



THURBER ENGINEERING LTD.

**FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17, FROM THE EAST JUNCTION OF SUDBURY RR 55 19.5KM TO
KUKAGAMI RD
EMBANKMENT FROM STA. 13+110 TO 13+179, AWREY TWP
ASSIGNMENT NO. 5019-E-0012
GWP 5168-16-00**

GEOCRES NO.: 41I-373

Report Submitted to:

McIntosh Perry Consulting Engineers

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for a high fill section of Highway 17 (Sta. 13+110 to Sta. 13+179) approximately 400 m west of Kukagami Lake Road, within the Township of Awrey, Ontario.

Thurber Engineering Ltd. (Thurber) is supporting McIntosh Perry Consulting Engineers (MPCE) for the design of the rehabilitation of Highway 17 for Assignment 5019-E-0012. Part of this assignment required providing foundation engineering services for a 69 m long section of highway embankment. This assessment is part of the larger rehabilitation assignment (GWP 5168-16-00) which extends from the East Junction of Sudbury Regional Road 55 / Southeast Bypass easterly to Kukagami Lake Road, a length of approximately 19.5 km.

The purpose of this investigation was to explore the subsurface conditions at the site and based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results, and a written description of the subsurface conditions.

2 SITE DESCRIPTION

Within the study area (Sta. 13+110 to Sta. 13+179 Awrey Township), Highway 17 is a two-lane highway with a gravel shoulder and a paved shoulder on the north and south sides, respectively. Steel beam guiderails are present along the edges of the embankment shoulders.

This is a high fill embankment section that crosses a valley with bedrock outcrops to the east and west of the site and a meandering creek at the bottom of the valley. Historical aerial photographs which show the creek alignment over several years are provided in Appendix D.

The surface of the highway within the study area is gently sloping to the east with a ground surface elevation of about 259.2 m to 256.9 m. The natural ground surface elevation at the low points of the toes of the embankment ranges from about 245.7 m to 244.3 m on the north side and from about 248.1 m to 244.1 m on the south side. The maximum height of the embankment is about 14.5 m at Sta. 13+120.

The existing embankment slopes vary in inclination. On the north side, the embankment slopes are approximately inclined between 1.5H:1V and 2H:1V and generally consist of granular material with rock pieces on the surface of the lower portions of the slopes. On the south side, the existing embankment slopes are approximately inclined between 1.75H:1V and 2H:1V and are generally covered with rock pieces on the lower portions of the slopes and granular fill on the upper portions of the slopes. Erosion gullies down the slopes from the crest are present at several locations along both sides of the embankment. Some spot repairs with crushed rock were observed at the time of the field visit.

The land adjacent to the highway and valley is generally forested with sparse residential properties. Currently, the area to the north of the embankment is flooded. It is understood that a beaver dam has been present north of the site for some time.

A 1.8 m by 1.4 m by 59.7 m reinforced box culvert is present crossing underneath the embankment and is indicated to be near Sta. 13+140 as shown on the drawings provided to the Design Team. The culvert alignment bends to the east just prior to the outlet. It is understood that the invert elevation is at approximate elevation 242.3 m and 242.2 m at the inlet and outlet, respectively. At the time of the investigation the inlet was below water level and could not be observed. A bedrock outcrop was noted to the west of the existing culvert outlet.

A watermain is present running parallel to the south side of the embankment. The watermain is within the existing embankment slope and its alignment crosses overtop of the box culvert, see Markstay Water Works Drawing 9 in Appendix A. A buried bell line runs just north of the north embankment toe.

Traffic volumes on this section of Highway 17 were understood to be 7,100 AADT in 2016¹.

Photographs showing the existing conditions of the embankment slope and the surrounding area at the time of the field visits are included in Appendix D for reference.

3 BACKGROUND STUDY AND SITE RECONNAISSANCE

3.1 General

The Terms of Reference (TOR) indicate that the north side of the Highway 17 embankment has shown signs of instability between Sta. 13+110 and Sta. 13+179. This section of embankment was partially re-built under Contract 91-0234 and incorporated geogrid/geotextile placed within the upper 2.5 m of the shoulders.

3.2 Historical Reports

During preparation of this report, Thurber reviewed the following historical foundation document available within the online Geocres database:

Memorandum by the Ministry of Transportation Foundation Design Section, titled "Embankment Instabilities, W.P. 114-86-00, Site N/A, Hwy. 17, District 17, Sudbury (From Sudbury East Limits Easterly 18.7 km)", dated October 25, 1989. [Geocres No. 41100-132]

¹ <https://www.library.mto.gov.on.ca/SydneyPLUS/TechPubs/Portal/tp/tvSplash.aspx>

Geocres Report 41I00-132, dated October 1989, indicates that areas of the north shoulder have been washed out causing distress to the guiderails. The investigation presented in the report indicates 2.5 m to 5.7 m of granular materials; boreholes were not advanced deeper than 6 m. Boreholes west of Sta. 13+126 were terminated at depths ranging from 2.5 m to 3.7 m below the ground surface due to no further progress on suspected rockfill. The report recommended the remedial measures which were included in the 1991 Contract (see Section 3.3) but suggested that more robust measures will be required to permanently stabilize the slope, such as rebuilding and flattening portions of the embankment with rock fill.

The relevant factual information from the above documents, such as borehole plans, boreholes records and select laboratory testing results, are provided for reference in Appendix A, Appendix B, and Appendix C, respectively.

It must be recognized that the service provider that produced the historical document is solely responsible for the accuracy and quality of the subsurface information presented in their document.

3.3 Contract Drawings

A drawing package was provided by MPCE that included the remedial measures for the north side of the slope:

Drawing package by Dennis Consultants Ltd. for the Ministry of Transportation, titled "Contract No. 91-234, W.P. No 85-86-01, 114-86-01 and 114-86-00, Work of Grading, Drainage, Granular Base, Hot Mix Paving and Structure, Hwy No. 17 and 537, District No. 17 – Sudbury, Location from Sudbury East Limits Easterly to the Intersection of Kukagami Lake Road, 19 km Including Coniston Creek Bridge", dated 1991.

Sheet 12 of 108 within the 1991 Contract drawings indicates that shoulder repairs were to be completed in the upper 2.5 m of embankment at the crests. The treatment consisted of removal of existing material to allow placement of four 500 mm lifts of Granular A wrapped in SR2 Tensar Geogrid. The cut into the embankment for the installation of the geogrid is understood to have been at 1H:1V and the outer face of the slope was reconstructed as steep as 1.5H:1V. The 1991 Contract drawings also indicated the embankment below the Granular A repair consists of rock fill beneath a 2.5 m to 6 m granular overlay.

3.4 Aerial Photographs

Historical aerial photographs were obtained of the site from the online *City of Greater Sudbury Aerial Photo App*². The historic photographs are provided in Appendix D. The historical photos show the Highway 17 embankment in 1946, 1975 and 1991.

Google earth imagery was obtained to supplement the arial photo data from dates 2012 through 2016 and 2019. These images show a history of variable water level conditions on the north and south side of the embankment.

² <https://www.greatersudbury.ca/play/maps/>

3.5 Site Geology and Geomorphology

According to the Quaternary Geology Map 2555 from the Ministry of Northern Development of Mines, the site consists of bedrock overlain by a discontinuous thin layer of drift. Glaciofluvial ice-contact deposits in the area are described as “gravel and sand; minor till.”

The overburden in the vicinity of creek and within the bedrock valley may consist of alluvial creek deposits of interbedded sand, silt and organic matter. As seen in the aerial photographs discussed in Section 3.4, the creek and flood plain conditions have been variable over the years. Furthermore, highway and culvert construction activities have altered the soil stratigraphy locally by cutting and filling areas.

The Ontario Geological Survey Sudbury Geological Compilation indicates the bedrock in the study area is magmatic biotite gneiss with gneissic gabbro and minor diorite intrusions.

3.6 Site Reconnaissance Visit

A site reconnaissance visit was carried out by Thurber on September 22, 2020. Discussion and photographs from the site reconnaissance can be found in Thurber’s memo dated September 29, 2020.

The culvert outlet was observed during the December 2020 field investigation. A bedrock outcrop was noted to the west of the existing culvert (see Photo 6 in Appendix D).

4 SITE INVESTIGATIONS AND FIELD TESTING

Hand auger holes, identified as HA1 through HA9, were advanced along the north embankment toe of slope on October 14.

The site investigation and field-testing program for both on-road and off-road phases were carried out by Thurber between November 9 and December 9, 2020. The field investigation consisted of advancing three on-road boreholes identified as KL20-01 through KL20-03, as well as three off-road boreholes identified as KL20-04 through KL20-06. All on-road drilling was carried out using a truck mounted CME 55 drill rig. All off-road drilling was completed using a portable tripod drill rig. Test pits, identified as TP1 and TP2, were advanced on the south side of the embankment toe of slope with a hand shovel.

A test hole summary is provided in Table 4-1. Borehole elevations were surveyed relative to benchmark “HCP 164” from a base plan drawing provided by MPCE with a Nikon AP-8 auto level, which has a reported accuracy of 1.5 mm. The elevations of the test pits and the hand augers were obtained from cross-sections provided by MPCE. Test hole locations were determined by direct measurement from site features with known locations. It is understood that the horizontal accuracy of the base plan drawing is within 0.5 m. The site is within MTM Zone 12.

Table 4-1: Test Hole Summary

Test Hole ID.	Drilled Location	Northing (m) (Latitude°)	Easting (m) (Longitude°)	Existing Ground Surface Elevation (m)	Termination Depth Below Existing Ground Surface (m)
Foundation Borehole					
KL20-01	Westbound Lane West of Culvert	5153784.1 (46.523185°)	331347.9 (-80.653973°)	259.2	16.2
KL20-02	Eastbound Lane West of Culvert	5153777.1 (46.523122°)	331362.2 (-80.653788°)	258.4	16.6
KL20-02B	Eastbound Lane West of Culvert	5153777.4 (46.523125°)	331358.1 (-80.653841°)	258.5	19.2
KL20-03	Westbound Lane East of Culvert	5153777.9 (46.523128°)	331387.6 (-80.653457°)	257.7	20.9
KL20-04	South Toe, East of Culvert	5153737.9 (46.522768°)	331392.9 (-80.653391°)	243.6	5.4
KL20-05	South Toe, East of Culvert	5153739.3 (46.522781°)	331378.8 (-80.653573°)	243.6	2.9
KL20-06	North Toe, East of Culvert	5153807.3 (46.523392°)	331400.1 (-80.653292°)	244.3	7.5
Hand Augers					
HA1	North Toe 13+156 33m LT	5153808.3 (46.523401°)	331393.3 (-80.653381°)	244.5*	0.3
HA2	North Toe 13+148 33m LT	5153808.7 (46.523405°)	331386.1 (-80.653475°)	244.5*	0.6
HA3	North Toe 13+142 31m LT	5153808.6 (46.523404°)	331379.2 (-80.653564°)	244.5*	0.6
HA4	North Toe 13+136 30m LT	5153808.4 (46.523403°)	331373.2 (-80.653642°)	244.5*	0.8
HA5	North Toe 13+130 30m LT	5153809.1 (46.52341°)	331367.4 (-80.653719°)	244.5*	0.3
HA6	North Toe 13+120 34m LT	5153814.8 (46.523461°)	331357.6 (-80.653846°)	244.5*	0.1
HA7	North Toe 13+113 30m LT	5153812.1 (46.523437°)	331349.9 (-80.653946°)	244.5*	0.6
HA8	North Toe 13+106 35m LT	5153817.8 (46.523489°)	331343.5 (-80.654029°)	244.5*	0.5
HA9	North Toe 13+100 37m LT	5153820.4 (46.523512°)	331337.0 (-80.654114°)	244.5*	0.8
Test Pits					
TP1	South Toe 13+107 29m RT	5153754.3 (46.522918°)	331335.9 (-80.654132°)	248.2*	0.2
TP2	South Toe 13+125 31m RT	5153749.5 (46.522874°)	331352.7 (-80.653913°)	246.1*	0.2

Note: (*) Elevation obtained from cross section AutoCAD drawings provided by MPCE

Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations. Soil samples were obtained at specified intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in accordance with ASTM D 1586. The off-road boreholes were advanced to spoon and/or casing refusal on probable bedrock. In the on-road boreholes, rock was cored for less than 3 m length and has therefore been classified as probable bedrock.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered rockfill, soil and bedrock samples for transport to Thurber's laboratory for further examination and testing.

A piezometer, consisting of a 25 mm diameter PVC pipe with a 1.5 m long slotted screen, was installed in Borehole KL20-06 to allow for measurements of the groundwater levels following completion of drilling. The monitoring well details are illustrated on the Record of Borehole sheets, provided in Appendix B. The piezometer was decommissioned on December 10, 2020 prior to demobilizing.

Following completion of the field investigation, all boreholes were decommissioned in general accordance with MOE requirements (O.Reg. 903 as amended). The boreholes were backfilled with a combination of cuttings and bentonite holeplug. The upper portion of the on-road boreholes were filled with granular and capped with cold patch asphalt. The concrete encountered in Borehole KL20-02 was reinstated.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevations of the test holes are provided on this drawing, Table 4-1 and on the Record of Borehole sheets included in Appendix B.

5 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to Atterberg Limit testing and gradation analysis (hydrometer and/or sieve). Five samples were submitted for organic content testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. Two samples were selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation are provided in Appendix C.

6 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes advanced during the current investigation, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the bedrock elevation, soil and groundwater conditions will vary between and beyond the borehole locations.

The following sections do not include the information from the historic reports, unless specified. Where reference is made to historical data, it must be recognized that the service provider that produced the historical document is solely responsible for the accuracy and quality of the subsurface information presented in their document.

In general terms, the encountered stratigraphy consisted of a sand to silty sand fill underlain by rockfill. Below the embankment, the soil consisted of sandy silt to silty sand underlain by silty sand till and sand over probable bedrock. A clayey silt layer was noted within the sandy silt to silty sand deposit.

Soil classification for the 2020 investigation is in accordance with ASTM D2487 with cohesive soils described as per the MTO Guidelines for Foundation Engineering Services, Version 2. Previous reports may have employed other soil description systems.

6.1 Rootmat and Amorphous Peat

Hand augers were advanced along the north embankment toe. The hand auger logs are provided in Appendix B.

A rootmat was encountered in hand auger holes HA-1 through HA-6, HA-8 and HA-9 from surface and ranged in thickness from 45 mm to 120 mm. Amorphous peat was encountered below the rootmat in HA-1 through HA-4, HA-8 and HA-9 and from the ground surface in HA-7. The peat extended to base depths ranging from 170 mm to 810 mm.

6.2 Pavement Structure and Embankment Fill

Asphalt

Asphalt was encountered at the ground surface in Boreholes KL20-01, KL20-02/2B and KL20-03. It ranged in thickness from 150 mm to 200 mm.

Sand with Silt and Gravel to Sand with Gravel to Silty Sand Fill

Sand with silt and gravel to sand with gravel to silty sand fill was encountered below the asphalt in Boreholes KL20-01, KL20-02/2B and KL20-03. The thickness of this layer ranged from 5.1 m to 11.3 m with a base depth ranging from 5.3 m to 11.5 m (elevations 253.9 m to 246.9 m). A 200 mm concrete piece was encountered in Borehole KL20-01 at a depth of 0.75 m.

SPT-N values recorded within this layer ranged from 1 blow per 300 mm to 100 blows per 125 mm indicating a very loose to very dense relative density. The recorded moisture contents ranged from 4% to 30%.

The results of gradation analyses completed on seven samples of the layer are illustrated in Figures C1 and C2 of Appendix C. The results are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)	
Gravel	1 to 32	
Sand	51 to 83	
Silt	4 to 31	37
Clay		9

Atterberg Limit testing was completed on one sample in the layer. The results of the test indicate the soil to be non-plastic. The result is noted on the corresponding Record of Borehole sheet in Appendix B.

Pavement logs from Geocres No. 41I00-132 are provided in Appendix B for reference.

Rockfill

Rockfill with particles varying from cobble to boulder size pieces was encountered below the fill in Boreholes KL20-01, KL20-02/2B and KL20-03. The thickness of this layer ranged from 2.8 m to 9.5 m with a base depth ranging from 14.3 m to 15.2 m (elevations 244.4 m to 242.5 m).

Boreholes were advanced through the rockfill using casing and coring techniques. Sampling was attempted, however due to the nature of this material sample recovery was generally poor. A silty sand matrix was observed in Borehole KL20-02 where samples could be obtained. SPT N values within the rockfill ranged from 15 blows per 300 mm to 100 blows for 50 mm; however, it should be recognized that the correlation between N values and relative density are not reliable for rock fill.

Rockfill pieces were cored and dimensions were measured up to 920 mm.

The recorded moisture contents of the embankment fill samples ranged from 3% to 26%.

The result of a gradation analysis completed on one sample of the layer is illustrated in Figure C3 of Appendix C. The result is summarized below and is presented on the corresponding Record of Borehole sheet in Appendix B.

Soil Particle	Percentage (%)
Gravel	10
Sand	41
Silt	41
Clay	8

Atterberg Limit testing was completed on one sample in the layer. The results of the test indicate the soil to be non-plastic. The result is noted on the corresponding Record of Borehole sheet in Appendix B.

Concrete

Concrete was encountered below the rockfill in Borehole KL20-02. The concrete had a thickness of 2.3 m and a base depth of 16.6 m (elevation 241.8 m). Photographs of the concrete core are provided in Appendix C. The borehole was abandoned at this depth and the cored concrete cavity was reinstated with concrete. Backfilling above the concrete was in general accordance with MOE requirements (O.Reg. 903 as amended).

6.3 Sandy Silt (SM) to Silty Sand (ML)

A deposit of sandy silt to silty sand was encountered below the rockfill in Boreholes KL20-02B, KL20-03, and from the ground surface in Boreholes KL20-04, KL20-05 and KL20-06. The thickness of this layer ranged from 1.2 m to 7.5 m with a base depth ranging from 1.2 m to 20.1 m (elevations 242.4 m to 237.6 m). Some organics were observed in this layer; generally decreasing with depth. Silty sand to sand was encountered in HA-5 and HA-6 to base depths of 300 mm and 110 mm, respectively. A layer of clayey silt was encountered within this layer in Boreholes KL20-04 and KL20-05. This layer is discussed further in Section 6.4.

SPT-N values recorded within this deposit ranged from 0 to 49 blows indicating a very loose to dense relative density. Higher SPT-N values were recorded in this deposit below the embankment. The recorded moisture contents ranged from 15% to 54%. The higher moisture contents were recorded in zones with organics. Measured organic contents ranged from 3% to 6%.

The results of gradation analyses completed on seven samples of the deposit are illustrated in Figures C4 and C5 of Appendix C. The results are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	0 to 4
Sand	10 to 55
Silt	42 to 87
Clay	2 to 11

Atterberg Limit testing was completed on seven samples in the deposit. The results of the tests indicate the soil to be non-plastic. The results are noted on the Record of Borehole sheets in Appendix B.

6.4 Clayey Silt (MI)

A layer of clayey silt was encountered within the sandy silt layer in Borehole KL20-04 and below the sandy silt layer in Borehole KL20-05. The thickness of this layer was 1.2 m with a base depth of 2.4 m (elevation 241.2 m).

SPT N-Values recorded within this layer typically ranged from 2 to 7 blows indicating a very loose to loose relative density. The recorded moisture contents ranged from 25% to 59%. Measured organic contents ranged from 3% to 4%.

The results of gradation analyses completed on two samples in this layer are illustrated in Figure C6 of Appendix C. The results are summarized below and are presented on the Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	0 to 3
Sand	20 to 24
Silt	61 to 68
Clay	12

Atterberg Limit testing was completed on one sample of the deposit. The results are illustrated in Figure C8 in Appendix C. The results are summarized below and are presented on the Record of Borehole sheets in Appendix B. The laboratory results indicate the deposit exhibits intermediate plasticity (MI).

Parameter	Value
Liquid Limit	43
Plastic Limit	34
Plasticity Index	9

6.5 Silty Sand (SM) to Sand (SP-SM) Till

A layer of silty sand till was encountered below the sandy silt in Boreholes KL20-02B through KL20-05. The thickness of this layer ranged from 0.5 m to 1.4 m with a base depth ranging from 2.9 m to 20.6 m (elevations 240.7 m to 237.1 m). Frequent gravel and cobbles were noted in this deposit in Borehole KL20-03. Gravel was noted in this layer in KL 20-2B, KL 20-4 and KL 20-5. All hand auger boreholes, except HA-4 encountered refusal on probable cobbles at their termination depth.

SPT-N values recorded within this deposit ranged from 12 to more than 100 blows. The higher blow counts were encountered at the base of the layer and are suspected to be a result of cobbles or probable bedrock. A compact to dense relative density is considered representative for this layer. The recorded moisture contents ranged from 8% to 24%.

The results of a gradation analyses completed on two samples of the layer are illustrated in Figure C7 of Appendix C. The result is summarized below and is presented on the corresponding Record of Borehole sheet in Appendix B.

Soil Particle	Percentage (%)	
Gravel	19 to 29	
Sand	53 to 70	
Silt	11	15
Clay		3

Atterberg Limit testing was completed on two samples from the deposit. The results of the tests indicate the soil to be non-plastic. The results are noted on the Record of Borehole sheet in Appendix B.

6.6 Refusal and Probable Bedrock

Probable bedrock was inferred in all drilled boreholes at the site based on limited coring lengths and encountering bouncing spoon refusal. A summary of the inferred bedrock/refusal depths and elevations is provided in Table 6-1.

Table 6-1. Refusal and Suspected Bedrock

Borehole	Depth Below Ground Surface (m)	Elevation (m)	Comment
KL20-01	14.8	244.4	1.4 m cored (NQ8*)
KL20-02B	18.2	240.3	1.0 m cored (NQ6*)
KL20-03	20.6	237.1	0.3m cored (NQ4*)
KL20-04	5.4	238.2	Spoon bouncing
KL20-05	2.9	240.7	Spoon bouncing
KL20-06	7.5	236.8	Spoon bouncing

Note: (*) Corresponding NQ label for core photos in Appendix C.

Bedrock coring was not part of the scope of this work. However, some bedrock was cored in the on-road boreholes. Photographs of the materials recovered in the core barrel are presented in Appendix C, labels as noted in Table 6-1. The probable bedrock that was cored is described as gneiss.

Two test pits were advanced on the south embankment toe, west of the existing culvert outlet. The test pits encountered shovel refusal at depths of 100 mm and 130 mm on a probable bedrock outcrop. The test pit logs are given in Appendix B.

6.7 Water Level

A piezometer was installed in Borehole KL20-06 with a screen installed to a tip depth 7.0 m below ground surface (elevation 237.3 m). The groundwater level measurements are summarized in the table below. The piezometer was decommissioned upon completion of the field program.

Table 6-2. Measured Water Levels in Monitoring Well

Piezometer Location	Depth Below Ground Surface (m)	Elevation (m)	Date
KL 20-06	-0.3*	244.6	December 8, 2020 (pm)**
	0.0	244.3	December 9, 2020 (am)
	0.0	244.3	December 9, 2020 (pm)
	0.0	244.3	December 10, 2020 (am)

Note: (*) Negative value denotes measurement above the ground surface, (**) Date of installation

The water level in the creek was measured on December 10, 2020 at elevation 243.7 m and 243.0 at the culvert inlet and outlet, respectively.

It should be noted that fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation and spring snow melt. The water level should also be expected to change based on the presence or removal of the upstream beaver dam.

6.8 Results of Analytical Tests

Two soil samples were submitted for analysis of pH, water soluble sulphate and chloride concentrations, resistivity and conductivity. The analysis results are included in Appendix C and are summarized in the following table.

Table 6-3. Analytical Testing

Borehole	KL20-02B	KL20-04
Sample	SS2	SS2
Depth (m)	16.0 to 16.6	0.6 to 1.2
Elevation (m)	242.5 to 241.9	243.0 to 242.4
Material	Sandy SILT	Sandy SILT
Conductivity (uS/cm)	713	616
pH (-)	7.33	6.14
Resistivity (Ohm-cm)	1400	1620
Chloride (ug/g)	347	586
Sulphate (ug/g)	31	158
Sulphide (%)	<0.04	<0.04

7 MISCELLANEOUS

Borehole locations were selected relative to the existing site features. Ground surface elevations at the investigated locations were recorded relative to benchmarks and cross-sections provided on plan and profile drawings received from MPCE.

George Downing Estate Drilling Ltd. from Hawkesbury, Ontario supplied and operated the truck-mounted drill rig to carry out the drilling, sampling, in-situ testing and borehole decommissioning for the on-road boreholes. Ohlmann Geotechnical Services (OGS) Inc. from Almonte, Ontario supplied and operated the portable tripod drill rig to carry out the drilling, sampling, in situ testing and borehole decommissioning for the off-road boreholes.

The field investigations were supervised by Richard Howarth, C.Tech. and Jamil Pirani, EIT of Thurber. Overall supervision of the investigation program was conducted by Stephen Peters, P.Eng. Routine geotechnical laboratory testing was carried out by Thurber's geotechnical laboratory in Ottawa, Ontario. Organic content testing was completed by Stantec's laboratory in Ottawa, Ontario. Analytical testing was carried out by Paracel

Laboratories Ltd. in Ottawa, Ontario. Interpretation of the data and preparation of this report were carried out by Deanna Pizycki, P.Eng and Stephen Peters, P.Eng. The report was reviewed by Dr. Fred Griffiths P.Eng and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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**FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17, FROM THE EAST JUNCTION OF SUDBURY RR 55 19.5KM TO
KUKAGAMI RD
EMBANKMENT FROM STA. 13+110 TO 13+179, AWREY TWP
ASSIGNMENT NO. 5019-E-0012
GWP 5168-16-00
GEOCRES NO.: 41I-373**

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

8 GENERAL

This section of the report presents interpretation of the factual data in Part 1 for a slope stability assessment of a high fill section of Highway 17 (Sta. 13+110 to Sta. 13+179) within the Township of Awrey, Ontario. The geotechnical assessment and recommendations are provided to assist the design team in evaluating possible remediation strategies for this section of highway as it pertains to the stability of the existing embankment. This assessment is part of the larger rehabilitation assignment (GWP 5168-16-00) which extends from the East Junction of Sudbury Regional Road 55 / Southeast Bypass easterly to Kukagami Lake Road, a length of approximately 19.5 km.

The discussion and recommendations presented in this report are based on the information presented by MPCE and the factual data obtained during the course of the investigation.

This foundation investigation and design report with the interpretation and recommendations contained herein are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The construction or design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

9 ENGINEERING ANALYSIS

9.1 General

Both the north and south embankment slopes were assessed as part of this investigation. The north embankment slope was observed to generally consist of a steeply inclined slope of granular materials (1.5H:1V to 2H:1V). The south embankment slope also generally consisted of granular materials and was observed to be slightly less steep than the north side (1.75H:1V to 2H:1V). Significant erosion gullies were present at the crest of both sides of the embankment. Localized areas appear to have been repaired with granular and crushed rock. The lower portion of both slopes is generally vegetated; where vegetation is not present, large rock pieces line the lower portion of both slopes. Water is ponded along

the toe of the north embankment slope. The aerial photographs in Appendix D2 suggest the ponding has been present for at least six years, with the exception of 2015.

Review of the construction history (Section 3.3) indicates that shoulder repairs were to be completed in the upper 2.5 m of embankment at the crests under Contract No. 91-234. The treatment consisted of a geogrid reinforced granular system.

