AGENCY OF TRANSPORTATION **OFFICE MEMORANDUM**

To: Paul Libby, Project Manager, Highway Safety and Design

MLM CEE

From: Marcy Meyers, Geotechnical Engineer, via Callie Ewald, P. E., Senior Geotechnical Engineer

Date: March 10th, 2014

Subject: Mount Holly STP 0133(8) – Revised Stationing

1.0 INTRODUCTION

We have completed our geotechnical investigation for the Mount Holly STP 0133(8) project, located along Vermont Route 155 near MM 5.57 in the Town of Mount Holly, Vermont. This project involves addressing a slope instability issue along the eastern slope adjacent to the Mill River. The high rain event that occurred during Tropical Storm Irene caused the river waters to rise and become more turbulent, as well as large amounts of water to run off VT 155 down the face of the slope. A combination of saturated surficial soils and raging river forces caused a significant amount of vegetation and soil to wash away down the river. As a result, an unvegetated and unstable slope now exists, threatening the stability of the roadway directly adjacent, as shown in Figure 1.1. Evidence of the threatened roadway stability is seen in the shoulder of the roadway where stone fill has been dumped over the side to prevent the raveling of roadbed material down the slope, as shown in Figure 1.2.

Figure 1.1. Unvegetated Slope from Across Mill River

Figure 1.2. Threatened Shoulder and Roadway Instability

Contained herein are the results of the field sampling and testing, laboratory analysis of soil samples, and subsequent slope stability analysis. The slope stability results are schematic in nature and proper engineering plans should be developed prior to any remediation of the slope failure.

2.0 FIELD INVESTIGATION

The field investigation was conducted from October 29th to October 30th, 2013. Two standard penetration borings were drilled to determine the subsurface profile to aid in the slope stability mitigation as well as one solid stem roadway boring to obtain pavement information. Locations for these 3 borings can be found in Table 2.1, as well as in the attached Boring Location Plan. Boring locations were discussed with the geotechnical section during a site visit on January 3rd, 2013 and then locations were plotted by Green International Affiliates, Inc. (Green) and attached as part of the boring request dated June 25th, 2013. Northings, Eastings, and elevations were provided on the plans and are based on the Vermont State Plane Grid NAD 83 coordinate system.

Table 2.1. Boring Locations

Boring	Station (ft)	Offset (ft)	Northing (ft)	Easting (ft)	Elevation (ft)
B-101	609+45	13.54	336758.86	1545810.98	1443.45
B-102	610+87	13.14	336895.91	1545772.74	1445.05
C-101	606+88	-8.47	336505.69	1545858.03	1446.83

Borings B-101 and B-102 were performed in general accordance with AASHTO T206, *Standard Method of Test for Penetration Test and Split-Barrel Sampling of Soils*. During the boring operations, split spoon samples and standard penetration tests (SPT) were taken at 5.0 foot intervals until a depth of approximately 70.0 feet.

Boring C-101 was performed in general accordance with AASHTO T306, *Processing Auger Borings for Geotechnical Explorations,* to determine the subsurface profile to aid in the pavement design for VT 155. A 4-inch solid stem auger flight was rotary drilled to 5 feet below the top of pavement. The auger was then removed so that a visual observation of the soil profile could be made. This method has proven to be an efficient and reasonably accurate way to view changes in the strata and obtain samples off the auger flights.

Soil samples were visually identified in the field and SPT blow counts were recorded on the boring logs when applicable. Soil samples were preserved and returned to the Materials and Research laboratory for testing and further evaluation. Upon completion of the laboratory testing, the boring logs were revised to reflect the results of the laboratory classification results.

3.0 FIELD AND LABORATORY TESTS

The standard penetration resistance of the in-situ soil is determined by the number of blows required to drive a 2 inch OD split barrel sampler into the soil with a 140 pound hammer dropped from a height of 30 inches, in accordance with procedures specified in AASHTO T206. During the standard penetration test (SPT), the sampler is driven for a total length of 2 feet, while counting the blows for each 6 inch increment. The SPT N-value, which is defined as the sum of the number of blows required to drive the sampler through the second and third increments, is commonly used with established correlations to estimate a number of soil parameters, particularly the shear strength and density of cohensionless soils. The N-values provided on the boring logs are raw values and have not been corrected for energy, borehole diameter, rod length, or overburden pressure. The VT Agency of Transportation has determined a hammer energy correction factor, C_E, to account for the efficiency of the SPT hammer on the drill rig. For this project, a CME 55 track rig was used, with a C_E of 1.46. This value, included on the boring logs, was used in soil parameter calculations. Laboratory tests were conducted on all samples to evaluate grain size, moisture content, percent finer than No. 200 sieve, and liquid and plastic limits when applicable.

