERFO 10(1) Theodore Roosevelt National Park, Various Sites

Submitted By: Braden Peters

Date Reported: 12/8/2011

Sample Number	Lab Number		11-1869-SB	11-1870-SB	11-1871-SB	11-1872-SB	11-1873-SB	11-1874-SB
	Hole Number							
	Field Number		1	2	3	4	1	2
Sample Location	Location		South Unit	South Unit	South Unit	South Unit	South Unit	South Unit
	Station		201+50	201+50	201+50	201+50	Buck Hill	Buck Hill
	Milepost		--	--	--	--	0.5	0.5
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			100			
	3/4"	19.0 mm		100	99			
	1/2"	12.5 mm		99	99	100		
	3/8"	9.5 mm		99	99	99		
	#4	4.75 mm	100	98	99	98		
	#8	2.36 mm						
	#10	2.00 mm	99	97	95	95		
	#16	1.18 mm	99	96	94	94		100
	#30	600 µm						
	#40	425 µm	98	95	90	92		99
	#50	300 µm						
	#100	150 µm	61	93	86	88		98
	#200	75 µm	40	83	83	80	100	97
		20 µm						
		2 µm						
AASHTO T 255	Moisture, %		26.9	25.5	26.4	36.7	36.8	27.2
AASHTO T 89 & T 90	Liquid Limit		33	37	50	88	51	48
	Plasticity Index		16	21	31	67	36	30
Soil Classification	AASHTO M 145		A-6 (2)	A-6 (16)	A-7-6 (26)	A-7-6 (57)	A-7-6 (39)	A-7-6 (31)
	ASTM D 2487		SC	CL	CH	CH	CH	CL
AASHTO T 190	R – Value							
AASHTO T 288	Min. Resistivity, ohm x cm							
AASHTO T 289	pH							
AASHTO T 290	Sulfate Content, % / ppm							
AASHTO T 291	Chloride Content, % / ppm							

Distribution:

Num. / Project File	
Laboratory	Darrell Harding
Geotechnical	Braden Peters
Materials	Mike Peabody

Remarks:

Reported By:

Darrell Harding
Laboratory Manager

Form FHWA 1702 Rev. 02/10

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 ERFO 10(1) Theodore Roosevelt National Park, Various Sites

Submitted By: Braden Peters

Date Reported: 12/8/2011

Sample Number	Lab Number		11-1875-SB	11-1876-SB	11-1877-SB	11-1878-SB		Blend *
	Hole Number							
	Field Number		1	1	1	2		1 - 3
Sample Location	Location		North Unit	North Unit	North Unit	North Unit		South Unit
	Station		375+00	601+00	604+00	604+00		201+50
	Milepost		--	--	--	--		--
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		100				
	3/4"	19.0 mm		99				
	1/2"	12.5 mm		97				
	3/8"	9.5 mm		96				
	#4	4.75 mm		91				
	#8	2.36 mm						
	#10	2.00 mm		84	100	100		
	#16	1.18 mm	100	73	99	99		
	#30	600 µm						
	#40	425 µm	99	40	98	99		
	#50	300 µm						
	#100	150 µm	93	22	97	97		
	#200	75 µm	65	18	93	94		
		20 µm						
		2 µm						
AASHTO T 255	Moisture, %		28.5	7.7	42.4	34.6		
AASHTO T 89 & T 90	Liquid Limit		24	19	51	50		
	Plasticity Index		5	5	31	31		
Soil Classification	AASHTO M 145		A-4 (1)	A-1-b (0)	A-7-6 (31)	A-7-6 (31)		
	ASTM D 2487		CL-ML	SC-SM	CH	CH		
AASHTO T 190	R – Value							
AASHTO T 288	Min. Resistivity, ohm x cm							1000
AASHTO T 289	pH							6.9
AASHTO T 290	Sulfate Content, % / ppm							0.472 / 4720
AASHTO T 291	Chloride Content, % / ppm							0.0008 / 8

Distribution:

	Num. / Project File
Laboratory	Darrell Harding
Geotechnical	Braden Peters
Materials	Mike Peabody

Remarks: * This material is a blend of 11-1869-SB, 11-1870-SB and 11-1871-SB.

Sulfate & chloride content testing was performed by FHWA consultant, Colorado Analytical Laboratories.

Reported By:

Darrell Harding
Laboratory Manager

Form FHWA 1702 Rev. 02/10

Appendix D

Theodore Roosevelt ERFO Multiple Slides

Report created by ReSSA(3.0): Copyright (c) 2001-2008, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title:	Theodore Roosevelt ERFO Multiple Slides
Project Number:	ND THRO ERFO 10(1) -
Client:	FHWA CFLHD
Designer:	Braden Peters
Station Number:	South Unit 201+50

Description:
Skyline Vista - Maximum Slope Height

Company's information:

Name:
Street:

Telephone #:
Fax #:
E-Mail:

Original file path and name: N:\ND\ND ERFO 10(1)\Geotech\5 Analysis\RSS 201+50.MSE
Original date and time of creating this file: Thu Jan 12 11:35:08 2012

PROGRAM MODE: Analysis of a General Slope using GEOSYNTHETIC as reinforcing material.

INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

========== Soil Layer #: ==========	Unit weight, γ [lb/ft ^{3}]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ^{2}]
....1.....	125.0	30.0	0.0
....2.....	130.0	45.0	0.0
....3.....	115.0	14.0	480.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Additional Reduction Factor, RFa	Coverage Ratio, Rc
1	Geosynthetic type #1	2000.00	1.20	1.10	1.67	1.00	1.00

Interaction Parameters Type #	Geosynthetic Designated Name	== Direct Sliding == Cds-phi	Cds-c	==== Pullout ==== Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 1.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50
Design method for Global Stability: AASHTO/FHWA Bishop.

WATER

Unit weight of water = 62.45 [lb/ft ^{3}]
Water ponding is defined by 'phreatic surface' in Total Stress Analysis.

SEISMICITY

Not Applicable

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DRAWING OF SPECIFIED GEOMETRY - COMPLEX - Quick Input

-- Problem geometry is defined along sections selected by user at x,y coordinates.
-- X1,Y1 represents the coordinates of soil surface. X2,Y2 represent the coordinates of the end of soil layer 1 and start of soil layer 2, and so on.
-- Xw,Yw represents the coordinates of phreatic surface.

GEOMETRY

Soil profile contains 3 layers (see details in next page)

WATER GEOMETRY

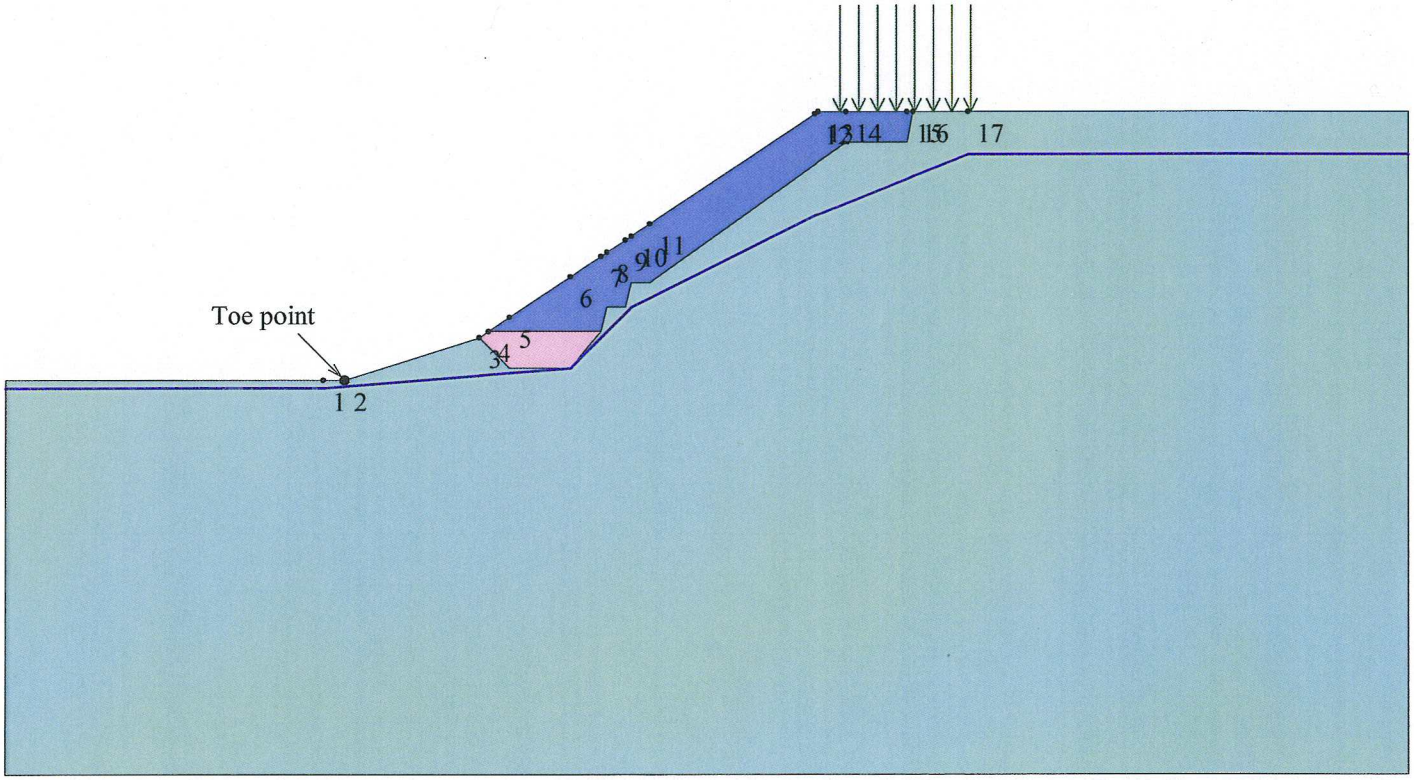
Phreatic line was specified.

UNIFORM SURCHARGE

Load Q1 = 250.00 [lb/ft²] inclined from verical at 0.00 degrees, starts at X1s = 399.00 and ends at X1e = 421.00 [ft].
Surcharge load, Q2.....None
Surcharge load, Q3.....None

STRIP LOAD

.....None.....



SCALE:

0 2 4 6 8 10 [ft]

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TABULATED DETAILS OF QUICK SPECIFIED GEOMETRY

Soil profile contains 3 layers. Coordinates in [ft.]
Water was described by phreatic line.

	#	Xi	Yi
Top of Layer 1	1	318.00	393.00
	2	340.00	400.00
	3	395.50	437.00
	4	411.00	437.00
Top of Layer 2	5	318.00	393.00
	6	340.00	400.00
	7	341.50	401.00
	8	360.00	401.00
	9	361.00	405.00
	10	364.00	405.00
	11	365.00	409.00
	12	368.00	409.00
	13	400.00	432.00
	14	410.00	432.00
	15	411.00	437.00
Top of Layer 3	16	318.00	393.00
	17	340.00	400.00
	18	345.00	395.00
	19	355.00	395.00
	20	360.00	401.00
	21	361.00	405.00
	22	364.00	405.00
	23	365.00	409.00
	24	368.00	409.00
	25	400.00	432.00
	26	410.00	432.00
	27	411.00	437.00
Top of Phreatic Line	29	314.50	391.70
	30	355.00	395.00
	31	365.00	405.00
	32	395.00	420.00
	33	420.00	430.00

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TABULATED DETAILS OF SPECIFIED GEOMETRY

Soil profile contains 3 layers. Coordinates in [ft.]
Water was described by phreatic line. Y values are tabulated in the right most column.

#	X	Y1	Y2	Y3	(phreatic) Yw
1	314.50	393.00	393.00	393.00	391.70
2	318.00	393.00	393.00	393.00	391.99
3	340.00	400.00	400.00	400.00	393.78
4	341.50	401.00	401.00	398.50	393.90
5	345.00	403.33	401.00	395.00	394.19
6	355.00	410.00	401.00	395.00	395.00
7	360.00	413.33	401.00	401.00	400.00
8	361.00	414.00	405.00	405.00	401.00
9	364.00	416.00	405.00	405.00	404.00
10	365.00	416.67	409.00	409.00	405.00
11	368.00	418.67	409.00	409.00	406.50
12	395.00	436.67	428.41	428.41	420.00
13	395.50	437.00	428.77	428.77	420.20
14	400.00	437.00	432.00	432.00	422.00
15	410.00	437.00	432.00	432.00	426.00
16	411.00	437.00	437.00	437.00	426.40
17	420.00	437.00	437.00	437.00	430.00

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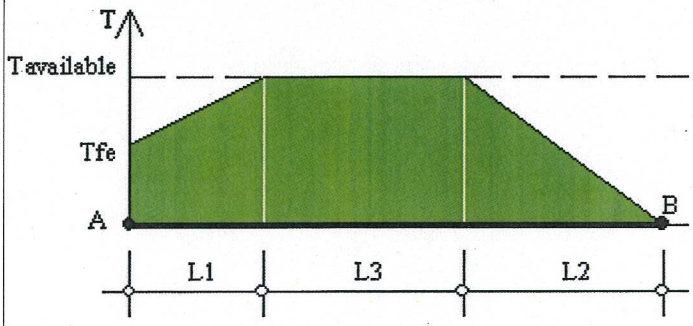
DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	8.00	18.00	0.00	0.75	17.25	907.28	907.28
2	Geosynthetic type #1	9.00	16.50	0.00	1.41	15.09	907.28	907.28
3	Geosynthetic type #1	10.00	14.00	0.00	1.71	12.29	907.28	907.28
4	Geosynthetic type #1	11.00	12.50	0.00	1.94	10.56	907.28	907.28
5	Geosynthetic type #1	12.00	16.00	0.00	1.35	14.65	907.28	907.28
6	Geosynthetic type #1	13.00	14.50	0.00	1.64	12.86	907.28	907.28
7	Geosynthetic type #1	14.00	13.00	0.00	1.84	11.16	907.28	907.28
8	Geosynthetic type #1	15.00	12.00	0.00	2.03	9.97	907.28	907.28
9	Geosynthetic type #1	16.00	16.00	0.00	1.35	14.65	907.28	907.28
10	Geosynthetic type #1	17.00	14.50	0.00	1.61	12.89	907.28	907.28
11	Geosynthetic type #1	18.00	13.00	0.00	1.84	11.16	907.28	907.28
12	Geosynthetic type #1	19.00	12.00	0.00	2.03	9.97	907.28	907.28
13	Geosynthetic type #1	20.00	12.00	0.00	2.03	9.97	907.28	907.28
14	Geosynthetic type #1	21.00	12.00	0.00	2.03	9.97	907.28	907.28
15	Geosynthetic type #1	22.00	12.00	0.00	2.03	9.97	907.28	907.28
16	Geosynthetic type #1	23.00	12.00	0.00	2.03	9.97	907.28	907.28
17	Geosynthetic type #1	24.00	12.00	0.00	2.03	9.97	907.28	907.28
18	Geosynthetic type #1	25.00	12.00	0.00	2.03	9.97	907.28	907.28
19	Geosynthetic type #1	26.00	12.00	0.00	2.03	9.97	907.28	907.28
20	Geosynthetic type #1	27.00	12.00	0.00	2.03	9.97	907.28	907.28
21	Geosynthetic type #1	28.00	12.00	0.00	2.03	9.97	907.28	907.28
22	Geosynthetic type #1	29.00	12.00	0.00	2.03	9.97	907.28	907.28
23	Geosynthetic type #1	30.00	12.00	0.00	2.03	9.97	907.28	907.28
24	Geosynthetic type #1	31.00	12.00	0.00	2.03	9.97	907.28	907.28
25	Geosynthetic type #1	32.00	12.00	0.00	2.03	9.97	907.28	907.28
26	Geosynthetic type #1	33.00	12.00	0.00	2.03	9.97	907.28	907.28
27	Geosynthetic type #1	34.00	12.00	0.00	2.03	9.97	907.28	907.28
28	Geosynthetic type #1	35.00	12.00	0.00	2.03	9.97	907.28	907.28
29	Geosynthetic type #1	36.00	12.00	0.00	2.03	9.97	907.28	907.28
30	Geosynthetic type #1	37.00	12.00	0.00	2.13	9.87	907.28	907.28
31	Geosynthetic type #1	38.00	12.00	0.00	2.46	9.54	907.28	907.28
32	Geosynthetic type #1	39.00	12.00	0.00	2.95	9.05	907.28	907.28
33	Geosynthetic type #1	40.00	22.00	0.00	2.33	19.67	907.28	907.28
34	Geosynthetic type #1	41.00	20.00	0.00	3.97	16.03	907.28	907.28
35	Geosynthetic type #1	42.00	18.00	0.00	7.38	10.62	907.28	907.28

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DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER (continues)

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
36	Geosynthetic type #1	43.00	16.00	0.00	14.76	1.24	907.28	907.28

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	385.00	430.00	320.72	394.10	341.47	432.45	43.60	1.74	
2	389.40	432.94	320.48	394.23	342.39	435.93	47.11	1.62	
3	393.80	435.87	320.13	394.41	343.76	438.61	50.12	1.55	
4	398.20	437.00	320.46	394.21	344.05	443.38	54.53	1.44	
5	402.60	437.00	320.67	394.08	342.97	451.18	61.30	1.36	
6	407.00	437.00	344.64	403.38	353.25	462.06	59.30	1.31	
7	411.40	437.00	320.17	394.21	342.68	464.87	74.16	1.27	
8	415.80	437.00	320.46	394.12	344.01	469.20	78.69	1.26	OK
9	420.20	437.00	320.75	394.03	345.36	473.64	83.33	1.27	
10	424.60	437.00	319.87	394.31	346.75	478.18	88.07	1.28	
11	429.00	437.00	312.25	393.28	345.49	482.26	94.99	1.31	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