The subsurface conditions were investigated in order to assess the stability of the existing embankment and underlying soils, as well as the potential for settlement under the embankment. Analyses were carried out based on soil profiles obtained from the borehole records and soil design parameters that were selected based on the results of the in-situ testing, laboratory testing and engineering judgement.

No peat, topsoil, organic deposits or other deleterious materials were observed beneath the embankment in any of the boreholes. Therefore, for the purpose of this geotechnical assessment, it has been assumed that such material was removed prior to constructing the existing embankment.

It is noted that utilities are present on both sides of the highway. A buried bell line runs just north of the north embankment toe. A watermain is present running parallel to the south side of the embankment. The watermain is within the existing embankment slope and its alignment crosses overtop of the box culvert, see Markstay Water Works Drawing 9 in Appendix A. It is noted that the exact location of the watermain is not known.

It is understood that the Ministry is going to assess the condition of the existing culvert. Should culvert rehabilitation or replacement be required, additional foundation recommendations will need to be provided.

9.2 Seismic Site Class

The GSC Seismic Hazard Calculation Sheet for the site is provided in Appendix E. In accordance with the CHBDC, the selection of the seismic site classification is based on the soil within the upper 30 m of the stratigraphy. As per Table 4.1 of the CHBDC, this site has been classified as a Seismic Site Class D based on the harmonic mean of the SPT-N values. The Site Class D PGA was calculated to be 0.097g based on a *reference* Site Class C PGA of 0.075g and an F(PGA) of 1.29.

As per Section 6.14.2.1 a *Major-Route* geotechnical system shall use ground motions with a return period of 475 years. Based on this return period, liquefaction is not a concern at this site.

9.3 Stability Analysis

9.3.1 Analysis Methodology

Stability analyses were carried out utilizing the commercially available slope stability program Slope/W (Version 10) of the GeoStudio software package developed by Geo-Slope International with the option for Morgenstern-Price method of slices for limit equilibrium analyses.

For all analyses, the factor of safety of numerous potential failure surfaces was computed in order to establish the minimum factor of safety. The target factor of safety under static loading conditions is 1.5 for drained (long term; no traffic loading) and 1.3 for drained (short term; with traffic loading). The minimum target factor of safety used for seismic loading conditions is 1.1.

The geometry of the analyzed embankment slopes was based on sections provided by MPCE. The stability analyses were carried out on the cross sections of the embankment that were selected to be the most critical, Sta. 13+130 for the north slope and Sta. 13+150 for the south slope. The critical section was determined based on the height and steepness of the embankment and the thickness of the overburden.

Given the embankment height, mid-height benches were incorporated into the analyses. A uniform traffic load of 18 kPa was added to the surface of the highway for the short-term, static loading case, as per Section 6.12.5 of the CHBDC.

Pseudo-static seismic slope stability analyses were also carried out using a horizontal acceleration of 0.05g (50 percent of the peak ground acceleration for the site as per CHBDC S6-19 6.14.9.1).

9.3.2 Geotechnical Soil Parameters and Groundwater Conditions

The material properties used in the analyses are summarized in Table 9-1 and were determined by in situ testing conducted during the current study as well as soil index correlations developed during current and past projects. It is noted that cohesive soils were not encountered at this site.

Table 9-1 Summary of Material Properties in Slope Stability Analyses

Material	Unit Weight (kN/m ³)	Static and Seismic Drained
		Friction Angle (degrees)
Slope Treatment*	22	High Strength
New SSM or Gran B Type I Fill	21	32
Sand to Silty Sand Fill	21	32
Rockfill	18	42
Sandy Silt to Silty Sand	19	30
Clayey Silt	18	28
Glacial Till	20	35
Bedrock	Assumed Stable/Non-Yielding	

Note: (*) Material properties assigned to the geogrid slope treatment in the upper 2.5 m of the embankment crest carried out under Contract No. 91-234.

The groundwater and surface water levels surveyed during the December 2020 investigation were used in the analysis. The upstream elevation was 244.3m and the downstream elevation was 243.0 m.

9.3.3 Analysis Results and Discussion

The slope stability output figures discussed in this section are presented in Appendix F. These figures also provide the input parameters and soil model used in the stability analyses, including soil stratigraphy, engineering properties, groundwater conditions and the embankment geometry.

9.3.3.1 Stability Results of Existing Conditions

The factors of safety for the existing embankment slopes are presented in Table 9-2.

Table 9-2 Summary of Slope Stability Analyses for Existing Embankment

Location	Minimum Factor of Safety
	Static (Long Term; no traffic)
North (Sta. 13+130)	1.0 (Figure F1)
South (Sta. 13+150)	1.3 (Figure F2)

Based on the above assessment, the existing embankment slopes yield low factor of safety values, particularly for the north slope, for shallow failures, which agrees with site observations. This suggests that the existing slopes are too steep for the granular materials encountered during the investigation. Based on discussion with the Ministry, it is understood that a factor of safety (FOS) of 1.3 for the south slope is acceptable. It should be noted that a higher FOS of 1.4 exists for a failure surface extending below the watermain. Analyses in the following sections have been carried out for the North and South slopes to present the level of efforts. Analysis for the temporary and pseudo-static seismic cases were not completed given the results of the long term assessment.

9.3.3.2 Remediation Options

Modifying the slopes is considered the most feasible option for improving the overall surficial stability of the embankment. Treatment of both the north and south embankment slopes with granular fill and rockfill was considered. The results are shown in Table 9-3 and Table 9-4 respectively.

The following remediation options have been considered for this embankment. Please see Appendix F for a representation of the geometry.

- Option 1: “Do nothing”, no change in embankment geometry from existing conditions. The conditions on site would only be repaired under a normal maintenance schedule or if emergency conditions became apparent. However, consideration should be given to adding curbs (OPSS 601.010) to direct surface runoff to defined rock lined channels to reduce the highway runoff onto the slopes.
- Option 2: Widen both embankment slopes by flattening to 2H:1V with granular material (SSM or Granular B Type I) with a mid height 2m wide bench.

- Option 3A: Widen the embankment on both sides using rock fill material placed at 1.25H:1V. A 2 m wide, mid height bench would be required on the north side. More than one, 2 m wide bench could be used on south side to reduce the volume of material required. The rockfill widening would be a minimum of 5 m wide for constructability purposes. Rockfill extends up the slope to 2 m below road grade with granular slopes above the rockfill.
- Option 3B Same as Option 3A, but only widening the embankment with rockfill to the north. The upper portions of the south slope should be graded flatter at the expense of shoulder width.
- Option 4: Widen the embankment to the north using rock fill material placed at 1.25H:1V. A 2 m wide, mid height bench would be required. The rock fill widening would require a minimum width of 6.5 m. It is noted that this will only require 1.5 m of additional widening to the north than presented in Option 3A/B.
- Shift the roadway alignment 3.3 m to the north (feasibility of a horizontal road alignment shift should be reviewed from a highway design point of view).
- Regrade the existing south embankment slope to 2H:1V by removing existing materials from the upper 6 m of the embankment slope and incorporating a 2 m wide bench.

Table G1 outlines the advantages and disadvantages of each of the remediation options and is provided in Appendix G. For Options 2 to 4, it should be noted that construction activities will be required adjacent to the existing embankment toe(s). Ponded water is present to the north of the embankment and it is understood that this area is considered suitable for fish and Blanding's Turtle habitat. Construction activities and permissible timing windows will be important considerations for carrying forward these remediation options as they will affect the allowable construction schedule. *Likewise, the condition of the existing culvert is unknown and the suitability of extending the existing culvert will need to be assessed.*

Consideration was also given to lowering the profile at the site. This would allow the upper slopes of the embankment to be flattened without widening the existing footprint. This solution would require grade lowering of 3.3 m and has been discarded as it will require extensive lengths of highway profile changes and significant cost.

9.3.3.3 Stability Results for Remediation Options

The computed factors of safety for Remediation Options 2, 3 and 4 are presented in Table 9-3, Table 9-4 Table 9-5, respectively. The factors of safety for Remediation Option 1 will be the same as presented in Table 9-2 for the existing conditions.

Table 9-3 Summary of Slope Stability Analyses for Remediation Option 2 (2H:1V Granular Widening)

Location	Minimum Factor of Safety
	Static (Long Term; no traffic)
North (Sta. 13+130)	1.5 (Figure F3)
South (Sta. 13+150)	1.5 (Figure F4)

Flattening with granular material does meet the factor of safety requirements discussed in Section 9.3.1. Further, it is noted that granular widening to the south will result in a relatively narrow widening to meet a 2H:1V slope and will not be constructible without additional widening to create a sufficient width for a working platform.

Table 9-4 Summary of Slope Stability Analyses for Remediation Option 3A/B (1.25H:1V Rockfill Widening) (*)

Location	Minimum Factor of Safety		
	Static (Long Term; no traffic)	Static (Short Term; with traffic)	Seismic (no traffic)
North (Sta. 13+130) (Option 3A/B)	1.5 (Figure F5)	1.5 (Figure F6)	1.3 (Figure F7)
South (Sta. 13+150) (Option 3A)	1.7 (Figure F8)	1.7 (Figure F9)	1.5 (Figure F10)

Note: () rockfill widening should be at least 5 m in width horizontally for constructability purposes.*

Flattening with rockfill will meet the factor of safety requirements discussed in Section 9.3.1.

It should be noted, however, that a watermain is present within the south embankment slope and a low slope factor of safety (Section 9.3.3.1) could pose a concern to the watermain. Furthermore, adding fill to the south slope, as required for Remediation Options 2 and 3A will require protection or relocation of the watermain. Option 3B increases the factor of safety of the North slope without adding additional loading to the South slope. Minor regrading of the upper south slope will further enhance the FOS.

An alternative solution, Remediation Option 4, was assessed where only the north embankment slope is widened and the existing south embankment slope is flattened to 2H:1V by removing material from the upper slope. Note that the slope treatment carried out under Contract No. 91-234 would be removed in this scenario. The location of the bell line north of the existing toe should be reviewed. The slope stability results are shown in Table 9-5.

Table 9-5 Summary of Slope Stability Analyses for Remediation Option 4 (1.25H:1V Rockfill Widened to the North, Highway Shifted to the North and South Slope Flattened)

Location	Minimum Factor of Safety		
	Static (Long Term; no traffic)	Static (Short Term; with traffic)	Seismic (no traffic)
North (Sta. 13+130)	1.5 (Figure F11)	1.5 (Figure F12)	1.3 (Figure F13)
South (Sta. 13+150)	1.5 (Figure F14)	1.4 (Figure F15)	1.3 (Figure F16)

The configuration of Remediation Option 4 meets the factor of safety requirements under seismic and both static cases as discussed in Section 9.3.1 and eliminates the requirement to place fill on the existing watermain. However, the feasibility of a horizontal road alignment shift was reviewed by MPCE from a highway design perspective and determined that 800-1000 m of highway would be affected. It is noted that there are potential conflicts with a buried Bell line to the north as well as potential property and environmental issues.

9.4 Settlement Analysis

In accordance with MTO's document "Embankment Settlement Criteria for Design" (March 2, 2010), the criteria adopted for embankment design is presented in Table 9 6.

Table 9-6 Summary of MTO Settlement Criteria

Type	Allowable Settlement for Embankment Widening During Design Life		Design Life (years)
	Total (mm)	Differential	
Non-Compressible Soils (Non-Freeway)	75	100:1	15

9.4.1 Foundation Settlement

Settlement analyses of the soils beneath the embankment were carried out utilizing the commercially available settlement program Settle3 (Version 5) developed by Rocscience Inc. Analyses were carried out for each of the three remediation options discussed in Section 9.1. Calculated settlement values at the existing north embankment toe and at the north crest/road shoulder are presented in Table 9-7.

Table 9-7 Settlement of Underlying Soils

Remediation Option	Total Settlement (mm)	
	Existing North Embankment Toe	North Embankment Crest / Road Shoulder
Remediation Option 2 2H:1V Granular Widening	40	<5
Remediation Option 3A/B 1.25H:1V Rockfill Widening	35	<5
Remediation Option 4 1.25H:1V Rockfill Widening (North) and Highway Shift	45	20*

Note: (*) settlement at the crest/shoulder of the widened alignment ~3.3 m north of existing shoulder

The estimated magnitudes of foundation settlement are considered approximate and may vary along and across the highway alignment subject to the thickness of soil layers at a particular location, variations in soil parameters with depth and location, the presence of organics within the various strata, the depth to bedrock, and the height of embankment.

It is anticipated that the settlements beneath the paved surface will occur during the period of fill placement and should be predominantly completed at end of construction, nonetheless it would be prudent to delay placing the final lift of asphalt in this area until at least a month after completion of the embankment widening.

It should be noted that amorphous peat was encountered at the toe of the north embankment slope (Section 6.1). It is not fully known what the near surface soils are under the ponded water at the north embankment toe. The settlement predictions assume organic material has been removed from the footprint of the proposed embankment. If organics materials are not effectively removed from the widened footprint, additional settlements are to be expected under the widenings and loss of new embankment fill into the peat deposits should also be expected and should be accounted for in the quantities.

The integrity of the existing culvert should be reviewed taking into consideration the proposed magnitude of settlement. A non-structural culvert extension to this existing culvert will be required as part of this embankment widening work (see Section 11.2). The culvert will undergo settlement at the culvert inlet as noted in Table 9-7 and should be reviewed by the designers. Lesser settlements are to be expected at the culvert outlet.

9.4.2 Fill Compression

In addition to the subsurface soils, an assessment of the short and long-term compression of fill materials under self-weight was completed. Settlement of rock fill, due to particle re-orientation and degradation of the interparticle contact, is expected at a decreasing rate over time. In accordance with the MTO document "Post-Construction Rock Fill Settlement and Guidelines for Estimating Rock Fill Quantity" (April 12, 2010), the estimated magnitude of this settlement for compacted rock fill placed in the dry is expected to be 0.5% of the rock fill thickness within 1 year of construction (90% in the first 6 months) and a further 0.1% of

the thickness after the 1 year period. The compression of new granular fill materials under the self-weight is estimated to be 0.5% of the newly placed fill height and will occur during and after fill placement. The calculated fill compression values are presented in Table 9-8.

Table 9-8 Self Compression of New Embankment Fill at North Slope

Remediation Option	Maximum Modeled Fill Thickness (m)	Fill Compression within 6 months (mm)	Fill Compression after 6 months (mm)
Remediation Option 2 2H:1V Granular Widening	4.8	25	N/A
Remediation Option 3A/B 1.25H:1V Rockfill Widening	4.8	25	<5
Remediation Option 4 1.25H:1V Rockfill Widening (North) and Highway Shift	5.8	30	<5

The settlement analysis indicates that the estimated total settlement induced beneath the embankment and in self compression from the slope modifications are expected to be in the range of the MTO's settlement criteria for the remediation options presented.

9.5 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in buried infrastructure. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater.

The class of concrete selected should consider the effects of road de-icing salts. The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 6.8 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

10 RECOMMENDED APPROACH FOR REMEDIATION

The options identified above are considered technically feasible. From a foundation perspective, Option 1 is considered to have the highest long-term risk as loss of material from both crests of slope is already occurring. However, consideration could be given to adding curbs (see Section 11.3) to reduce the risk and/or offer an interim solution. Options 3A/B and 4 are likely to be the more economical approaches if rock fill is generated as part of the overall project. Furthermore Options 3A/B and 4 have smaller footprints than Option 2 and thus represents less impact on property and the environment and results in shorter

culvert extensions. Options 3B and 4 require less rockfill than Option 3A, do not add additional loading to the watermain within the south embankment toe and will only require a culvert extension on the north side. Erosion protection will be required for all options at locations where rockfill is not utilized.

Option 2 will require dewatering so that granular fill is not placed below water. In addition, significant benching would be required during construction.

Although Option 4 is the preferred approach from a foundation perspective, it is understood that the northward shift in the highway centreline required for Option 4 would impact 800-1000 m of highway and would impact the existing rock cut to the northwest of the site. Once the costing is considered, Option 3B is the recommended approach.

The following sections assumes rockfill will be used to improve the stability of the existing embankment.

Property requirements and environmental considerations should be reviewed for all widening options.

11 CONSTRUCTION

11.1 Embankment Widening

The construction of the embankment widening should be carried out with rock fill and a 1.25H:1V slope, constructed starting from the base of the embankment. Rock fill should not be placed by dumping from the top of the slope. Construction operations are anticipated to have minimal impact to traffic when work is completed from the bottom.

Benching into the existing slope as per OPSD 208.010 should not be carried out for placement of rockfill. Stripping of the organic material from the footprint of the embankment widening is required. A typical stripping depth of 600 mm is recommended based on the hand auger probes.

Embankment widening construction should be carried out in accordance with OPSS.PROV 206. Rock size should be controlled in accordance with OPSS.PROV 206. Rock fill should be placed in a controlled manner (not end dumped) including blading, dozing and chinking of the rock to minimize voids and bridging. Rock fill must be compacted as per OPSS.PROV 206.

The geogrid treatment (Contract No. 91-234) at the crest of the slopes could be removed on both sides. The upper 3 m of the south slope should be regraded to 2H:1V at the expense of the shoulder width. A layer of Granular B Type II at least 2 m in width should be placed in the upper portion of the south slope and covered with rock protection, see Section 11.3 below.

Where granular fill is to be placed over rock fill, the rock fill subgrade must be blinded with spall material and rock fill chinking shall be in accordance with OPSS.PROV 206. This treatment could also be considered at the location of the benches. Slopes in granular pavement materials should be no steeper than 3H:1V as per OPSD 210.010. All granular

fill must be compacted as per OPSS 501.

The embankment widening should be at least 5 m in width horizontally, it is understood that this will be acceptable for constructability purposes. A 2 m wide mid-height bench should be incorporated into the slope. Northern Region Engineering Directive NRE 98-200 should be reviewed however, it is anticipated that if the foregoing geometric recommendations are followed the minimum overbuild requirements of the NRE will be achieved.

11.2 Culvert Extension

The existing box culvert should be extended where the embankment footprint is enlarged. Soft organic material was observed in the hand auger holes along the north toe of the embankment. All organics, existing fill, soft or loose deposits, disturbed soils, alluvial deposits and deleterious materials must be stripped from the footprint of the culvert extension to expose competent subgrade at or below the desired founding elevation. As soon as practical, the excavation should be backfilled to the underside of the design bedding elevation with granular fill consisting of OPSS.PROV 1010 Granular A or Granular B Type II material to protect the subgrade from disturbance during construction and weather. Construction equipment should not travel on the exposed subgrade. The granular fill should be compacted as per OPSS.PROV 501.

The culvert extension should be constructed following OPSS.PROV 401 and OPSS 422. In order to provide a more uniform foundation subgrade condition for a closed box culvert, bedding and cover material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010. The Granular bedding layer should be a minimum of 300 mm thick and covered with a 75 mm levelling course of Granular A.

It is noted that construction will extend below the observed water level to the north of the embankment. Dewatering and water diversion will be required to place the bedding and culvert in the dry. This work should be carried out in accordance with OPSS 517 and SP 517F01. It is noted that a preconstruction survey is not required for this site and that a minimum experience level is not required for the design Engineer and design-checking Engineer.

The backfill soils should be compacted in regular lifts as per OPSS.PROV 501, OPSS 206.07.05.02.01 and SP 102S05.

Heavy compaction equipment used adjacent to and directly above the culvert must be restricted in accordance with OPSS.PROV 501 to protect the culvert from damage.

11.3 Erosion Control

Erosion protection should be provided for the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all earth surfaces subjected to flowing water in accordance with OPSS.PROV 511. Treatment at the outlet should be in accordance with OPSD 810.010.

The granular fill on the upper portions of the existing embankment show signs of significant erosion due to surface water runoff and ravelling. Embankment slopes constructed of granular materials need to be protected from flowing surface water. For all slopes in granular materials, consideration could be given to adding curbs (OPSS 601.010) to direct surface runoff to defined rock lined channels leading across the granular slopes.

Consideration should be given to add rock protection (greater than 200 mm in nominal size) to the *upper* embankment slopes on the south side to limit the effects of future erosion. Considering the thickness of rockfill (≥ 5 m) that is recommended to be placed on the existing slopes, it is not considered necessary to provide a geotextile as a filter separation between the rockfill and existing slope.

12 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Seasonality: placement of rock fill during winter conditions typically results in an increased amount and duration of subsequent self settlement and a lower strength rock fill. If rockfill construction is carried out during winter months, care must be exercised to exclude snow and/or ice within the fill.
- Obstructions may be encountered during construction and interfere with excavations and temporary protection systems, where needed. The Contractor must be prepared to dislodge/remove obstructions. A draft Notice to Contractor has been provided in Appendix H.
- A watermain is located within the south embankment slope. Protection or relocation will be required if fill is to be placed on the south slope.
- A buried bell line runs adjacent to the north embankment toe. Protection or relocation may be required.
- Overhead utility lines are present along the north side of the embankment. The wires may interfere with construction activities and the poles may interfere with the embankment footprint.
- Although settlement predictions are within the MTO tolerance at the road surface, it is recommended that paving of the final asphalt lift be delayed for at least a month after the fill placement is complete. A settlement monitoring program is not warranted.
- Species at Risk (SAR): ponded water is prevalent north of the embankment and is considered suitable for fish and turtle habitat. Construction activities and timing should be carefully chosen.

13 CLOSURE

Engineering analysis and preparation of this report was carried out by Deanna Pizycki, P.Eng. and Stephen Peters, P.Eng. The report was reviewed by Dr. Fred

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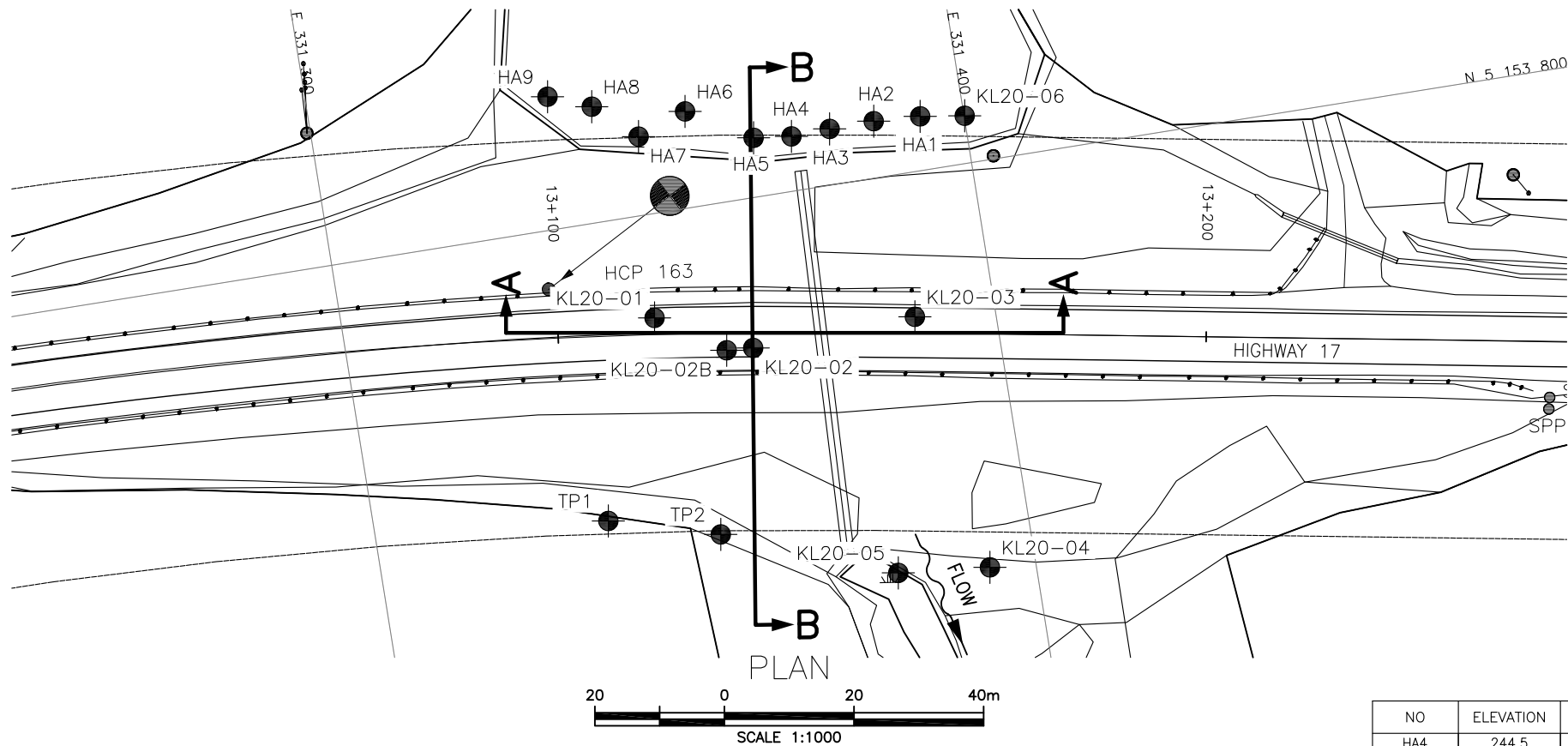
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Appendix A.