4.0 SOIL PROFILE

Review of laboratory data and boring logs revealed the following information pertaining to the soil strata.

Groundwater was encountered during drilling operations at depths of 11.7 feet and 41.2 feet below the ground surface in Borings B-101 and B-102, respectively. The slope appeared to have signs of surficial sloughing potentially from running surface water or groundwater seepage. As a result, the groundwater table was modeled at a higher elevation to be representative of what was expected to have occurred during the high rain events related to TS Irene.

The asphalt pavement thickness for the three borings ranged from 0.45-0.62 feet. The initial five to ten feet below the surface of the slope consists of medium dense to dense gravelly sand. Below the dense layer lies a ten to twenty foot stratum of medium dense silty sand overlying a dense layer of gravelly sand. A very dense sandy silt and silt layer exists below the sand layer to a depth of approximately 70 feet below the roadway, or fifteen feet below the toe of slope.

4.0 RECOMMENDATIONS

4.1 Stability Analysis

A computer model of the existing conditions was developed using the software program Slide, version 6.0, developed by Rocscience. A survey was completed by Green and sections were cut every 25 feet for evaluation. A critical cross-section of the slope was chosen by identifying the portion of the slide area with the highest potential for failure. The section analyzed was located at Sta. 609+55. A visual crack that exists along the guardrail posts at the top of the slope was used as the upper limit of the critical slip surface. Using the boring information, a conservative water table elevation, and assuming a factor of safety of 1.0 (immanent failure), soil properties were established. Table 4.1 below lists the soil properties used in analysis. All samples were conservatively modeled as being cohesionless.

Table 4.1. Soil Parameters

Layer	Soil Description	Unit Weight (pcf)	Friction Angle (degrees)
1	Medium Dense to Dense GrSa	130	36
2	Medium Dense to Dense SiSa	120	36
3	Dense to Very Dense GrSa	135	38
4	Very Dense Si	130	38

Based on the site visit and information gathered off of the boring logs, it was determined that a translational surficial failure in the slope is occurring as shown in Figure 4.1.

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (lb/ft2)	Phi	Water Surface	Hu Type
GrSa (m. dense-dense)		130	Mohr-Coulomb	0	36	Water Surface	Constant
SiSa (m. dense-dense)		120	Mohr-Coulomb	0	36	Water Surface	Constant
GrSa (dense-v. dense)		135	Mohr-Coulomb	0	38	Water Surface	Constant
Si (V. Dense)		130	Mohr-Coulomb	0	38	Water Surface	Constant