****

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	288.21	393.43	424.60	437.00	335.54	480.53	99.13	1.38	
2	296.47	393.26	420.20	437.00	337.10	475.21	91.47	1.34	
3	304.11	393.40	420.20	437.00	340.53	472.79	87.35	1.31	
4	312.25	393.28	420.20	437.00	342.44	473.87	86.06	1.28	
5	320.46	394.12	415.80	437.00	344.01	469.20	78.69	1.26	OK
6	328.61	396.60	415.80	437.00	348.28	468.45	74.49	1.28	
7	336.36	399.04	411.40	437.00	335.34	494.20	95.17	1.37	
8	344.28	403.40	411.40	437.00	351.14	473.54	70.47	1.28	
9	352.68	408.71	411.40	437.00	361.10	466.32	58.22	1.39	
10	361.00	414.00	411.40	437.00	367.46	466.58	52.97	1.53	
11	368.75	419.36	411.40	437.00	373.32	468.69	49.54	1.74	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.26
Critical Circle: Xc = 344.01[ft], Yc = 469.20[ft], R = 78.69[ft]. (Number of slices used = 59)

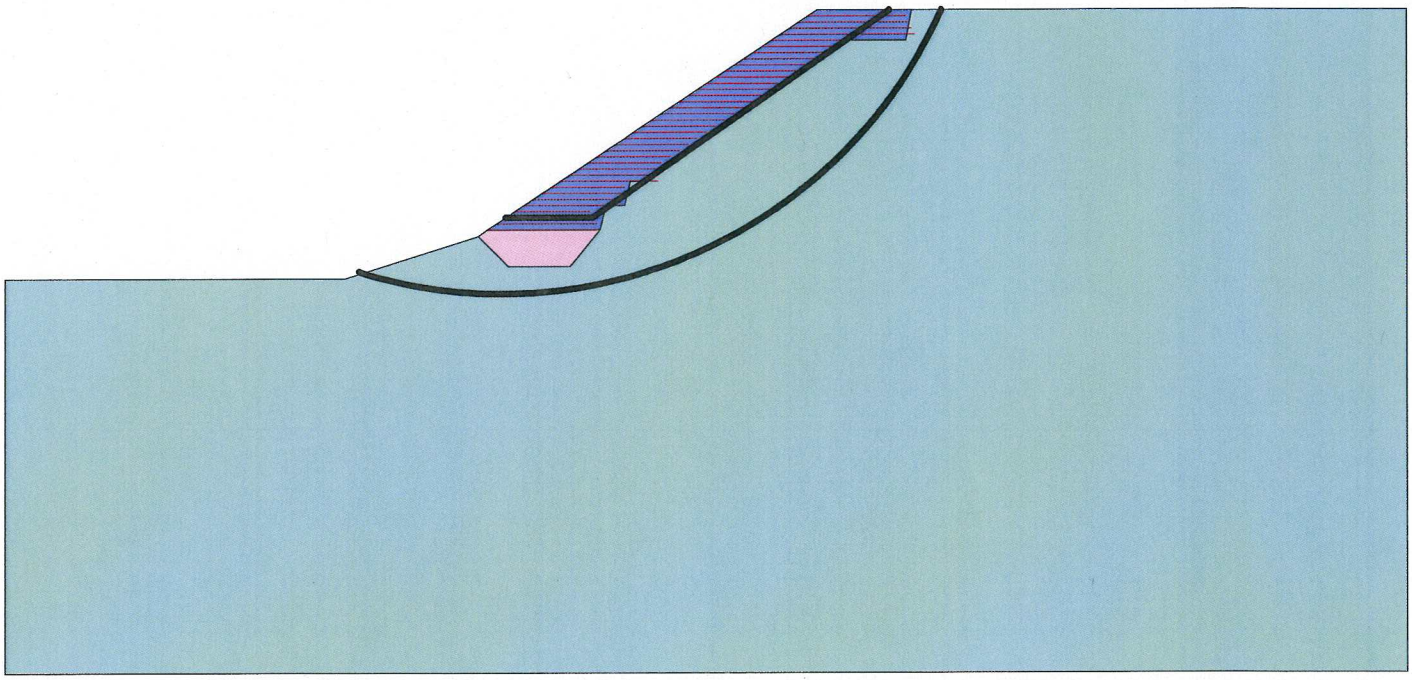
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

Minimum Factor of Safety = 1.31
Critical Two-Part Wedge: (Xa = 344.50, Ya = 403.00) [ft]
(Xb = 358.69, Yb = 403.00) [ft]
(Xc = 407.25, Yc = 437.00) [ft]
(Number of slices used = 30)
Interslice resultant force inclination = 29.50 [degrees]

Three-Part Wedge Stability Analysis

N O T C O N D U C T E D

REINFORCEMENT LAYOUT: DRAWING



SCALE:

024681([ft]

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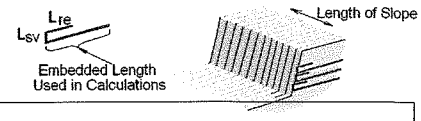

REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]		Lsv * [ft]	Lre [ft]
1	1	Geosynthetic type #1	8.00	18.00	1.00	1066.81	1297.37	1084.81	1297.37	0.00	0.00
2	1	Geosynthetic type #1	9.00	16.50	1.00	1068.31	1298.37	1084.81	1298.37	0.00	0.00
3	1	Geosynthetic type #1	10.00	14.00	1.00	1069.81	1299.37	1083.81	1299.37	0.00	0.00
4	1	Geosynthetic type #1	11.00	12.50	1.00	1071.31	1300.37	1083.81	1300.37	0.00	0.00
5	1	Geosynthetic type #1	12.00	16.00	1.00	1072.81	1301.37	1088.81	1301.37	0.00	0.00
6	1	Geosynthetic type #1	13.00	14.50	1.00	1074.31	1302.37	1088.81	1302.37	0.00	0.00
7	1	Geosynthetic type #1	14.00	13.00	1.00	1075.81	1303.37	1088.81	1303.37	0.00	0.00
8	1	Geosynthetic type #1	15.00	12.00	1.00	1077.31	1304.37	1089.31	1304.37	0.00	0.00
9	1	Geosynthetic type #1	16.00	16.00	1.00	1078.81	1305.37	1094.81	1305.37	0.00	0.00
10	1	Geosynthetic type #1	17.00	14.50	1.00	1080.31	1306.37	1094.81	1306.37	0.00	0.00
11	1	Geosynthetic type #1	18.00	13.00	1.00	1081.81	1307.37	1094.81	1307.37	0.00	0.00
12	1	Geosynthetic type #1	19.00	12.00	1.00	1083.31	1308.37	1095.31	1308.37	0.00	0.00
13	1	Geosynthetic type #1	20.00	12.00	1.00	1084.81	1309.37	1096.81	1309.37	0.00	0.00
14	1	Geosynthetic type #1	21.00	12.00	1.00	1086.31	1310.37	1098.31	1310.37	0.00	0.00
15	1	Geosynthetic type #1	22.00	12.00	1.00	1087.81	1311.37	1099.81	1311.37	0.00	0.00
16	1	Geosynthetic type #1	23.00	12.00	1.00	1089.31	1312.37	1101.31	1312.37	0.00	0.00
17	1	Geosynthetic type #1	24.00	12.00	1.00	1090.81	1313.37	1102.81	1313.37	0.00	0.00
18	1	Geosynthetic type #1	25.00	12.00	1.00	1092.31	1314.37	1104.31	1314.37	0.00	0.00
19	1	Geosynthetic type #1	26.00	12.00	1.00	1093.81	1315.37	1105.81	1315.37	0.00	0.00
20	1	Geosynthetic type #1	27.00	12.00	1.00	1095.31	1316.37	1107.31	1316.37	0.00	0.00
21	1	Geosynthetic type #1	28.00	12.00	1.00	1096.81	1317.37	1108.81	1317.37	0.00	0.00
22	1	Geosynthetic type #1	29.00	12.00	1.00	1098.31	1318.37	1110.31	1318.37	0.00	0.00
23	1	Geosynthetic type #1	30.00	12.00	1.00	1099.81	1319.37	1111.81	1319.37	0.00	0.00
24	1	Geosynthetic type #1	31.00	12.00	1.00	1101.31	1320.37	1113.31	1320.37	0.00	0.00
25	1	Geosynthetic type #1	32.00	12.00	1.00	1102.81	1321.37	1114.81	1321.37	0.00	0.00
26	1	Geosynthetic type #1	33.00	12.00	1.00	1104.31	1322.37	1116.31	1322.37	0.00	0.00
27	1	Geosynthetic type #1	34.00	12.00	1.00	1105.81	1323.37	1117.81	1323.37	0.00	0.00
28	1	Geosynthetic type #1	35.00	12.00	1.00	1107.31	1324.37	1119.31	1324.37	0.00	0.00
29	1	Geosynthetic type #1	36.00	12.00	1.00	1108.81	1325.37	1120.81	1325.37	0.00	0.00
30	1	Geosynthetic type #1	37.00	12.00	1.00	1110.31	1326.37	1122.31	1326.37	0.00	0.00
31	1	Geosynthetic type #1	38.00	12.00	1.00	1111.81	1327.37	1123.81	1327.37	0.00	0.00
32	1	Geosynthetic type #1	39.00	12.00	1.00	1113.31	1328.37	1125.31	1328.37	0.00	0.00
33	1	Geosynthetic type #1	40.00	22.00	1.00	1114.81	1329.37	1136.81	1329.37	0.00	0.00
34	1	Geosynthetic type #1	41.00	20.00	1.00	1116.31	1330.37	1136.31	1330.37	0.00	0.00
35	1	Geosynthetic type #1	42.00	18.00	1.00	1117.81	1331.37	1135.81	1331.37	0.00	0.00
36	1	Geosynthetic type #1	43.00	16.00	1.00	1119.31	1332.37	1135.31	1332.37	0.00	0.00

* Vertical distance between layers.

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]
1	Geosynthetic type #1	1.00	488.00

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Theodore Roosevelt ERFO Multiple Slides

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PROJECT IDENTIFICATION

Title: Theodore Roosevelt ERFO Multiple Slides
Project Number: ND THRO ERFO 10(1) -
Client: FHWA CFLHD
Designer: Braden Peters
Station Number: 375+00

Description:

Company's information:

Name:
Street:

Telephone #:
Fax #:
E-Mail:

Original file path and name: N:\ND\ND ERFO 10(1)\Geotech\5 Analysis\RSS 375+00.MSE
Original date and time of creating this file: Thu Jan 12 11:35:08 2012

PROGRAM MODE: Analysis of a General Slope using GEOSYNTHETIC as reinforcing material.

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INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

========== Soil Layer #: ==========	Unit weight, γ [lb/ft ^{3}]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ^{2}]
....1.....	125.0	30.0	0.0
....2.....	130.0	45.0	0.0
....3.....	115.0	14.0	480.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Additional Reduction Factor, RFa	Coverage Ratio, Rc
1	Geosynthetic type #1	4800.00	1.20	1.10	1.67	1.00	1.00
2	Type #2	2000.00	1.20	1.10	1.67	1.00	1.00

Interaction Parameters		== Direct Sliding ==		===== Pullout =====	
Type #	Geosynthetic Designated Name	Cds-phi	Cds-c	Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80
2	Type #2	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 1.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50
Design method for Global Stability: AASHTO/FHWA Bishop.

WATER

Unit weight of water = 62.45 [lb/ft ^{3}]
Water ponding is defined by 'phreatic surface' in Total Stress Analysis.

SEISMICITY

Not Applicable

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DRAWING OF SPECIFIED GEOMETRY - COMPLEX - Quick Input

-- Problem geometry is defined along sections selected by user at x,y coordinates.
-- X1,Y1 represents the coordinates of soil surface. X2,Y2 represent the coordinates of the end of soil layer 1 and start of soil layer 2, and so on.
-- Xw,Yw represents the coordinates of phreatic surface.

GEOMETRY

Soil profile contains 3 layers (see details in next page)

WATER GEOMETRY

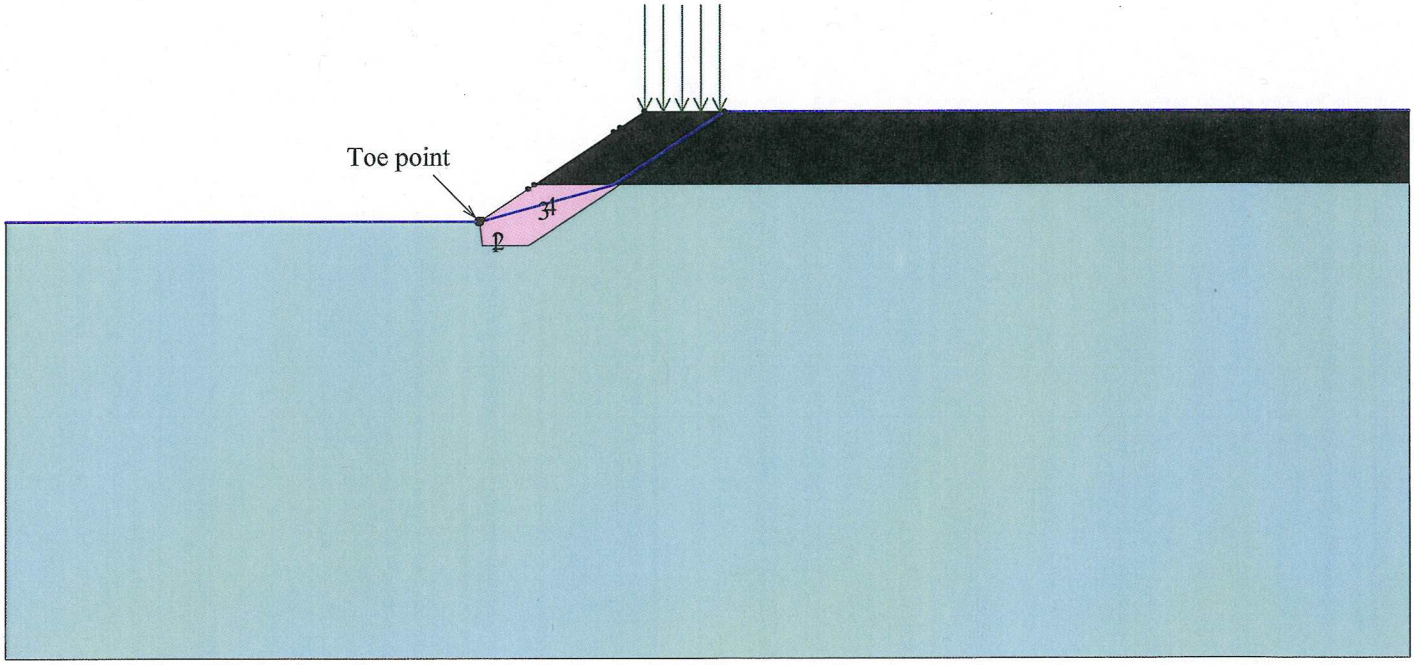
Phreatic line was specified.

UNIFORM SURCHARGE

Load Q1 = 250.00 [lb/ft²] inclined from verical at 0.00 degrees, starts at X1s = 367.00 and ends at X1e = 380.00 [ft].
Surcharge load, Q2.....None
Surcharge load, Q3.....None

STRIP LOAD

.....None.....



SCALE:

0246 [ft]

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TABULATED DETAILS OF QUICK SPECIFIED GEOMETRY

Soil profile contains 3 layers. Coordinates in [ft.]
Water was described by phreatic line.

	#	Xi	Yi
Top of Layer 1	1	340.00	400.00
	2	367.00	418.00
Top of Layer 2	3	340.00	400.00
	4	349.00	406.00
Top of Layer 3	5	340.00	400.00
	6	340.50	396.00
	7	348.00	396.00
	8	363.00	406.00
Top of Phreatic Line	10	340.00	400.00
	11	362.00	406.00
	12	380.00	418.00

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TABULATED DETAILS OF SPECIFIED GEOMETRY

Soil profile contains 3 layers. Coordinates in [ft.]
Water was described by phreatic line. Y values are tabulated in the right most column.