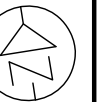
Drawings



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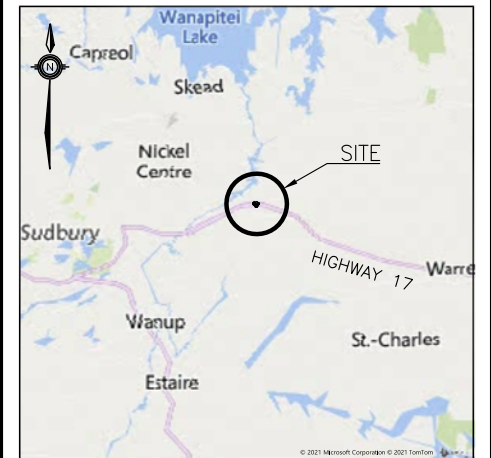
HIGHWAY 17
KUKAGAMI SLOPE
INSTABILITY
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

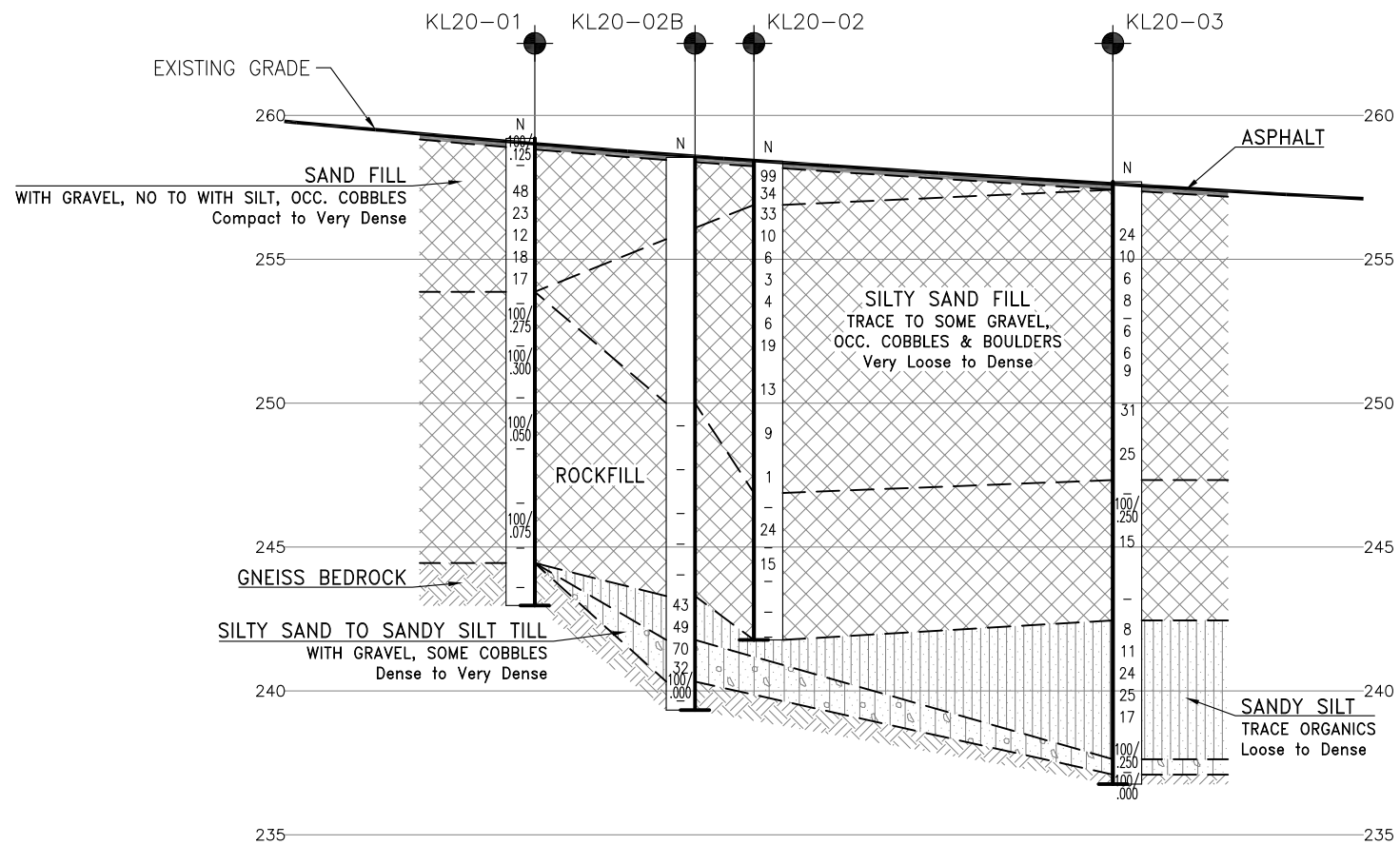
	Borehole (Current Investigation by Thurber)
	Borehole (Previous Investigation by Others)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
S/R	Spoon Refusal

NO	ELEVATION	NORTHING	EASTING
KL20-01	259.2	5 153 784.1	331 347.9
KL20-02	258.4	5 153 777.1	331 362.2
KL20-02B	258.5	5 153 777.4	331 358.1
KL20-03	257.7	5 153 777.9	331 387.6
KL20-04	243.6	5 153 737.9	331 392.9
KL20-05	243.6	5 153 739.3	331 378.8
KL20-06	243.3	5 153 807.3	331 400.1
TP1	248.2	5 153 754.3	331 335.9
TP2	246.1	5 153 749.5	331 352.7
HA1	244.5	5 153 808.3	331 393.3
HA2	244.5	5 153 808.7	331 386.1
HA3	244.5	5 153 808.6	331 379.2

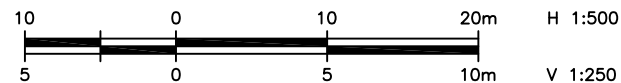
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 12.

GEOCRES No. 411-373



PROFILE A-A



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DJP	CHK SBP	CODE
DRAWN	MFA	CHK DJP	SITE
LOAD	DATE	MAY 2021	
STRUCT	DWG	1	

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
WP No 5168-16-00

HIGHWAY 17
KUKAGAMI SLOPE
INSTABILITY
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEYPLAN

LEGEND

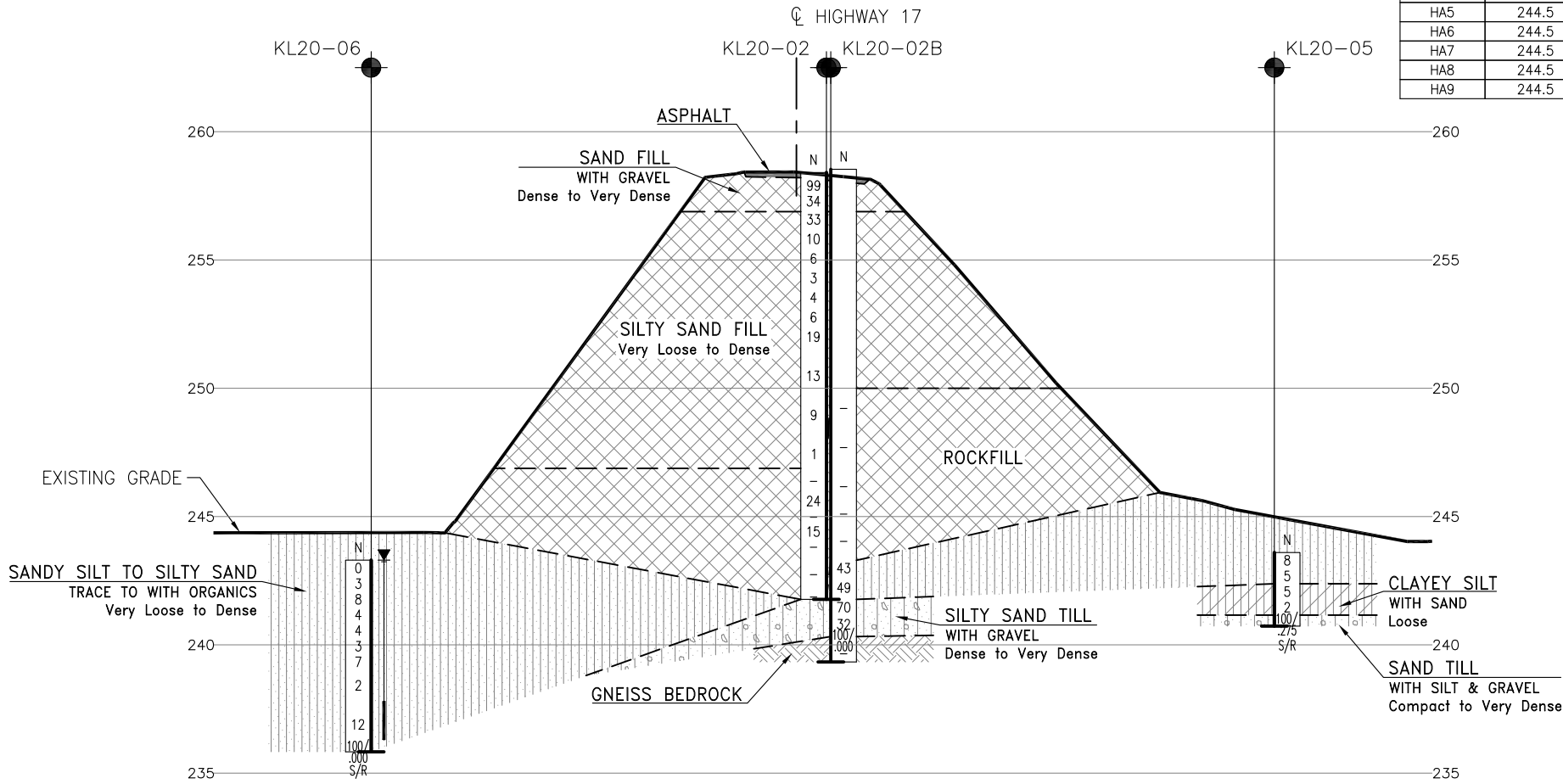
	Borehole (Current Investigation by Thurber)
	Borehole (Previous Investigation by Others)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
S/R	Spoon Refusal

NO	ELEVATION	NORTHING	EASTING
KL20-01	259.2	5 153 784.1	331 347.9
KL20-02	258.4	5 153 777.1	331 362.2
KL20-02B	258.5	5 153 777.4	331 358.1
KL20-03	257.7	5 153 777.9	331 387.6
KL20-04	243.6	5 153 737.9	331 392.9
KL20-05	243.6	5 153 739.3	331 378.8
KL20-06	243.3	5 153 807.3	331 400.1
TP1	248.2	5 153 754.3	331 335.9
TP2	246.1	5 153 749.5	331 352.7
HA1	244.5	5 153 808.3	331 393.3
HA2	244.5	5 153 808.7	331 386.1
HA3	244.5	5 153 808.6	331 379.2

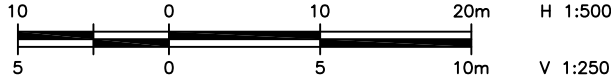
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 12.

GEOCRES No. 411-373



SECTION B-B



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DJP	CHK SBP	CODE
DRAWN	MFA	CHK DJP	SITE
			LOAD
			DATE
			MAY 2021
			STRUCT
			DWG 2

METRIC

PLATE No

CONT No 91-234

WP No 114-86-00

STA TO STA
Survey Revised

SHEET

1

FROST HEAVES							
No.	Station to Station	Township	Location	Taper Length (m)	(*) Depth (m)	Gran. 'A' (tonnes)	Gran. 'B' Type 'I' (tonnes)
FH 1	15 + 450 - 15 + 460	NEELON	Full Width	20	1.20	281	927
FH 2	15 + 550 - 15 + 600	NEELON	Full Width	20	1.20	536	2,538
FH 3	15 + 685 - 15 + 720	NEELON	Full Width	20	1.20	431	1,786
FH 4	16 + 635 - 16 + 664	NEELON	Main Lanes	See Sheet No. 6	1.20	207	686
"	16 + 710 - 17 + 038	NEELON	Main Lanes	See Sheet No. 6	1.20	1,393	5,961
"	17 + 077 - 17 + 175	NEELON	Main Lanes	See Sheet No. 6	1.20	477	1,822
FH 5	19 + 700 - 19 + 715	NEELON	Full Width	See Sheet No. 6	1.40	256	1,351
FH 6	11 + 475 - 11 + 725	DRYDEN	Full Width	5	1.20	2,088	11,647
FH 7	12 + 125 - 12 + 175	DRYDEN	Right Lane Taper Left Side	5	1.20	101	631
FH 8	13 + 000 - 13 + 178	DRYDEN	Full Width	5	1.20	1,267	7,801
FH 9	13 + 575 - 13 + 835	DRYDEN	Full Width	5	1.20	2,048	12,650
FH 10	13 + 995 - 14 + 185	DRYDEN	Passing Lane	5	1.20	577	3,234
FH 11	14 + 815 - 14 + 870	DRYDEN	Right Lane Taper Left Side	5	1.20	159	826
FH 12	15 + 300 - 15 + 475	DRYDEN	Full Width	20	1.20	1,363	7,618
FH 13	16 + 000 - 16 + 050	DRYDEN	Full Width	20	1.20	529	2,549
FH 14	16 + 175 - 16 + 235	DRYDEN	Full Width	5	1.20	413	2,798
FH 15	19 + 100 - 19 + 240	DRYDEN	Full Width	20	1.20	1,210	6,868
FH 16	10 + 960 - 11 + 400	AWREY	Main Lanes	20	1.20	2,466	17,160
FH 17	11 + 700 - 11 + 800	AWREY	Full Width	5	1.20	655	4,084
FH 18	12 + 200 - 12 + 250	AWREY	Full Width	5	1.20	365	2,010
FH 19	12 + 700 - 12 + 740	AWREY	Full Width	5	1.00	296	1,189

NOTE: (*) STATIONS SHOWN INDICATE TREATED LENGTH EXCLUDING TAPERS
 (**) DEPTH AS NOTED OR MATCH EXISTING - SEE SHEET No. 7 & 8
 FOR CONC. PAVEMENT REMOVAL - SEE SHEET No. 7

NOTE
 (**) INCLUDES SUPERELEVATION CORRECTION
 * ASPHALT INCLUDES AC

PAVING DETAILS									
DESCRIPTION	Surface	OPTION 'A'				OPTION 'B'			
		Binder		Levelling Course		Binder		Levelling Course	
		HL 4 50	HL 4 40	HL 4 50 Avg 40 Min.	(*) X-Fall Correction 50 Min. As Req'd	Upper Recycled 40	Lower Recycled 40	Recycled 50 Avg 40 Min.	(*) X-Fall Correction
MAIN HIGHWAY (RESURFACING) PROBLEM FILL No. 1 (RESURFACING) SIDEROADS, RIGHT TURN TAPERS AND ENTRANCES. (RESURFACING AREAS)	X				X			X	X
GRANULAR LIFTS FROST HEAVES SUPERELEVATION CORRECTION (GRAN. 'A') CULVERT FROST TREATMENT 2 LEFT TURN LANE WIDENING	X		X	X		X	X		
HWY 537, COMM. ENTRANCES (12+80 LT & 12+890 RT, DRYDEN TWP)	X		X			X			
BRIDGE DECKS APPROACH SLABS PAVED SHOULDERS	X								
REMAINING SIDEROADS, RIGHT TURN TAPERS AND ENTRANCES	X								
BOULEVARDS & ISLANDS (MISC. PAVING)									
W.P. 85-86-01	X	X	X			X	X		

EXISTING CULVERT - FROST TAPERS					
No.	Station to Station	Township	Location	Gran. 'A' (tonnes)	Gran. 'B' Type 'I' (tonnes)
CFT 1	18 + 310 - 18 + 348	NEELON	Full Width	228	1,859
CFT 2	11 + 275 - 11 + 311	DRYDEN	Full Width	273	1,224

SUPERELEVATION DATA					FULL PAVEMENT WIDTH ON CURVE
TWP	P.L.	RADIUS	S.E.		
NEELON	19 + 708.320	875	8.0		7.3 m
DRYDEN	10 + 981.647	1800	3.3		10.95 m
DRYDEN	11 + 790.983	1700	3.4		10.95 m
DRYDEN	12 + 485.733	1700	2.6		7.3 m
DRYDEN	13 + 140.251	850	4.1		7.3 m
DRYDEN	13 + 811.012	575	5.8		11.25
DRYDEN	14 + 805.515	1750	2.2		7.3 m
DRYDEN	15 + 132.841	900	3.4		7.3 m
DRYDEN	15 + 388.363	340	5.4		7.6
DRYDEN	15 + 705.956	250	6.0		7.8
DRYDEN	16 + 302.586	875	5.0		7.3 m
DRYDEN	16 + 820.137	875	5.0		7.3 m
DRYDEN	17 + 628.949	1800	3.3		10.95 m
DRYDEN	18 + 864.416	350	5.4		7.6
DRYDEN	19 + 097.369	350	5.4		7.6
DRYDEN	19 + 281.645	420	5.0		7.6
DRYDEN	20 + 031.204	580	5.8		11.25
DRYDEN	20 + 381.411	875	5.0		10.95 m
AWREY	10 + 858.101	875	5.0		10.95 m
AWREY	12 + 993.371	873.188	5.0		7.3 m

TO BE USED IN CONJUNCTION WITH O.P.S.D. 213.01
 NOTE: (X) INDICATES NO WIDENING ON CURVE

Legend

- FROST HEAVE TREATMENT
- GRANULAR LIFT
- PROBLEM FILL AREA
- CULVERT FROST TAPER
- CROSS-FALL & SUPERELEVATION CORRECTION

NOT TO SCALE

GRANULAR LIFTS						
No.	Station to Station	Township	Depth (mm)	Gran. 'A' (tonnes)	Taper Length (m)	
GL 1	19 + 250 - 19 + 310	NEELON	200	1,126	80	80
GL 2	14 + 185 - 14 + 305	DRYDEN	200	2,676	65	95
GL 3	14 + 740 - 14 + 920	DRYDEN	300	3,941	120	112
GL 4	17 + 410 - 17 + 610	DRYDEN	300	5,551	120	120
GL 5	19 + 200 - 20 + 590	DRYDEN	400	32,831	160	
GL 6	10 + 000 - 10 + 960	AWREY	400	24,065		160

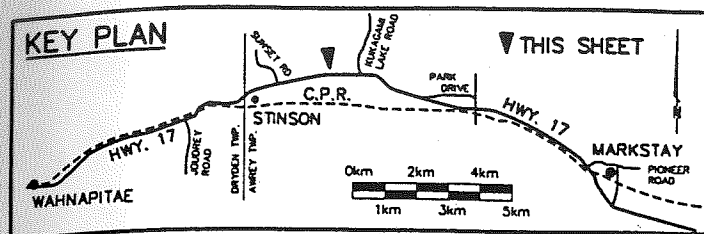
NOTE: (*) STATIONS SHOWN INDICATE TREATED LENGTH EXCLUDING TAPERS

PROBLEM FILL LOCATIONS						
No.	Station to Station	Township	Location	Gran. 'A' (tonnes)	Gran. 'B' Type 'I' (tonnes)	
*P.F. 1	19 + 540 - 19 + 630	NEELON	RT	45	344	
P.F. 2	10 + 380 - 10 + 510	DRYDEN	LT & RT	1912	258	
P.F. 3	10 + 700 - 10 + 930	DRYDEN	LT & RT	3167	400	
P.F. 4	13 + 110 - 13 + 170	AWREY	LT & RT	2022	NIL	

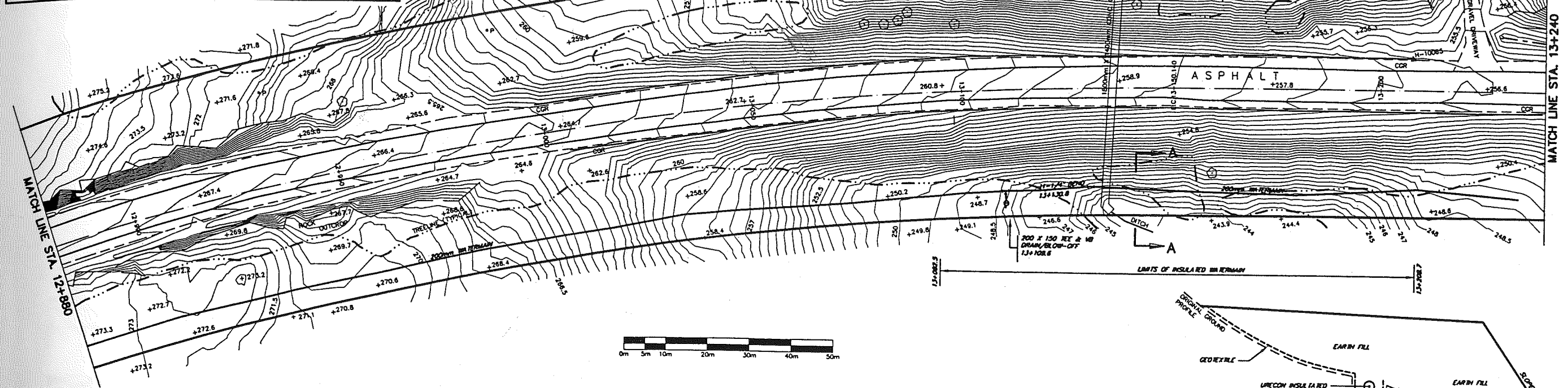
* BENCHING REQUIRED



DENNIS CONSULTANTS LTD.
 CIVIL ENGINEERS
 128 Pine Street, Sudbury, Ontario P3C 1X3

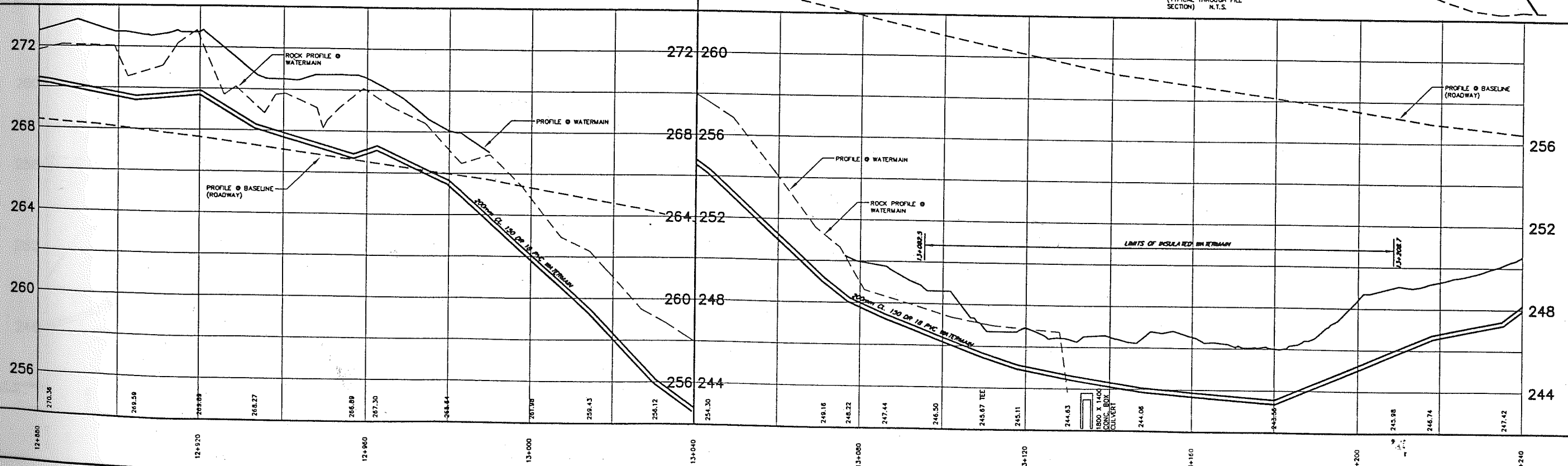


EXISTING UTILITY INFORMATION SHOWN ON THIS DRAWING IS APPROXIMATE AND MUST BE FIELD CONFIRMED WITH THE APPROPRIATE UTILITY.



YEAR OF CONSTRUCTION
WATERMAIN - 1996

A-A
(TYPICAL THROUGH FILL SECTION)
N.T.S.



NOTES

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. LOCATION OF UTILITIES ONLY APPROXIMATE.

REVISIONS

DATE	DETAILS	BY
FEB. 98	ISSUED AS RECORD DRAWING	D.K.W.

DRAWN: D.K.W.
DATE: FEBRUARY 1998
CHECKED:
DESIGNED:

DENNIS CONSULTANTS
CIVIL ENGINEERS
a division of R.V. Anderson Associates Limited

ONTARIO CLEAN WATER AGENCY

THE CORPORATION OF THE TOWNSHIP OF HAGAR
MARKSTAY WATER WORKS PROJECT

RECORD DRAWING
HIGHWAY No. 17
STA. 12+880 TO STA. 13+240

SCALE:
CONTRACT NO.: O.C.W.A. 53-0136-01
FILE #: 4187-20
PAGE NO.: 9

Appendix B.

Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

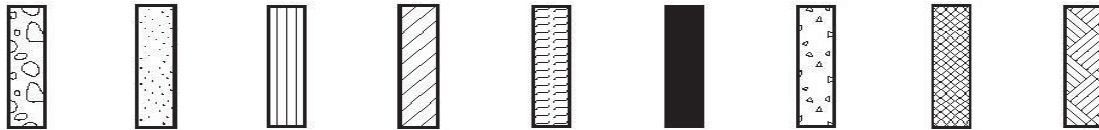
DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders
Cobbles
Gravel Sand Silt Clay Organics Asphalt Concrete Fill Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

STRENGTH CLASSIFICATION


Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

RECORD OF BOREHOLE No KL20-01

1 OF 2

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523185°, Long: -80.653973° Slope Instability: Sta.13+110 to 13+179, MTM Zone 12: N 5 153 784.1 E 331 347.9 ORIGINATED BY JP
 HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY JP
 DATUM Geodetic DATE 2020.11.13 - 2020.11.14 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
259.2	Pavement Surface																	
0.0	ASPHALT (150mm)																	
0.2	SAND with silt and gravel, occ. cobbles Compact to very dense FILL - 200mm concrete piece at 0.75 m		1	SS	100/ 125mm		259											
			1	NQ	-													
			2	SS	48													
			3	SS	23													
			4	SS	12													
	- poor recovery from 2.3 m to 5.3 m																	

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20
15
10
(%) STRAIN AT FAILURE

DOUBLE LINE 28408 HWY 17 RR 55 TO KUKAGAMI RD - INSTABILITY.GPJ 2012TEMPLATE(MTO).GDT 11/2/21

RECORD OF BOREHOLE No KL20-01

2 OF 2

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523185°, Long: -80.653973°
Slope Instability; Sta. 13+110 to 13+179, MTM Zone 12: N 5 153 784.1 E 331 347.9 ORIGINATED BY JP
HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY JP
DATUM Geodetic DATE 2020.11.13 - 2020.11.14 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100	○ UNCONFINED + FIELD VANE			w _p w w _L				
						● QUICK TRIAXIAL × LAB VANE										
Continued From Previous Page																
244.4 14.8	ROCKFILL - 160 mm cobble at 10.1 m - 130 mm cobble at 10.3 m - 260 mm boulder at 10.4 m - 290 mm boulder at 10.7 m - 90 mm cobble at 12.1 m - 390 mm boulder at 12.2 m - 90 mm cobble at 12.8 m - 160 mm cobble at 13 m - 290 mm boulder at 13.1 m - 290 mm boulder at 13.5 m - 650 mm boulder at 13.9 m - 170 mm cobble at 14.5 m		9	SS	100/ 50mm		249									
			5	NQ	-											
243.0 16.2	GNEISS BEDROCK (inferred)		10	SS	100/ 75mm											
			7	NQ	-		245									
			8	NQ	-		244									
							243									
	End of Borehole															

+³, ×³: Numbers refer to Sensitivity 20
15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KL20-02

1 OF 2

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523122°, Long: -80.653788° Slope Instability: Sta.13+110 to 13+179, MTM Zone 12: N 5 153 777.1 E 331 362.2 ORIGINATED BY JP
 HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY MW
 DATUM Geodetic DATE 2020.11.09 - 2020.11.11 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
258.4	Pavement Surface																		
0.0	ASPHALT (200 mm)																		
0.2	SAND with gravel Dense to very dense Brown FILL		1	SS	99		258										32	64	4 (SI+CL)
			2	SS	34														
256.9							257												
1.5	SILTY SAND Very loose to dense Brown FILL		3	SS	33												1	83	16 (SI+CL)
			4	SS	10		256												
			5	SS	6		255												
			6	SS	3														
			7	SS	4		254												
			8	SS	6		253										3	51	37 9 - non-plastic
			9	SS	19		252												
							251												
			10	SS	13		250												
			11	SS	9		249												

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KL20-02

2 OF 2

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523122°, Long: -80.653788° Slope Instability: Sta.13+110 to 13+179, MTM Zone 12: N 5 153 777.1 E 331 362.2 ORIGINATED BY JP
 HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY MW
 DATUM Geodetic DATE 2020.11.09 - 2020.11.11 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
								WATER CONTENT (%)						
	Continued From Previous Page						20 40 60 80 100		PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L			
246.9	SILTY SAND Very loose to dense Brown FILL		12	SS	1								3 83 14 (SI+CL)	
11.5	ROCKFILL with SILTY SAND matrix - 240 mm cobble at 11.5 m - 440 mm boulder at 11.9 m		1	NQ	-									
			13	SS	24									
	- 400 mm boulder at 13.1 m		2	NQ	-									
244.1			14	SS	15								10 41 41 8 - non-plastic	
14.3	CONCRETE		3	NQ	-									
			4	NQ	-									
241.8			5	NQ	-									
16.6	End of Borehole This borehole was abandoned and moved to KL20-02B. The concrete was reinstated from 14.3 m to 16.6 m.													