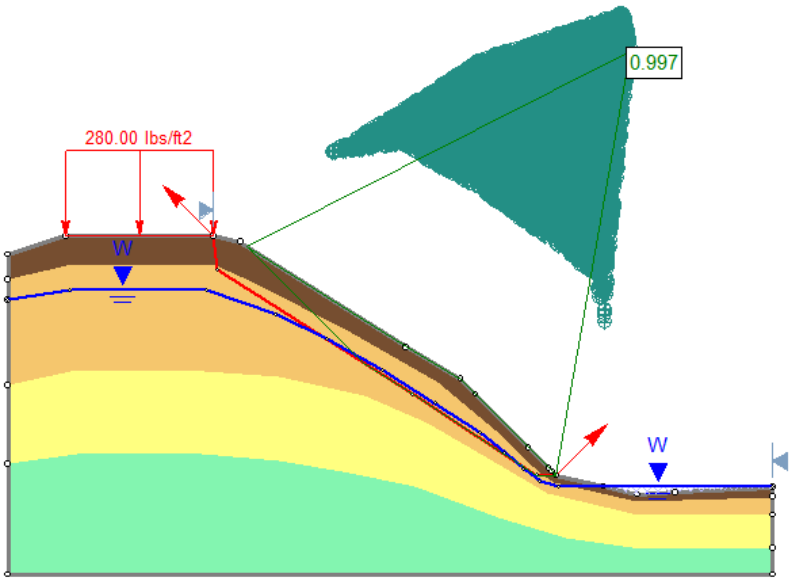


Figure 4.1. Translational Failure with a Factor of Safety = 0.997

4.2 Mitigation Design

The entire length of slope evaluated had a couple different geometries throughout. In addition, a large portion of the slope was very steep with almost no vegetation. This section of slope is anticipated to slowly creep toward the road until the material becomes stable at its internal angle of repose. This portion of slope is evident in Figure 1.1. Two sections of the slope exist where stone fill has been dumped to stabilize the shoulder and top of the slope (one of these being evident in Figure 1.2). Based on the current geometry of the slope, it appears excessive surface water has caused sloughing just off of the roadway pavement and a natural berm has been scoured away at the toe of slope. It is evident that the roadway shoulder material will continue to ravel down the slope creating an unstable shoulder and distress in the pavement if the slope is not stabilized surficially from the toe up the slope.

In order to remediate the surficial stability of the slope, as well as to provide adequate armoring of the toe to prevent future material loss, several options were considered. Re-grading the slope to a 1V:1.5H and armoring the toe proved to be the best alternative to mitigate the continuing material sloughing on the slope. As a result, two typical sections were designed to help better accommodate the varying geometries of the slope. These sections incorporate a combination of Type II and Type IV stone fill as well as granular borrow to act as a filter medium. Both typical sections are attached to this report.

5.0 RECOMMENDATIONS

We recommend beginning the surficial slope remediation at Station 606+80 using Typical Section 1. However, as noted during the site visit, the drainage ditch located around Sta. 606+45 that transmits water from the culvert down the slope, has eroded significantly. As a result, we recommend continuing the stone fill to the drainage ditch creating a swale to prevent further erosion and then transition the stone fill into the existing vegetated slope just past Sta. 606+45. Typical Section 1 includes re-grading the slope to a 1V:1.5H with Type II and Type IV stone fill. The Type IV stone fill should be keyed into the slope a minimum of four feet at the toe. A minimum of four feet of Type IV stone should be brought up to elevation 1410 feet. Two feet of Type II stone should be used to blanket the slope from the top of the Type IV to the roadway shoulder. Granular Borrow should be placed between the native soil and the stone fill to aid in re-grading the slope as well as help facilitate drainage and help to keep the native material from piping through the coarser stone fill.

Typical Section 1 should be applied to the length of the slope until approximately Sta. 610+05 to 610+30 where Typical Section 2 should then be implemented and continued to the end of the project around Sta. 611+30. Typical Section 2 also includes re-grading the slope to a 1V:1.5H with Type II and Type IV stone fill, however, since the natural berm is still intact, not as much Granular Borrow will be needed. The Type IV stone should be keyed into the slope a minimum of four feet at the toe. A minimum of four feet of Type IV stone should be brought up to elevation 1410 feet. The shoulder material along the roadway should be extended and a minimum two foot thick blanket of Type II stone should continue along a 1V:1.5H until it reaches either the berm or Type IV stone. This part of the typical section is important as the surficial stability of the upper portion of the slope is key in maintaining stability of the roadway and shoulder. We recommend Granular Borrow be placed between the native material and the stone fill to aid in re-grading the slope as well as help facilitate drainage and help keep the native soil from piping through the coarser stone fill.

Granular Borrow should meet the requirements of Item 703.04 of the VTrans *2011 Standard Specifications for Construction* with a slight modification indicating a maximum of 80% passing the 4.75mm (No. 4) sieve in order to better facilitate drainage. To help tie in the existing slope with the fill material in the top 20 feet (min.) of vertical slope, we recommend benching the native material as shown in the attached typical section and specified in Standard B-5. The upper portion of this slope is very steep and this will aid in preventing sliding surfaces to occur during construction and after. The Type II and Type IV stone fill shall meet the requirements of Item 706.04 *Stone for Stone fill* as stated in the VTrans *2011 Standard Specifications for Construction.*