#	X	Y1	Y2	Y3	Yw (phreatic)
1	340.00	400.00	400.00	400.00	400.00
2	340.50	400.33	400.33	396.00	400.14
3	348.00	405.33	405.33	396.00	402.18
4	349.00	406.00	406.00	396.67	402.45
5	362.00	414.67	406.00	405.33	406.00
6	363.00	415.33	406.00	406.00	406.67
7	367.00	418.00	406.00	406.00	409.33
8	380.00	418.00	406.00	406.00	418.00

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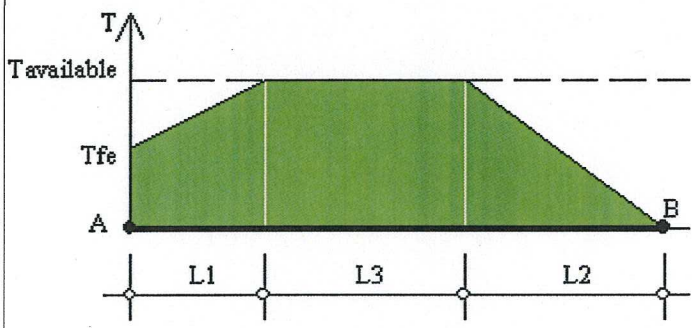
DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	6.00	12.00	0.00	2.92	9.08	2177.46	2177.46
2	Type #2	7.00	4.00	0.00	4.00	0.00	325.76	325.76 (*)
3	Geosynthetic type #1	8.00	12.00	7.62	4.38	0.00	21.77	1625.60 (*)
4	Type #2	9.00	4.00	1.87	2.13	0.00	18.15	173.20 (*)
5	Geosynthetic type #1	10.00	12.00	7.62	4.38	0.00	21.77	1625.60 (*)
6	Type #2	11.00	4.00	1.87	2.13	0.00	18.15	173.20 (*)
7	Geosynthetic type #1	12.00	12.00	7.29	4.71	0.00	21.77	1541.41 (*)
8	Type #2	13.00	4.00	1.87	2.13	0.00	18.15	173.20 (*)
9	Geosynthetic type #1	14.00	12.00	6.25	5.75	0.00	21.77	1169.70 (*)
10	Type #2	15.00	4.00	1.87	2.13	0.00	18.15	173.20 (*)
11	Geosynthetic type #1	16.00	12.00	5.89	6.11	0.00	21.77	657.31 (*)
12	Type #2	17.00	4.00	1.81	2.19	0.00	18.15	109.07 (*)

(*) This Tavailable is dictated by the pullout resistance capacity, which is smaller than the long-term strength of the reinforcement that is related to its specified ultimate strength

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	360.00	413.34	340.80	400.66	340.63	421.81	21.14	2.95	
2	362.50	415.00	340.95	400.66	339.68	425.95	25.32	2.88	
3	365.00	416.67	337.32	400.09	346.09	416.85	18.92	2.74	
4	367.50	418.00	354.89	410.00	354.49	424.56	14.57	2.35	
5	370.00	418.00	351.45	407.70	357.42	418.80	12.61	1.95	
6	372.50	418.00	351.40	407.71	357.38	422.22	15.70	1.62	
7	375.00	418.00	351.38	407.70	357.25	426.48	19.67	1.49	OK
8	377.50	418.00	351.39	407.69	357.03	431.63	24.59	1.52	
9	380.00	418.00	340.91	400.66	332.09	473.27	73.15	1.61	
10	382.50	418.00	340.62	400.61	326.11	494.66	95.16	1.70	
11	385.00	418.00	340.76	400.62	320.41	517.45	118.59	1.79	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

****

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	319.44	400.38	380.00	418.00	342.63	433.56	40.48	2.00	
2	323.47	400.02	380.00	418.00	344.11	432.98	38.89	1.94	
3	326.48	400.31	380.00	418.00	345.61	432.23	37.22	1.88	
4	330.22	400.16	380.00	418.00	347.42	430.53	34.90	1.83	
5	333.61	400.14	380.00	418.00	346.41	436.05	38.13	1.83	
6	337.17	400.06	377.50	418.00	344.27	438.40	38.99	1.75	
7	340.76	400.65	377.50	418.00	335.95	458.40	57.96	1.57	
8	344.13	403.01	377.50	418.00	345.24	445.18	42.19	1.63	
9	347.84	405.36	377.50	418.00	352.71	435.06	30.09	1.74	
10	351.38	407.70	375.00	418.00	357.25	426.48	19.67	1.49	OK
11	354.82	410.08	375.00	418.00	360.97	424.07	15.29	1.70	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.49

Critical Circle: Xc = 357.25[ft], Yc = 426.48[ft], R = 19.67[ft]. (Number of slices used = 52)

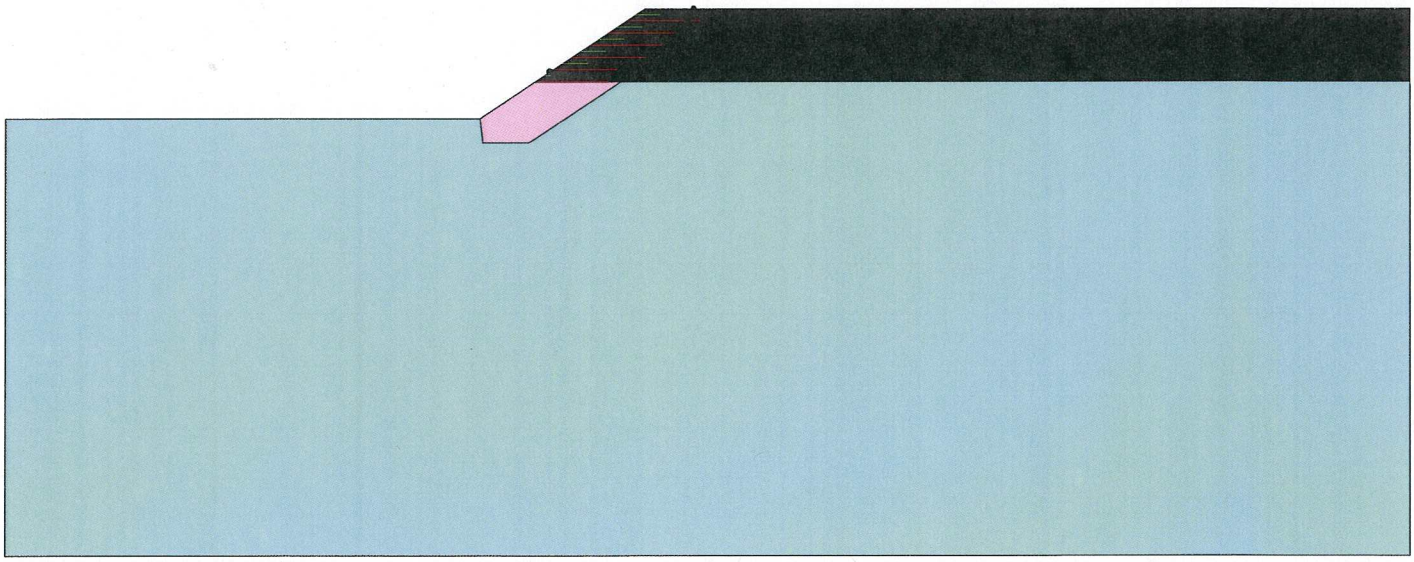
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

N O T C O N D U C T E D

Three-Part Wedge Stability Analysis

N O T C O N D U C T E D

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0246 [ft]

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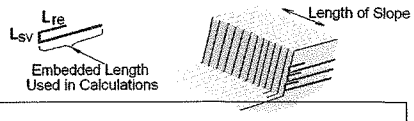

REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]		Lsv * [ft]	Lre [ft]
1	1	Geosynthetic type #1	6.00	12.00	1.00	1124.49	1318.34	1136.49	1318.34	1.00	3.00
2	2	Type #2	7.00	4.00	1.00	1125.99	1319.34	1129.99	1319.34	1.00	3.00
3	1	Geosynthetic type #1	8.00	12.00	1.00	1127.49	1320.34	1139.49	1320.34	1.00	3.00
4	2	Type #2	9.00	4.00	1.00	1128.99	1321.34	1132.99	1321.34	1.00	3.00
5	1	Geosynthetic type #1	10.00	12.00	1.00	1130.49	1322.34	1142.49	1322.34	1.00	3.00
6	2	Type #2	11.00	4.00	1.00	1131.99	1323.34	1135.99	1323.34	1.00	3.00
7	1	Geosynthetic type #1	12.00	12.00	1.00	1133.49	1324.34	1145.49	1324.34	1.00	3.00
8	2	Type #2	13.00	4.00	1.00	1134.99	1325.34	1138.99	1325.34	1.00	3.00
9	1	Geosynthetic type #1	14.00	12.00	1.00	1136.49	1326.34	1148.49	1326.34	1.00	3.00
10	2	Type #2	15.00	4.00	1.00	1137.99	1327.34	1141.99	1327.34	1.00	3.00
11	1	Geosynthetic type #1	16.00	12.00	1.00	1139.49	1328.34	1151.49	1328.34	1.00	3.00
12	2	Type #2	17.00	4.00	1.00	1140.99	1329.34	1144.99	1329.34	1.00	3.00

* Vertical distance between layers.

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]	
1	Geosynthetic type #1	1.00	(including Lsv & Lre)	96.00
2	Type #2	1.00		48.00

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Theodore Roosevelt ERFO Multiple Slides

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PROJECT IDENTIFICATION

Title: Theodore Roosevelt ERFO Multiple Slides
Project Number: ND THRO ERFO 10(1) -
Client: FHWA CFLHD
Designer: Braden Peters
Station Number: 501+00

Description:
Maximum Slope Height

Company's information:

Name:
Street:
,
Telephone #:
Fax #:
E-Mail:

Original file path and name: N:\ND\ND ERFO 10(1)\Geotech\5 Analysis\RSS 501+00.MSE
Original date and time of creating this file: Thu Jan 12 11:35:08 2012

PROGRAM MODE: Analysis of a Simplified Slope using GEOSYNTHETIC as reinforcing material.

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INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

========== Soil Layer #: ==========	Unit weight, γ [lb/ft ^{3}]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ^{2}]
REINFORCED SOIL.....	125.0	30.0	0.0
RETAINED SOIL.....	125.0	14.0	480.0
FOUNDATION SOIL.....	125.0	14.0	480.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Additional Reduction Factor, RFa	Coverage Ratio, Rc
1	Geosynthetic type #1	4800.00	1.20	1.10	1.67	1.00	1.00
2	Type #2	2300.00	1.20	1.10	1.67	1.00	1.00

Interaction Parameters		== Direct Sliding ==		==== Pullout ====	
Type #	Geosynthetic Designated Name	Cds-phi	Cds-c	Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80
2	Type #2	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 1.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50
Design method for Global Stability: AASHTO/FHWA Bishop.

WATER

Unit weight of water = 62.45 [lb/ft ^{3}]
Water ponding is defined by 'phreatic surface' in Total Stress Analysis.

SEISMICITY

Not Applicable

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DRAWING OF SPECIFIED GEOMETRY - SIMPLE

GEOMETRY

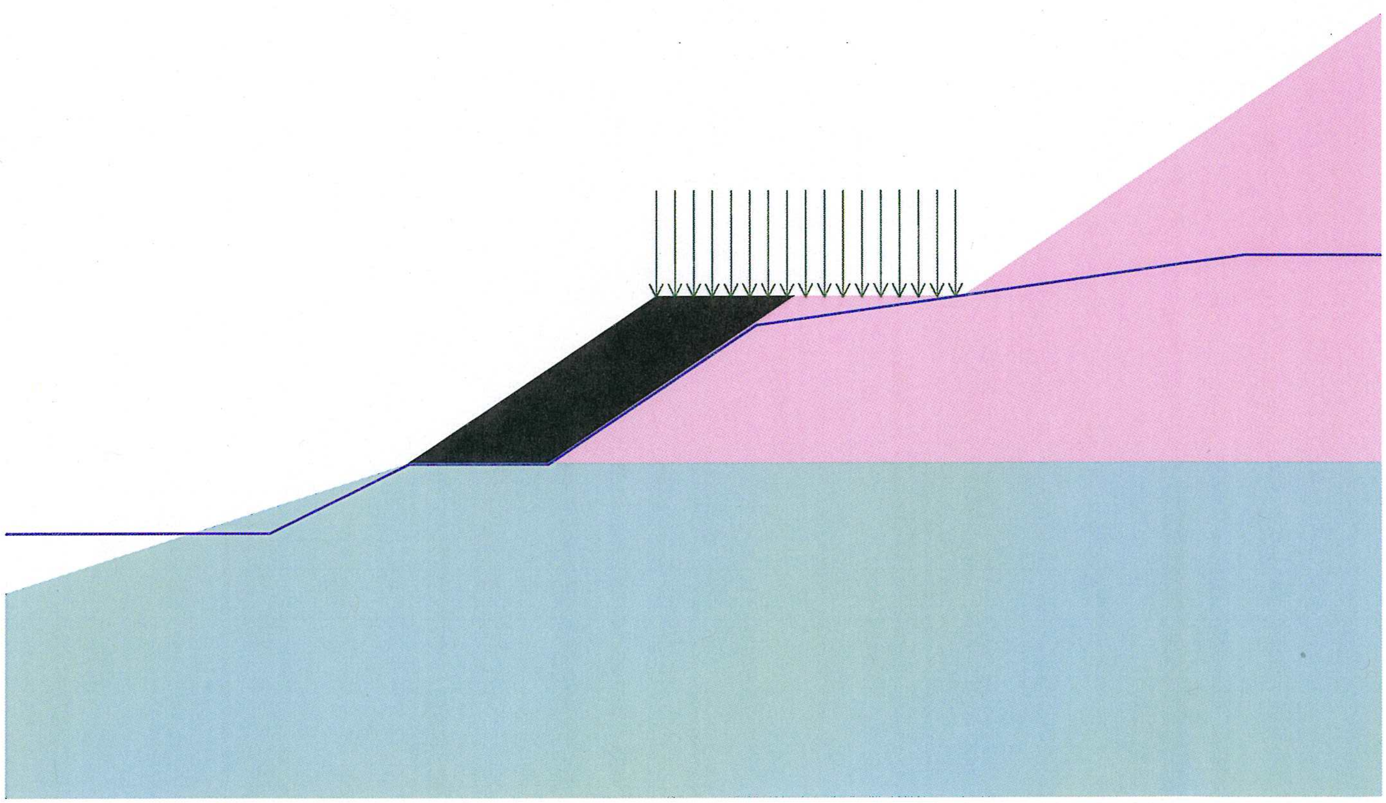
Height of slope, H	12.00	[ft]
Slope angle, i	34.00	[deg.]
Horizontal crest length, A	22.00	[ft]
Horizontal crest length, B	22.00	[ft]
Backslope angle, β	34.00	[deg.]
Sloping angle, α	18.00	[deg.]

UNIFORM SURCHARGE

Surcharge load over A, Q1	250.00	[lb/ft²]
Surcharge load over backslope B, Q2	0.00	[lb/ft²]
Surcharge load away from backslope, Q3	0.00	[lb/ft²]

WATER GEOMETRY Coordinates of water line in [ft]

#	1	Xw =	-10.00	Yw =	-5.00
#	2	Xw =	0.00	Yw =	0.00
#	3	Xw =	10.00	Yw =	0.00
#	4	Xw =	25.00	Yw =	10.00
#	5	Xw =	60.00	Yw =	15.00



SCALE:

0 5 10 15 20 25 30 [ft]

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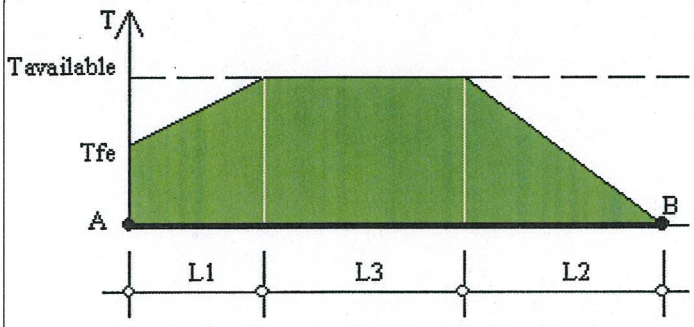
DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	0.20	10.00	0.00	10.00	0.00	2070.13	2070.13 (*)
2	Type #2	1.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
3	Geosynthetic type #1	2.00	10.00	0.00	10.00	0.00	2070.13	2070.13 (*)
4	Type #2	3.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
5	Geosynthetic type #1	4.00	10.00	0.00	10.00	0.00	2070.13	2070.13 (*)
6	Type #2	5.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
7	Geosynthetic type #1	6.00	10.00	0.00	10.00	0.00	2045.54	2045.54 (*)
8	Type #2	7.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
9	Geosynthetic type #1	8.00	10.00	0.00	10.00	0.00	1728.90	1728.90 (*)
10	Type #2	9.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
11	Geosynthetic type #1	10.00	10.00	0.00	10.00	0.00	1047.05	1047.05 (*)
12	Type #2	11.00	4.00	0.00	4.00	0.00	199.67	199.67 (*)

(*) This Tavailable is dictated by the pullout resistance capacity, which is smaller than the long-term strength of the reinforcement that is related to its specified ultimate strength

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	20.00	12.00	14.99	10.12	16.03	14.97	4.96	1.35	
2	22.50	12.00	0.84	0.70	4.44	20.21	19.84	1.35	
3	25.00	12.00	0.77	0.68	2.01	29.63	28.97	1.33	OK
4	27.50	12.00	0.76	0.64	-6.68	55.32	55.18	1.61	
5	30.00	12.00	-20.45	-6.25	-3.24	25.02	35.70	2.07	
6	32.50	12.00	-20.29	-6.35	-2.55	27.74	38.43	2.05	
7	35.00	12.00	-20.13	-6.43	-1.56	29.69	40.62	2.05	
8	37.50	12.00	-20.57	-6.21	-0.88	32.70	43.61	2.06	
9	40.00	12.14	-20.42	-6.29	0.10	34.70	45.84	2.08	
10	42.50	13.83	-20.21	-6.40	0.73	36.01	47.29	2.14	
11	45.00	15.51	-20.00	-6.50	2.13	35.12	47.14	2.18	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

****

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	-20.13	-6.43	35.00	12.00	-1.56	29.69	40.62	2.05	
2	-16.51	-5.36	32.50	12.00	-0.23	26.56	35.83	2.07	
3	-13.02	-4.22	32.50	12.00	1.81	26.15	33.79	2.11	
4	-9.71	-2.98	30.00	12.00	3.19	22.94	28.95	2.15	
5	-6.35	-1.94	25.00	12.00	-5.30	37.93	39.89	2.08	
6	-2.80	-0.81	25.00	12.00	-1.90	33.81	34.63	1.90	
7	0.77	0.68	25.00	12.00	2.01	29.63	28.97	1.33	OK
8	4.29	3.07	25.00	12.00	7.75	23.54	20.76	1.41	
9	7.96	5.41	25.00	12.00	12.46	19.11	14.42	1.61	
10	11.37	7.81	25.00	12.00	15.67	18.08	11.14	2.03	
11	14.99	10.12	20.00	12.00	16.03	14.97	4.96	1.35	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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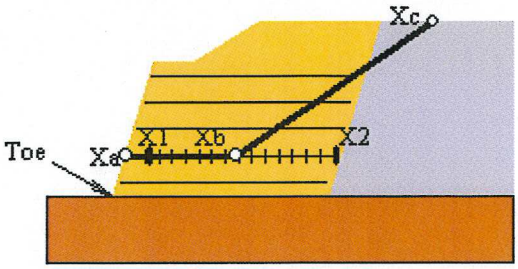
RESULTS OF TRANSLATIONAL ANALYSIS



Results in the table below represent critical two-part wedges identified between specified starting (X1) and ending (X2) search points. Wedges along all reinforcement layers and at elevation zero are reported. The critical two-part wedge, one for each predetermined elevation, is defined by Xa, Xb and Xc where Xa is the front end of the passive wedge (slope face), Xb is where the passive wedge ends and the active one starts, and Xc is the X-ordinate at which the active wedge starts.