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KL20-02B

1 OF 2

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523125°, Long: -80.653841° Slope Instability: Sta.13+110 to 13+179, MTM Zone 12: N 5 153 777.4 E 331 358.1 ORIGINATED BY JP
HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY JP
DATUM Geodetic DATE 2020.11.14 - 2020.11.17 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE						
								20 40 60 80 100				20 40 60					
258.5	Pavement Surface																
0.0	ASPHALT (200mm)																
0.2	Inferred FILL Refer to Borehole KL20-02 for statigraphy Advance borehole to 8.5 m																

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KL20-02B

2 OF 2

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523125°, Long: -80.653841°
Slope Instability; Sta. 13+110 to 13+179, MTM Zone 12: N 5 153 777.4 E 331 358.1 ORIGINATED BY JP
HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY JP
DATUM Geodetic DATE 2020.11.14 - 2020.11.17 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								<div><div><div></div><div></div><div></div><div></div><div></div></div><div>20406080100</div></div>							<div><div><div></div><div></div><div></div></div><div>W P W W L</div></div>		
	Continued From Previous Page																
243.3	ROCKFILL - 120 mm cobble at 10.1 m - 80 mm cobble at 10.4 m - 920 mm boulder at 10.7 m - 110 mm cobble at 11.6 m - 240 mm boulder at 11.8 m - 100 mm cobble at 12.1 m - 430 mm boulder at 12.4 m - 250 mm boulder at 12.9 m - 230 mm boulder at 13.1 m - 280 mm boulder at 13.4 m - 110 mm cobble at 13.7 m - 460 mm boulder at 14.0 m - 290 mm boulder at 14.8 m		2	NQ	-		248										
									247								
									246								
									245								
15.2	Sandy SILT (ML) , trace organics Dense Brown		1	SS	43		243									4 39 50 7 - non-plastic	
			2	SS	49		242										
241.7																	
16.8	SILTY SAND (SM) with gravel Dense to Very Dense Brown TILL		3	SS	70											29 53 15 3 - non-plastic	
			4	SS	32		241										
240.3																	
18.2	GNEISS BEDROCK (inferred)		5	SS	100/ 0mm												
			6	NQ	-		240										
239.3																	
19.2	End of Borehole																

+³, ×³: Numbers refer to
Sensitivity 20
15 10
(%) STRAIN AT FAILURE


DOUBLE LINE 28408 HWY 17 RR 55 TO KUKAGAMI RD - INSTABILITY.GPJ 2012TEMPLATE(MTO).GDT 11/2/21

RECORD OF BOREHOLE No KL20-03

1 OF 3

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523128°, Long: -80.653457° Slope Instability: Sta.13+110 to 13+179, MTM Zone 12: N 5 153 777.9 E 331 387.6 ORIGINATED BY JP
 HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY MW
 DATUM Geodetic DATE 2020.11.11 - 2020.11.12 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)						
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	W _P	W	W _L					
257.7	Pavement Surface							20	40	60	80	100		20	40	60	kN/m ³	GR SA SI CL	
0.0	ASPHALT (200 mm)							20	40	60	80	100		20	40	60			
0.2	SILTY SAND, trace to some gravel, occ. cobbles and boulders Loose to dense Brown FILL - 270 mm boulder at 4.6 m																		
			1	SS	24											○			
			2	SS	10											○			
			3	SS	6											○			
			4	SS	8											○			
			1	NQ	-														
			5	SS	6											○			
6	SS	6											○						
7	SS	9											○						

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KL20-03

2 OF 3

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523128°, Long: -80.653457° Slope Instability; Sta. 13+110 to 13+179, MTM Zone 12: N 5 153 777.9 E 331 387.6 ORIGINATED BY JP
HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2020.11.11 - 2020.11.12 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)			GR	SA	SI	CL
								20	40	60	80					100	20	40	60			
Continued From Previous Page																						
247.3	SILTY SAND FILL																					
10.4	ROCKFILL - frequent cobbles and gravels (10mm to 90mm) from 10.4 m to 11.3 m		2	NQ	-		247															
			10	SS	100/ 250mm		246															
			11	SS	15		245															
	- poor recovery at 12.2 m																					
	- 130 mm cobble at 13.8 m																					
	- 80 mm cobble at 14.3 m		3	NQ	-		243															
242.5	- 100 mm cobble at 15.1 m																					
15.2	Sandy SILT (ML), trace organics Loose to compact Grey brown to brown		12	SS	8		242															
			13	SS	11		241															
			14	SS	24																	
			15	SS	25		240															
	16	SS	17		239																	

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KL20-03

3 OF 3

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523128°, Long: -80.653457° Slope Instability; Sta.13+110 to 13+179, MTM Zone 12: N 5 153 777.9 E 331 387.6 ORIGINATED BY JP
 HWY 17 BOREHOLE TYPE CME75 Truckmount, HW Casing, NW Casing, NQ Coring COMPILED BY MW
 DATUM Geodetic DATE 2020.11.11 - 2020.11.12 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE					w P w w L							
								● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page							20	40	60	80	100								
237.6						250mm														
20.1		Inferred TILL - frequent gravel and cobbles from 20.1m to 20.6 m		4	NQ	-														
237.1																				
20.6		GNEISS BEDROCK (inferred)					237													
236.8				18	SS	100/														
20.9		End of Borehole				0mm														

RECORD OF BOREHOLE No KL20-04

1 OF 1

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.522768°, Long: -80.653391° Slope Instability: Sta. 13+110 to 13+179, MTM Zone 12: N 5 153 737.9 E 331 392.9 ORIGINATED BY JP
 HWY 17 BOREHOLE TYPE Portable Tripod, NW Casing COMPILED BY MW
 DATUM Geodetic DATE 2020.12.09 - 2020.12.09 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								20 40 60 80 100							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
						WATER CONTENT (%)									
						PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _p w _L w									
243.6	Ground Surface														
0.0	Sandy SILT (ML) with organics Very loose to compact Grey to grey-brown		1	SS	0									org content=4%	
			2	SS	0										
242.4															
1.2	CLAYEY SILT (MI) with sand Loose Brown		3	SS	5									0 20 68 12	
			4	SS	7									org content=4%	
241.2															
2.4	Sandy SILT (ML) Loose Grey		5	SS	7										
			6	SS	7									0 41 54 5 - non-plastic	
			7	SS	7										
239.0															
4.6	SAND (SP-SM) with silt and gravel Compact Grey TILL		8	SS	12										
238.2			9	SS	100/										
5.4	End of Borehole. Spoon bouncing on suspected bedrock.				175mm										




+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KL20-05

1 OF 1

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.522781°, Long: -80.653573° Slope Instability: Sta. 13+110 to 13+179, MTM Zone 12: N 5 153 739.3 E 331 378.8 ORIGINATED BY JP
 HWY 17 BOREHOLE TYPE Portable Tripod, NW Casing COMPILED BY MW
 DATUM Geodetic DATE 2020.12.09 - 2020.12.09 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								20	40	60	80	100			W _P	W	W _L
243.6	Ground Surface																
0.0	Sandy SILT (ML), trace to with organics Loose Brown to grey		1	SS	8		243							o	org content=6%		
			2	SS	5												o
242.4	CLAYEY SILT (MI) with sand Loose Brown		3	SS	5			242								o	3 24 61 12 - non-plastic
			4	SS	2												
241.2	SAND (SP-SM) with silt and gravel Compact Grey		5	SS	100/ 275mm				241								
240.7			TILL End of Borehole. Spoon bouncing on suspected bedrock.														
2.9																	

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No KL20-06

1 OF 1

METRIC

GWP# 5168-16-00 LOCATION Lat: 46.523392°, Long: -80.653292° Slope Instability; Sta.13+110 to 13+179, MTM Zone 12: N 5 153 807.3 E 331 400.1 ORIGINATED BY JP
 HWY 17 BOREHOLE TYPE Portable Tripod, NW Casing COMPILED BY MW
 DATUM Geodetic DATE 2020.12.07 - 2020.12.08 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _P w w _L																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
244.3	Ground Surface							20	40	60	80	100	20	40	60																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
0.0	Sandy SILT (ML) to SILTY SAND (SM), trace to with organics Very loose to compact Brown to grey - with organics from 0m to 1.2m		1	SS	0		244																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	

DOUBLE LINE 28408 HWY 17 RR 55 TO KUKAGAMI RD - INSTABILITY.GPJ 2012TEMPLATE(MTO).GDT 11/2/21

Hwy 17 RR 55 to Kukagami Rd

Borehole Records

Page 1 of 1

Hand Auger Holes

13+156 **33 LT CL**
HA-1
0 - 60 Rootmat
60 - 330 Blk-Br Amor. Peat Tr Sa, moist, soft
330 - NFP Cob

13+148 **33 LT CL**
HA-2
0 - 45 Rootmat
45 - 600 Blk-Br Amor. Peat Tr Sa, moist, soft
600 - NFP Cob/Gr

13+142 **31 LT CL**
HA-3
0 - 100 Rootmat
100 - 550 Blk-Br Amor. Peat Tr Sa Tr Si
moist, soft
550 - NFP Cob/Blds

13+136 **30 LT CL**
HA-4
0 - 90 Rootmat
90 - 810 Blk-Br Amor. Peat Tr Sa Tr Si Tr Cl
moist, soft
810 - NFP

13+130 **30 LT CL**
HA-5
0 - 90 Rootmat
90 - 300 Blk-Br Si(y) Sa Tr Peat, moist, soft

13+120 **34 LT CL**
HA-6
0 - 60 Rootmat
60 - 110 Br Sa Tr Si Tr Cl Tr Peat, moist,
soft
110 - NFP Cob/Blds

13+113 **30 LT CL**
HA-7
0 - 110 Br Peat Tr Sa, moist, soft
110 - 630 Blk-Br Amor. Peat Tr Sa Tr Si,
moist, soft
630 - NFP Cob/Blds

13+106 **35 LT CL**
HA-8
0 - 120 Rootmat
120 - 520 Blk-Br Amor. Peat Tr Sa Tr Si
moist, soft
520 - NFP Cob/Gr

13+100 **37 LT CL**
HA-9
0 - 90 Rootmat/Cl(y)
90 - 170 Br-Gry Peat Tr Sa Tr Si Tr Cl,
moist, soft
170 - NFP Poss BR

Test Pits

13+107 **29 RT CL**
TP-1
0 - 100 Si(y) Sa w Gr w Org,
Occ Cobb/Bldr
100 - NFP Poss BR

13+125 **31 RT CL**
TP-2
0 - 130 Si(y) Sa w Gr w Org
Occ Cobb/Bldr
130 - NFP Poss BR

WP 114-85-00
TWP AWREY
HWY 17
89 06 05

13+108 4.70 RT C/L (Short 10% to
refill hole)

0	-	050	Asph
050	-	250	Conc Gutter
250	-	380	F-M Sa with Gr & Cr Gr
380	-	1.80	F-M Sa with Gr Tr Si
1.80	-	2.50	F-M Sa with Gr Tr Si & Sh Rk Mix

13+118 4.70 RT C/L Painted W Lmt
(Req'd 20% extra
to refill hole)

0	-	080	Asph
080	-	280	Conc Gutter
280	-	450	F-M Sa with Cr Gr
450	-	570	M Sa Gr
570	-	1.60	F-M Sa with Gr
1.60	-	3.70	F-M Sa with Gr Tr Si & Sh Rk Mix
3.70			NFP RF

13+126 4.70 RT C/L Painted Low Spot
(Req'd 20% extra
mat'l to refill
hole)

0	-	100	Asph
100	-	340	Conc Gutter
340	-	660	M Sa Gr
660	-	2.00	F-M Sa with Gr
2.00	-	2.60	F Sa with Si Wet
			89 MBL 43 SM
			w @ 2.30 = 14.0%
			% Pass 5 mm = 96
			" 2 mm = 95
			" 425 um = 88
			" 75 um = 59
			" 5 um = 32
			LSFH
2.60	-	3.00	F Sa Tr Si Wet
3.00			NFP RF

13+140 4.70 RT C/L Painted E Limit

0	-	090	Asph
090	-	390	Conc Gutter
390	-	780	M Sa Gr
780	-	1.60	F-M Sa with Gr Tr Si
1.60	-	2.60	F Sa with Si Wet
2.60	-	6.00	F Sa Tr Si Moist

13+150 4.70 RT C/L

0	-	070	Asph
070	-	280	Conc gutter
280	-	700	M Sa Gr
700	-	1.60	F-M Sa with Gr Tr Si
1.60	-	2.60	F Sa with Si Wet
2.60	-	3.00	F Sa Tr Si Wet
3.00	-	3.40	Si with F Sa Wet
3.40	-	6.00	F Sa Tr Si Wet

13+150 4.70 LT C/L

0	-	070	Asph Gutter
070	-	400	Cr Gr
400	-	830	F-M Sa with Gr Tr Si
830	-	1.60	F-M Sa Tr Gr
1.60	-	2.60	F Sa with Si Wet
2.60	-	6.00	F Sa Tr Si Wet

13+137 4.70 LT C/L

0	-	170	Asph Gutter
170	-	480	Cr Gr
480	-	950	F-M Sa with Gr Tr Si
950	-	1.60	F-M Sa Tr Si
1.60	-	3.00	F Sa with Si Wet
3.00	-	6.00	F Sa Tr Si Wet

13+108 4.70 LT C/L

0	-	120	Asph Gutter
120	-	460	Cr Gr
460	-	760	F-M Sa with Gr Tr Si
760	-	1.30	F Sa with Si
1.30	-	2.50	F-M Sa with Gr Tr Si
2.50			NFP RF

Appendix C.
Laboratory Testing

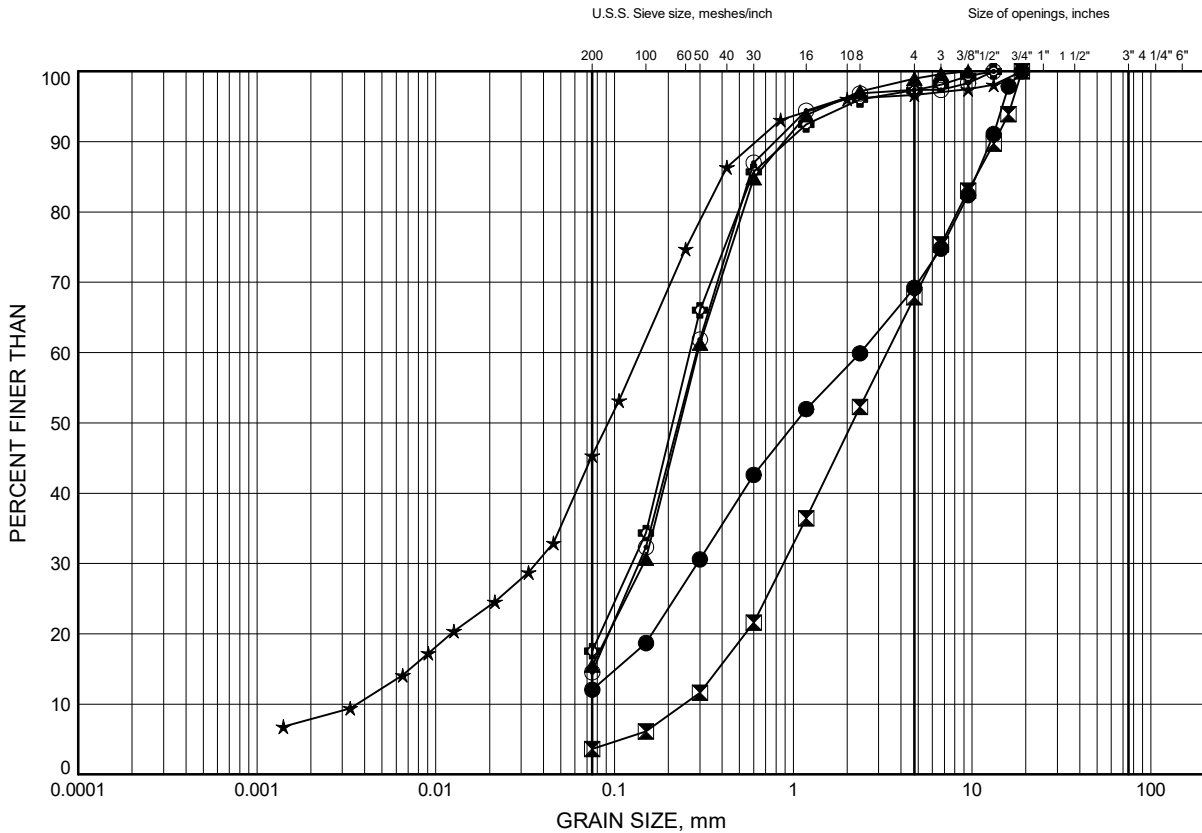
Appendix C.1

Particle Size Analysis and Atterberg Limits Testing

Hwy 17 RR 55 to Kukagami Rd GRAIN SIZE DISTRIBUTION

FIGURE C1

Sand with Silt and Gravel to Sand with Gravel to Silty Sand Fill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KL20-01	1.8	257.4
⊠	KL20-02	0.5	257.9
▲	KL20-02	1.8	256.6
★	KL20-02	5.6	252.8
⊙	KL20-02	11.0	247.4
⊕	KL20-03	4.1	253.6

Date February 2021
GWP# 5168-16-00

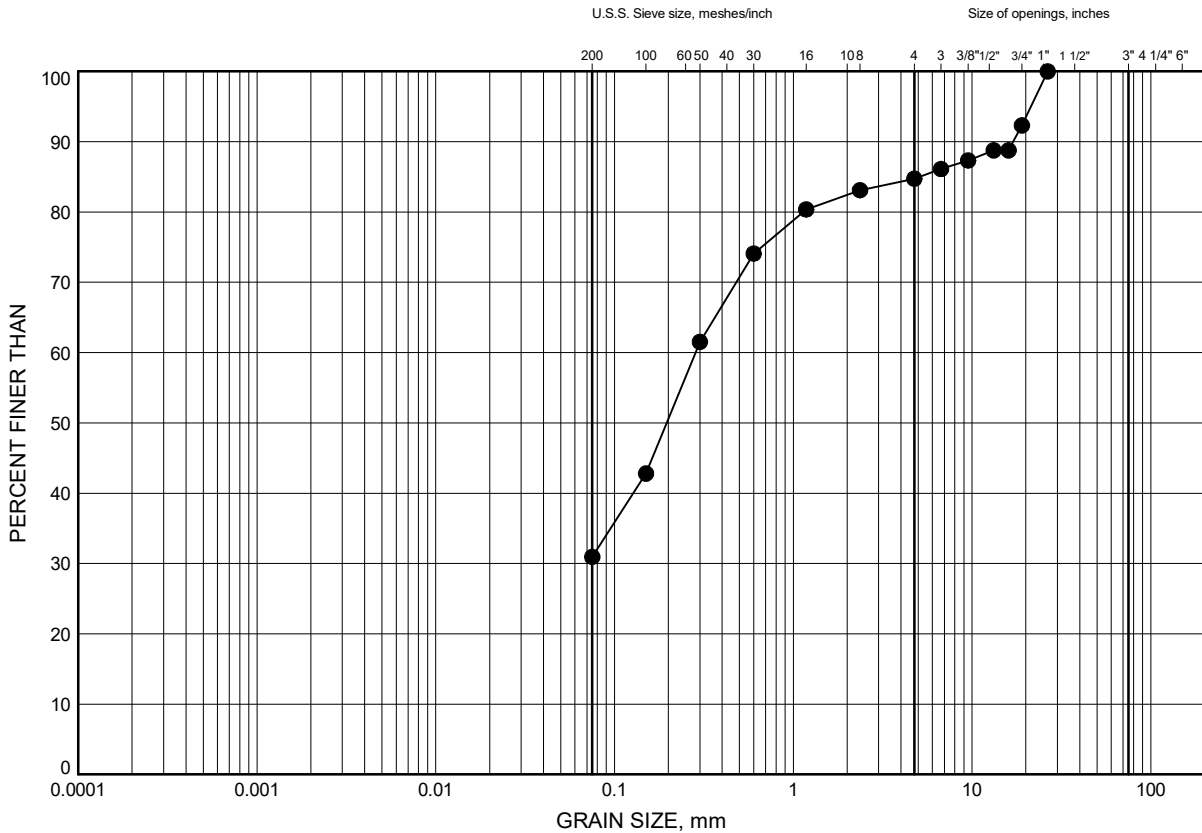


Prep'd DP
Chkd. FG

Hwy 17 RR 55 to Kukagami Rd
GRAIN SIZE DISTRIBUTION

FIGURE C2

Sand with Silt and Gravel to Sand with Gravel to Silty Sand Fill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KL20-03	6.4	251.3

Date February 2021
 GWP# 5168-16-00

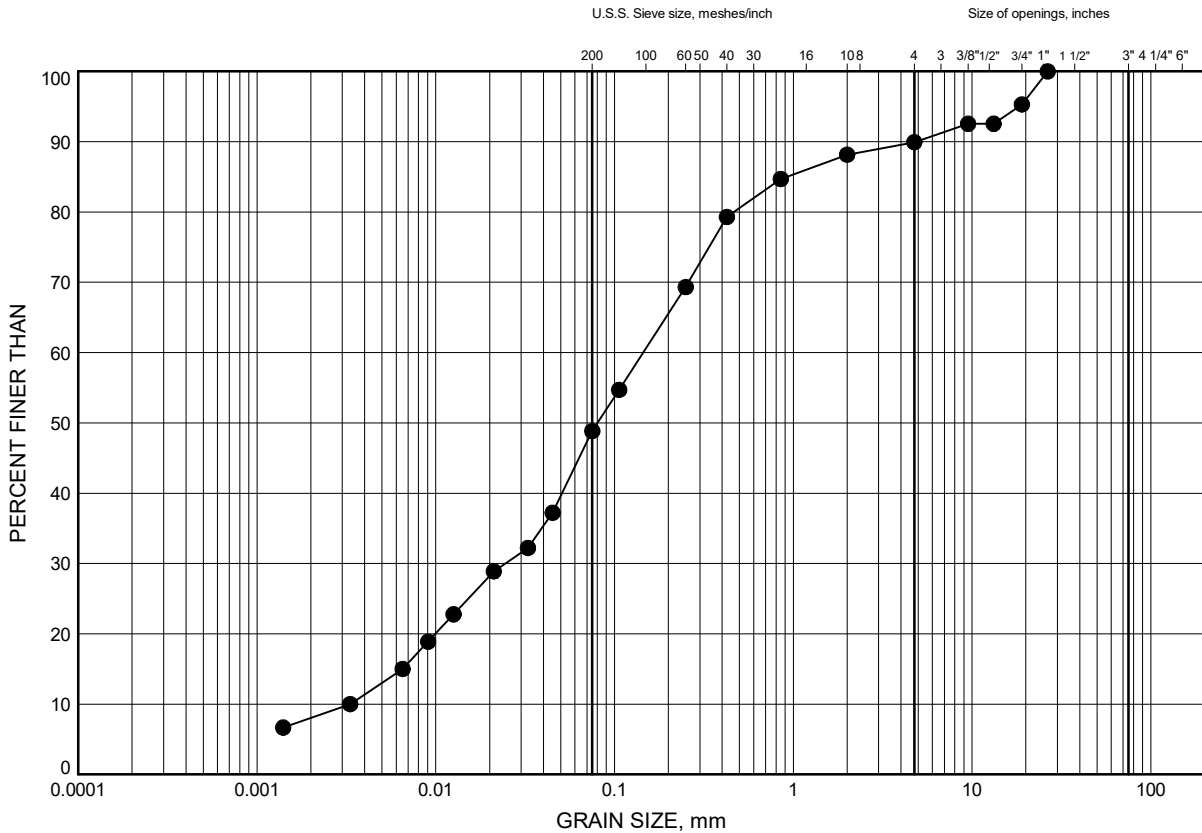


Prep'd DP
 Chkd. FG

Hwy 17 RR 55 to Kukagami Rd GRAIN SIZE DISTRIBUTION

FIGURE C3

Rockfill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KL20-02	14.0	244.4

Date February 2021
GWP# 5168-16-00

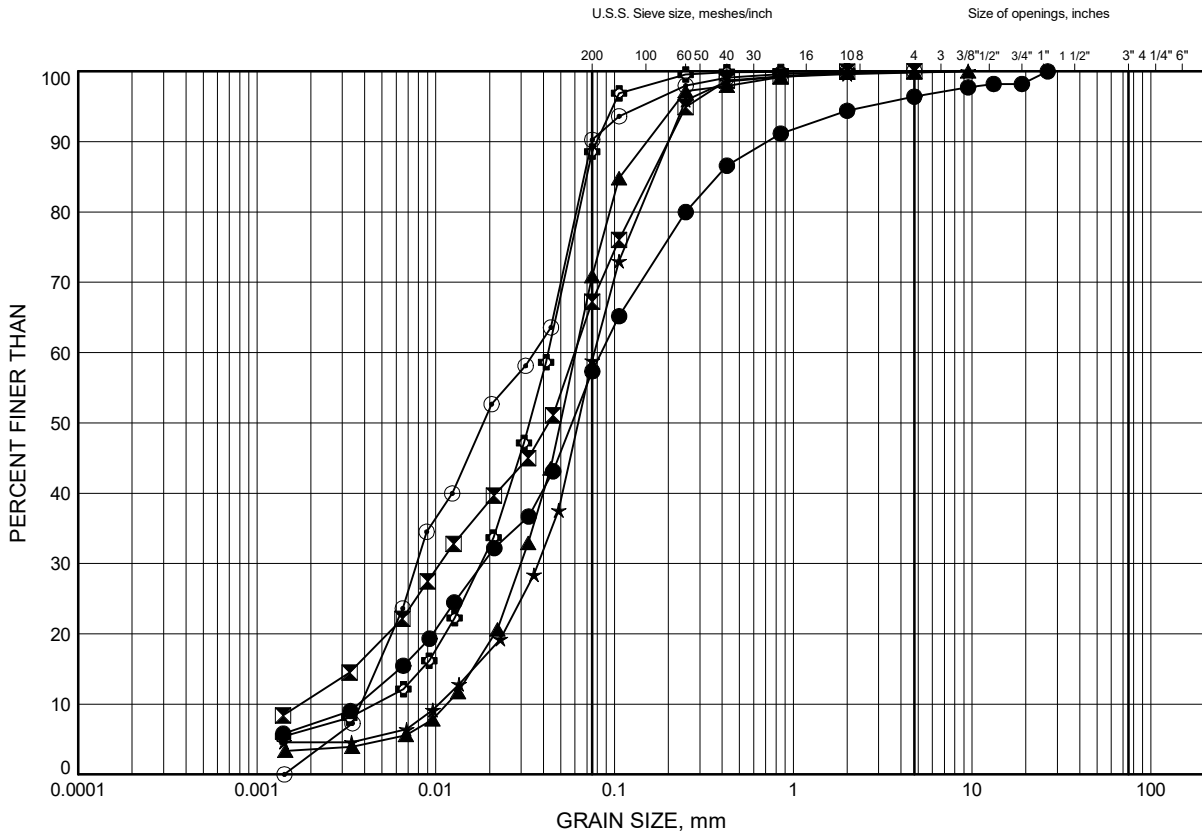


Prep'd DP
Chkd. FG

Hwy 17 RR 55 to Kukagami Rd
GRAIN SIZE DISTRIBUTION

FIGURE C4

Sandy Silt (SM) to Silty Sand (ML)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KL20-02B	15.5	243.0
⊠	KL20-03	15.5	242.2
▲	KL20-03	17.8	239.9
★	KL20-04	3.4	240.2
⊙	KL20-06	0.9	243.4
⊕	KL20-06	2.1	242.2