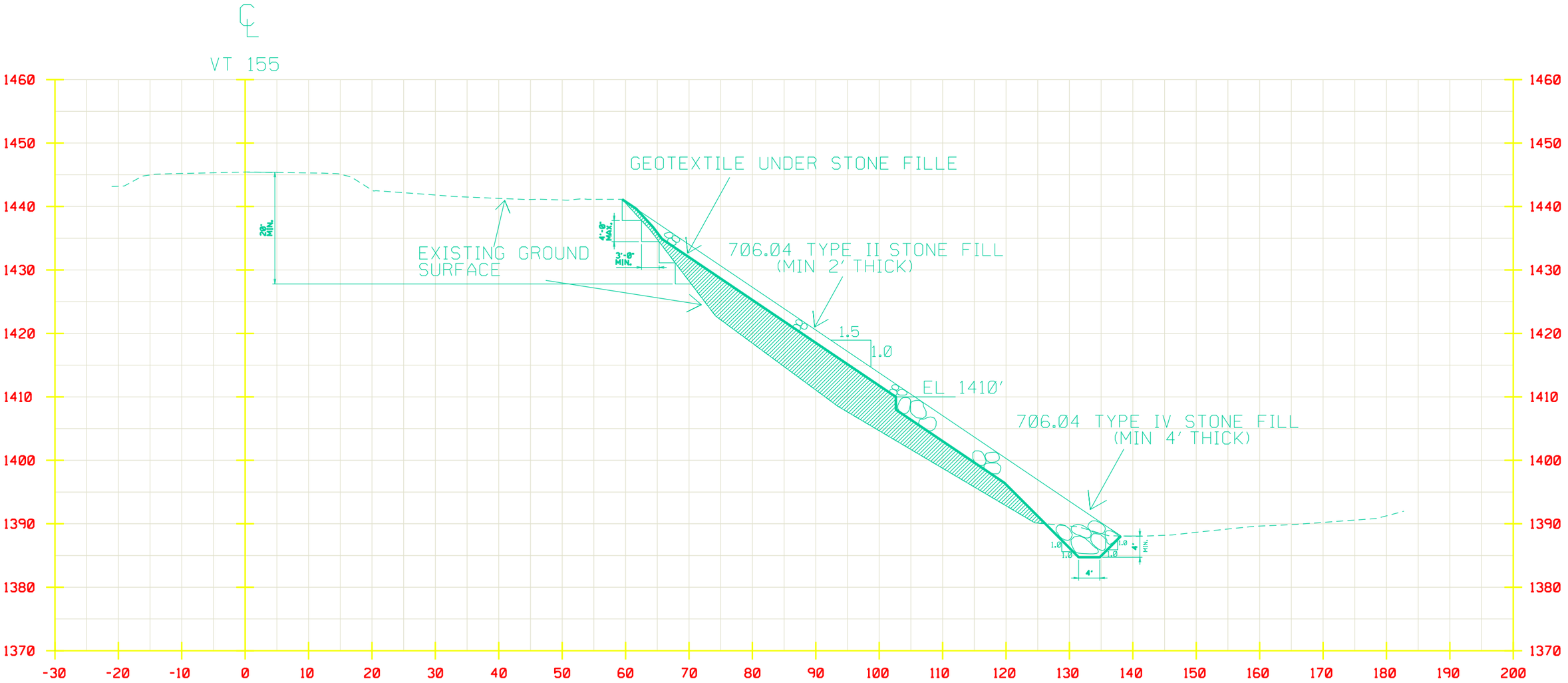
6.0 CONCLUSION

These recommendations are preliminary in nature and prior to construction of the remediation, proper construction details should be developed. If any further analysis is needed or you would like to discuss this report, please contact us at (802) 828-2561. Computer generated boring logs are attached and are also available in the CADD design files:
M:\Projects\12c406\Materials&Research.

Attachments: Typical Remediation Sections (2 pages)
Boring Logs (3 pages)
Boring Location Plan (1 page)