Critical two-part wedge along each interface:

Interface	Height Relative to Toe [ft]	(Xa, Ya) [ft]		(Xb, Yb) [ft]		(Xc, Yc) [ft]		Fs	STATUS
At toe elevation	0.00	0.00	0.00	9.80	0.00	27.59	12.00	1.36	Minimum on Edge
Reinf. Layer #1	0.20	0.30	0.20	10.19	0.20	27.68	12.00	1.25	Minimum on Edge
Reinf. Layer #2	1.00	1.48	1.00	5.39	1.00	24.44	12.00	2.17	Minimum on Edge
Reinf. Layer #3	2.00	2.97	2.00	12.89	2.00	27.72	12.00	1.31	Minimum on Edge
Reinf. Layer #4	3.00	4.45	3.00	8.29	3.00	23.88	12.00	2.24	Minimum on Edge
Reinf. Layer #5	4.00	5.93	4.00	15.79	4.00	27.65	12.00	1.42	Minimum on Edge
Reinf. Layer #6	5.00	7.41	5.00	11.29	5.00	23.41	12.00	2.22	Minimum on Edge
Reinf. Layer #7	6.00	8.90	6.00	18.79	6.00	26.75	12.00	1.67	Minimum on Edge
Reinf. Layer #8	7.00	10.38	7.00	14.29	7.00	22.95	12.00	2.13	Minimum on Edge
Reinf. Layer #9	8.00	11.86	8.00	17.91	8.00	22.68	12.00	2.03	OK
Reinf. Layer #10	9.00	13.34	9.00	17.19	9.00	19.06	12.00	1.88	Minimum on Edge
Reinf. Layer #11	10.00	14.83	10.00	18.88	10.00	21.44	12.00	2.63	OK
Reinf. Layer #12	11.00	16.31	11.00	17.98	11.00	18.46	12.00	1.44	OK

Note: In the 'Status' column, OK means the critical two part-wedge was identified within the specified search domain. 'Minimum on Edge' means the critical result corresponds to a minimum on the edge of the search domain; i.e., either on X1 or X2 or the internally preset limits on Xc.

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.33
Critical Circle: Xc = 2.01[ft], Yc = 29.63[ft], R = 28.97[ft]. (Number of slices used = 53)

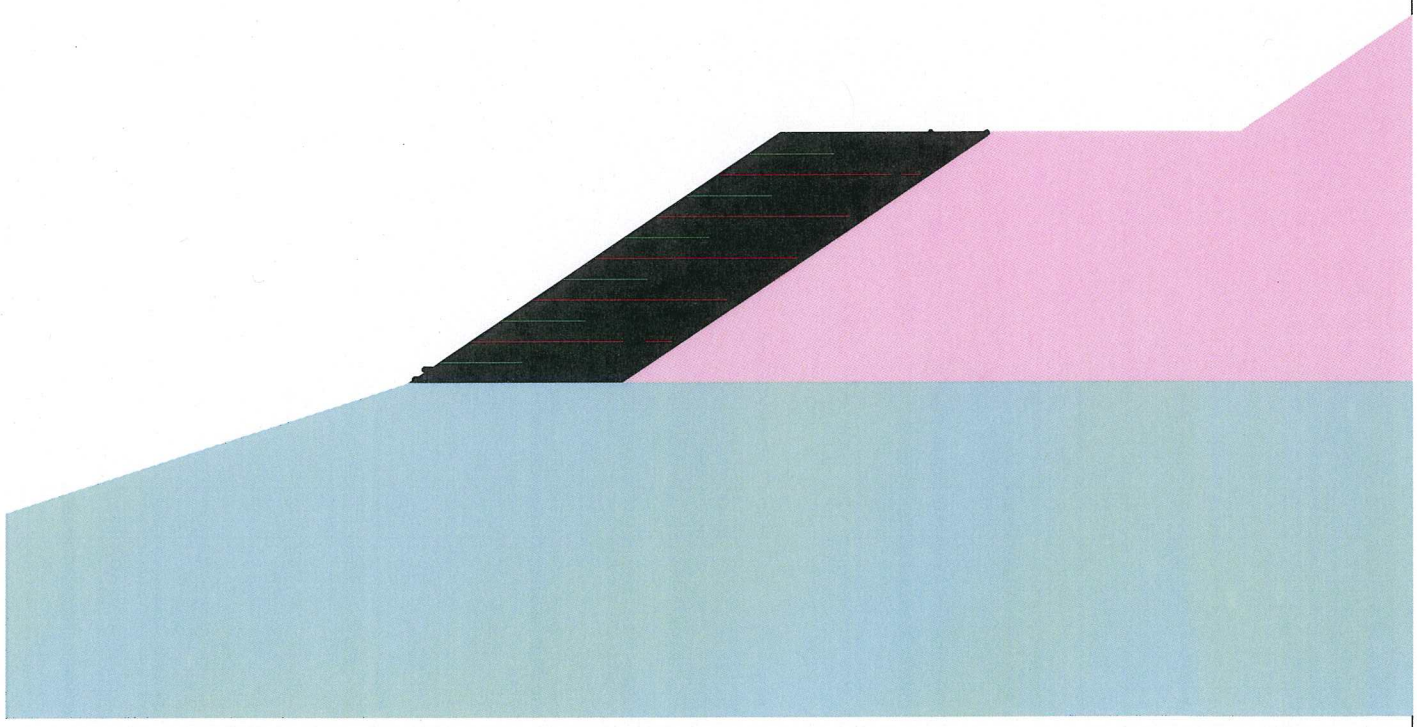
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

Minimum Factor of Safety = 1.25
Critical Two-Part Wedge: (Xa = 0.30, Ya = 0.20) [ft]
(Xb = 10.19, Yb = 0.20) [ft]
(Xc = 27.68, Yc = 12.00) [ft]
(Number of slices used = 30)
Interslice resultant force inclination = 25.35 [degrees]

Three-Part Wedge Stability Analysis

N O T C O N D U C T E D

REINFORCEMENT LAYOUT: DRAWING



SCALE:

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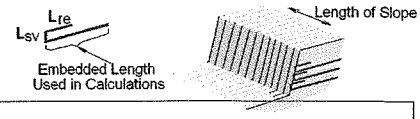

REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]		Lsv * [ft]	Lre [ft]
1	1	Geosynthetic type #1	0.20	10.00	1.00	0.30	0.20	10.30	0.20	0.00	0.00
2	2	Type #2	1.00	4.00	1.00	1.48	1.00	5.48	1.00	0.00	0.00
3	1	Geosynthetic type #1	2.00	10.00	1.00	2.97	2.00	12.97	2.00	0.00	0.00
4	2	Type #2	3.00	4.00	1.00	4.45	3.00	8.45	3.00	0.00	0.00
5	1	Geosynthetic type #1	4.00	10.00	1.00	5.93	4.00	15.93	4.00	0.00	0.00
6	2	Type #2	5.00	4.00	1.00	7.41	5.00	11.41	5.00	0.00	0.00
7	1	Geosynthetic type #1	6.00	10.00	1.00	8.90	6.00	18.90	6.00	0.00	0.00
8	2	Type #2	7.00	4.00	1.00	10.38	7.00	14.38	7.00	0.00	0.00
9	1	Geosynthetic type #1	8.00	10.00	1.00	11.86	8.00	21.86	8.00	0.00	0.00
10	2	Type #2	9.00	4.00	1.00	13.34	9.00	17.34	9.00	0.00	0.00
11	1	Geosynthetic type #1	10.00	10.00	1.00	14.83	10.00	24.83	10.00	0.00	0.00
12	2	Type #2	11.00	4.00	1.00	16.31	11.00	20.31	11.00	0.00	0.00

* Vertical distance between layers.

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]
1	Geosynthetic type #1	1.00	60.00
2	Type #2	1.00	24.00

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Theodore Roosevelt ERFO Multiple Slides

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PROJECT IDENTIFICATION

Title:	Theodore Roosevelt ERFO Multiple Slides
Project Number:	ND THRO ERFO 10(1) -
Client:	FHWA CFLHD
Designer:	Braden Peters
Station Number:	501+50

Description:

Company's information:

Name:
Street:

Telephone #:
Fax #:
E-Mail:

Original file path and name: N:\ND\ND ERFO 10(1)\Geotech\5 Analysis\RSS 501+50.MSE
Original date and time of creating this file: Thu Jan 12 11:35:08 2012

PROGRAM MODE: Analysis of a Simplified Slope using GEOSYNTHETIC as reinforcing material.

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INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

========== Soil Layer #: ==========	Unit weight, γ [lb/ft ^{3}]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ^{2}]
REINFORCED SOIL.....	125.0	30.0	0.0
RETAINED SOIL.....	125.0	14.0	480.0
FOUNDATION SOIL.....	125.0	14.0	480.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Additional Reduction Factor, RFa	Coverage Ratio, Rc
1	Geosynthetic type #1	4800.00	1.20	1.10	1.67	1.00	1.00
2	Type #2	2000.00	1.20	1.10	1.67	1.00	1.00

Interaction Parameters		== Direct Sliding ==		==== Pullout ====	
Type #	Geosynthetic Designated Name	Cds-phi	Cds-c	Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80
2	Type #2	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 1.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50
Design method for Global Stability: AASHTO/FHWA Bishop.

WATER

Unit weight of water = 62.45 [lb/ft ^{3}]
Water ponding is defined by 'phreatic surface' in Total Stress Analysis.

SEISMICITY

Not Applicable

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DRAWING OF SPECIFIED GEOMETRY - SIMPLE

GEOMETRY

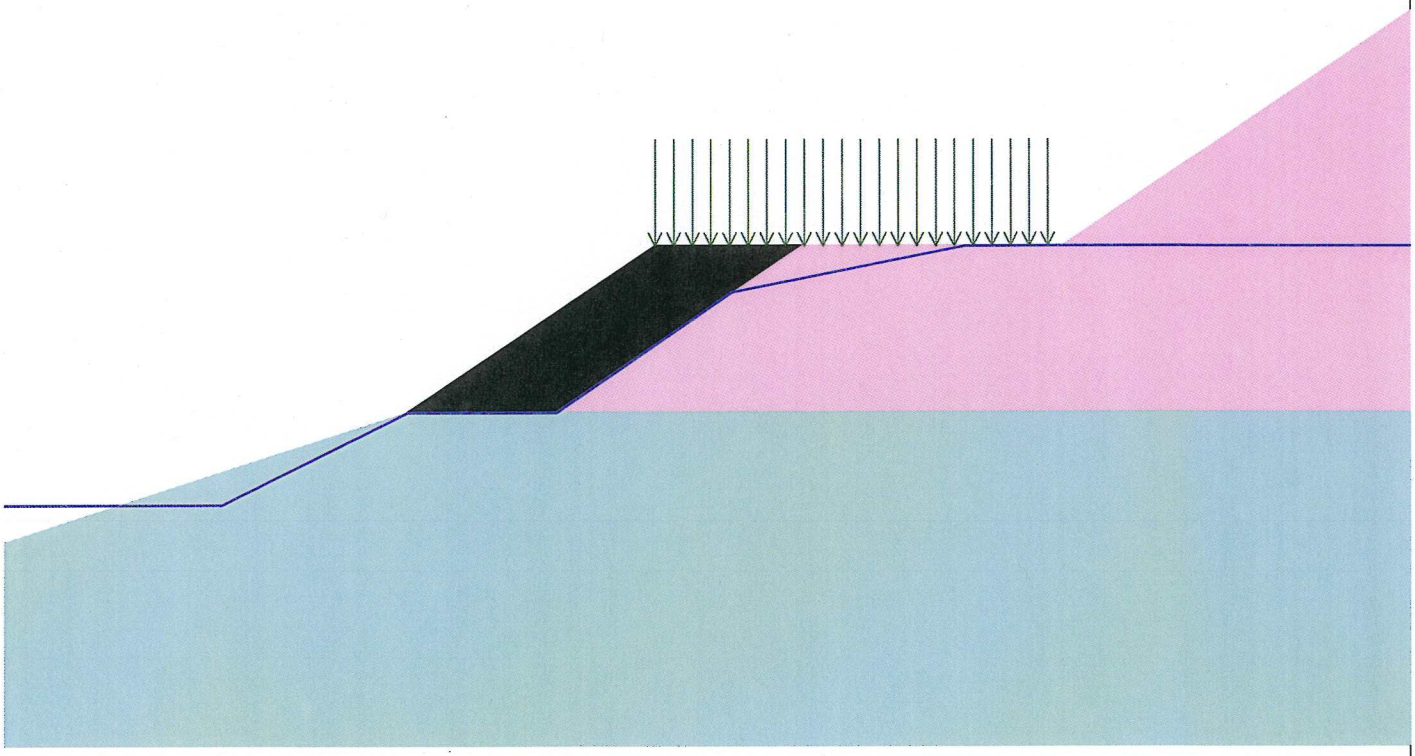
Height of slope, H	9.00	[ft]
Slope angle, i	34.00	[deg.]
Horizontal crest length, A	22.00	[ft]
Horizontal crest length, B	22.00	[ft]
Backslope angle, β	34.00	[deg.]
Sloping angle, α	18.00	[deg.]

UNIFORM SURCHARGE

Surcharge load over A, Q1	250.00	[lb/ft²]
Surcharge load over backslope B, Q2	0.00	[lb/ft²]
Surcharge load away from backslope, Q3	0.00	[lb/ft²]

WATER GEOMETRY Coordinates of water line in [ft]

#	1	Xw =	-10.00	Yw =	-5.00
#	2	Xw =	0.00	Yw =	0.00
#	3	Xw =	8.00	Yw =	0.00
#	4	Xw =	17.50	Yw =	6.50
#	5	Xw =	30.00	Yw =	9.00



SCALE:

0 2 4 6 8 10 [ft]

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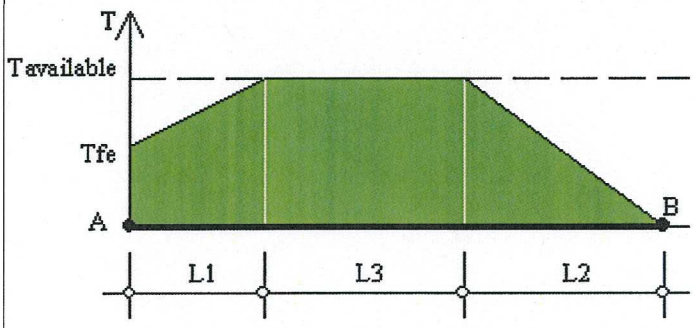
DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	0.20	8.00	0.00	8.00	0.00	1323.79	1323.79 (*)
2	Type #2	1.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
3	Geosynthetic type #1	2.00	8.00	0.00	8.00	0.00	1323.79	1323.79 (*)
4	Type #2	3.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
5	Geosynthetic type #1	4.00	8.00	0.00	8.00	0.00	1317.03	1317.03 (*)
6	Type #2	5.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
7	Geosynthetic type #1	6.00	8.00	0.00	8.00	0.00	1064.12	1064.12 (*)
8	Type #2	7.00	4.00	0.00	4.00	0.00	308.04	308.04 (*)
9	Geosynthetic type #1	8.00	8.00	0.00	8.00	0.00	446.01	446.01 (*)

(*) This Tavailable is dictated by the pullout resistance capacity, which is smaller than the long-term strength of the reinforcement that is related to its specified ultimate strength

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	15.00	9.00	0.90	0.70	4.08	11.43	11.19	1.60	
2	18.00	9.00	0.92	0.69	3.58	16.94	16.47	1.30	OK
3	21.00	9.00	0.94	0.67	-2.96	38.39	37.92	1.52	
4	24.00	9.00	-20.04	-6.47	-4.64	20.11	30.72	2.36	
5	27.00	9.00	-20.30	-6.33	-3.66	22.98	33.70	2.32	
6	30.00	9.00	-20.08	-6.46	-2.69	26.06	36.87	2.32	
7	33.00	9.00	-20.40	-6.28	-1.44	28.41	39.53	2.34	
8	36.00	9.44	-20.19	-6.40	-0.29	30.58	41.99	2.39	
9	39.00	11.47	-20.51	-6.22	0.50	32.05	43.66	2.47	
10	42.00	13.49	-20.26	-6.36	1.30	33.57	45.38	2.51	
11	45.00	15.51	-20.01	-6.49	2.49	34.07	46.39	2.52	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

****

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	-20.08	-6.46	30.00	9.00	-2.69	26.06	36.87	2.32	
2	-17.13	-5.45	27.00	9.00	-1.71	22.06	31.54	2.34	
3	-14.23	-4.43	27.00	9.00	0.02	21.83	29.87	2.39	
4	-11.10	-3.52	27.00	9.00	1.99	20.87	27.68	2.45	
5	-8.19	-2.58	18.00	9.00	-4.64	24.80	27.61	2.50	
6	-5.13	-1.61	18.00	9.00	-2.07	22.24	24.05	2.34	
7	-2.00	-0.65	21.00	9.00	-7.60	44.93	45.92	2.08	
8	0.92	0.69	18.00	9.00	3.58	16.94	16.47	1.30	OK
9	3.98	2.70	18.00	9.00	7.00	14.74	12.41	1.44	
10	6.99	4.72	18.00	9.00	9.36	14.94	10.49	1.62	
11	9.97	6.76	15.00	9.00	11.38	10.35	3.86	1.84	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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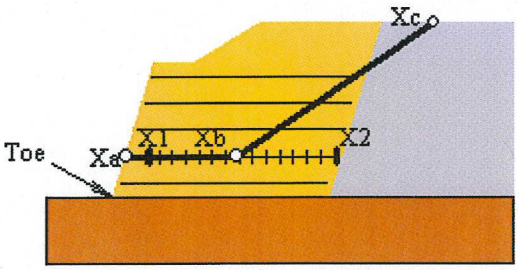
RESULTS OF TRANSLATIONAL ANALYSIS



Results in the table below represent critical two-part wedges identified between specified starting (X1) and ending (X2) search points. Wedges along all reinforcement layers and at elevation zero are reported. The critical two-part wedge, one for each predetermined elevation, is defined by Xa, Xb and Xc where Xa is the front end of the passive wedge (slope face), Xb is where the passive wedge ends and the active one starts, and Xc is the X-ordinate at which the active wedge starts.