Date February 2021

GWP# 5168-16-00



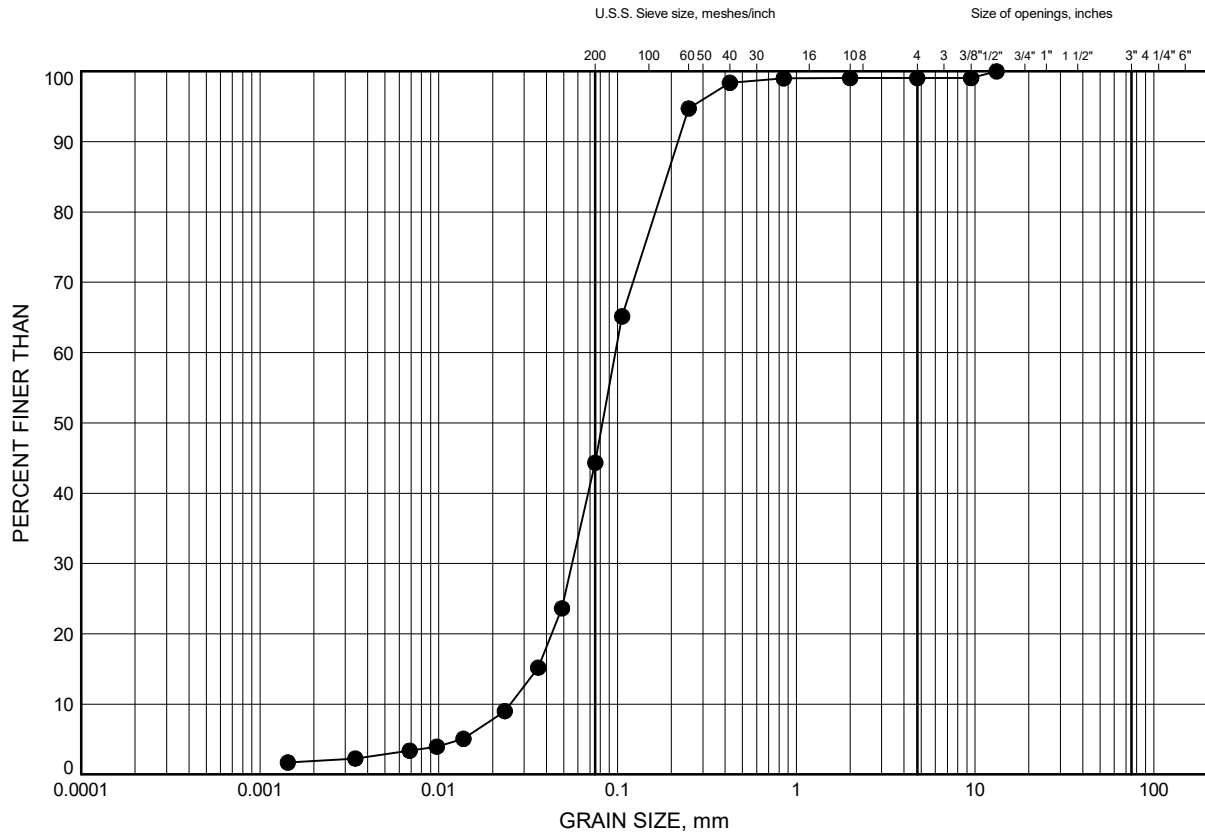
Prep'd DP

Chkd. FG

Hwy 17 RR 55 to Kukagami Rd GRAIN SIZE DISTRIBUTION

FIGURE C5

Sandy Silt (SM) to Silty Sand (ML)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KL20-06	4.9	239.4

Date February 2021
GWP# 5168-16-00

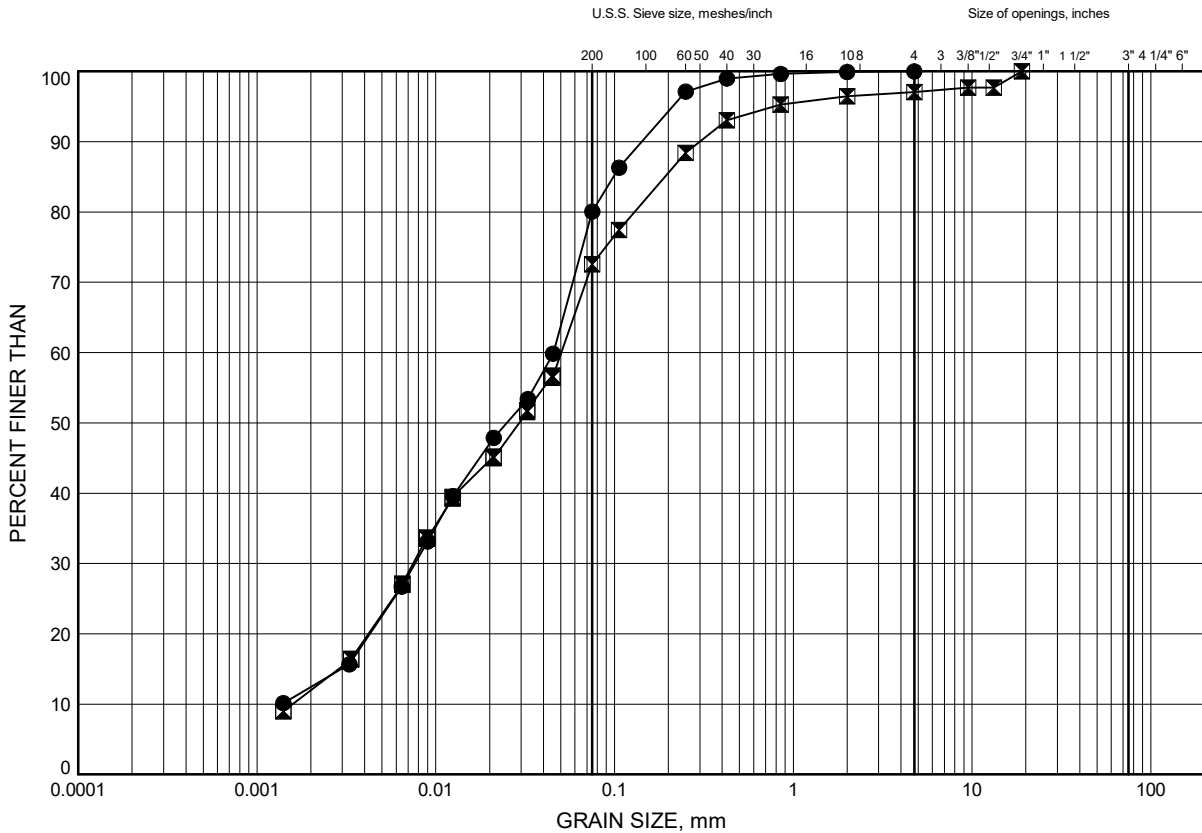


Prep'd DP
Chkd. FG

Hwy 17 RR 55 to Kukagami Rd GRAIN SIZE DISTRIBUTION

FIGURE C6

Clayey Silt (MI)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KL20-04	1.5	242.1
◻	KL20-05	1.5	242.1

Date February 2021
GWP# 5168-16-00

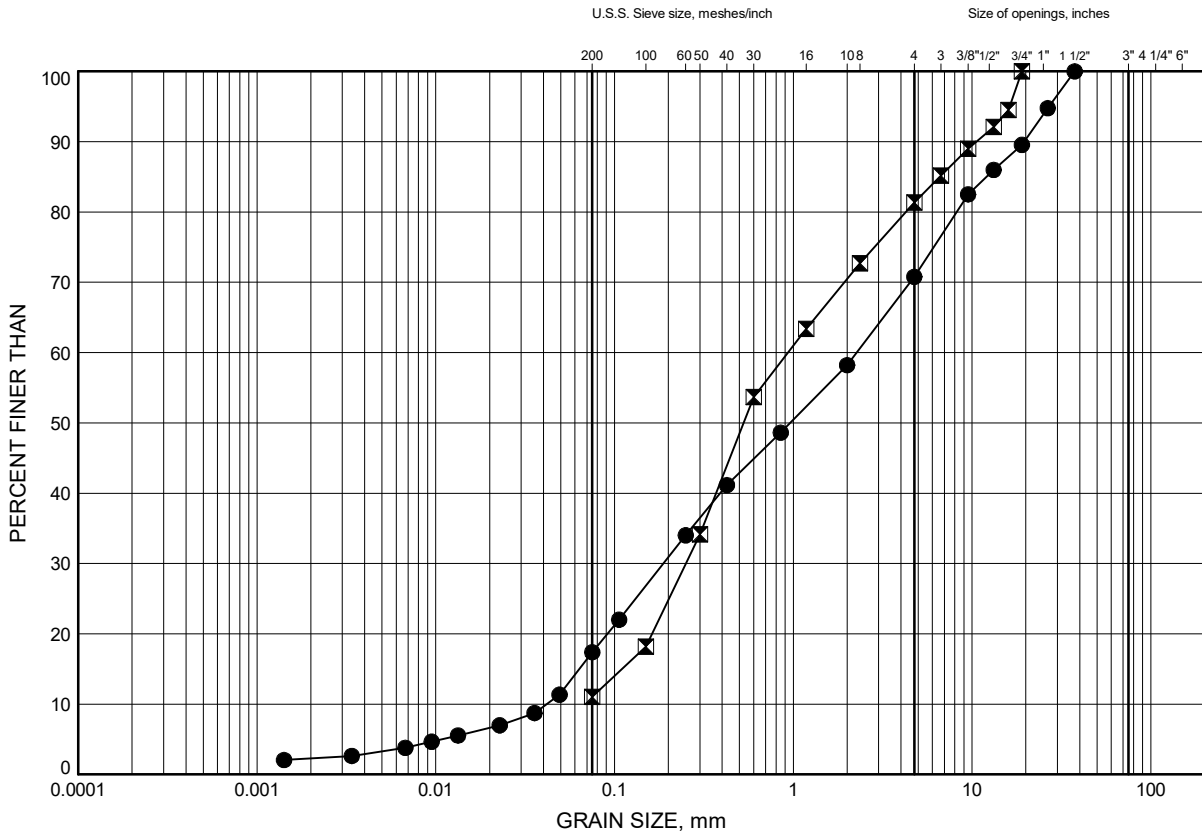


Prep'd DP
Chkd. FG

Hwy 17 RR 55 to Kukagami Rd
GRAIN SIZE DISTRIBUTION

FIGURE C7

Silty Sand (SM) to Sand (SP-SM) Till



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KL20-02B	17.1	241.4
⊠	KL20-05	2.7	240.9

Date February 2021
 GWP# 5168-16-00

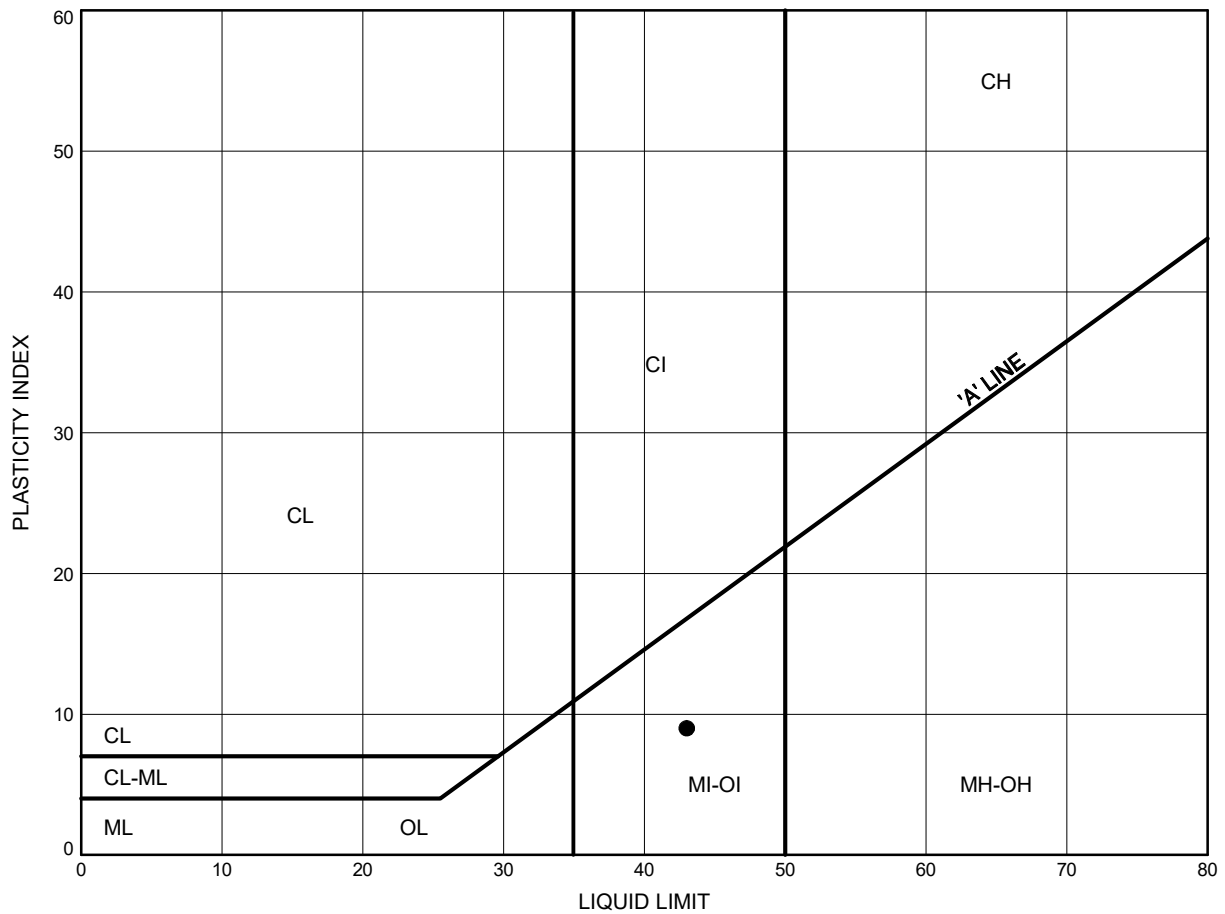


Prep'd DP
 Chkd. FG

Hwy 17 RR 55 to Kukagami Rd
ATTERBERG LIMITS TEST RESULTS

FIGURE C8

Clayey Silt (MI)



LEGEND

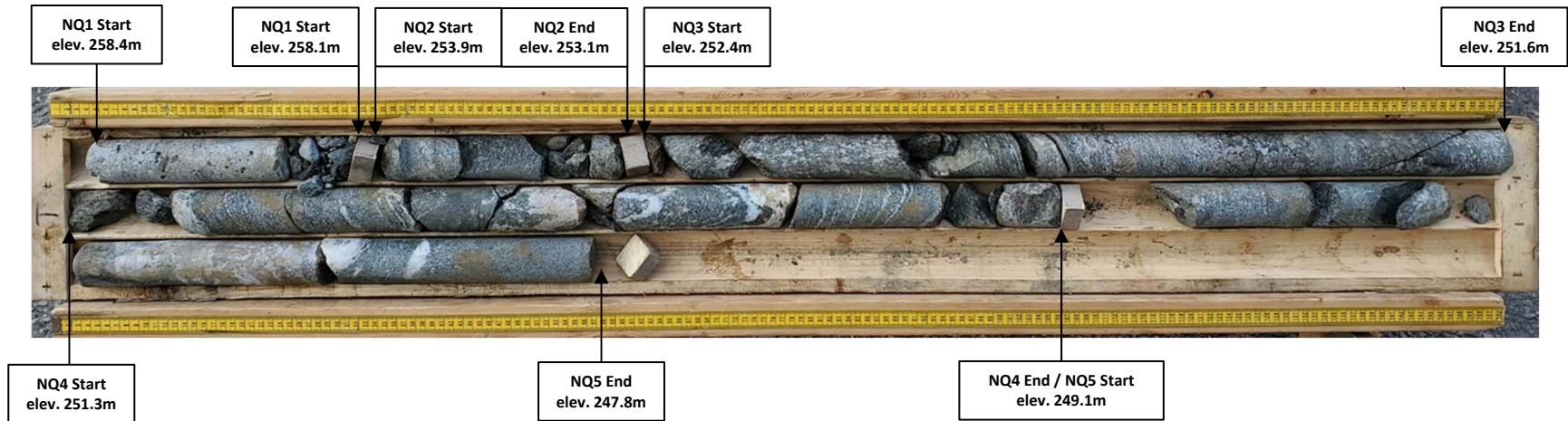
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	KL20-04	1.5	242.1

Date February 2021
 GWP# 5168-16-00



Prep'd DP
 Chkd. FG

KL20-01
NQ 1 to 5 (of 8)
Elevation 258.5 m to 247.8 m



THURBER ENGINEERING LTD.

Geotechnical Investigation
Highway 17 Embankment Instability
Sta. 13+110 to 13+179
Awrey Township, Ontario

KL20-01
Project No.: 28408

KL20-01
NQ 6 to 8 (of 8)
Elevation 247.4 m to 243.0 m

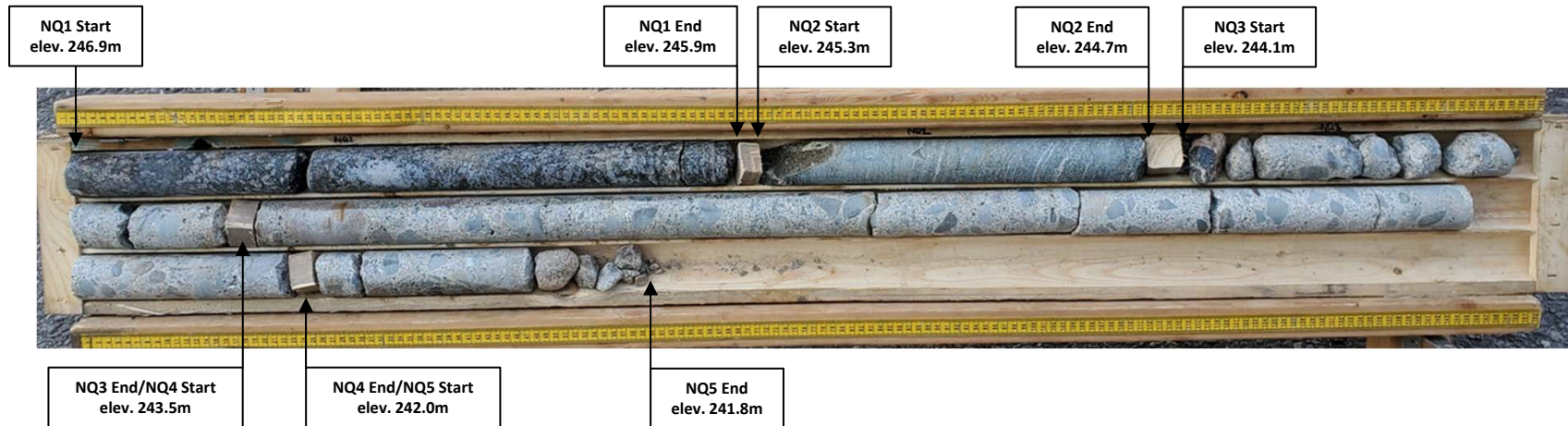


THURBER ENGINEERING LTD.

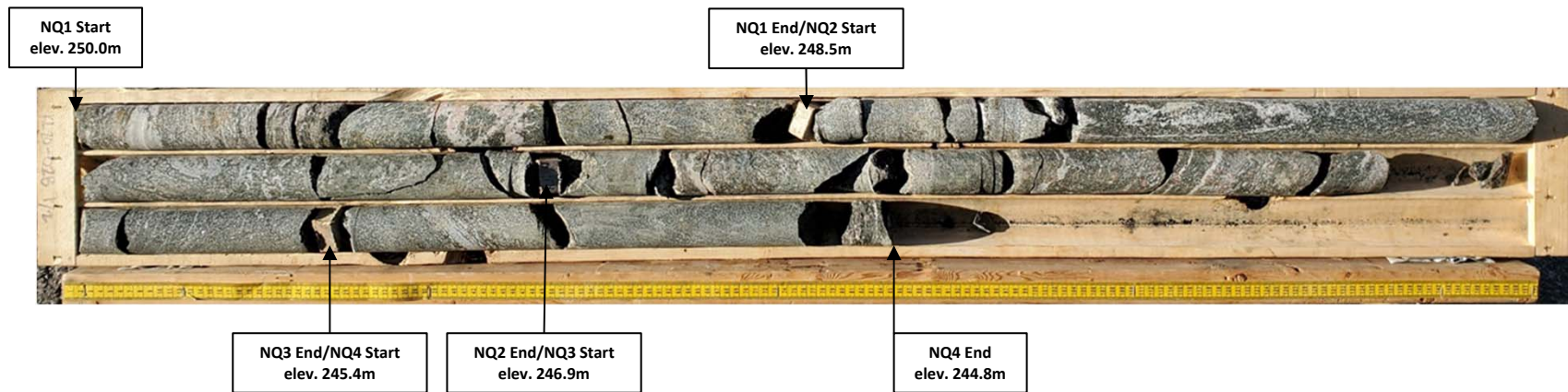
Geotechnical Investigation
Highway 17 Embankment Instability
Sta. 13+110 to 13+179
Awrey Township, Ontario

KL20-01
Project No.: 28408

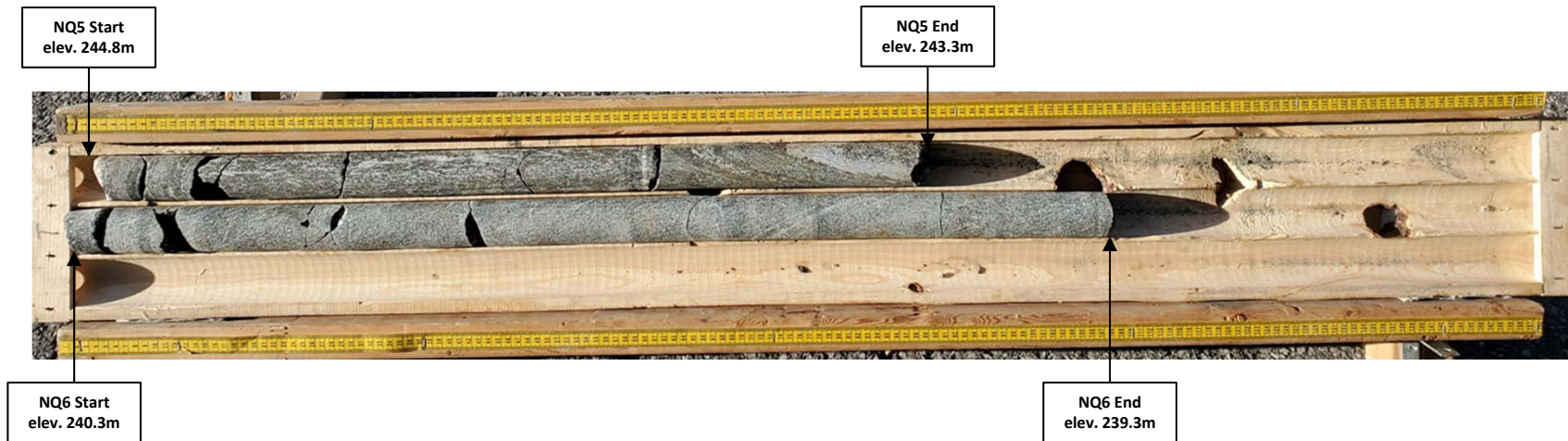
KL20-02
NQ 1 to 5 (of 5)
Elevation 246.9 m to 241.8 m



KL20-02B
NQ 1 to 4 (of 6)
Elevation 250.0 m to 244.8 m



KL20-02B
NQ 5 to 6 (of 6)
Elevation 244.8 m to 239.3 m

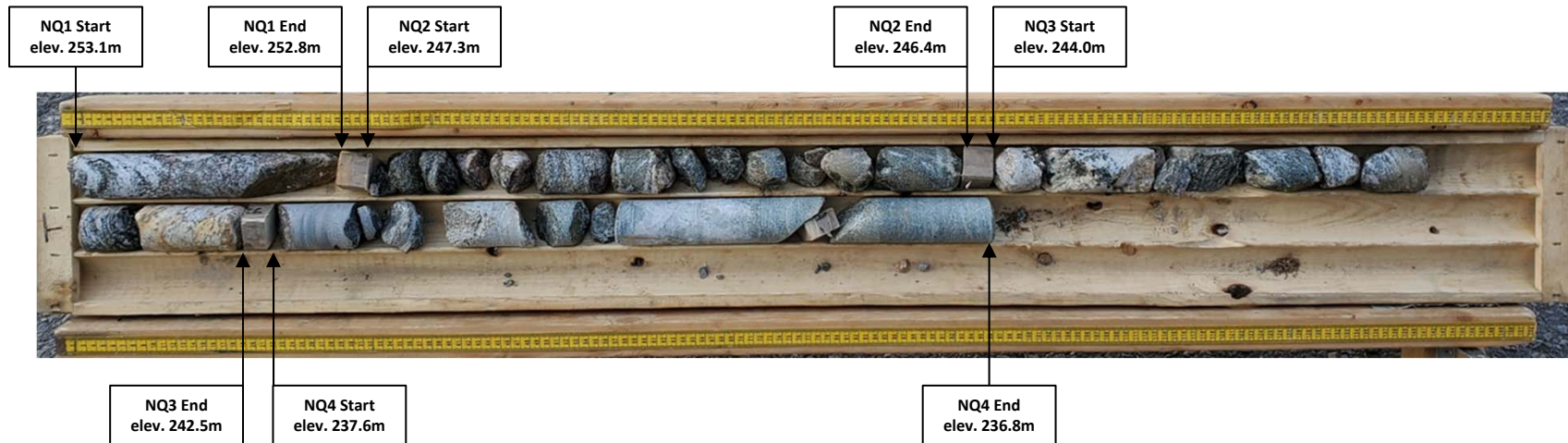


THURBER ENGINEERING LTD.

Geotechnical Investigation
Highway 17 Embankment Instability
Sta. 13+110 to 13+179
Awrey Township, Ontario

KL20-02B
Project No.: 28408

KL20-03
NQ 1 to 4 (of 4)
Elevation 253.1 m to 236.8 m



Appendix C.2
Analytical Testing Results and Organic Content

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Deanna Pizycki

Client PO:
Project: 28408
Custody: 125256

Report Date: 14-Dec-2020
Order Date: 9-Dec-2020

Order #: 2050291

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID

2050291-01

Client ID

KL 20-02B SS2 52'6"-54'6"

Approved By:



Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis

Report Date: 14-Dec-2020

Client: Thurber Engineering Ltd.

Order Date: 9-Dec-2020

Client PO:

Project Description: 28408

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	11-Dec-20	12-Dec-20
Conductivity	MOE E3138 - probe @25 °C, water ext	10-Dec-20	10-Dec-20
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	9-Dec-20	10-Dec-20
Resistivity	EPA 120.1 - probe, water extraction	10-Dec-20	10-Dec-20
Solids, %	Gravimetric, calculation	9-Dec-20	10-Dec-20

Certificate of Analysis

Report Date: 14-Dec-2020

Client: Thurber Engineering Ltd.

Order Date: 9-Dec-2020

Client PO:

Project Description: 28408

Client ID:	KL 20-02B SS2	-	-	-
	52'6"-54'6"	-	-	-
Sample Date:	17-Nov-20 09:00	-	-	-
Sample ID:	2050291-01	-	-	-
MDL/Units	Soil	-	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	84.5	-	-	-
----------	--------------	------	---	---	---

General Inorganics

Conductivity	5 uS/cm	713	-	-	-
pH	0.05 pH Units	7.33	-	-	-
Resistivity	0.10 Ohm.m	14.0	-	-	-

Anions

Chloride	5 ug/g dry	347	-	-	-
Sulphate	5 ug/g dry	31	-	-	-

Certificate of Analysis

Report Date: 14-Dec-2020

Client: Thurber Engineering Ltd.