cc: Read File/WEA
Project File/CCB
MLM

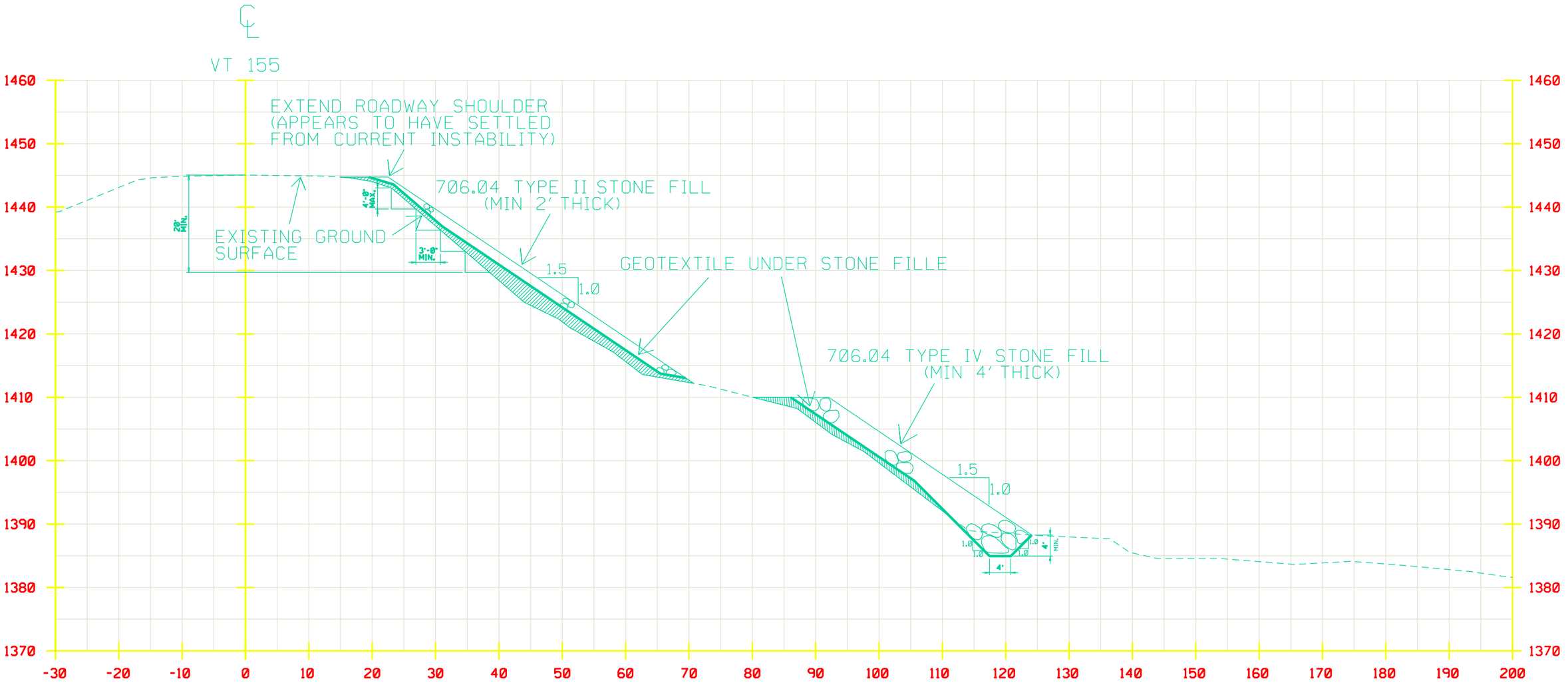
G:\Soils and Foundations\Projects\Mount Holly STP 0133(8)\REPORTS\Mount Holly STP 0133(8) Geotechnical Report_revised stationing.doc



TYPICAL SECTION 1

(Sta. 607+80)

MIN. 9" THICK GRANULAR BORROW (MAXIMUM % PASSING THE NO. 4 SIEVE = 80%)



TYPICAL SECTION 2

(Sta. 610+80)

MIN. 9" THICK GRANULAR BORROW (MAXIMUM % PASSING THE NO. 4 SIEVE = 80%)

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH SECTION
SUBSURFACE INFORMATION

BORING LOG

MOUNT HOLLY
STP 0133(8)
VT-155 MM 5.57

Boring No.: **B-101**
Page No.: 1 of 1
Pin No.: 12C406
Checked By: MLM

Boring Crew: JUDKINS, DAIGNEAULT, GARROW
Date Started: 10/29/13 Date Finished: 10/29/13
VTSPG NAD83: N 336758.86 ft E 1545810.98 ft
Station: 609+45 Offset: 13.54
Ground Elevation: 1443.45 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	4.25 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:	Auto/AWJ	
Rig:	CME 55 TRACK	C_F = 1.46

Groundwater Observations

Date	Depth (ft)	Notes
10/29/13	11.7	While drilling.