Critical two-part wedge along each interface:

Interface	Height Relative to Toe [ft]	(Xa, Ya) [ft]		(Xb, Yb) [ft]		(Xc, Yc) [ft]		Fs	STATUS
At toe elevation	0.00	0.00	0.00	7.80	0.00	21.14	9.00	1.36	Minimum on Edge
Reinf. Layer #1	0.20	0.30	0.20	8.19	0.20	21.24	9.00	1.26	Minimum on Edge
Reinf. Layer #2	1.00	1.48	1.00	5.39	1.00	19.25	9.00	1.75	Minimum on Edge
Reinf. Layer #3	2.00	2.97	2.00	10.89	2.00	21.27	9.00	1.34	Minimum on Edge
Reinf. Layer #4	3.00	4.45	3.00	8.29	3.00	18.68	9.00	1.81	Minimum on Edge
Reinf. Layer #5	4.00	5.93	4.00	13.79	4.00	19.96	9.00	1.54	Minimum on Edge
Reinf. Layer #6	5.00	7.41	5.00	11.29	5.00	17.45	9.00	1.79	Minimum on Edge
Reinf. Layer #7	6.00	8.90	6.00	13.71	6.00	17.17	9.00	1.94	OK
Reinf. Layer #8	7.00	10.38	7.00	13.55	7.00	15.11	9.00	1.53	OK
Reinf. Layer #9	8.00	11.86	8.00	13.64	8.00	14.24	9.00	2.50	OK

Note: In the 'Status' column, OK means the critical two part-wedge was identified within the specified search domain. 'Minimum on Edge' means the critical result corresponds to a minimum on the edge of the search domain; i.e., either on X1 or X2 or the internally preset limits on Xc.

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.30
Critical Circle: Xc = 3.58[ft], Yc = 16.94[ft], R = 16.47[ft]. (Number of slices used = 54)

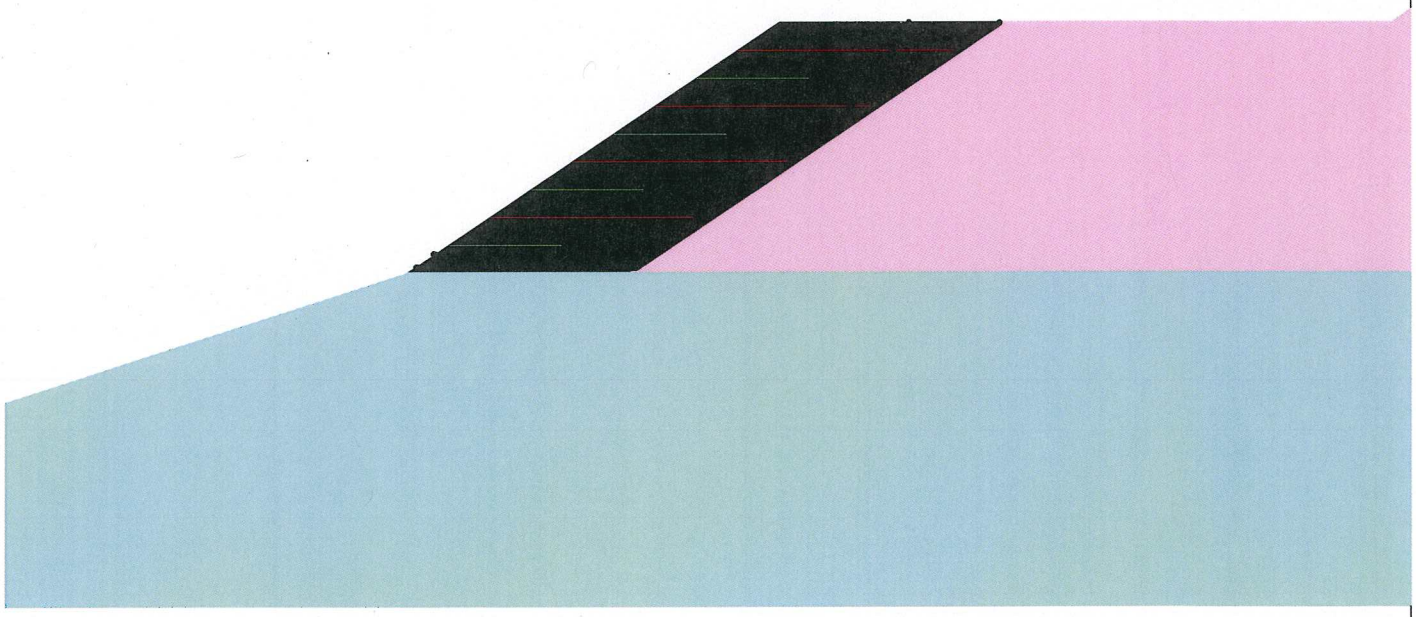
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

Minimum Factor of Safety = 1.26
Critical Two-Part Wedge: (Xa = 0.30, Ya = 0.20) [ft]
(Xb = 8.19, Yb = 0.20) [ft]
(Xc = 21.24, Yc = 9.00) [ft]
(Number of slices used = 30)
Interslice resultant force inclination = 25.03 [degrees]

Three-Part Wedge Stability Analysis

N O T C O N D U C T E D

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0 2 4 6 8 10 [ft]

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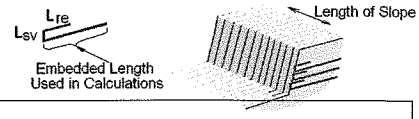

REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]		Lsv * [ft]	Lre [ft]
1	1	Geosynthetic type #1	0.20	8.00	1.00	0.30	0.20	8.30	0.20	0.80	3.00
2	2	Type #2	1.00	4.00	1.00	1.48	1.00	5.48	1.00	1.00	3.00
3	1	Geosynthetic type #1	2.00	8.00	1.00	2.97	2.00	10.97	2.00	1.00	3.00
4	2	Type #2	3.00	4.00	1.00	4.45	3.00	8.45	3.00	1.00	3.00
5	1	Geosynthetic type #1	4.00	8.00	1.00	5.93	4.00	13.93	4.00	1.00	3.00
6	2	Type #2	5.00	4.00	1.00	7.41	5.00	11.41	5.00	1.00	3.00
7	1	Geosynthetic type #1	6.00	8.00	1.00	8.90	6.00	16.90	6.00	1.00	3.00
8	2	Type #2	7.00	4.00	1.00	10.38	7.00	14.38	7.00	1.00	3.00
9	1	Geosynthetic type #1	8.00	8.00	1.00	11.86	8.00	19.86	8.00	1.00	3.00

* Vertical distance between layers.

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]	
1	Geosynthetic type #1	1.00	(including Lsv & Lre)	59.80
2	Type #2	1.00		32.00

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Theodore Roosevelt ERFO Multiple Slides

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PROJECT IDENTIFICATION

Title:	Theodore Roosevelt ERFO Multiple Slides
Project Number:	ND THRO ERFO 10(1) -
Client:	FHWA CFLHD
Designer:	Braden Peters
Station Number:	600+70

Description:

Company's information:

Name:
Street:

Telephone #:
Fax #:
E-Mail:

Original file path and name: N:\ND\ND ERFO 10(1)\Geotech\5 Analysis\RSS 600+70.MSE
Original date and time of creating this file: Thu Jan 12 11:35:08 2012

PROGRAM MODE: Analysis of a Simplified Slope using GEOSYNTHETIC as reinforcing material.

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INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

========== Soil Layer #: ==========	Unit weight, γ [lb/ft ^{3}]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ^{2}]
REINFORCED SOIL.....	125.0	30.0	0.0
RETAINED SOIL.....	115.0	14.0	480.0
FOUNDATION SOIL.....	115.0	14.0	480.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Additional Reduction Factor, RFa	Coverage Ratio, Rc
1	Geosynthetic type #1	4800.00	1.20	1.10	1.67	1.00	1.00
2	Type #2	2000.00	1.20	1.10	1.67	1.00	1.00

Interaction Parameters Type #	Geosynthetic Designated Name	== Direct Sliding == Cds-phi	Cds-c	==== Pullout ==== Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80
2	Type #2	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 1.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50
Design method for Global Stability: AASHTO/FHWA Bishop.

WATER

Unit weight of water = 62.45 [lb/ft ^{3}]
Water ponding is defined by 'phreatic surface' in Total Stress Analysis.

SEISMICITY

Not Applicable

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DRAWING OF SPECIFIED GEOMETRY - SIMPLE

GEOMETRY

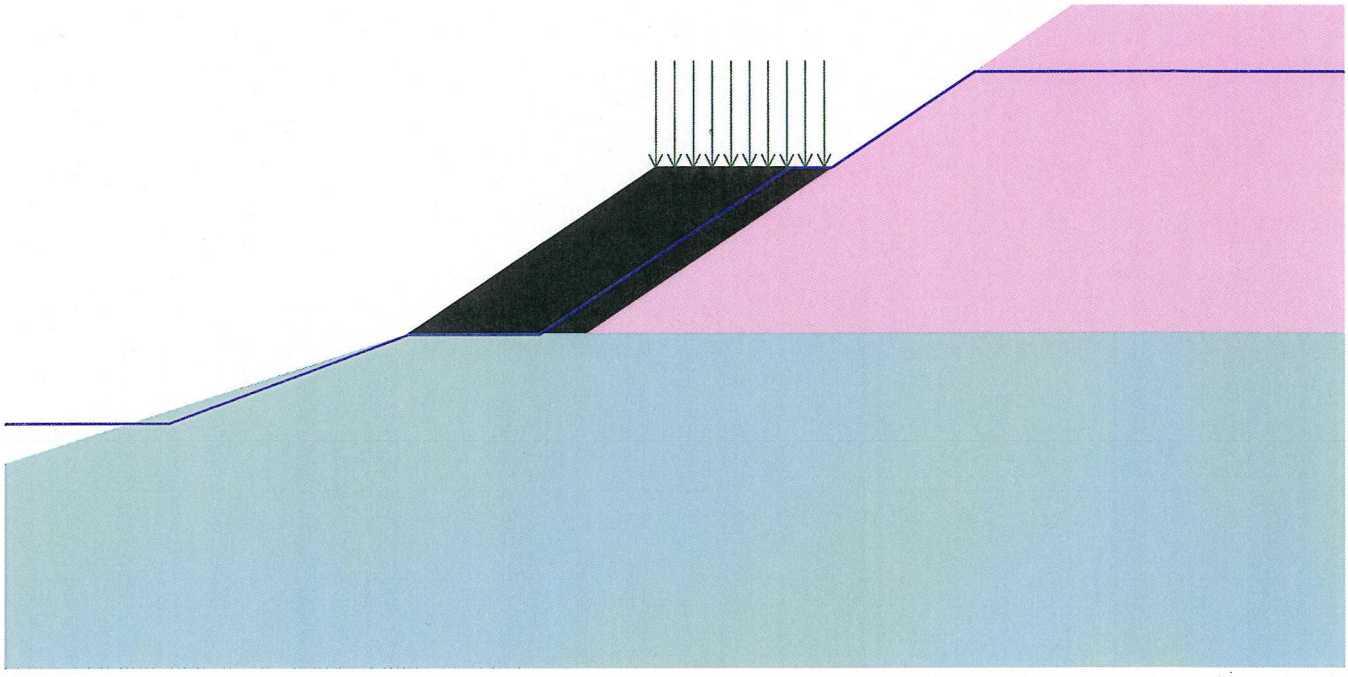
Height of slope, H	28.00	[ft]
Slope angle, i	34.00	[deg.]
Horizontal crest length, A	30.00	[ft]
Horizontal crest length, B	30.00	[ft]
Backslope angle, β	34.00	[deg.]
Sloping angle, α	18.00	[deg.]

UNIFORM SURCHARGE

Surcharge load over A, Q1	250.00	[lb/ft²]
Surcharge load over backslope B, Q2	0.00	[lb/ft²]
Surcharge load away from backslope, Q3	0.00	[lb/ft²]

WATER GEOMETRY Coordinates of water line in [ft]

#	1	Xw =	-40.00	Yw =	-15.00
#	2	Xw =	0.00	Yw =	0.00
#	3	Xw =	22.00	Yw =	0.00
#	4	Xw =	64.00	Yw =	28.00
#	5	Xw =	71.00	Yw =	28.00
#	6	Xw =	95.00	Yw =	44.00



SCALE:

0 5 10 15 20 25 30 [ft]

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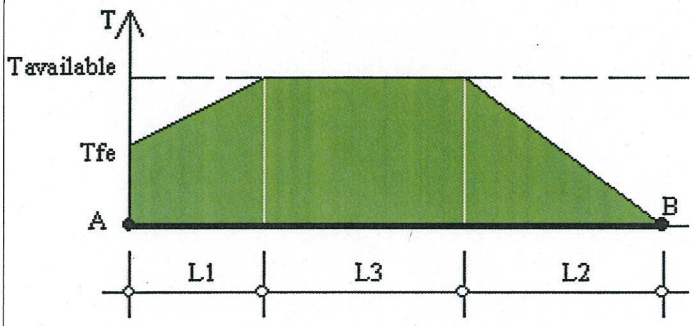
DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	0.20	22.00	0.00	2.56	19.44	2177.46	2177.46
2	Type #2	1.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
3	Geosynthetic type #1	2.00	20.00	0.00	2.85	17.15	2177.46	2177.46
4	Type #2	3.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
5	Geosynthetic type #1	4.00	22.00	0.00	2.56	19.44	2177.46	2177.46
6	Type #2	5.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
7	Geosynthetic type #1	6.00	20.00	0.00	2.85	17.15	2177.46	2177.46
8	Type #2	7.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
9	Geosynthetic type #1	8.00	22.00	0.00	2.56	19.44	2177.46	2177.46
10	Type #2	9.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
11	Geosynthetic type #1	10.00	20.00	0.00	2.85	17.15	2177.46	2177.46
12	Type #2	11.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
13	Geosynthetic type #1	12.00	22.00	0.00	2.56	19.44	2177.46	2177.46
14	Type #2	13.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
15	Geosynthetic type #1	14.00	20.00	0.00	2.85	17.15	2177.46	2177.46
16	Type #2	15.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
17	Geosynthetic type #1	16.00	22.00	0.00	2.95	19.05	2177.46	2177.46
18	Type #2	17.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
19	Geosynthetic type #1	18.00	20.00	0.00	3.54	16.46	2177.46	2177.46
20	Type #2	19.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
21	Geosynthetic type #1	20.00	22.00	0.00	4.43	17.57	2177.46	2177.46
22	Type #2	21.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
23	Geosynthetic type #1	22.00	20.00	0.00	5.91	14.09	2177.46	2177.46
24	Type #2	23.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
25	Geosynthetic type #1	24.00	30.00	0.00	8.86	21.14	2177.46	2177.46
26	Type #2	25.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
27	Geosynthetic type #1	26.00	28.00	0.00	17.68	10.32	2177.46	2177.46
28	Type #2	27.00	4.00	0.00	4.00	0.00	199.67	199.67 (*)

(*) This Tavailable is dictated by the pullout resistance capacity, which is smaller than the long-term strength of the reinforcement that is related to its specified ultimate strength

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	40.00	26.98	-20.46	-6.22	0.40	27.45	39.61	2.03	
2	43.00	28.00	-20.10	-6.44	1.82	28.43	41.18	1.82	
3	46.00	28.00	-20.61	-6.09	3.28	29.35	42.74	1.70	
4	49.00	28.00	-20.44	-6.24	3.11	33.53	46.22	1.57	
5	52.00	28.00	-20.27	-6.37	2.33	39.28	50.94	1.47	
6	55.00	28.00	-20.09	-6.46	1.25	46.09	56.72	1.40	
7	58.00	28.00	-20.75	-6.22	1.05	51.34	61.55	1.38	
8	61.00	28.00	-20.54	-6.32	0.71	57.23	67.01	1.37	
9	64.00	28.00	-20.31	-6.40	0.95	62.01	71.64	1.36	OK
10	67.00	28.00	-20.04	-6.49	2.67	63.28	73.37	1.37	
11	70.00	28.00	-20.78	-6.24	3.68	66.38	76.62	1.40	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