Order Date: 9-Dec-2020

Client PO:

Project Description: 28408

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis

Report Date: 14-Dec-2020

Client: Thurber Engineering Ltd.

Order Date: 9-Dec-2020

Client PO:

Project Description: 28408

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	169	5	ug/g dry	158			6.4	20	
Sulphate	54.9	5	ug/g dry	48.6			12.2	20	
General Inorganics									
Conductivity	313	5	uS/cm	312			0.3	5	
pH	4.97	0.05	pH Units	4.92			1.0	2.3	
Resistivity	31.9	0.10	Ohm.m	32.0			0.3	20	
Physical Characteristics									
% Solids	94.3	0.1	% by Wt.	94.6			0.3	25	

Certificate of Analysis

Report Date: 14-Dec-2020

Client: Thurber Engineering Ltd.

Order Date: 9-Dec-2020

Client PO:

Project Description: 28408

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	254	5	ug/g	158	95.3	82-118			
Sulphate	147	5	ug/g	48.6	98.1	80-120			

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO:

Report Date: 14-Dec-2020

Order Date: 9-Dec-2020

Project Description: 28408

Qualifier Notes:

Login Qualifiers :

Sample - One or more parameter received past hold time - SULPHIDE

Applies to samples: KL 20-02B SS2 52'6"-54'6"

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

NC: Not Calculated

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Subcontracted Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Deanna Pizycki

Tel: (613) 247-2121
Fax: (613) 247-2185

Paracel Report No **2050291**

Client Project(s): **28408**

Client PO:

Reference: **Standing Offer**

CoC Number: **125256**

Order Date: 09-Dec-20
Report Date: 23-Dec-20

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
2050291-01	KL 20-02B SS2 52'6"-54'6"	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

23-December-2020

Date Rec. : 10 December 2020
LR Report: CA13295-DEC20
Reference: Project#:2050291

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide (Na ₂ CO ₃) %
1: Analysis Start Date		22-Dec-20
2: Analysis Start Time		14:16
3: Analysis Completed Date		22-Dec-20
4: Analysis Completed Time		14:24
5: QC - Blank		< 0.04
6: QC - STD % Recovery		102%
7: QC - DUP % RPD		ND
8: RL		0.02
9: KL 20-02B SS2 52'6"-54'6"	17-Nov-20	< 0.04

RL - SGS Reporting Limit
ND - Not Detected

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Deanna Pizycki

Client PO:
Project: 28408
Custody: 125253

Report Date: 7-Jan-2021
Order Date: 4-Jan-2021

Order #: 2102041

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
2102041-01	KL20-04 SS2 2'-4'

Approved By:



Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis

Report Date: 07-Jan-2021

Client: Thurber Engineering Ltd.

Order Date: 4-Jan-2021

Client PO:

Project Description: 28408

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	6-Jan-21	6-Jan-21
Conductivity	MOE E3138 - probe @25 °C, water ext	7-Jan-21	7-Jan-21
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	6-Jan-21	6-Jan-21
Resistivity	EPA 120.1 - probe, water extraction	7-Jan-21	7-Jan-21
Solids, %	Gravimetric, calculation	5-Jan-21	5-Jan-21

Certificate of Analysis

Report Date: 07-Jan-2021

Client: Thurber Engineering Ltd.

Order Date: 4-Jan-2021

Client PO:

Project Description: 28408

Client ID:	KL20-04 SS2 2'-4'	-	-	-
Sample Date:	09-Dec-20 09:00	-	-	-
Sample ID:	2102041-01	-	-	-
MDL/Units	Soil	-	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	76.2	-	-	-
----------	--------------	------	---	---	---

General Inorganics

Conductivity	5 uS/cm	616	-	-	-
pH	0.05 pH Units	6.14	-	-	-
Resistivity	0.10 Ohm.m	16.2	-	-	-

Anions

Chloride	5 ug/g dry	586	-	-	-
Sulphate	5 ug/g dry	158	-	-	-

Certificate of Analysis

Report Date: 07-Jan-2021

Client: Thurber Engineering Ltd.

Order Date: 4-Jan-2021

Client PO:

Project Description: 28408

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis

Report Date: 07-Jan-2021

Client: Thurber Engineering Ltd.

Order Date: 4-Jan-2021

Client PO:

Project Description: 28408

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	16.3	5	ug/g dry	16.3			0.2	20	
Sulphate	11.2	5	ug/g dry	10.5			6.2	20	
General Inorganics									
Conductivity	611	5	uS/cm	616			0.8	5	
pH	7.52	0.05	pH Units	7.51			0.1	2.3	
Resistivity	16.4	0.10	Ohm.m	16.2			0.8	20	
Physical Characteristics									
% Solids	91.3	0.1	% by Wt.	91.5			0.2	25	

Certificate of Analysis

Report Date: 07-Jan-2021

Client: Thurber Engineering Ltd.

Order Date: 4-Jan-2021

Client PO:

Project Description: 28408

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	114	5	ug/g	16.3	97.8	82-118			
Sulphate	111	5	ug/g	10.5	100	80-120			

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO:

Report Date: 07-Jan-2021

Order Date: 4-Jan-2021

Project Description: 28408

Qualifier Notes:

Login Qualifiers :

Sample - One or more parameter received past hold time - Sulphide

Applies to samples: KL20-04 SS2 2'-4'

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

NC: Not Calculated

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Subcontracted Analysis

Thurber Engineering Ltd.2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Deanna PizyckiTel: (613) 247-2121
Fax: (613) 247-2185Paracel Report No **2102041**Client Project(s): **28408**

Client PO:

Reference: **Standing Offer**CoC Number: **125253**Order Date: 04-Jan-21
Report Date: 7-Jan-21

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
2102041-01	KL20-04 SS2 2'-4'	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

13-January-2021

Date Rec. : 06 January 2021
LR Report: CA12119-JAN21
Reference: Project#: 2102041

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide (Na ₂ CO ₃) %
1: Analysis Start Date		13-Jan-21
2: Analysis Start Time		13:16
3: Analysis Completed Date		13-Jan-21
4: Analysis Completed Time		13:23
5: QC - Blank		< 0.04
6: QC - STD % Recovery		101%
7: QC - DUP % RPD		ND
8: RL		0.02
9: KL20-04 SS2 2'-4'	09-Dec-20	< 0.04 UAL

RL - SGS Reporting Limit
UAL - Unreliable: Sample Age Exceeds Normal Limit
Processed past holding time as per client's instructions.

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety



Stantec

Stantec Consulting Ltd
100 A&B – 2781 Lancaster Rd
Ottawa, ON K1B 1A7
Tel: (613) 738-6075
Fax: (613) 738-6067

January 14, 2021
File: 122410864

Attention: **Thurber Engineering, File #28408**

Reference: **ASTM D2974 Organic Content, Highway 17, Kukagami**

The following table summarizes five Organic Content results.

Source	Depth	Date Sampled	Organic Content (%)
KL20-04 SS1	0-2'	December 9, 2020	4.1
KL20-04 SS4	6'-8'	December 9, 2020	4.3
KL20-05 SS2	2'-4'	December 9, 2020	6.1
KL20-05 SS4	6'-8'	December 9, 2020	3.1
KL20-06 SS2	2'-4'	December 7, 2020	2.9

Sincerely,

Stantec Consulting Ltd.

Brian Prevost

Brian Prevost
Laboratory Supervisor
Tel: 613-738-6075
Fax: 613-738-6067
brian.prevost@stantec.com

Appendix D.
Photographs

Appendix D.1
Site Photographs



Photo 1: Looking northeast along north embankment slope. Granular slope, erosion gullies, localized crushed rock repairs, vegetation at the east end of embankment and body of water at embankment toe. Photo taken near location of culvert crossing. [taken September 2020]



Photo 2: Looking southeast along north embankment slope. Large rocks present along slope. Exposed bedrock present in near side of photo (west end of body of water) [taken September 2020]



Photo 3: Looking eastward along north embankment toe. Water at toe of rock lined slope. Utility lines overhead and Buried Bell utility. [taken September 2020]



Photo 4: Presumed location of north end of culvert. Water vortex entering under pile of wooded debris. [taken September 2020]



Photo 5. Looking westward along south slope, similar conditions as noted along the north slope. [taken September 2020]



Photo 6. Looking north at culvert outlet, showing bedrock on west side. [taken December 2020]

Appendix D.2

Historical Aerial Photographs



Photo 1: _1946_15840_1946_15840_024_154_0090_CP_P_1200dpi



Photo 2: _1975_30000_1975_30000_002_010_0092_NP_P_1200dpi



Photo 3: _1991_30000_Sudbury_1991_30000_724_003_0051_NP_P_1200dpi



Photo 4: Google Earth Image dated September 30, 2012



Photo 5: Google Earth Image dated July 5, 2013



Photo 6: Google Earth Image dated June 5, 2014



Photo 7: Google Earth Image dated July 23, 2015



Photo 8: Google Earth Image dated May 4, 2016



Photo 9: Google Earth Image dated July 2, 2019

Appendix E.
GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Site: 46.523N 80.654W

User File Reference: Highway 17 Sta. 13+110 to 13+179, Awrey Township 2021-02-05 00:52 UT

Requested by: Thurber Engineering Ltd.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.097	0.059	0.037	0.011
Sa (0.1)	0.132	0.083	0.054	0.018
Sa (0.2)	0.126	0.081	0.053	0.019
Sa (0.3)	0.106	0.068	0.046	0.016
Sa (0.5)	0.084	0.054	0.036	0.013
Sa (1.0)	0.049	0.032	0.021	0.006
Sa (2.0)	0.025	0.016	0.010	0.003
Sa (5.0)	0.006	0.004	0.002	0.001
Sa (10.0)	0.003	0.002	0.001	0.000
PGA (g)	0.075	0.047	0.030	0.010
PGV (m/s)	0.069	0.042	0.026	0.007

Notes: Spectral ($S_a(T)$, where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information



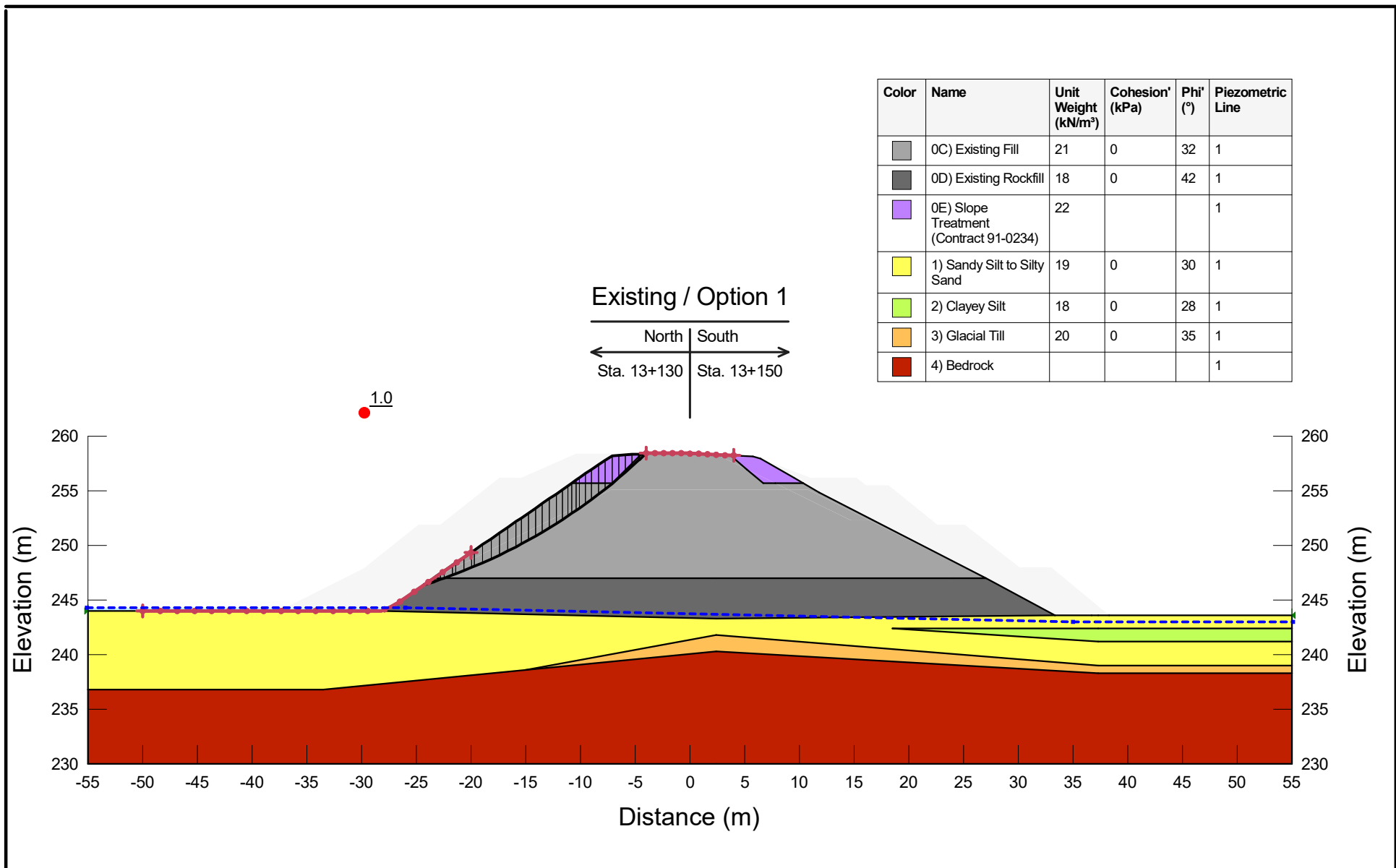
Natural Resources
Canada

Ressources naturelles
Canada

Canada

Appendix F.

Select Slope Stability Outputs



Project Name:
Highway 17 Instability

Analysis Title:
1N - Existing

Project No.:
28408

Date:
05/27/2021

Seismic Coeff.:
H: 0g, V: 0g

Scale:
1:500

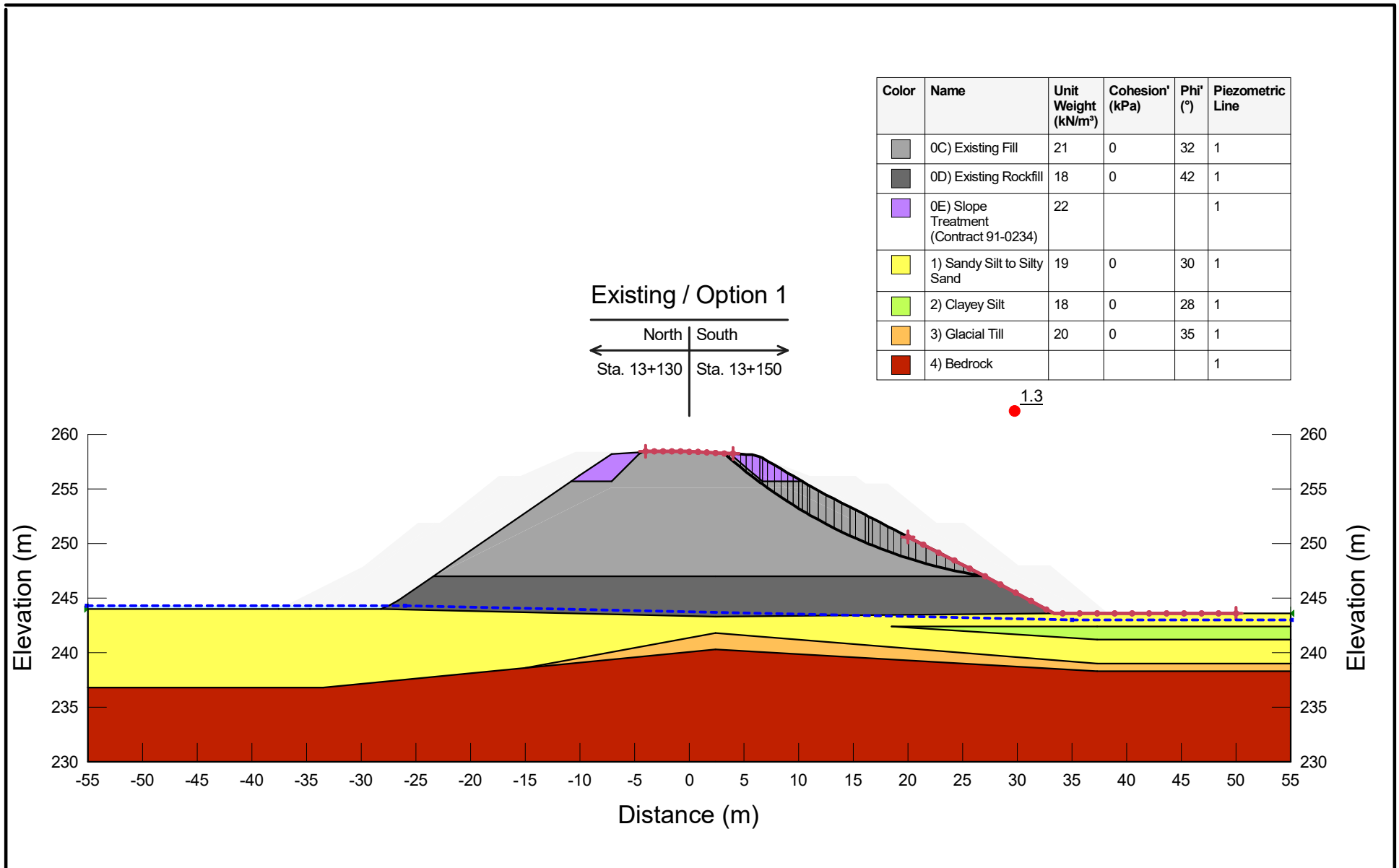
Prepared by:
DP/SP

Reviewed by:
FG

Analysis Details:

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Center: (-39.838674, 295.70371) m w/ Radius: 51.708172 m
PWP Conditions from: Piezometric Line
Horz Seismic Coef.: 0 g

Figure F1




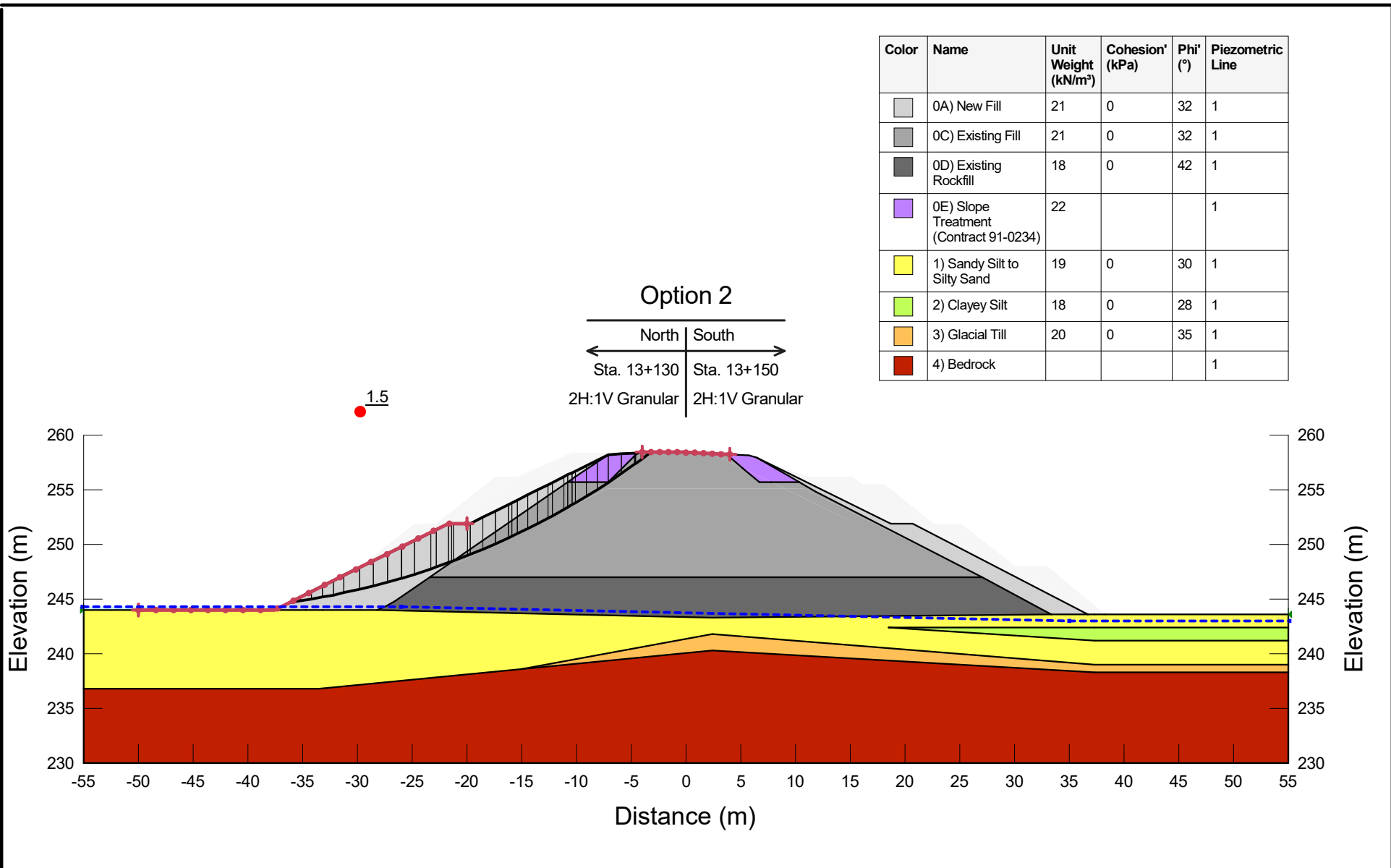

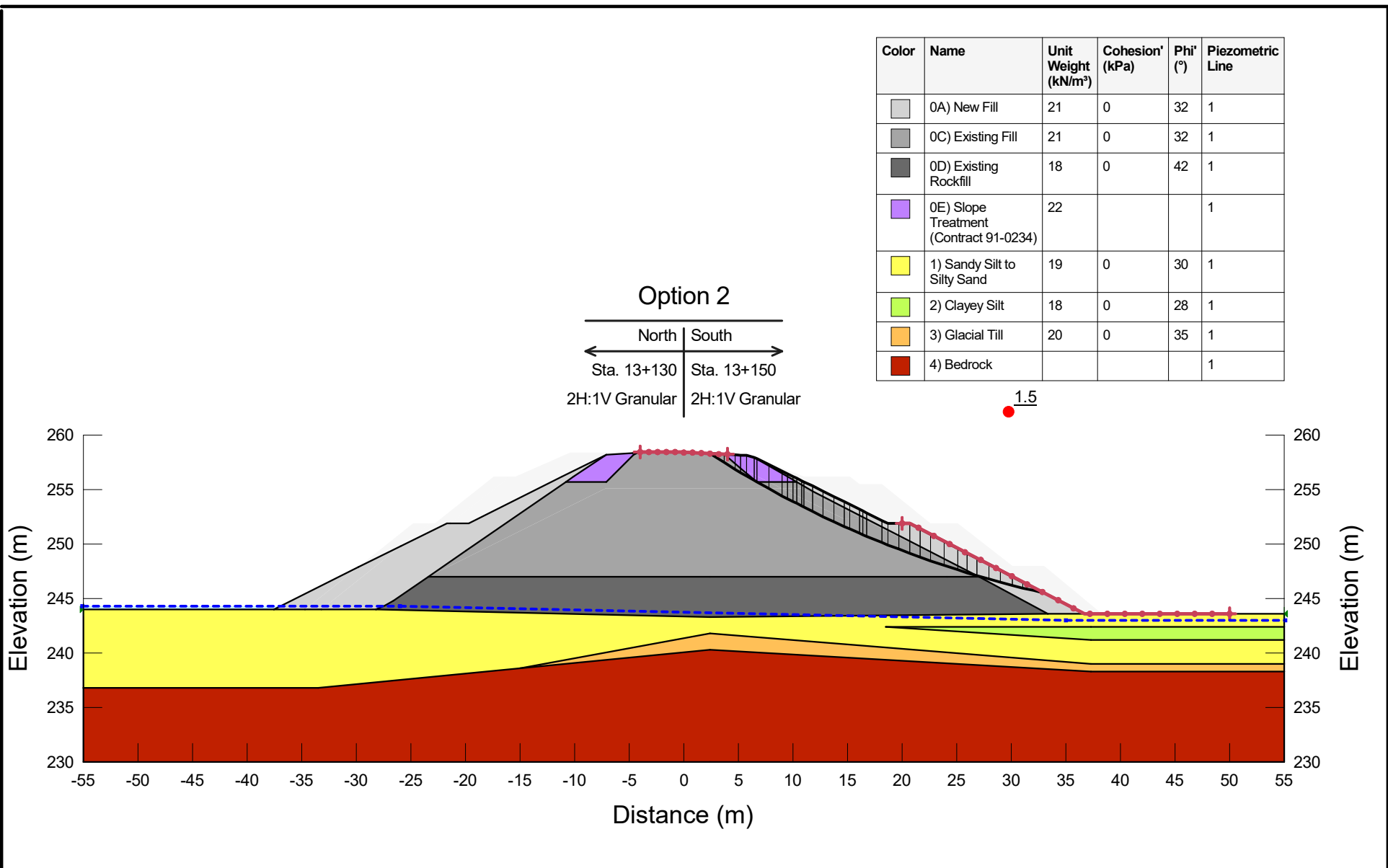
 THURBER	Project Name: Highway 17 Instability			Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (34.07839, 292.70469) m w/ Radius: 46.251114 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0 g
	Analysis Title: 1S - Existing			
	Project No.: 28408	Seismic Coeff.: H: 0g, V: 0g	Prepared by: DP/SP	
	Date: 05/27/2021	Scale: 1:500	Reviewed by: FG	