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %	LL %	PI %
		Asphalt Pavement, 0.0 ft - 0.45 ft							
		A-1-b, GrSa, brn, Moist, Rec. = 0.5 ft	6-21-17-19 (38)	11.7	28.7	56.9	14.4		
		Field Note:, No Recovery	R@2.5"						
10		Field Note:, Cobbles, Cleaned out casing							
		A-4, SaSi, brn, Moist, Rec. = 0.7 ft	7-3-6-6 (9)	25.9	6.5	20.9	72.6	26	2
		A-4, Si, brn, Moist, Rec. = 0.3 ft	3-4-11-5 (15)	25.0	13.3	17.7	69.0		
20		A-2-4, GrSiSa with varved layers, brn, Moist, Rec. = 1.1 ft, Lab Note: Broken Rock was within sample.	8-25-28-R@3.5" (53)	11.5	24.7	41.6	33.7		
		Field Note:, Cleaned out casing. Appears to be Sandy Gravel							
		A-4, SaSi (HP), gry, Moist, Rec. = 0.7 ft	35-R@5.0"	11.5	16.5	33.6	49.9		
30		A-4, SaSi, gry, Moist, Rec. = 0.2 ft	R@3.5"	10.4	12.4	43.7	43.9		
		Field Note:, No Recovery	R@2.5"						
40		A-4, SiSa, gry, Moist, Rec. = 0.5 ft, Lab Note: Broken Rock was within sample.	42-R@5.0"	12.6	12.2	46.4	41.4		
		Field Note:, No Recovery. Appears to be Sandy Silt	R@5.0"						
50		Field Note:, No Recovery. Appears to be Sandy Silt	R@6.0"						
		A-4, SaSi, gry, Moist, Rec. = 0.5 ft	28-R@5.0"	21.2	2.9	37.8	59.3		
60		A-4, GrSaSi, gry, Moist, Rec. = 0.3 ft	R@3.5"	10.3	26.8	35.2	38.0		
		A-4, Si, gry, Moist, Rec. = 1.2 ft, Lab Note: A very small layer of Clay was noticeable, but not enough for testing.	28-35-R@6.0" (R)	25.3	0.4	2.0	97.6		
70		A-4, Si, gry, Moist, Rec. = 1.3 ft	13-32-R@6.0" (R)	27.9		0.9	99.1	32	4
		Hole stopped @ 72.0 ft							

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.

BORING LOG 2 MOUNT HOLLY STP 0133(8).GPJ VERMONT AOT.GDT 3/10/14

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH SECTION
SUBSURFACE INFORMATION

BORING LOG

MOUNT HOLLY
STP 0133(8)
VT-155 MM 5.57

Boring No.: **B-102**
Page No.: 1 of 1
Pin No.: 12C406
Checked By: MLM

Boring Crew: JUDKINS, DAIGNEAULT, GARROW
Date Started: 10/30/13 Date Finished: 10/30/13
VTSPG NAD83: N 336895.91 ft E 1545772.74 ft
Station: 610+87 Offset: 13.14
Ground Elevation: 1445.05 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	4.25 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:	Auto/AWJ	
Rig:	CME 55 TRACK	C_E = 1.46

Groundwater Observations

Date	Depth (ft)	Notes
10/30/13	41.2	Casing in ground.