****

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	-20.31	-6.40	64.00	28.00	0.95	62.01	71.64	1.36	On extreme X-exit
2	-14.52	-4.70	64.00	28.00	4.28	60.77	68.12	1.37	
3	-9.43	-2.81	61.00	28.00	6.79	56.02	61.02	1.39	
4	-3.76	-1.06	61.00	28.00	11.58	51.45	54.70	1.42	
5	1.65	1.40	58.00	28.00	10.58	55.49	54.82	1.43	
6	7.35	5.09	58.00	28.00	16.02	53.36	49.05	1.51	
7	12.54	8.85	61.00	28.00	21.51	57.04	49.02	1.66	
8	18.24	12.51	64.00	28.00	25.22	67.23	55.16	1.93	
9	23.83	16.25	61.00	28.00	35.13	45.18	31.06	2.30	
10	29.25	19.99	64.00	28.00	40.32	51.33	33.24	3.06	
11	34.99	23.61	49.00	28.00	39.02	35.29	12.36	3.77	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.36
Critical Circle: Xc = 0.95[ft], Yc = 62.01[ft], R = 71.64[ft]. (Number of slices used = 55)

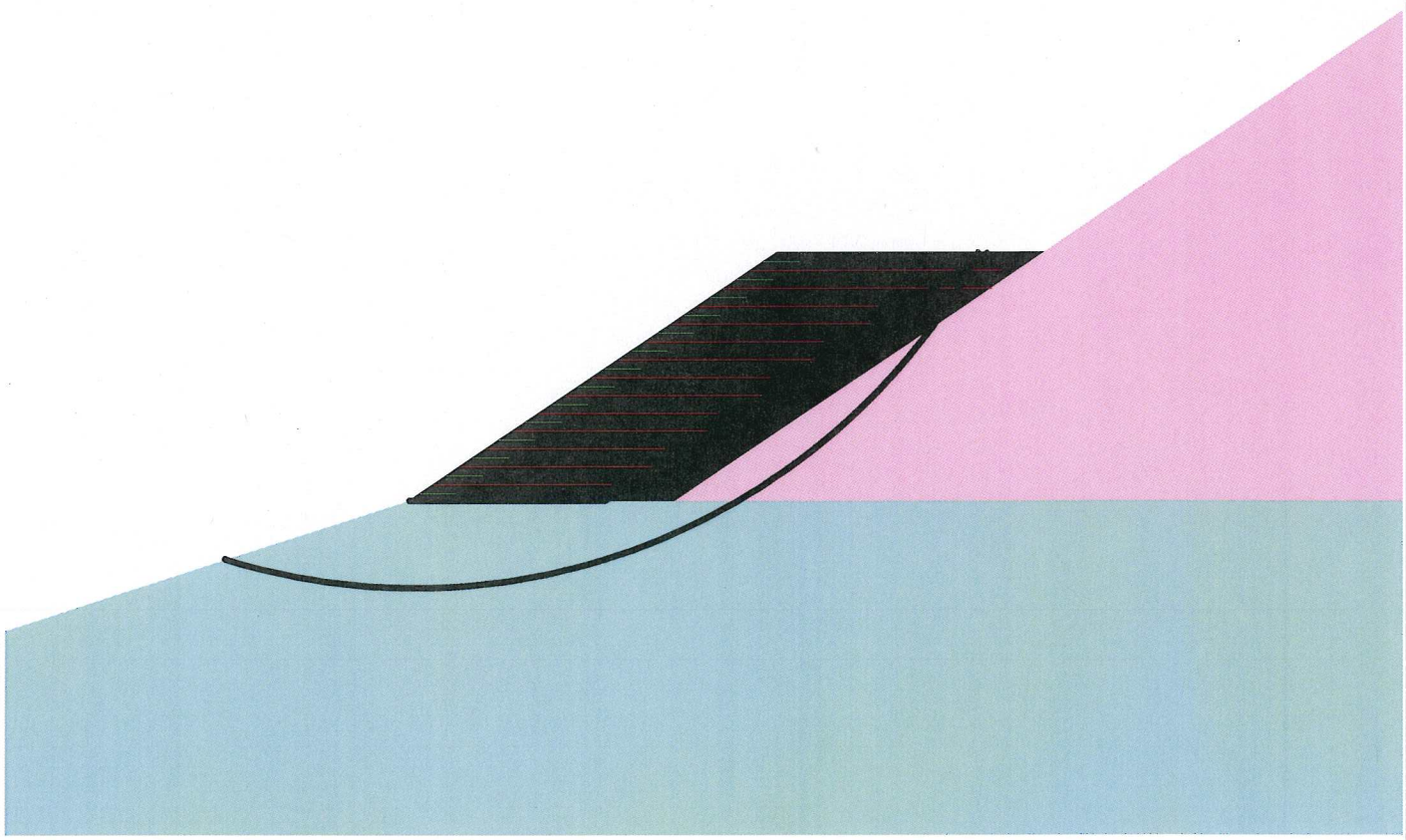
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

Minimum Factor of Safety = 1.32
Critical Two-Part Wedge: (Xa = 0.30, Ya = 0.20) [ft]
(Xb = 22.19, Yb = 0.20) [ft]
(Xc = 65.00, Yc = 28.00) [ft]
(Number of slices used = 30)
Interslice resultant force inclination = 23.26 [degrees]

Three-Part Wedge Stability Analysis

N O T C O N D U C T E D

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0 5 10 15 20 25 30 [ft]

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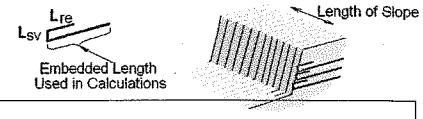

REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]		Lsv * [ft]	Lre [ft]
1	1	Geosynthetic type #1	0.20	22.00	1.00	0.30	0.20	22.30	0.20	0.00	0.00
2	2	Type #2	1.00	4.00	1.00	1.48	1.00	5.48	1.00	0.00	0.00
3	1	Geosynthetic type #1	2.00	20.00	1.00	2.97	2.00	22.97	2.00	0.00	0.00
4	2	Type #2	3.00	4.00	1.00	4.45	3.00	8.45	3.00	0.00	0.00
5	1	Geosynthetic type #1	4.00	22.00	1.00	5.93	4.00	27.93	4.00	0.00	0.00
6	2	Type #2	5.00	4.00	1.00	7.41	5.00	11.41	5.00	0.00	0.00
7	1	Geosynthetic type #1	6.00	20.00	1.00	8.90	6.00	28.90	6.00	0.00	0.00
8	2	Type #2	7.00	4.00	1.00	10.38	7.00	14.38	7.00	0.00	0.00
9	1	Geosynthetic type #1	8.00	22.00	1.00	11.86	8.00	33.86	8.00	0.00	0.00
10	2	Type #2	9.00	4.00	1.00	13.34	9.00	17.34	9.00	0.00	0.00
11	1	Geosynthetic type #1	10.00	20.00	1.00	14.83	10.00	34.83	10.00	0.00	0.00
12	2	Type #2	11.00	4.00	1.00	16.31	11.00	20.31	11.00	0.00	0.00
13	1	Geosynthetic type #1	12.00	22.00	1.00	17.79	12.00	39.79	12.00	0.00	0.00
14	2	Type #2	13.00	4.00	1.00	19.27	13.00	23.27	13.00	0.00	0.00
15	1	Geosynthetic type #1	14.00	20.00	1.00	20.76	14.00	40.76	14.00	0.00	0.00
16	2	Type #2	15.00	4.00	1.00	22.24	15.00	26.24	15.00	0.00	0.00
17	1	Geosynthetic type #1	16.00	22.00	1.00	23.72	16.00	45.72	16.00	0.00	0.00
18	2	Type #2	17.00	4.00	1.00	25.20	17.00	29.20	17.00	0.00	0.00
19	1	Geosynthetic type #1	18.00	20.00	1.00	26.69	18.00	46.69	18.00	0.00	0.00
20	2	Type #2	19.00	4.00	1.00	28.17	19.00	32.17	19.00	0.00	0.00
21	1	Geosynthetic type #1	20.00	22.00	1.00	29.65	20.00	51.65	20.00	0.00	0.00
22	2	Type #2	21.00	4.00	1.00	31.13	21.00	35.13	21.00	0.00	0.00
23	1	Geosynthetic type #1	22.00	20.00	1.00	32.62	22.00	52.62	22.00	0.00	0.00
24	2	Type #2	23.00	4.00	1.00	34.10	23.00	38.10	23.00	0.00	0.00
25	1	Geosynthetic type #1	24.00	30.00	1.00	35.58	24.00	65.58	24.00	0.00	0.00
26	2	Type #2	25.00	4.00	1.00	37.06	25.00	41.06	25.00	0.00	0.00
27	1	Geosynthetic type #1	26.00	28.00	1.00	38.55	26.00	66.55	26.00	0.00	0.00
28	2	Type #2	27.00	4.00	1.00	40.03	27.00	44.03	27.00	0.00	0.00

* Vertical distance between layers.

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]
1	Geosynthetic type #1	1.00	310.00
2	Type #2	1.00	56.00

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Theodore Roosevelt ERFO Multiple Slides

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PROJECT IDENTIFICATION

Title: Theodore Roosevelt ERFO Multiple Slides
Project Number: ND THRO ERFO 10(1) -
Client: FHWA CFLHD
Designer: Braden Peters
Station Number: 601+00

Description:
Maximum Slope Height

Company's information:

Name:
Street:

Telephone #:
Fax #:
E-Mail:

Original file path and name: N:\ND\ND ERFO 10(1)\Geotech\5 Analysis\RSS 601+00.MSE
Original date and time of creating this file: Thu Jan 12 11:35:08 2012

PROGRAM MODE: Analysis of a Simplified Slope using GEOSYNTHETIC as reinforcing material.

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INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

========== Soil Layer #: ==========	Unit weight, γ [lb/ft ^{3}]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ^{2}]
REINFORCED SOIL.....	125.0	30.0	0.0
RETAINED SOIL.....	115.0	14.0	480.0
FOUNDATION SOIL.....	115.0	14.0	480.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Additional Reduction Factor, RFa	Coverage Ratio, Rc
1	Geosynthetic type #1	4800.00	1.20	1.10	1.67	1.00	1.00
2	Type #2	2000.00	1.20	1.10	1.67	1.00	1.00

Interaction Parameters		== Direct Sliding ==		==== Pullout ====	
Type #	Geosynthetic Designated Name	Cds-phi	Cds-c	Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80
2	Type #2	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 1.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50
Design method for Global Stability: Comprehensive Bishop.

WATER

Unit weight of water = 62.45 [lb/ft ^{3}]
Water ponding is defined by 'phreatic surface' in Total Stress Analysis.

SEISMICITY

Not Applicable

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Version 3.0 ReSSA Version 3.0

DRAWING OF SPECIFIED GEOMETRY - SIMPLE

GEOMETRY

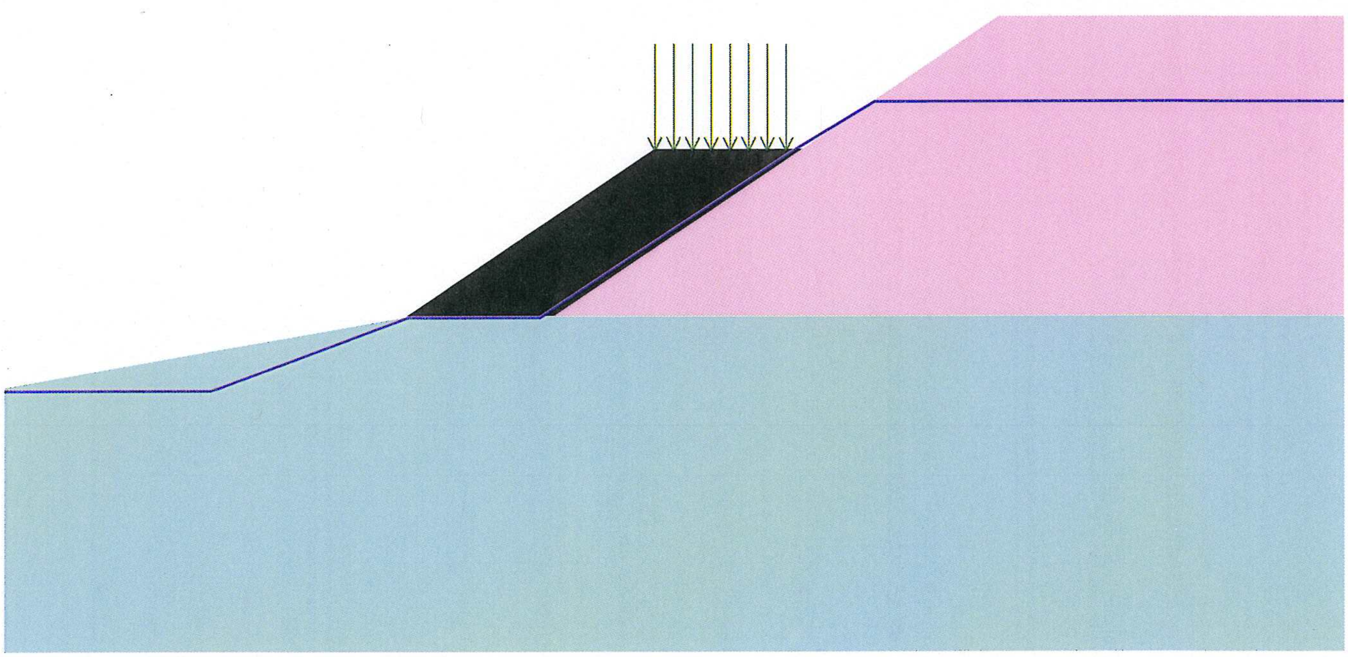
Height of slope, H .... 34.00 [ft]
Slope angle, i .... 34.00 [deg.]
Horizontal crest length, A .... 30.00 [ft]
Horizontal crest length, B .... 30.00 [ft]
Backslope angle, β .... 34.00 [deg.]
Sloping angle, α .... 10.00 [deg.]

WATER GEOMETRY Coordinates of water line in [ft]

#	1	Xw =	-40.00	Yw =	-15.00
#	2	Xw =	0.00	Yw =	0.00
#	3	Xw =	27.00	Yw =	0.00
#	4	Xw =	80.00	Yw =	35.00
#	5	Xw =	95.00	Yw =	44.00

UNIFORM SURCHARGE

Surcharge load over A, Q1............................ 250.00 [lb/ft^2]
Surcharge load over backslope B, Q2........... 0.00 [lb/ft^2]
Surcharge load away from backslope, Q3...... 0.00 [lb/ft^2]



SCALE:

0 5 1015202530 [ft]

Version 3.0 ReSSA Version 3.0

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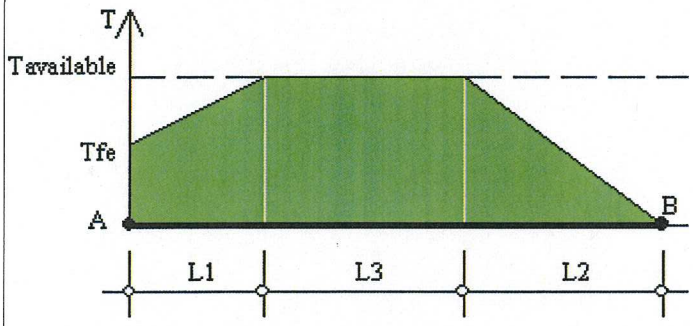
DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	0.20	27.00	0.00	2.03	24.97	2177.46	2177.46
2	Type #2	1.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
3	Geosynthetic type #1	2.00	24.00	0.00	2.30	21.70	2177.46	2177.46
4	Type #2	3.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
5	Geosynthetic type #1	4.00	27.00	0.00	2.03	24.97	2177.46	2177.46
6	Type #2	5.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
7	Geosynthetic type #1	6.00	24.00	0.00	2.30	21.70	2177.46	2177.46
8	Type #2	7.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
9	Geosynthetic type #1	8.00	27.00	0.00	2.03	24.97	2177.46	2177.46
10	Type #2	9.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
11	Geosynthetic type #1	10.00	24.00	0.00	2.30	21.70	2177.46	2177.46
12	Type #2	11.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
13	Geosynthetic type #1	12.00	27.00	0.00	2.03	24.97	2177.46	2177.46
14	Type #2	13.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
15	Geosynthetic type #1	14.00	24.00	0.00	2.30	21.70	2177.46	2177.46
16	Type #2	15.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
17	Geosynthetic type #1	16.00	27.00	0.00	2.03	24.97	2177.46	2177.46
18	Type #2	17.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
19	Geosynthetic type #1	18.00	24.00	0.00	2.33	21.67	2177.46	2177.46
20	Type #2	19.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
21	Geosynthetic type #1	20.00	27.00	0.00	2.53	24.47	2177.46	2177.46
22	Type #2	21.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
23	Geosynthetic type #1	22.00	24.00	0.00	2.95	21.05	2177.46	2177.46
24	Type #2	23.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
25	Geosynthetic type #1	24.00	27.00	0.00	3.54	23.46	2177.46	2177.46
26	Type #2	25.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
27	Geosynthetic type #1	26.00	24.00	0.00	4.43	19.57	2177.46	2177.46
28	Type #2	27.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
29	Geosynthetic type #1	28.00	27.00	0.00	5.91	21.09	2177.46	2177.46
30	Type #2	29.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
31	Geosynthetic type #1	30.00	30.00	0.00	8.86	21.14	2177.46	2177.46
32	Type #2	31.00	4.00	0.00	4.00	0.00	329.59	329.59 (*)
33	Geosynthetic type #1	32.00	28.00	0.00	17.68	10.32	2177.46	2177.46
34	Type #2	33.00	4.00	0.00	4.00	0.00	199.67	199.67 (*)