Figure F2

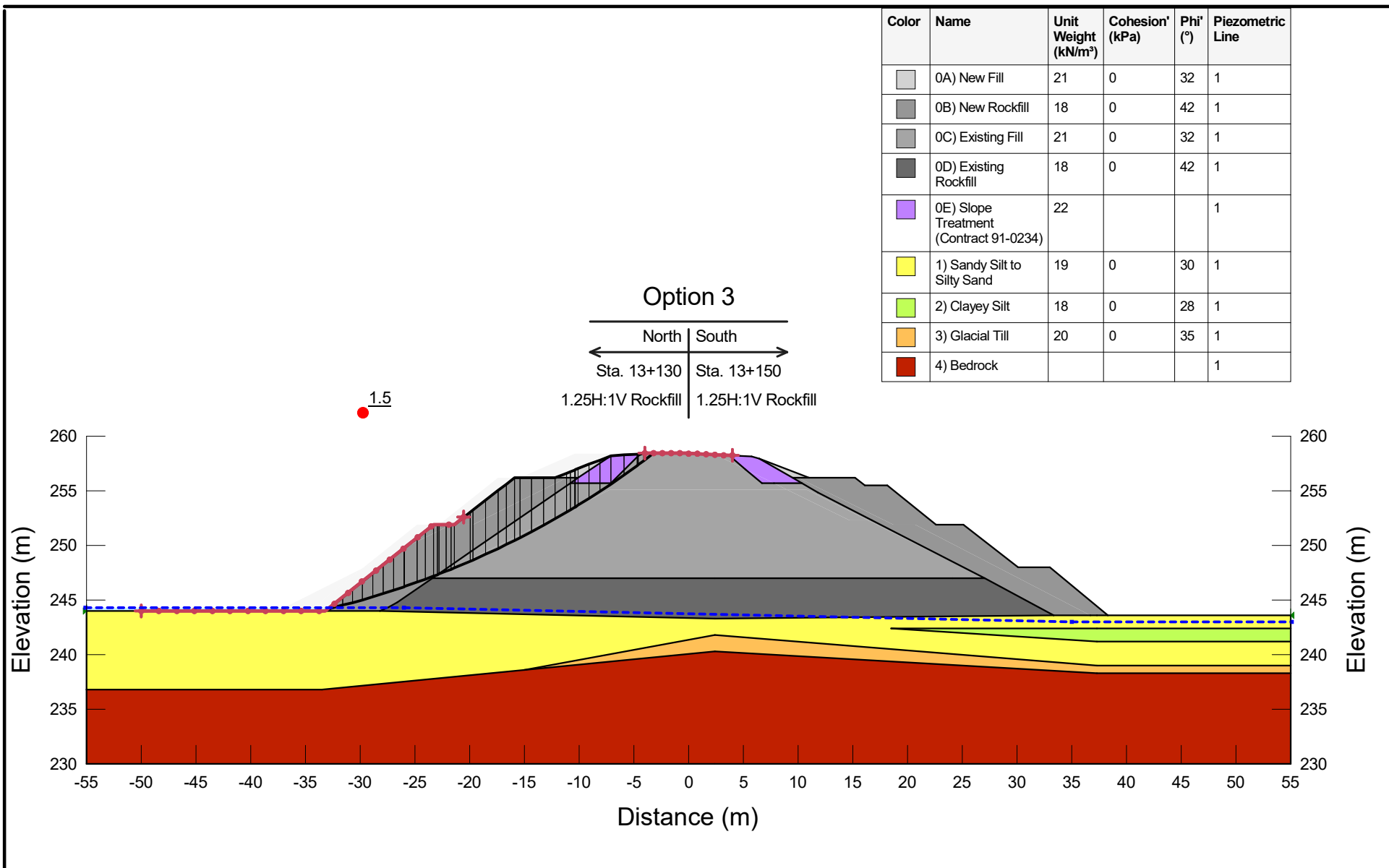
Figure F2




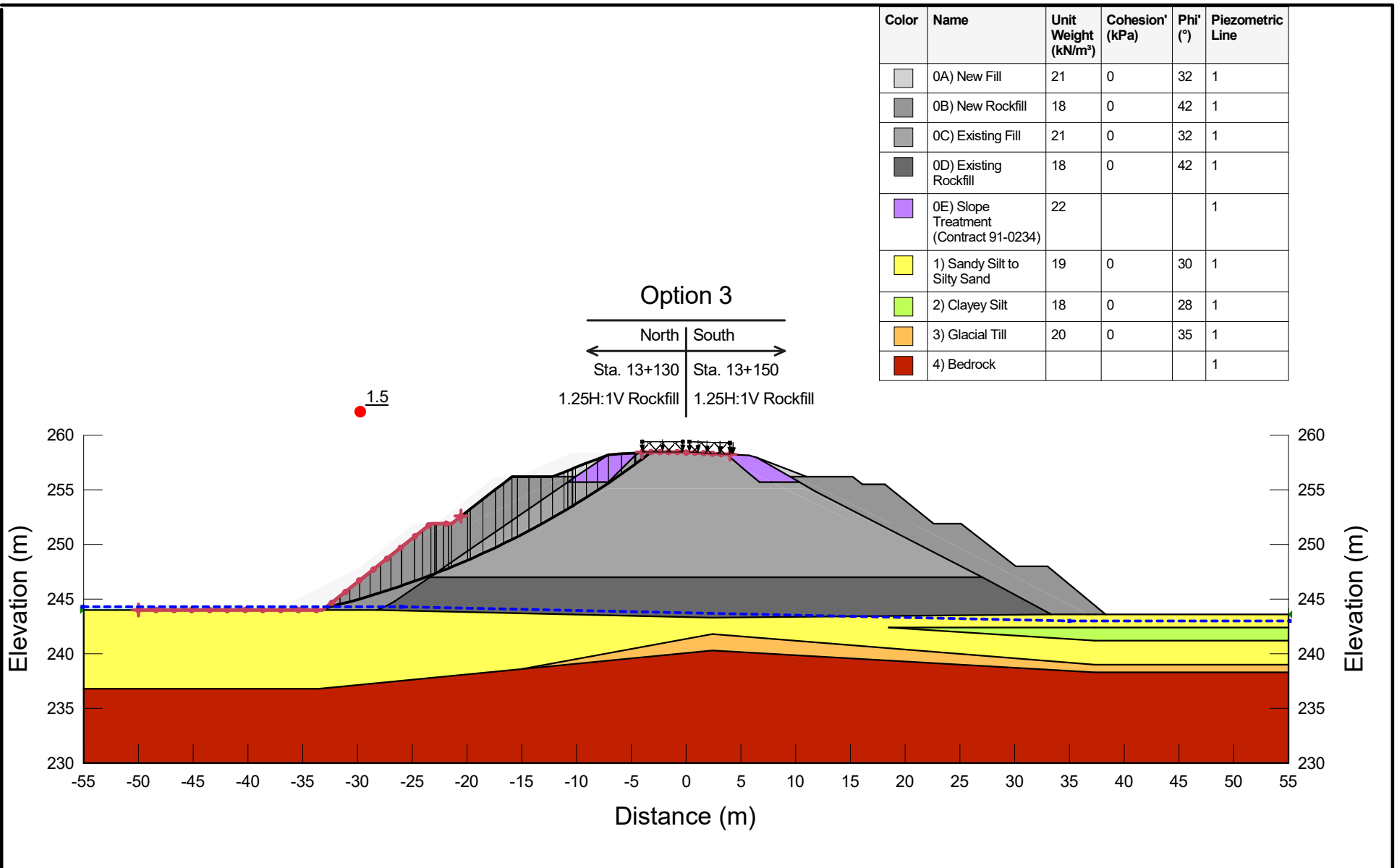
	Project Name: Highway 17 Instability		Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (-46.119011, 315.02381) m w/ Radius: 71.027208 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0 g	
	Analysis Title: 2N - 2H:1V Granular			
	Project No.: 28408	Seismic Coeff.: H: 0g, V: 0g	Prepared by: DP/SP	
	Date: 05/27/2021	Scale: 1:500	Reviewed by: FG	
				Figure F3




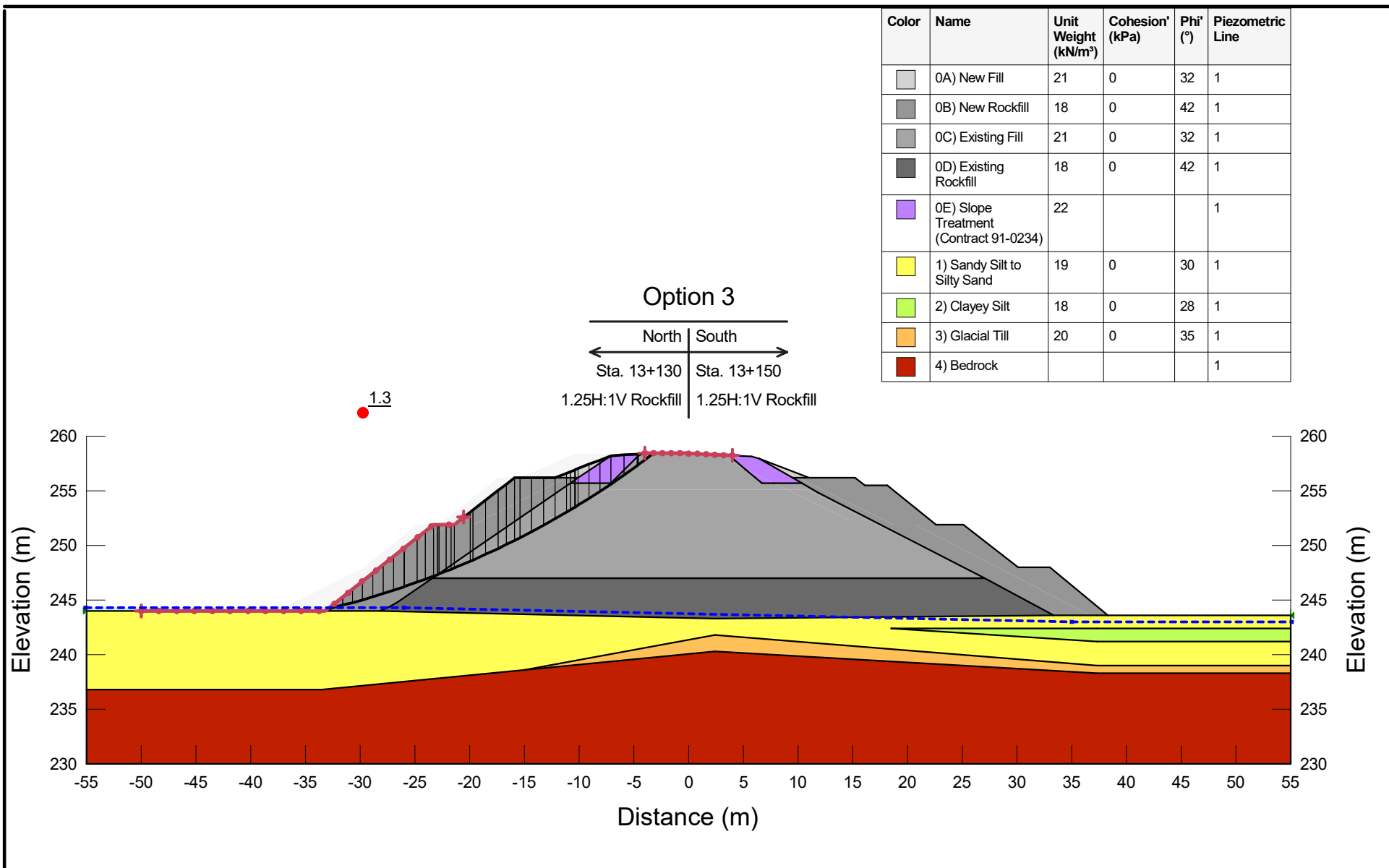
 THURBER	Project Name: Highway 17 Instability		Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (53.659336, 337.83473) m w/ Radius: 94.61399 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0 g	
	Analysis Title: 2S - 2H:1V Granular			
	Project No.: 28408	Seismic Coeff.: H: 0g, V: 0g		Prepared by: DP/SP
	Date: 05/27/2021	Scale: 1:500		Reviewed by: FG
	Figure F4			




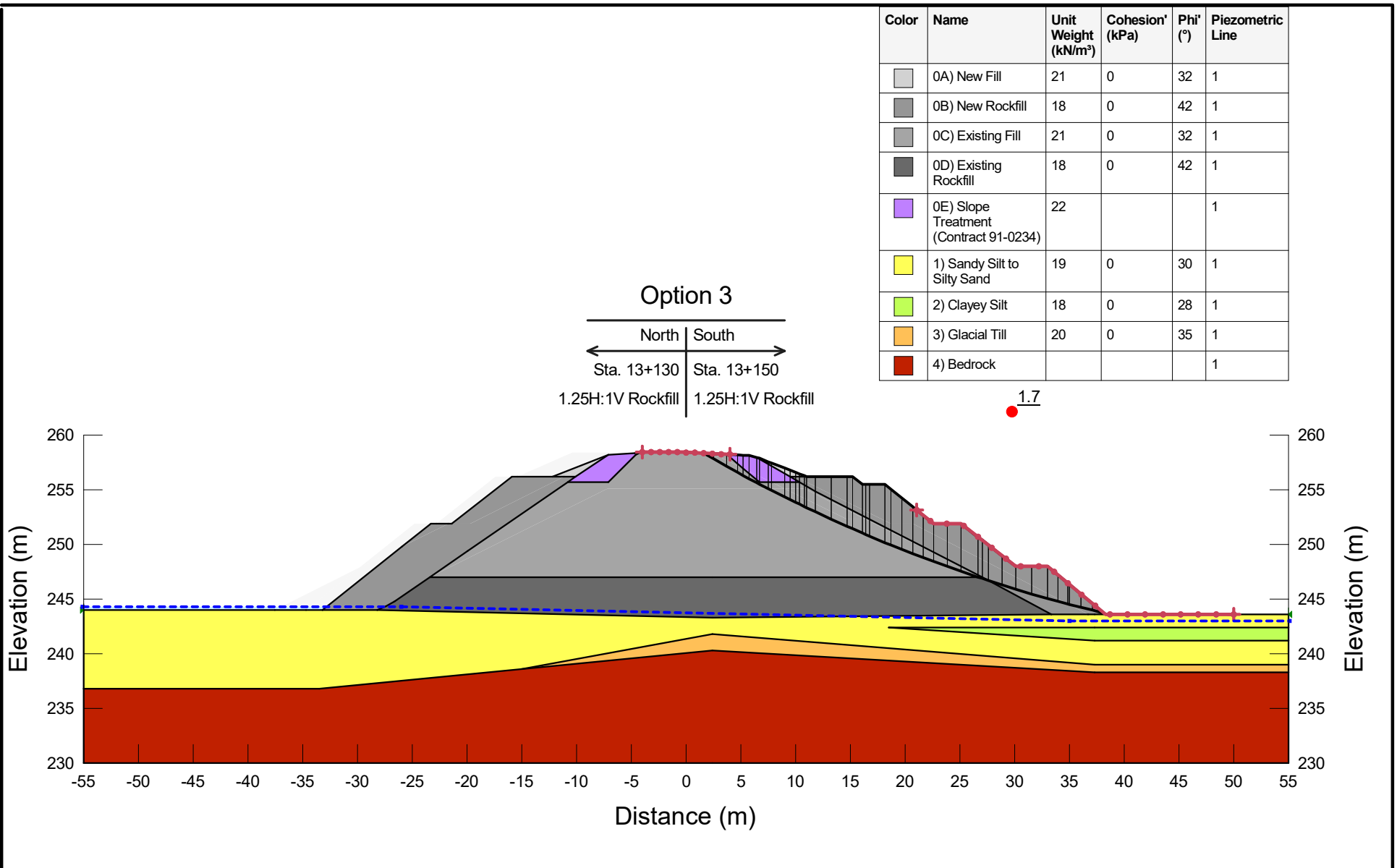
	Project Name: Highway 17 Instability		Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (-51.580695, 321.32163) m w/ Radius: 79.347399 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0 g	
	Analysis Title: 3N - 1.25H:1V Rockfill			
	Project No.: 28408	Seismic Coeff.: H: 0g, V: 0g		Prepared by: DP/SP
	Date: 05/27/2021	Scale: 1:500		Reviewed by: FG
		Figure F5		




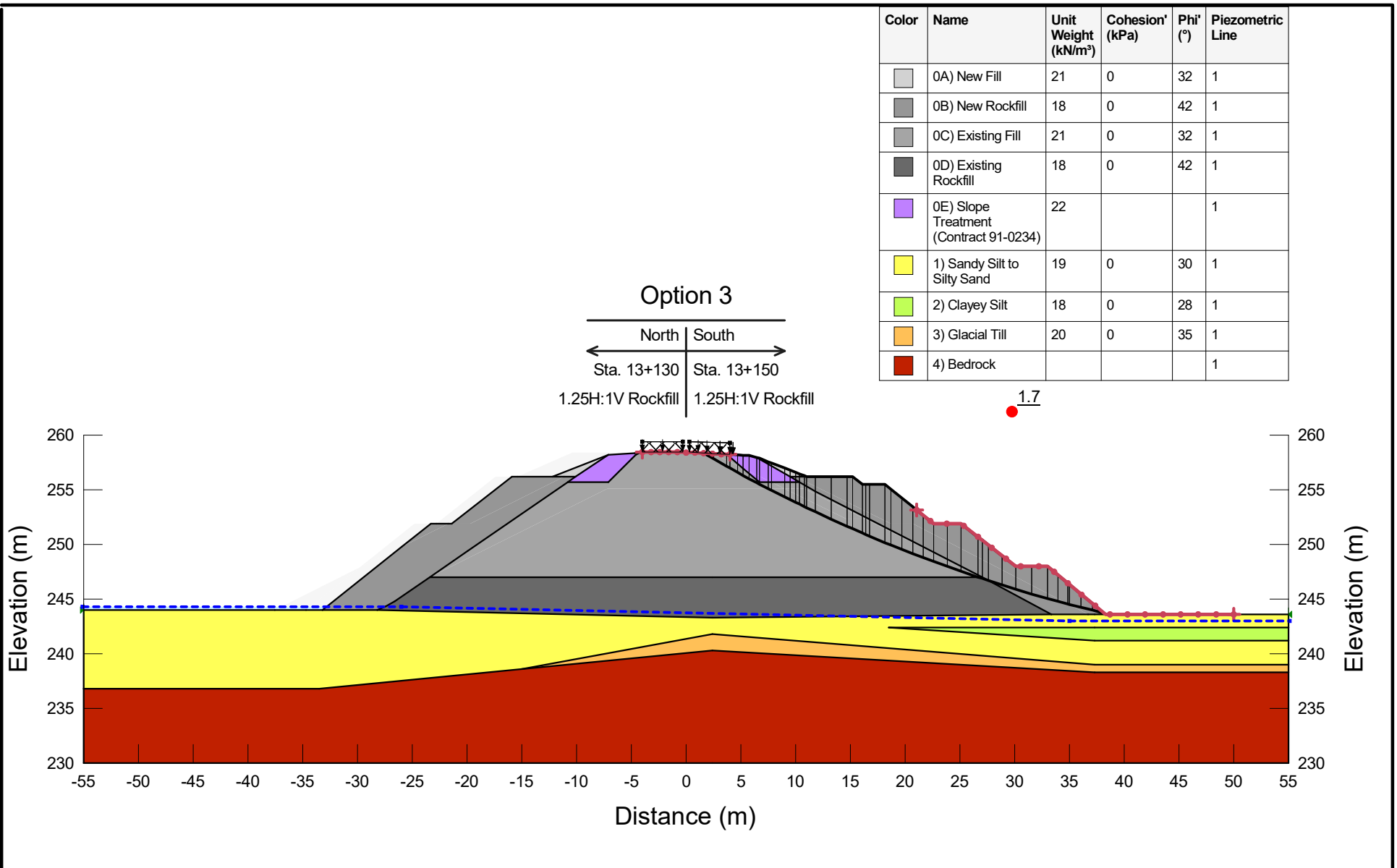
 THURBER	Project Name: Highway 17 Instability		Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (-51.580695, 321.32163) m w/ Radius: 79.347399 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0 g Surcharge (Unit Weight): 18 kN/m³	
	Analysis Title: 3N - 1.25H:1V Rockfill (traffic)			
	Project No.: 28408	Seismic Coeff.: H: 0g, V: 0g	Prepared by: DP/SP	
	Date: 05/27/2021	Scale: 1:500	Reviewed by: FG	
		Figure F6		



	Project Name: Highway 17 Instability		Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (-51.580695, 321.32163) m w/ Radius: 79.347399 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0.05 g	
	Analysis Title: 3N - 1.25H:1V Rockfill (seismic)			
	Project No.: 28408	Seismic Coeff.: H: 0.05g, V: 0g		Prepared by: DP/SP
	Date: 05/27/2021	Scale: 1:500		Reviewed by: FG
			Figure F7	



	Project Name: Highway 17 Instability		Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (69.265462, 374.48444) m w/ Radius: 134.411 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0 g	
	Analysis Title: 3S - 1.25H:1V Rockfill			
	Project No.: 28408	Seismic Coeff.: H: 0g, V: 0g	Prepared by: DP/SP	
	Date: 05/27/2021	Scale: 1:500	Reviewed by: FG	
				Figure F8




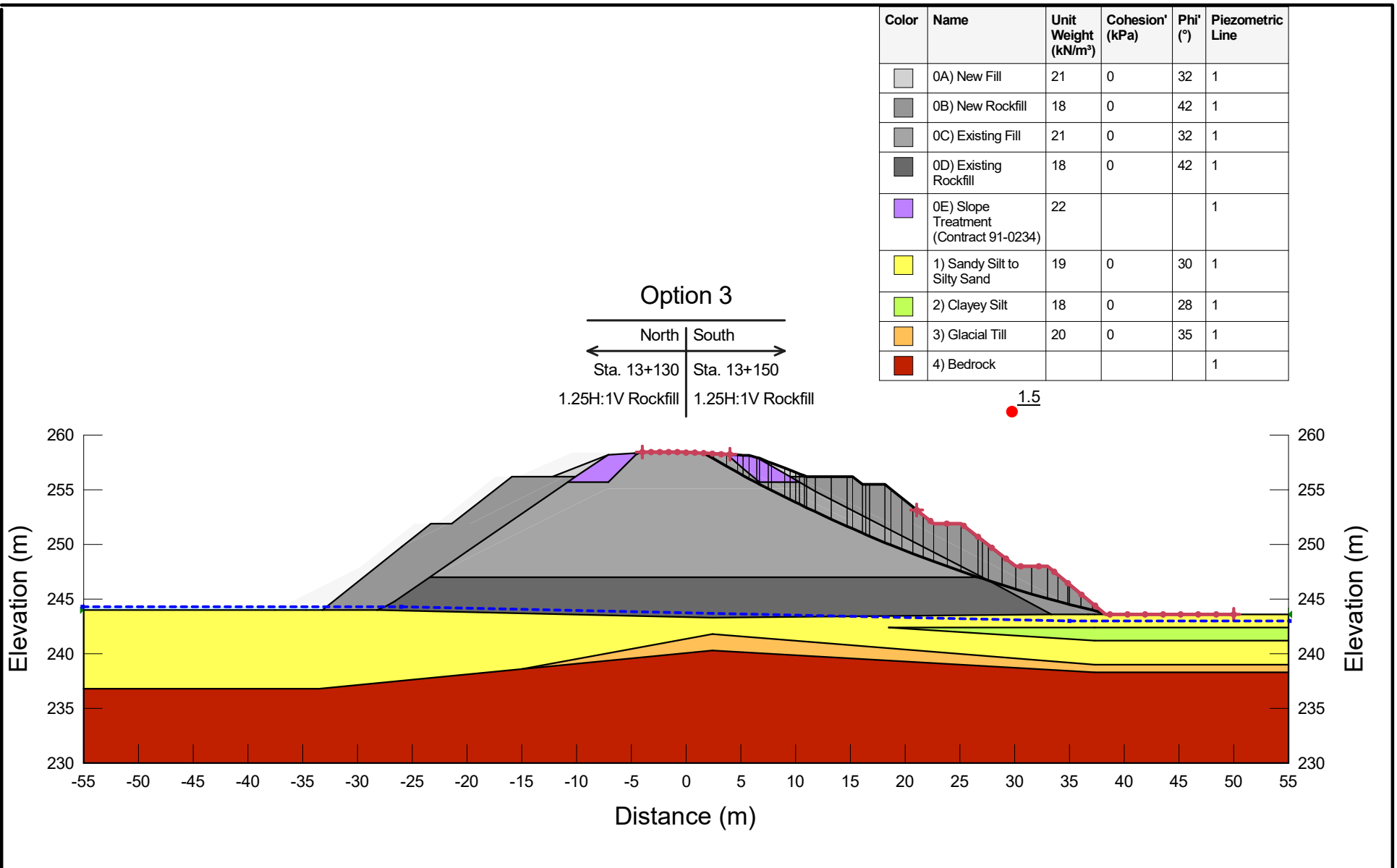

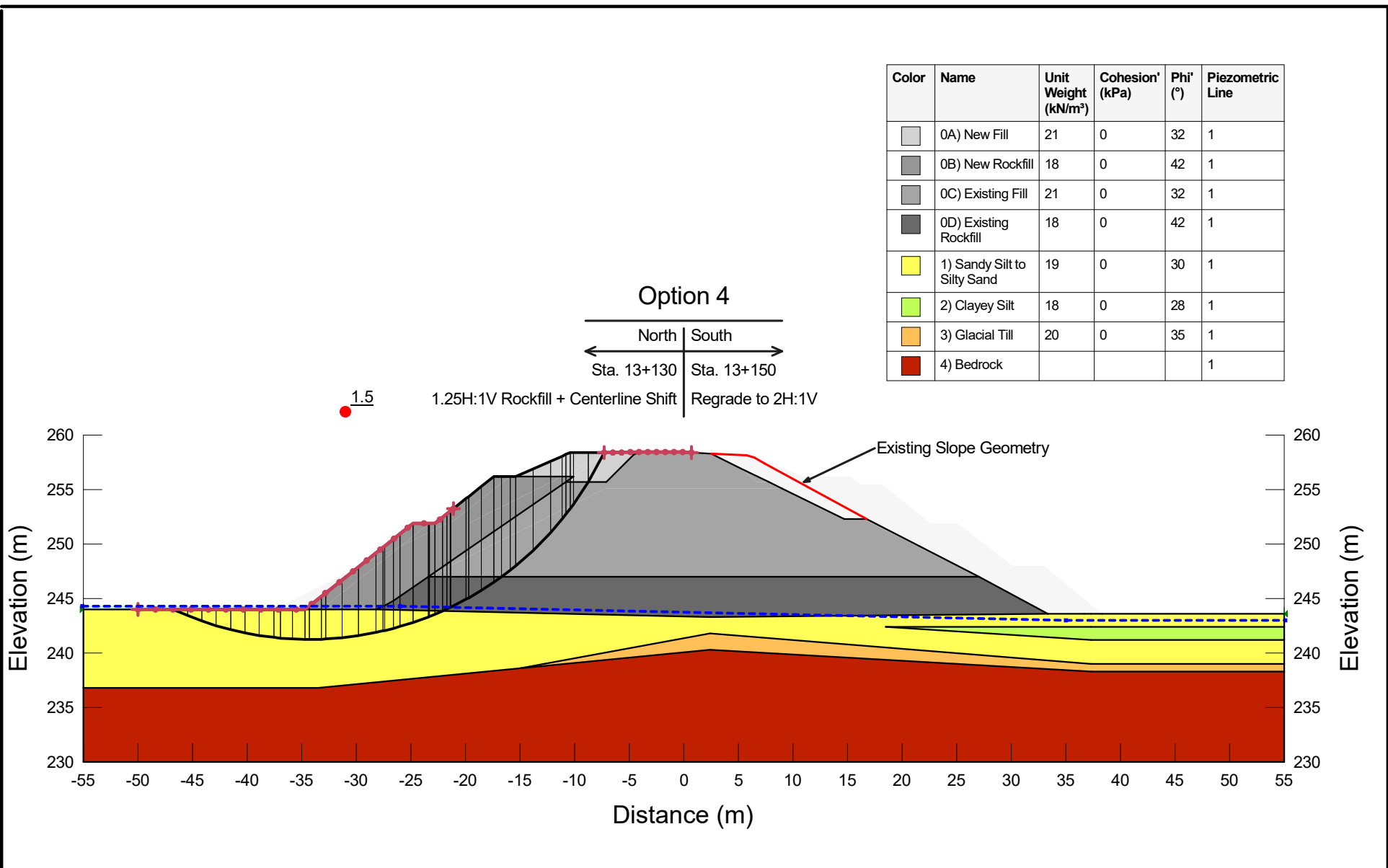
	Project Name: Highway 17 Instability		Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (69.265462, 374.48444) m w/ Radius: 134.411 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0 g Surcharge (Unit Weight): 18 kN/m³	
	Analysis Title: 3S - 1.25H:1V Rockfill (Traffic)			
	Project No.: 28408	Seismic Coeff.: H: 0g, V: 0g	Prepared by: DP/SP	
	Date: 05/27/2021	Scale: 1:500	Reviewed by: FG	