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %	LL %	PI %
		Asphalt Pavement, 0.0 ft - 0.6 ft							
		A-1-a, SaGr, brn-white, Moist, Rec. = 0.8 ft, Lab Note: Broken Rock was within sample.	4-9-10-15 (19)	8.9	62.3	24.6	13.1		
		Field Note:, Cleaned out casing. Appears to be Silty Sand							
		A-2-4, GrSiSa, brn, Moist, Rec. = 0.7 ft	12-12-9-6 (21)	18.1	23.7	49.0	27.3		
10		Field Note:, Cleaned out casing. Appears to be Gravelly Sand							
		A-1-b, SiGrSa, brn, Moist, Rec. = 0.8 ft	7-7-7-13 (14)	11.1	29.4	48.1	22.5		
		Field Note:, Cobbles							
		A-2-4, GrSiSa, brn, Moist, Rec. = 1.0 ft, Lab Note: Broken Rock was within sample.	6-5-8-10 (13)	14.6	23.6	47.4	29.0		
20		Field Note:, Cobbles & Gravel							
		A-1-b, SaGr, brn, Moist, Rec. = 0.7 ft, Lab Note: Broken Rock was within sample.	18-30-21-30 (51)	8.5	43.1	39.9	17.0		
		Field Note:, Cleaned out casing. Appears to be Sandy Silt							
		A-2-4, SaSi, brn, Moist, Rec. = 0.8 ft	9-9-10-R@3.5" (19)	15.0	17.2	57.9	24.9		
30		Field Note:, Cleaned out casing. Appears to be Gravel							
		Visual Description:, Broken Rock with sand, brn, Moist, Rec. = 0.2 ft, Insufficient sample for testing.	15-14-14-28 (28)						
		Field Note:, Cleaned out casing. Appears to be Gravelly Silty Sand							
		A-1-b, GrSa, brn, Moist, Rec. = 0.8 ft, Lab Note: Broken Rock was within sample.	27-24-19-20 (43)	13.6	29.8	57.6	12.6		
40		Field Note:, Cleaned out casing. Appears to be Sand							
		A-2-4, Sa, brn, Moist, Rec. = 0.8 ft	8-7-7-13 (14)	19.4	0.9	80.4	18.7		
		A-4, SaGrSi, brn, Moist, Rec. = 0.5 ft, Lab Note: Broken Rock was within sample.	32-26-20-16 (46)	9.3	34.3	28.6	37.1		
50		Field Note:, Lost water at 49.0 ft.							
		A-4, SaGrSi, gry, Moist, Rec. = 1.3 ft, Lab Note: Broken Rock was within sample.	25-40-R@6.0" (R)	14.0	25.5	20.3	54.2		
		A-4, Si, gry, Moist, Rec. = 1.4 ft, Lab Note: Sample was tested for Limits.	19-28-45-R@1.0" (73)	24.5	0.6	1.5	97.9		
60		A-4, ClSi, gry, Moist, Rec. = 0.4 ft	R@5.0"	26.2	3.5	2.2	94.3	37	9
		Field Note:, No Recovery	R@5.0"						
70		A-4, Si, gry, Moist, Rec. = 1.0 ft, Lab Note: Sample was tested for Limits.	26-32-R@6.0" (R)	28.0	0.2	6.6	93.2		
		Hole stopped @ 71.5 ft							

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.

BORING LOG 2 MOUNT HOLLY STP 0133(8).GPJ VERMONT AOT.GDT 3/10/14

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH SECTION
SUBSURFACE INFORMATION

BORING LOG

MOUNT HOLLY
STP 0133(8)
VT-155 MM 5.57

Boring No.: **C-101**
Page No.: 1 of 1
Pin No.: 12C406
Checked By: MLM

Boring Crew: JUDKINS, DAIGNEAULT, GARROW
Date Started: 10/30/13 Date Finished: 10/30/13
VTSPG NAD83: N 336505.69 ft E 1545858.03 ft
Station: 606+88 Offset: -8.47
Ground Elevation: 1446.83 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	4.25 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:		Auto/AWJ
Rig:	CME 55 TRACK	C_F = 1.46