(*) This Tavailable is dictated by the pullout resistance capacity, which is smaller than the long-term strength of the reinforcement that is related to its specified ultimate strength

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	45.00	30.36	-29.34	-4.45	-0.55	30.86	45.56	2.08	
2	51.50	34.00	-17.81	-3.13	6.64	34.49	44.87	1.74	
3	58.00	34.00	-7.29	-1.04	15.92	34.06	42.08	1.47	
4	64.50	34.00	-7.08	-1.20	13.56	47.21	52.62	1.36	
5	71.00	34.00	-7.77	-1.02	10.48	64.02	67.55	1.30	OK
6	77.50	34.00	-12.47	-2.17	9.33	73.60	78.84	1.32	
7	82.63	34.00	-18.78	-2.80	9.72	76.80	84.54	1.37	
8	86.68	34.00	-23.76	-3.89	8.32	82.51	92.16	1.39	
9	90.52	34.00	-29.68	-4.64	6.11	90.31	101.48	1.40	
10	94.53	34.00	-29.33	-4.77	7.61	94.44	105.87	1.40	
11	94.75	34.00	-28.80	-5.00	-1.34	123.21	131.12	1.43	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

****

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	-34.50	-5.78	77.50	34.00	0.10	74.35	87.28	1.36	
2	-29.05	-4.85	71.00	34.00	1.27	65.33	76.45	1.34	
3	-23.86	-3.82	71.00	34.00	4.19	63.70	73.12	1.32	
4	-18.44	-2.90	71.00	34.00	6.47	63.56	70.97	1.31	
5	-12.78	-2.06	71.00	34.00	8.82	63.12	68.66	1.30	
6	-7.77	-1.02	71.00	34.00	10.48	64.02	67.55	1.30	OK
7	-2.40	-0.08	71.00	34.00	13.74	61.25	63.41	1.30	
8	3.57	2.65	71.00	34.00	21.72	51.80	52.40	1.33	
9	8.68	6.33	71.00	34.00	21.80	60.79	56.02	1.43	
10	14.29	9.93	71.00	34.00	27.44	57.78	49.63	1.58	
11	19.68	13.55	77.50	34.00	31.43	72.30	59.91	1.78	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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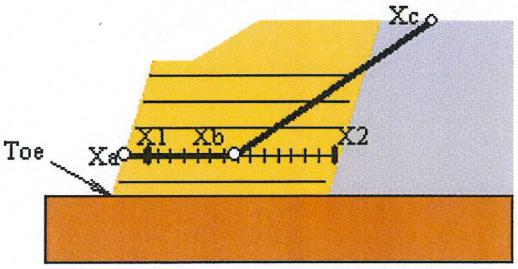
RESULTS OF TRANSLATIONAL ANALYSIS



Results in the table below represent critical two-part wedges identified between specified starting (X1) and ending (X2) search points. Wedges along all reinforcement layers and at elevation zero are reported. The critical two-part wedge, one for each predetermined elevation, is defined by Xa, Xb and Xc where Xa is the front end of the passive wedge (slope face), Xb is where the passive wedge ends and the active one starts, and Xc is the X-ordinate at which the active wedge starts.

Critical two-part wedge along each interface:

Interface	Height Relative to Toe [ft]	(Xa, Ya) [ft]		(Xb, Yb) [ft]		(Xc, Yc) [ft]		Fs	STATUS
At toe elevation	0.00	0.00	0.00	29.80	0.00	76.60	34.00	1.39	Minimum on Edge
Reinf. Layer #1	0.20	0.30	0.20	27.19	0.20	79.24	34.00	1.28	Minimum on Edge
Reinf. Layer #2	1.00	1.48	1.00	5.39	1.00	62.55	34.00	2.93	Minimum on Edge
Reinf. Layer #3	2.00	2.97	2.00	26.89	2.00	80.15	34.00	1.43	Minimum on Edge
Reinf. Layer #4	3.00	4.45	3.00	8.29	3.00	61.98	34.00	2.99	Minimum on Edge
Reinf. Layer #5	4.00	5.93	4.00	32.79	4.00	78.99	34.00	1.34	Minimum on Edge
Reinf. Layer #6	5.00	7.41	5.00	11.29	5.00	61.52	34.00	3.03	Minimum on Edge
Reinf. Layer #7	6.00	8.90	6.00	32.79	6.00	79.39	34.00	1.52	Minimum on Edge
Reinf. Layer #8	7.00	10.38	7.00	14.29	7.00	61.06	34.00	3.08	Minimum on Edge
Reinf. Layer #9	8.00	11.86	8.00	38.79	8.00	78.83	34.00	1.42	Minimum on Edge
Reinf. Layer #10	9.00	13.34	9.00	17.19	9.00	60.49	34.00	3.15	Minimum on Edge
Reinf. Layer #11	10.00	14.83	10.00	38.69	10.00	80.26	34.00	1.60	Minimum on Edge
Reinf. Layer #12	11.00	16.31	11.00	20.19	11.00	60.03	34.00	3.21	Minimum on Edge
Reinf. Layer #13	12.00	17.79	12.00	44.69	12.00	78.57	34.00	1.54	Minimum on Edge
Reinf. Layer #14	13.00	19.27	13.00	23.19	13.00	59.56	34.00	3.15	Minimum on Edge
Reinf. Layer #15	14.00	20.76	14.00	44.69	14.00	79.33	34.00	1.75	Minimum on Edge
Reinf. Layer #16	15.00	22.24	15.00	26.09	15.00	59.00	34.00	3.34	Minimum on Edge
Reinf. Layer #17	16.00	23.72	16.00	50.59	16.00	78.31	34.00	1.75	Minimum on Edge
Reinf. Layer #18	17.00	25.20	17.00	29.09	17.00	58.53	34.00	3.39	Minimum on Edge
Reinf. Layer #19	18.00	26.69	18.00	50.59	18.00	78.30	34.00	2.01	Minimum on Edge
Reinf. Layer #20	19.00	28.17	19.00	32.09	19.00	58.07	34.00	3.45	Minimum on Edge
Reinf. Layer #21	20.00	29.65	20.00	56.59	20.00	78.15	34.00	2.17	Minimum on Edge
Reinf. Layer #22	21.00	31.13	21.00	34.99	21.00	57.51	34.00	3.53	Minimum on Edge
Reinf. Layer #23	22.00	32.62	22.00	56.49	22.00	77.27	34.00	2.53	Minimum on Edge
Reinf. Layer #24	23.00	34.10	23.00	37.99	23.00	57.04	34.00	3.50	Minimum on Edge
Reinf. Layer #25	24.00	35.58	24.00	62.49	24.00	78.49	34.00	2.85	Minimum on Edge
Reinf. Layer #26	25.00	37.06	25.00	40.99	25.00	56.58	34.00	3.62	Minimum on Edge
Reinf. Layer #27	26.00	38.55	26.00	48.18	26.00	58.79	34.00	3.11	OK
Reinf. Layer #28	27.00	40.03	27.00	43.89	27.00	56.01	34.00	3.64	Minimum on Edge
Reinf. Layer #29	28.00	41.51	28.00	47.04	28.00	55.93	34.00	3.56	OK
Reinf. Layer #30	29.00	42.99	29.00	46.89	29.00	55.21	34.00	3.49	Minimum on Edge
Reinf. Layer #31	30.00	44.48	30.00	50.64	30.00	54.37	34.00	3.58	OK
Reinf. Layer #32	31.00	45.96	31.00	49.89	31.00	53.73	34.00	3.23	Minimum on Edge
Reinf. Layer #33	32.00	47.44	32.00	53.14	32.00	56.10	34.00	5.45	OK
Reinf. Layer #34	33.00	48.92	33.00	50.58	33.00	51.61	34.00	1.44	OK

Note: In the 'Status' column, OK means the critical two part-wedge was identified within the specified search domain. 'Minimum on Edge' means the critical result corresponds to a minimum on the edge of the search domain; i.e., either on X1 or X2 or the internally preset limits on Xc.

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.30
Critical Circle: Xc = 10.48[ft], Yc = 64.02[ft], R = 67.55[ft]. (Number of slices used = 54)

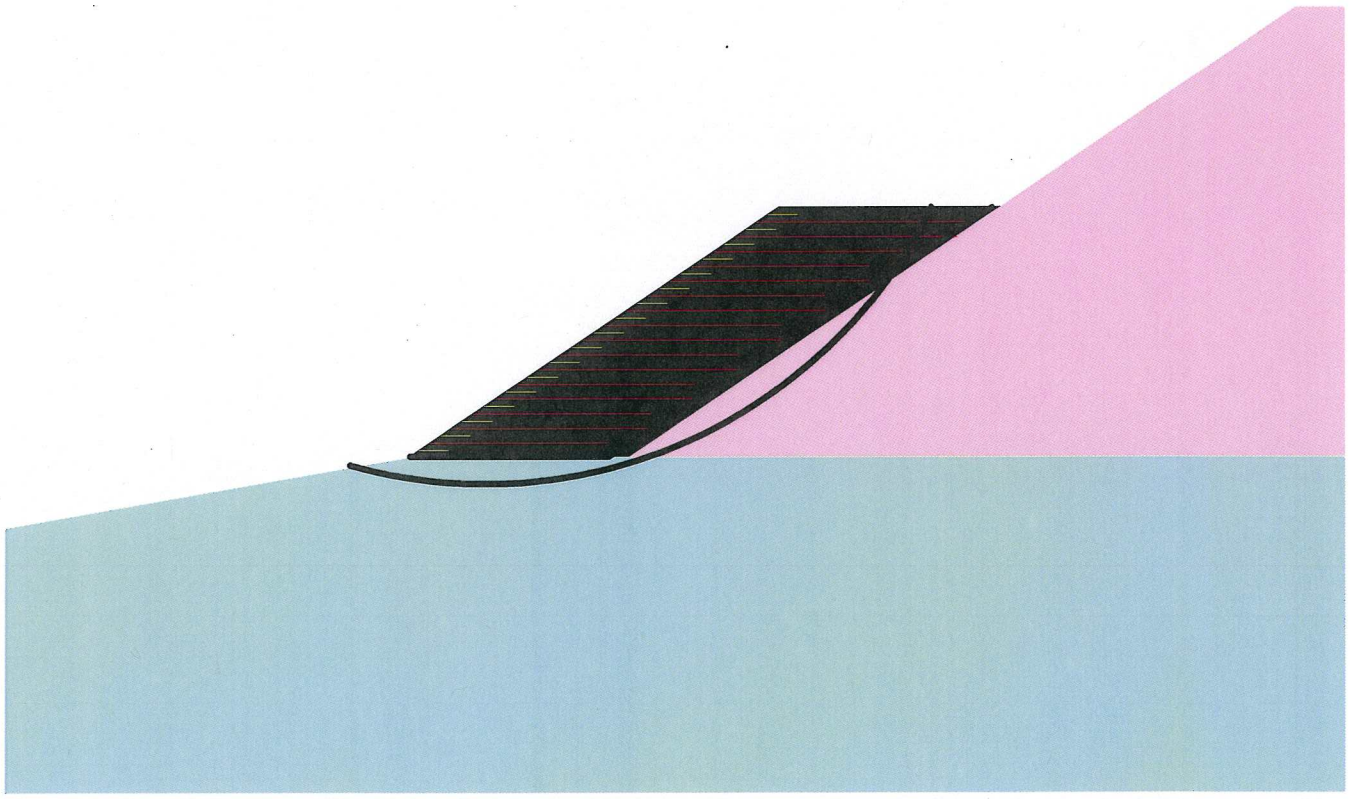
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

Minimum Factor of Safety = 1.28
Critical Two-Part Wedge: (Xa = 0.30, Ya = 0.20) [ft]
(Xb = 27.19, Yb = 0.20) [ft]
(Xc = 79.24, Yc = 34.00) [ft]
(Number of slices used = 30)
Interslice resultant force inclination = 24.42 [degrees]

Three-Part Wedge Stability Analysis

N O T C O N D U C T E D

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0 5 10 15 20 25 30 [ft]

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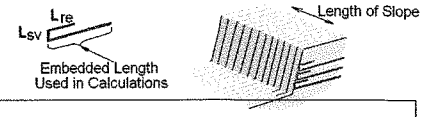

REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]		Lsv * [ft]	Lre [ft]
1	1	Geosynthetic type #1	0.20	27.00	1.00	0.30	0.20	27.30	0.20	0.00	0.00
2	2	Type #2	1.00	4.00	1.00	1.48	1.00	5.48	1.00	0.00	0.00
3	1	Geosynthetic type #1	2.00	24.00	1.00	2.97	2.00	26.97	2.00	0.00	0.00
4	2	Type #2	3.00	4.00	1.00	4.45	3.00	8.45	3.00	0.00	0.00
5	1	Geosynthetic type #1	4.00	27.00	1.00	5.93	4.00	32.93	4.00	0.00	0.00
6	2	Type #2	5.00	4.00	1.00	7.41	5.00	11.41	5.00	0.00	0.00
7	1	Geosynthetic type #1	6.00	24.00	1.00	8.90	6.00	32.90	6.00	0.00	0.00
8	2	Type #2	7.00	4.00	1.00	10.38	7.00	14.38	7.00	0.00	0.00
9	1	Geosynthetic type #1	8.00	27.00	1.00	11.86	8.00	38.86	8.00	0.00	0.00
10	2	Type #2	9.00	4.00	1.00	13.34	9.00	17.34	9.00	0.00	0.00
11	1	Geosynthetic type #1	10.00	24.00	1.00	14.83	10.00	38.83	10.00	0.00	0.00
12	2	Type #2	11.00	4.00	1.00	16.31	11.00	20.31	11.00	0.00	0.00
13	1	Geosynthetic type #1	12.00	27.00	1.00	17.79	12.00	44.79	12.00	0.00	0.00
14	2	Type #2	13.00	4.00	1.00	19.27	13.00	23.27	13.00	0.00	0.00
15	1	Geosynthetic type #1	14.00	24.00	1.00	20.76	14.00	44.76	14.00	0.00	0.00
16	2	Type #2	15.00	4.00	1.00	22.24	15.00	26.24	15.00	0.00	0.00
17	1	Geosynthetic type #1	16.00	27.00	1.00	23.72	16.00	50.72	16.00	0.00	0.00
18	2	Type #2	17.00	4.00	1.00	25.20	17.00	29.20	17.00	0.00	0.00
19	1	Geosynthetic type #1	18.00	24.00	1.00	26.69	18.00	50.69	18.00	0.00	0.00
20	2	Type #2	19.00	4.00	1.00	28.17	19.00	32.17	19.00	0.00	0.00
21	1	Geosynthetic type #1	20.00	27.00	1.00	29.65	20.00	56.65	20.00	0.00	0.00
22	2	Type #2	21.00	4.00	1.00	31.13	21.00	35.13	21.00	0.00	0.00
23	1	Geosynthetic type #1	22.00	24.00	1.00	32.62	22.00	56.62	22.00	0.00	0.00
24	2	Type #2	23.00	4.00	1.00	34.10	23.00	38.10	23.00	0.00	0.00
25	1	Geosynthetic type #1	24.00	27.00	1.00	35.58	24.00	62.58	24.00	0.00	0.00
26	2	Type #2	25.00	4.00	1.00	37.06	25.00	41.06	25.00	0.00	0.00
27	1	Geosynthetic type #1	26.00	24.00	1.00	38.55	26.00	62.55	26.00	0.00	0.00
28	2	Type #2	27.00	4.00	1.00	40.03	27.00	44.03	27.00	0.00	0.00
29	1	Geosynthetic type #1	28.00	27.00	1.00	41.51	28.00	68.51	28.00	0.00	0.00
30	2	Type #2	29.00	4.00	1.00	42.99	29.00	46.99	29.00	0.00	0.00
31	1	Geosynthetic type #1	30.00	30.00	1.00	44.48	30.00	74.48	30.00	0.00	0.00
32	2	Type #2	31.00	4.00	1.00	45.96	31.00	49.96	31.00	0.00	0.00
33	1	Geosynthetic type #1	32.00	28.00	1.00	47.44	32.00	75.44	32.00	0.00	0.00
34	2	Type #2	33.00	4.00	1.00	48.92	33.00	52.92	33.00	0.00	0.00

* Vertical distance between layers.

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]
1	Geosynthetic type #1	1.00	442.00
2	Type #2	1.00	68.00

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Theodore Roosevelt ERFO Multiple Slides

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PROJECT IDENTIFICATION

Title: Theodore Roosevelt ERFO Multiple Slides
Project Number: ND THRO ERFO 10(1) -
Client: FHWA CFLHD
Designer: Braden Peters
Station Number: 603+80

Description:

Company's information:

Name:
Street:

Telephone #:
Fax #:
E-Mail:

Original file path and name: N:\ND\ND ERFO 10(1)\Geotech\5 Analysis\RSS 603+80.MSE
Original date and time of creating this file: Thu Jan 12 11:35:08 2012

PROGRAM MODE: Analysis of a Simplified Slope using GEOSYNTHETIC as reinforcing material.