Figure F9

Figure F9



	Project Name: Highway 17 Instability		Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (69.265462, 374.48444) m w/ Radius: 134.411 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0.05 g
	Analysis Title: 3S - 1.25H:1V Rockfill (Seismic)		
	Project No.: 28408	Seismic Coeff.: H: 0.05g, V: 0g	Prepared by: DP/SP
	Date: 05/27/2021	Scale: 1:500	Reviewed by: FG
			Figure F10



Project Name:
Highway 17 Instability

Analysis Title:
4N - 1.25H:1V Rockfill (North), Regrade South

Project No.:
28408

Date:
05/27/2021

Seismic Coeff.:
H: 0g, V: 0g

Scale:
1:500

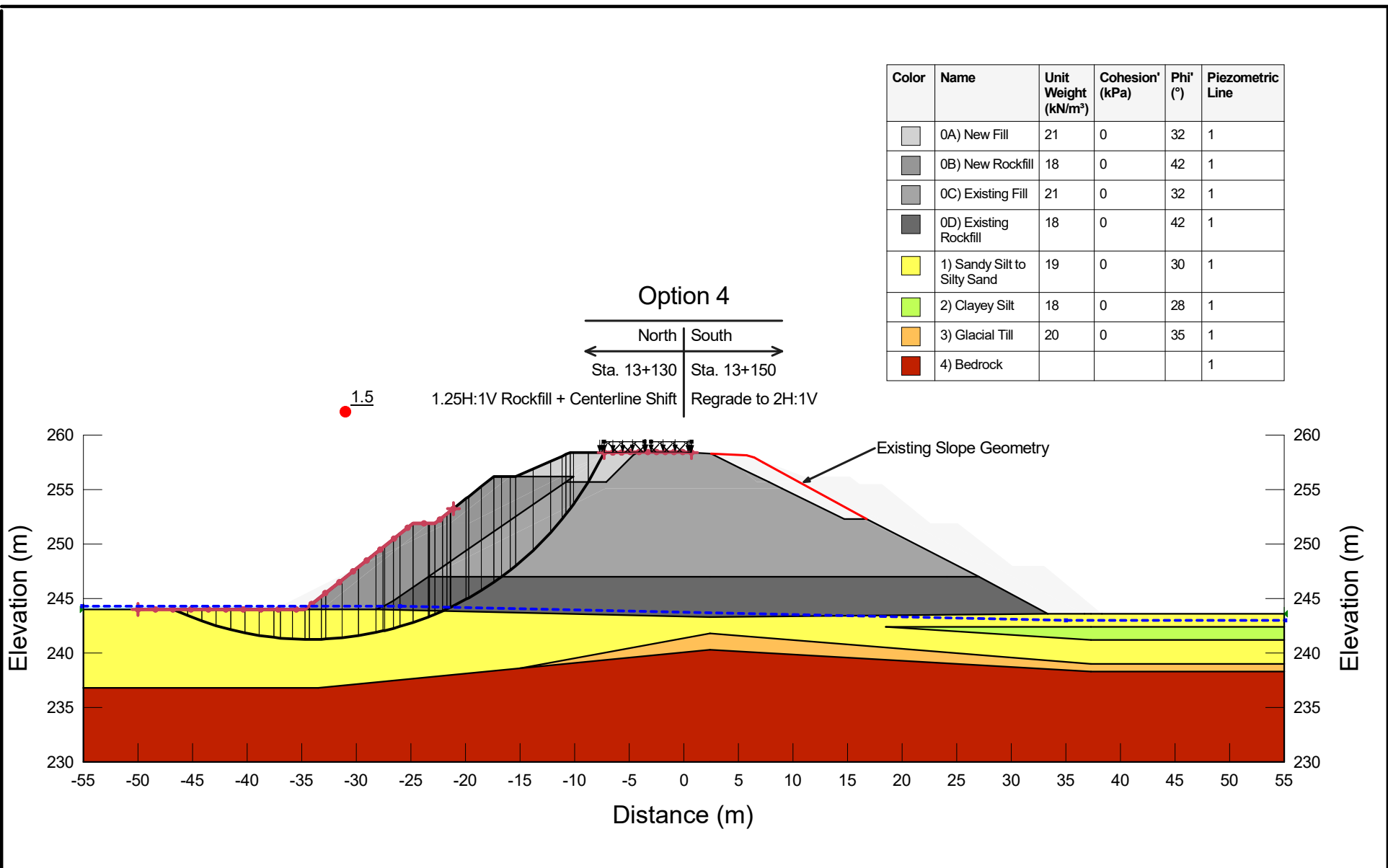
Prepared by:
DP/SP

Reviewed by:
FG

Analysis Details:

Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 2 m
 Center: (-34.286586, 271.052) m w/ Radius: 29.798928 m
 PWP Conditions from: Piezometric Line
 Horz Seismic Coef.: 0 g

Figure F11



Project Name:
Highway 17 Instability

Analysis Title:
4N - 1.25H:1V Rockfill (North), Regrade South (Traffic)

Project No.:
28408

Seismic Coeff.:
H: 0g, V: 0g

Prepared by:
DP/SP

Date:
05/27/2021

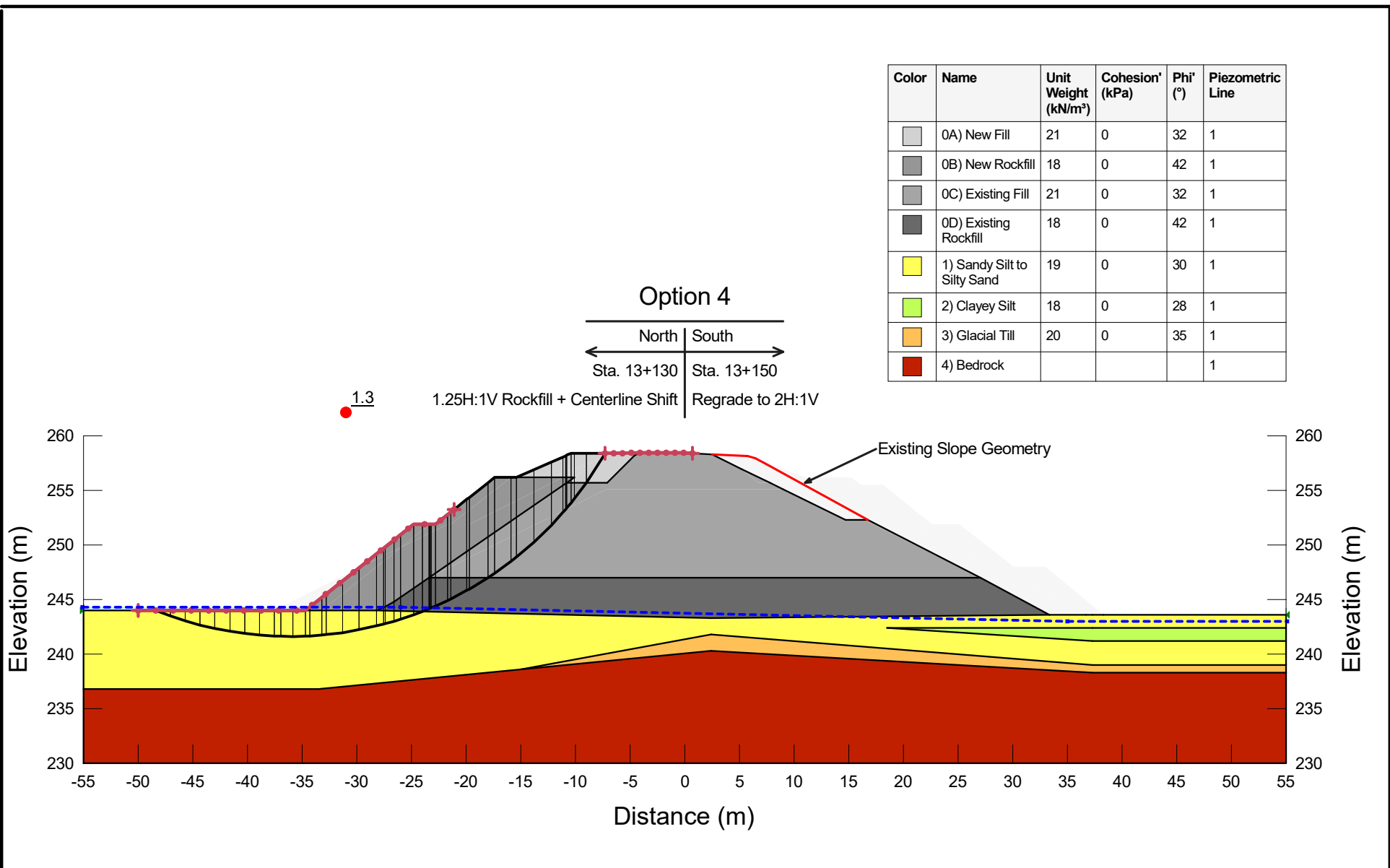
Scale:
1:500

Reviewed by:
FG

Analysis Details:

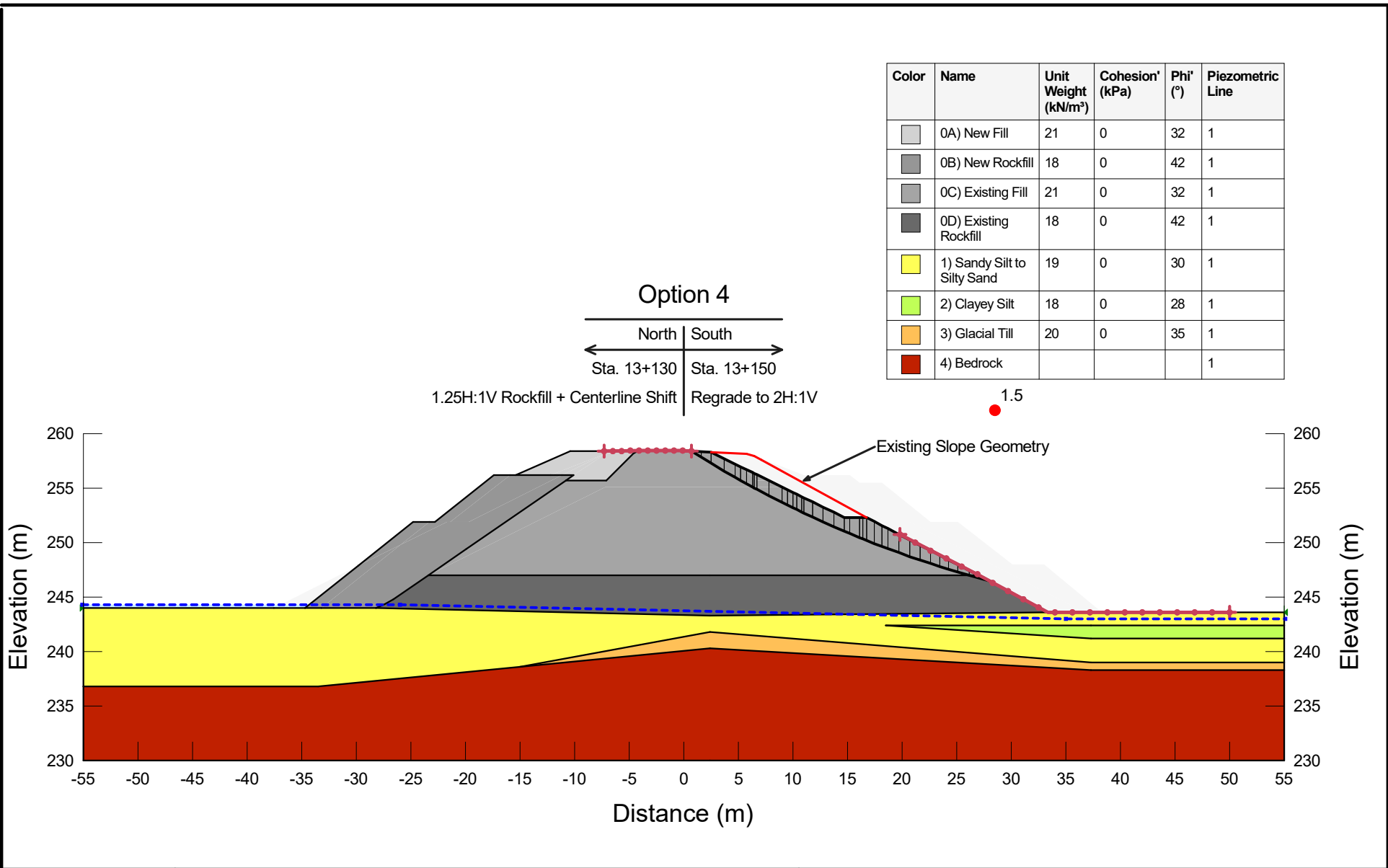
Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 2 m
 Center: (-34.286586, 271.052) m w/ Radius: 29.798928 m
 PWP Conditions from: Piezometric Line
 Horz Seismic Coef.: 0 g
 Surcharge (Unit Weight): 18 kN/m³


Figure F12

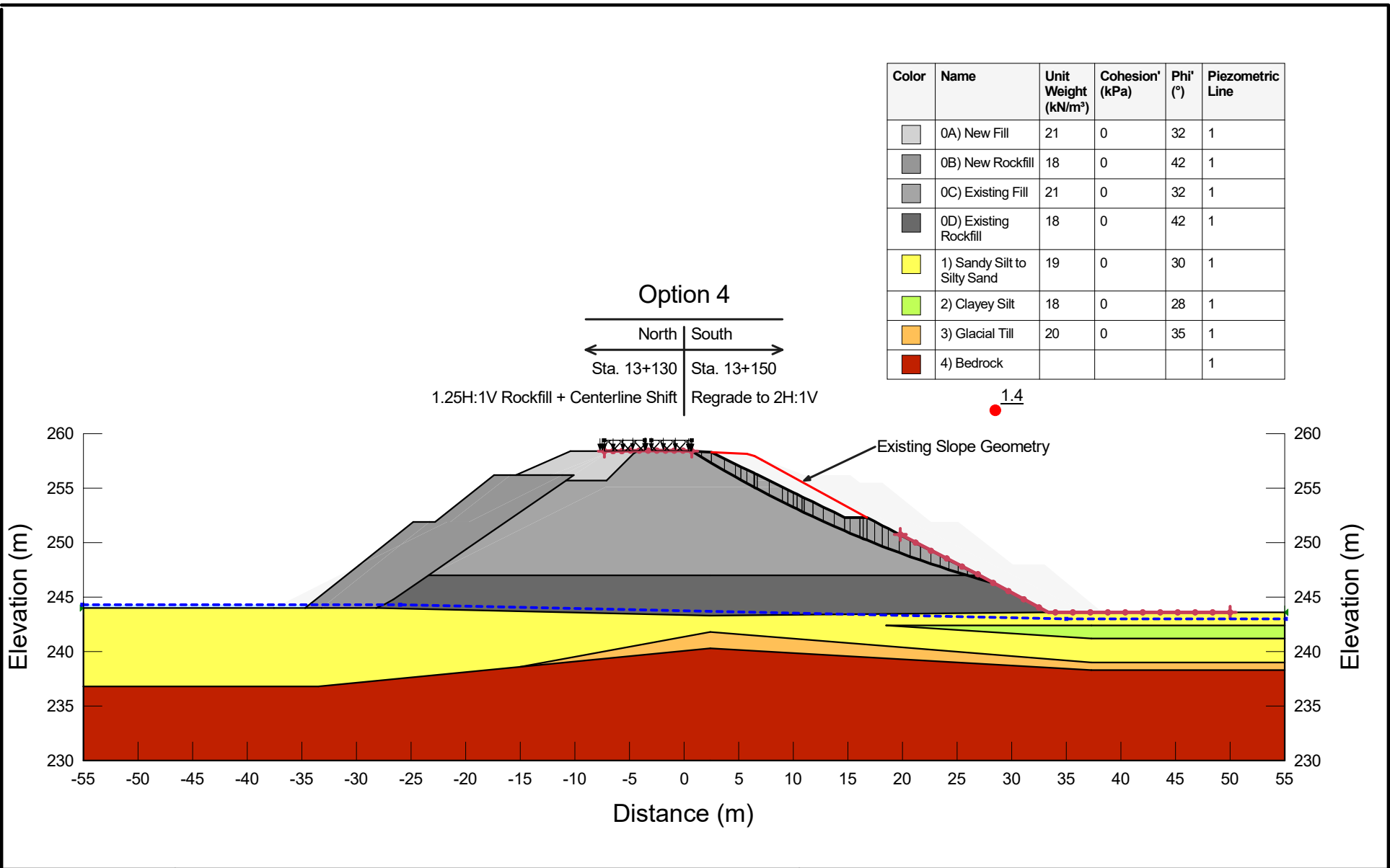


Project Name: Highway 17 Instability		
Analysis Title: 4N - 1.25H:1V Rockfill (North), Regrade South (Seismic)		
Project No.: 28408	Seismic Coeff.: H: 0.05g, V: 0g	Prepared by: DP/SP
Date: 05/27/2021	Scale: 1:500	Reviewed by: FG

Analysis Details:	
Method: Morgenstern-Price, Half-Sine	
Minimum Slip Surface Depth: 2 m	
Center: (-36.082571, 274.68765) m w/ Radius: 33.064239 m	
PWP Conditions from: Piezometric Line	
Horz Seismic Coef.: 0.05 g	
Figure F13	



	Project Name: Highway 17 Instability			Analysis Details: Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 2 m Center: (52.646634, 340.34517) m w/ Radius: 97.031177 m PWP Conditions from: Piezometric Line Horz Seismic Coef.: 0 g
	Analysis Title: 4S - 1.25H:1V Rockfill (North), Regrade South			
	Project No.: 28408	Seismic Coeff.: H: 0g, V: 0g	Prepared by: DP/SP	
	Date: 05/27/2021	Scale: 1:500	Reviewed by: FG	
				Figure F14



Project Name:
Highway 17 Instability

Analysis Title:
4S - 1.25H:1V Rockfill (North), Regrade South (Traffic)

Project No.:
28408

Date:
05/27/2021

Seismic Coeff.:
H: 0g, V: 0g

Scale:
1:500

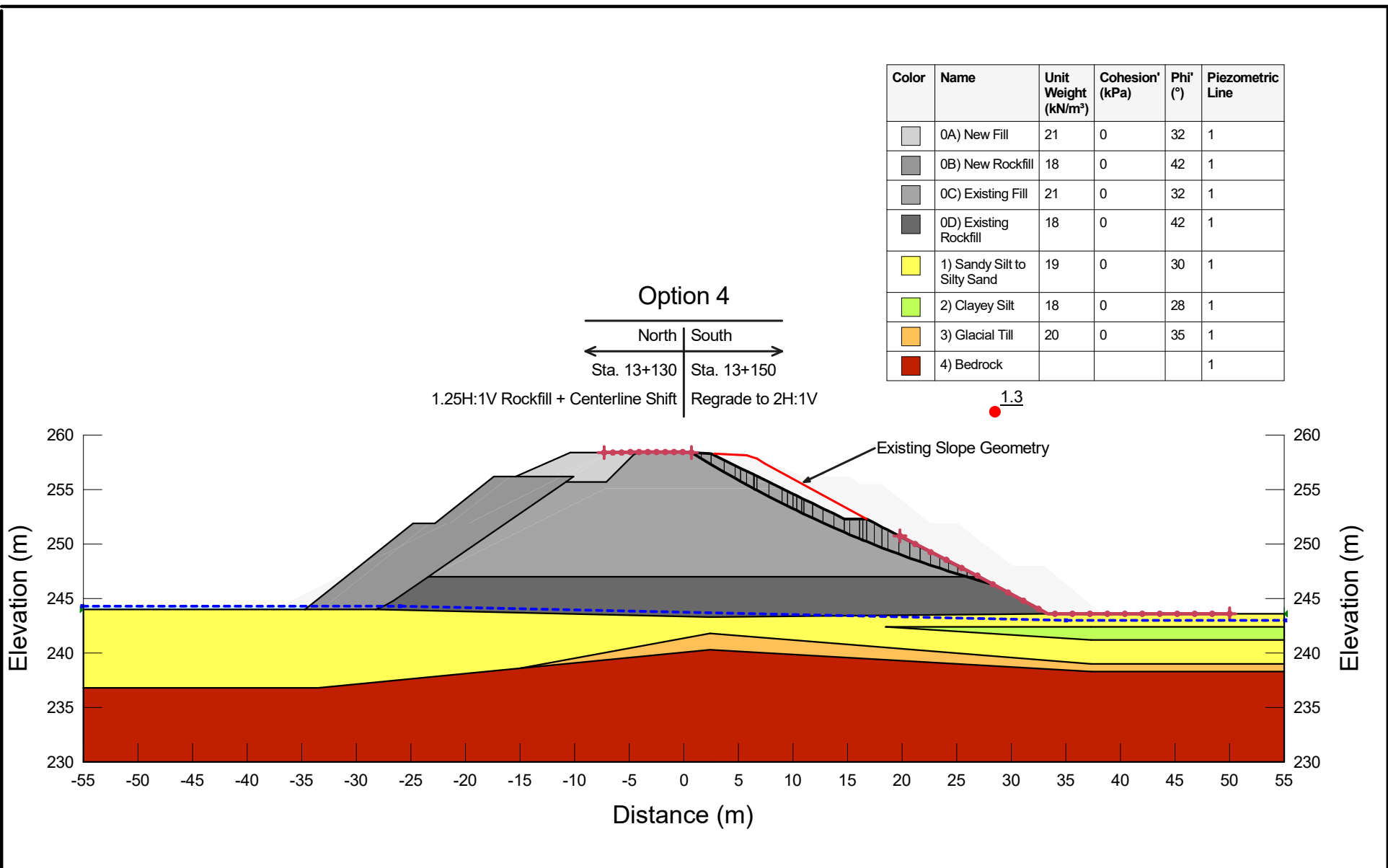
Prepared by:
DP/SP

Reviewed by:
FG

Analysis Details:

Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 2 m
 Center: (56.227089, 347.75212) m w/ Radius: 105.20831 m
 PWP Conditions from: Piezometric Line
 Horz Seismic Coef.: 0 g
 Surcharge (Unit Weight): 18 kN/m³

Figure F15



Project Name: Highway 17 Instability		
Analysis Title: 4S - 1.25H:1V Rockfill (North), Regrade South (Seismic)		
Project No.: 28408	Seismic Coeff.: H: 0.05g, V: 0g	Prepared by: DP/SP
Date: 05/27/2021	Scale: 1:500	Reviewed by: FG

Analysis Details:	
Method: Morgenstern-Price, Half-Sine	
Minimum Slip Surface Depth: 2 m	
Center: (56.227089, 347.75212) m w/ Radius: 105.20831 m	
PWP Conditions from: Piezometric Line	
Horz Seismic Coef.: 0.05 g	
Figure F16	

Appendix G.

Embankment Remediation Options Table

Table G1 – Embankment Remediation Options

Remediation Option	Advantages	Disadvantages	Risks/Consequences	Relative Construction Cost
(1) Do nothing	<ul style="list-style-type: none"> - no construction cost - no disruption to traffic due to construction - no construction impacts to natural environment - could add asphalt curbs to better control drainage 	<ul style="list-style-type: none"> - no improvement to highway performance - erosion on the side slopes will continue unabated - ongoing maintenance measures including addition of Granular A on shoulder will periodically be required to address safety concerns as erosion negatively impacts the performance of the roadway or guiderails - with asphalt curbs, the drainage needs to be directed to protected channels on the existing steep slopes. 	- further erosion/unscheduled road closures to address maintenance	Low (higher maintenance costs)
(2) Flatten both embankment slopes to 2H:1V with granular material with a mid height bench 2m in width.	<ul style="list-style-type: none"> - minimal time-dependant self compression of the granular fill - no migration of fines from the existing embankment into the widened granular - minimal impact to traffic during construction 	<ul style="list-style-type: none"> - will need a wider footprint for embankment widening on both sides resulting in more property acquisition issues, longer culvert extensions, possible environmental impacts, and potential conflicts with buried utilities. - requires the greatest quantity of fill material - constructability issues; narrow bench and construction equipment maneuverability. - benching existing slope from the bottom up poses additional risk. 	<ul style="list-style-type: none"> - unknown impact to the natural environment - presence of additional deposit(s) of organics within widened footprint/ would increase fill quantities - placement of fill on the north side could require dewatering to allow compaction 	Moderate
(3A) Widen the embankment 5 m on both sides with rockfill material placed at 1.25H:1V and with a 2 m wide, mid-height bench. More than one bench may be required on the south side.	<ul style="list-style-type: none"> - can have steeper slopes resulting in smaller footprint for embankment widening thus reducing property acquisition issues, length of culvert extensions and possible environmental impacts - rockfill may be readily available given other rock scaling and blasting operations as part of this project. - can place rockfill without dewatering - minimal impact on traffic during construction 	<ul style="list-style-type: none"> - time dependant self-settlement of the rockfill - requires the second greatest quantity of fill material - requires culvert extension at both ends of culvert - potential conflicts with buried utilities on both sides 	<ul style="list-style-type: none"> - unknown impact to the natural environment - presence of additional deposit(s) of organics within widened footprint/ would increase fill quantities 	Moderate
(3B) Same as 3A, but only widening the embankment with rockfill to the north. Slope flattening for upper portions of south side.	<ul style="list-style-type: none"> - same as 3A - requires less rockfill quantity then 3A - less impact to watermain located on south side of embankment 	<ul style="list-style-type: none"> - time dependant self-settlement of the rockfill - requires culvert extension at the north end of culvert - potential conflicts with buried utility on north side 	- same as 3A	Low to Moderate
(4) Widen the embankment 6.5 m to the north with rockfill material placed at 1.25H:1V and with a 2 m wide, mid-height bench. Shift the roadway alignment ~3.3 m to the north. Regrade the upper 6 m of the existing south embankment slope to 2H:1V with a 2 m wide bench.	<ul style="list-style-type: none"> - can have steeper slopes resulting in smaller footprint for embankment widening thus reducing property acquisition issues, length of culvert extensions and possible environmental impacts - rockfill may be readily available given other rock scaling and blasting operations as part of this project. - can place rockfill without dewatering - minimal impact on traffic during construction - does not conflict with the watermain within the south embankment toe. - culvert extension only required for the north embankment widening 	<ul style="list-style-type: none"> - time dependant self-settlement of the rockfill, may have settlement of new WBL in area of embankment shift - requires slight realignment of the highway to the north and associated highway shifts extending west and east of embankment area. - Will require further review and work to be completed outside of the embankment area, such as property acquisition and rock cut widening to allow for the highway realignment - requires removal of the geogrid slope protection system in the north embankment shoulder. 	<ul style="list-style-type: none"> - unknown impact to the natural environment presence of additional deposit(s) of organics within widened footprint/ would increase fill quantities. 	Low to Moderate (Moderate to High when including costs adjacent to embankment work area such as costs associated with extended length of highway realignment)

Appendix H.

List of Referenced Specifications

1. The following Special Provisions and OPSS Documents are referenced in this report

- OPSS.PROV 206
- OPSS.PROV 401
- OPSS 422
- OPSS 501
- OPSS 517
- OPSS 601.010
- OPSS.PROV 1010
- SP 102S05
- OPSD 100.060
- OPSD 210.010
- OPSD 208.010
- OPSD 803.010
- OPSD 810.010

2. Notice to Contactor – Obstructions

The Contractor is advised that obstructions could be encountered during excavation. Appropriate equipment and procedures will be required by the Contractor.