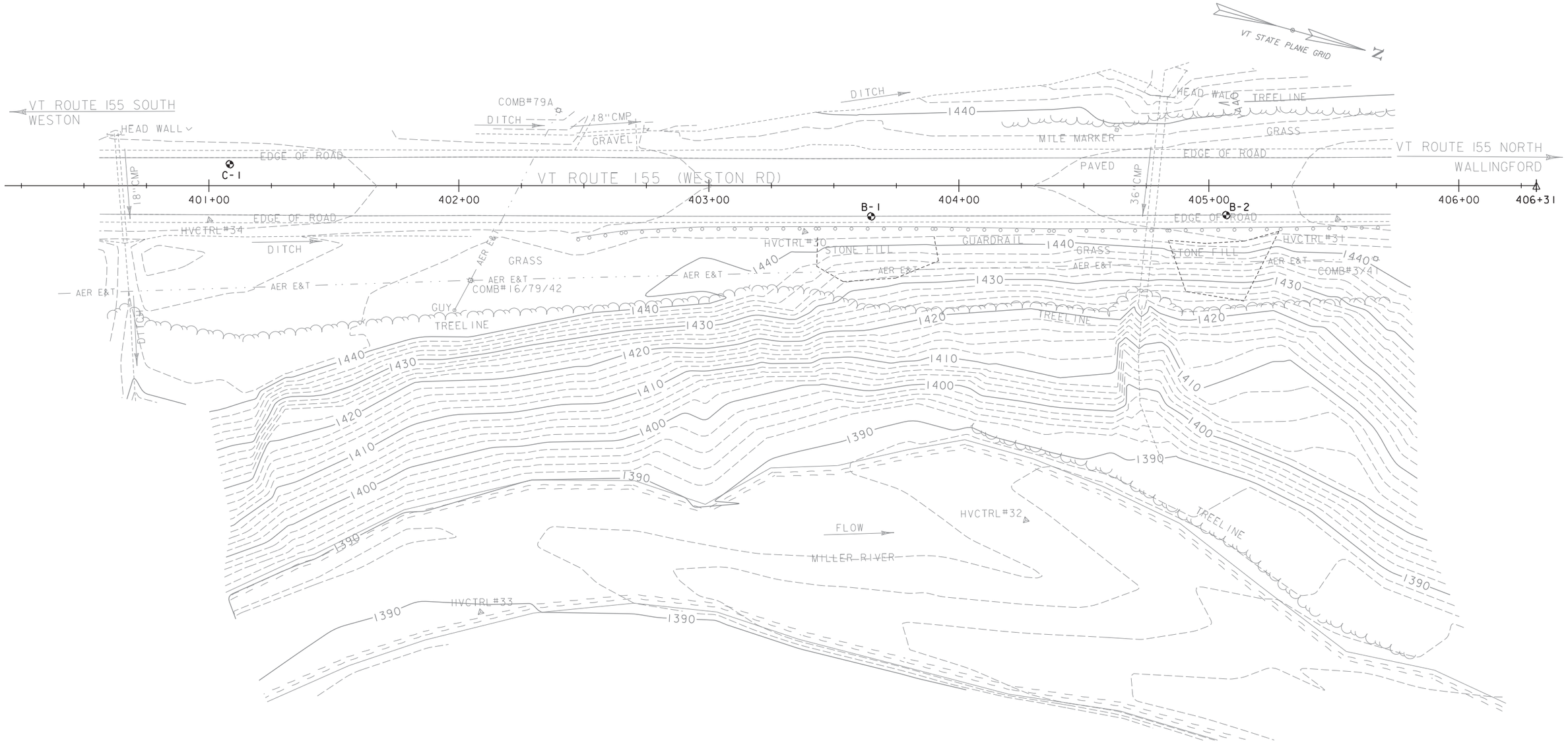
Groundwater Observations

Date	Depth (ft)	Notes
		No water to depth.

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Asphalt Pavement, 0.0 ft - 0.62 ft					
		A-1-b, GrSa, brn, Moist, Rec. = 1.3 ft	12-16-13-16 (29)	8.6	26.2	56.4	17.4
2.5		A-1-b, GrSa, brn, Moist, Rec. = 2.0 ft	13-15-15-17 (30)	9.9	25.3	58.3	16.4
5.0		Hole stopped @ 5.0 ft					
7.5							
10.0							
12.5							
15.0							
17.5							
20.0							
22.5							

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.

BORING LOG 2 MOUNT HOLLY STP 0133(8).GPJ VERMONT AOT.GDT 3/10/14



PAVEMENT CORING CHART

HOLE NO.	STATION	OFFSET (ft)	NORTHING (FT)	EASTING (FT)	ELEVATION (FT)
C-1	VT ROUTE 155 606+88	8.47 LT	336505.69	1545858.03	1446.83

Note: Stationing has changed. This has been added as a visual reference.

BORING CHART

HOLE NO.	STATION	OFFSET (ft)	NORTHING (FT)	EASTING (FT)	ELEVATION (FT)
B-1*	VT ROUTE 155 609+45	13.54	336758.86	1545810.98	1443.45
B-2*	VT ROUTE 155 610+87	13.14	336895.91	1545772.74	1445.05

* MINIMUM DEPTH OF 70-FEET, INCLUDE PAVEMENT CORE.

0 20 40
SCALE IN FEET

GREEN INTERNATIONAL AFFILIATES, INC.
CIVIL AND STRUCTURAL ENGINEERS

PROJECT NAME: MOUNT HOLLY
PROJECT NUMBER: STP 0133(8)

FILE NAME: z12c406bor.dgn
PROJECT LEADER: ERIK ATKINS
DESIGNED BY: M. BRADLEY
BORING REQUEST PLAN

PLOT DATE: 6/25/2013
DRAWN BY: M. BRADLEY
CHECKED BY: ERIK ATKINS
SHEET 1 OF 1