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INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

========== Soil Layer #: ==========	Unit weight, γ [lb/ft ^{3}]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ^{2}]
REINFORCED SOIL.....	125.0	30.0	0.0
RETAINED SOIL.....	115.0	14.0	480.0
FOUNDATION SOIL.....	115.0	14.0	480.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Additional Reduction Factor, RFa	Coverage Ratio, Rc
1	Geosynthetic type #1	2000.00	1.20	1.10	1.67	1.00	1.00

Interaction Parameters Type #	Geosynthetic Designated Name	== Direct Sliding == Cds-phi	Cds-c	==== Pullout ==== Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 1.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50
Design method for Global Stability: AASHTO/FHWA Bishop.

WATER

Unit weight of water = 62.45 [lb/ft ^{3}]
Water ponding is defined by 'phreatic surface' in Total Stress Analysis.

SEISMICITY

Not Applicable

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DRAWING OF SPECIFIED GEOMETRY - SIMPLE

GEOMETRY

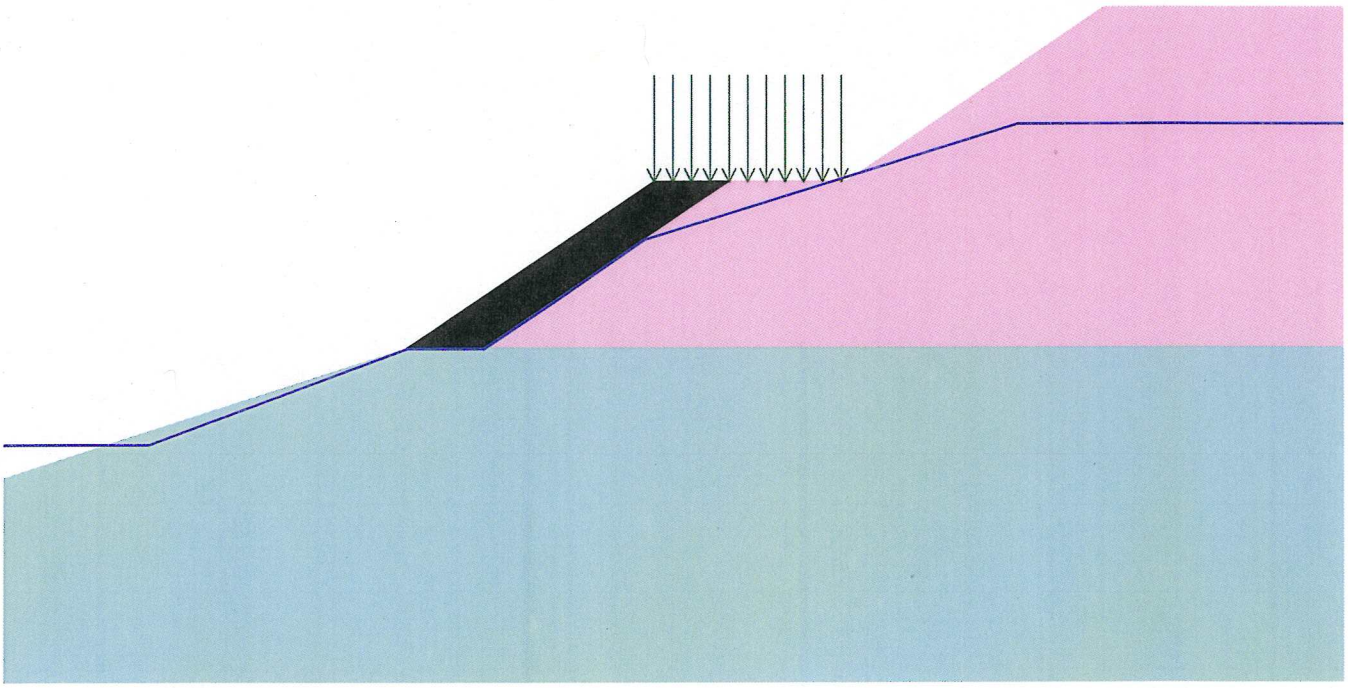
Height of slope, H	26.00	[ft]
Slope angle, i	34.00	[deg.]
Horizontal crest length, A	30.00	[ft]
Horizontal crest length, B	30.00	[ft]
Backslope angle, β	34.00	[deg.]
Sloping angle, α	18.00	[deg.]

UNIFORM SURCHARGE

Surcharge load over A, Q1	250.00	[lb/ft²]
Surcharge load over backslope B, Q2	0.00	[lb/ft²]
Surcharge load away from backslope, Q3	0.00	[lb/ft²]

WATER GEOMETRY Coordinates of water line in [ft]

#	1	Xw =	-40.00	Yw =	-15.00
#	2	Xw =	0.00	Yw =	0.00
#	3	Xw =	12.00	Yw =	0.00
#	4	Xw =	24.00	Yw =	8.00
#	5	Xw =	37.00	Yw =	17.00
#	6	Xw =	95.00	Yw =	35.00



SCALE:

0 5 10 15 20 25 30 [ft]

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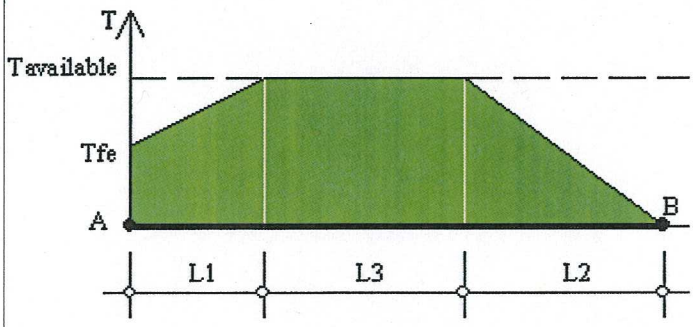
DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	0.20	12.00	0.00	2.00	10.00	907.28	907.28
2	Geosynthetic type #1	1.20	10.50	0.00	2.36	8.14	907.28	907.28
3	Geosynthetic type #1	2.20	9.00	0.00	2.92	6.08	907.28	907.28
4	Geosynthetic type #1	3.20	7.50	0.00	4.00	3.50	907.28	907.28
5	Geosynthetic type #1	4.20	12.00	0.00	2.00	10.00	907.28	907.28
6	Geosynthetic type #1	5.20	10.50	0.00	2.36	8.14	907.28	907.28
7	Geosynthetic type #1	6.20	9.00	0.00	2.92	6.08	907.28	907.28
8	Geosynthetic type #1	7.20	7.50	0.00	4.00	3.50	907.28	907.28
9	Geosynthetic type #1	8.20	12.00	0.00	2.00	10.00	907.28	907.28
10	Geosynthetic type #1	9.20	10.50	0.00	2.36	8.14	907.28	907.28
11	Geosynthetic type #1	10.20	9.00	0.00	2.92	6.08	907.28	907.28
12	Geosynthetic type #1	11.20	7.50	0.00	4.00	3.50	907.28	907.28
13	Geosynthetic type #1	12.20	12.00	0.00	2.00	10.00	907.28	907.28
14	Geosynthetic type #1	13.20	10.50	0.00	2.36	8.14	907.28	907.28
15	Geosynthetic type #1	14.20	9.00	0.00	2.92	6.08	907.28	907.28
16	Geosynthetic type #1	15.20	7.50	0.00	4.00	3.50	907.28	907.28
17	Geosynthetic type #1	16.20	12.00	0.00	2.00	10.00	907.28	907.28
18	Geosynthetic type #1	17.20	10.50	0.00	2.36	8.14	907.28	907.28
19	Geosynthetic type #1	18.20	9.00	0.00	2.92	6.08	907.28	907.28
20	Geosynthetic type #1	19.20	7.50	0.00	4.00	3.50	907.28	907.28
21	Geosynthetic type #1	20.20	12.00	0.00	2.56	9.44	907.28	907.28
22	Geosynthetic type #1	21.20	10.50	0.00	3.08	7.42	907.28	907.28
23	Geosynthetic type #1	22.20	9.00	0.00	3.94	5.06	907.28	907.28
24	Geosynthetic type #1	23.20	7.50	0.00	6.40	1.10	907.28	907.28
25	Geosynthetic type #1	24.20	12.00	0.00	8.20	3.80	907.28	907.28
26	Geosynthetic type #1	25.20	12.00	0.00	12.00	0.00	561.17	561.17 (*)

(*) This Tavailable is dictated by the pullout resistance capacity, which is smaller than the long-term strength of the reinforcement that is related to its specified ultimate strength

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	40.00	26.00	1.69	1.34	0.46	45.34	44.01	1.64	
2	43.00	26.00	1.84	1.33	-3.91	57.61	56.57	1.42	
3	46.00	26.00	1.99	1.35	-11.28	76.65	76.46	1.35	OK
4	49.00	26.00	1.52	1.36	2.97	56.64	55.30	1.43	
5	52.00	26.00	1.85	1.37	8.20	51.82	50.85	1.46	
6	55.00	26.00	-20.26	-6.40	0.92	48.01	58.39	1.47	
7	58.00	26.00	-20.87	-6.16	1.95	50.68	61.25	1.47	
8	61.00	26.00	-20.64	-6.26	2.37	54.95	65.39	1.48	
9	64.00	26.00	-20.39	-6.36	3.41	57.81	68.44	1.49	
10	67.00	26.00	-20.13	-6.45	4.46	60.71	71.53	1.50	
11	70.00	26.98	-20.81	-6.20	5.33	63.11	74.07	1.52	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

****

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	-20.87	-6.16	58.00	26.00	1.95	50.68	61.25	1.47	
2	-15.19	-4.46	55.00	26.00	4.26	46.83	54.85	1.49	
3	-9.74	-2.68	55.00	26.00	7.12	46.68	52.16	1.51	
4	-3.98	-1.01	49.00	26.00	7.86	41.25	43.88	1.53	
5	1.99	1.35	46.00	26.00	-11.28	76.65	76.46	1.35	OK
6	7.47	5.06	46.00	26.00	1.52	61.91	57.17	1.36	
7	12.82	8.77	46.00	26.00	12.27	50.38	41.62	1.37	
8	18.50	12.48	46.00	26.00	21.08	41.96	29.60	1.40	
9	24.00	16.19	46.00	26.00	29.16	34.19	18.73	1.63	
10	29.42	19.92	49.00	26.00	34.79	37.20	18.10	1.99	
11	34.96	23.62	43.00	26.00	37.33	30.38	7.17	2.88	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.35

Critical Circle: Xc = -11.28[ft], Yc = 76.65[ft], R = 76.46[ft]. (Number of slices used = 54)

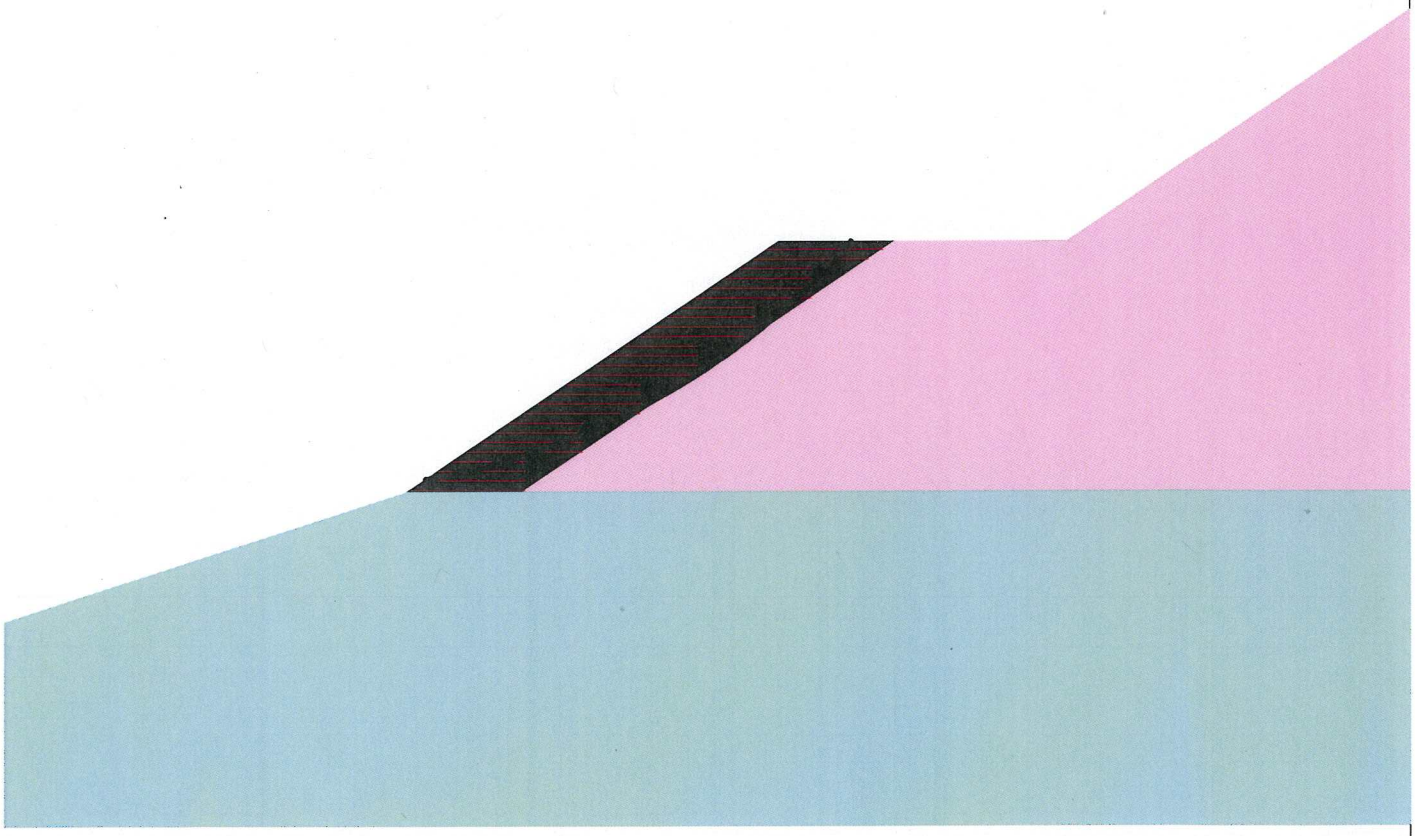
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

N O T C O N D U C T E D

Three-Part Wedge Stability Analysis

N O T C O N D U C T E D

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0 5 10 15 20 25 30 [ft]

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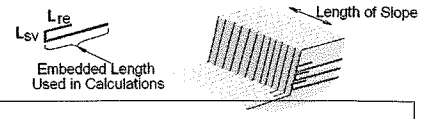

REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]		Lsv * [ft]	Lre [ft]
1	1	Geosynthetic type #1	0.20	12.00	1.00	0.30	0.20	12.30	0.20	0.00	0.00
2	1	Geosynthetic type #1	1.20	10.50	1.00	1.78	1.20	12.28	1.20	0.00	0.00
3	1	Geosynthetic type #1	2.20	9.00	1.00	3.26	2.20	12.26	2.20	0.00	0.00
4	1	Geosynthetic type #1	3.20	7.50	1.00	4.74	3.20	12.24	3.20	0.00	0.00
5	1	Geosynthetic type #1	4.20	12.00	1.00	6.23	4.20	18.23	4.20	0.00	0.00
6	1	Geosynthetic type #1	5.20	10.50	1.00	7.71	5.20	18.21	5.20	0.00	0.00
7	1	Geosynthetic type #1	6.20	9.00	1.00	9.19	6.20	18.19	6.20	0.00	0.00
8	1	Geosynthetic type #1	7.20	7.50	1.00	10.67	7.20	18.17	7.20	0.00	0.00
9	1	Geosynthetic type #1	8.20	12.00	1.00	12.16	8.20	24.16	8.20	0.00	0.00
10	1	Geosynthetic type #1	9.20	10.50	1.00	13.64	9.20	24.14	9.20	0.00	0.00
11	1	Geosynthetic type #1	10.20	9.00	1.00	15.12	10.20	24.12	10.20	0.00	0.00
12	1	Geosynthetic type #1	11.20	7.50	1.00	16.60	11.20	24.10	11.20	0.00	0.00
13	1	Geosynthetic type #1	12.20	12.00	1.00	18.09	12.20	30.09	12.20	0.00	0.00
14	1	Geosynthetic type #1	13.20	10.50	1.00	19.57	13.20	30.07	13.20	0.00	0.00
15	1	Geosynthetic type #1	14.20	9.00	1.00	21.05	14.20	30.05	14.20	0.00	0.00
16	1	Geosynthetic type #1	15.20	7.50	1.00	22.53	15.20	30.03	15.20	0.00	0.00
17	1	Geosynthetic type #1	16.20	12.00	1.00	24.02	16.20	36.02	16.20	0.00	0.00
18	1	Geosynthetic type #1	17.20	10.50	1.00	25.50	17.20	36.00	17.20	0.00	0.00
19	1	Geosynthetic type #1	18.20	9.00	1.00	26.98	18.20	35.98	18.20	0.00	0.00
20	1	Geosynthetic type #1	19.20	7.50	1.00	28.47	19.20	35.97	19.20	0.00	0.00
21	1	Geosynthetic type #1	20.20	12.00	1.00	29.95	20.20	41.95	20.20	0.00	0.00
22	1	Geosynthetic type #1	21.20	10.50	1.00	31.43	21.20	41.93	21.20	0.00	0.00
23	1	Geosynthetic type #1	22.20	9.00	1.00	32.91	22.20	41.91	22.20	0.00	0.00
24	1	Geosynthetic type #1	23.20	7.50	1.00	34.40	23.20	41.90	23.20	0.00	0.00
25	1	Geosynthetic type #1	24.20	12.00	1.00	35.88	24.20	47.88	24.20	0.00	0.00
26	1	Geosynthetic type #1	25.20	12.00	1.00	37.36	25.20	49.36	25.20	0.00	0.00

* Vertical distance between layers.

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]
1	Geosynthetic type #1	1.00	258.00

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