THURBER ENGINEERING LTD.

January 31, 2025 File No.: 34041

BC Ministry of Transportation and Transit
Suite 310 – 1500 Woolridge Street
Coquitlam, BC
V3K 0B8

Attention: Scott Cosman, P.Eng.

HWY 1 LOWER FRASER CANYON FLOOD RECOVERY: CPS PROJECT NO. 14054, SA07-1-12 CORRIDOR SA07 HOPE TO JACKASS COOPER'S CORNER PULLOUT CULVERT UPSIZING (49°45'32"N, 121°25'10"W) 100% DETAILED DESIGN, REV. 1

Dear Scott,

Thurber was retained by the British Columbia Ministry of Transportation and Transit (MOTT) to carry out a preliminary review and provide ongoing geotechnical design and construction support during remediation works at the above location. We understand the above site was damaged during November 2021 flood events.

Our services have been provided under the Consulting Services Contract 862 CS 1195. It is a condition of this memo that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1. SCOPE OF SERVICES

This letter provides geotechnical recommendations to supplement information and design work provided by other consultants. This includes a set of recommendations related to geotechnical aspects of remediation proposed at the above location. Our work includes geotechnical input for the design of the culvert and slope recommendations for the downslope area. This letter does not address potential environmental concerns.

2. BACKGROUND INFORMATION

We understand that the culvert at Cooper's Corner pullout is to be replaced with a 3050 mm by 2745 mm precast concrete box culvert. This will replace the existing 1800 mm CSP culvert and was selected from several replacement options provided by Associated Engineering (AE) in their report "Cooper's Corner Draft Hydrotechnical Assessment and Options Analysis Report" dated March 2024. Immediately around the existing culvert outlet a "headwall" constructed of stacked pre-cast concrete barriers is in place.

Thurber previously provided input for 50% detailed design of the culvert replacement in a report dated June 13, 2024. The recommendations provided in that report are superseded by those provided herein.

Thurber completed a geotechnical investigation at this location, and the results were provided in a separate report dated May 6, 2024. Finalized versions of the test hole location plan (Dwg. 34041-2) and test hole logs are attached to this report. Thurber completed a geohazard assessment and presented the results in a draft report dated October 11, 2024. Those reports should be reviewed together with this report. Thurber and AE are also working on a culvert replacement for a site located about 250 m southeast of the project site. Geotechnical design input for that culvert replacement (i.e., at the 'Cooper's Corner slide' location) will be provided in a separate report.

The existing downslope geometry is likely oversteepened when assessed against current design guidelines, although it is consistent with the highway corridor and appears to be performing acceptably geotechnically.

3. DESIGN CRITERIA

The geotechnical design considers the following documents:

- Ministry technical circulars
- CSA S6-19 Canadian Highway Bridge Design Code S6-19
- BC MOTT Supplement to CHBDC S6-19
- BC MOTT Supplement to CHBDC S6-14
- CSA A23.3 Design of Concrete Structures
- FHWA-IF-99-015 Ground Anchors and Anchored Systems
- Post-Tensioning Institute DC3.1-14: Recommendations for Prestressed Rock and Soil Anchors

Based on the investigation and laboratory testing completed to date, we consider a typical degree of understanding per the BC MOTT Supplement to CHBDC S6-19 suitable for design.

4. RECOMMENDATIONS

Our recommendations for the culvert upsizing are based on 100% design drawings provided by AE on January 17, 2025. The culvert includes an inlet headwall, an outlet headwall, and an outlet spillway.

The drawings show the spillway as nominally 14.4 m long, dipping downslope at about 35 degrees from the horizontal. The spillway apron is 4 m wide at the top and 8 m wide the base. The spillway structure is supported on a 4 m long by 1 m wide by 2 m deep footing located below the top of the apron and an 8 m long by 1.5 m wide by 3 m deep footing located below the base of the apron. AE reported that the weight of the spillway is about 4200 kN and the spillway will be subjected to a hydrodynamic force of about 88 kN acting down the apron. We understand that the culvert headwalls and spillway will be cast-in-place concrete.

4.1 Seismic Site Class

There were no shear wave velocity measurements collected during the 2022 geotechnical investigation. Based on the site location and overall geography, a Site Class C designation per Table 4.1 of CHBDC S6-19 would be expected. We recommend that the design of the culvert consider a Site Class D designation due to the lack of available shear wave velocity measurements. The Site Class D hazard values obtained from the NBCC online hazard calculator tool are shown in Table 4-1.

Table 4-1: NBCC 2020 Seismic Hazard Values for Project Site per Online Calculator

Return Period (years)	Spectral Acceleration Values (g)							
	PGA	PGV	T = 0.2 s	0.5 s	1.0 s	2.0 s	5.0 s	10.0 s
2475	**0.23**	0.34	0.54	0.52	0.38	0.25	0.09	0.04
975	**0.14**	0.23	0.37	0.36	0.25	0.15	0.05	0.02
475	**0.11**	0.15	0.26	0.26	0.17	0.10	0.03	0.01

4.2 Slope Stabilization

4.2.1 Assessment

We have completed slope stability assessment using the limit equilibrium program Slide2 by Rocscience. Our model geometry is based on the slope geometry provided by AE with soil properties based on the results of our geotechnical investigation. Output figures from our assessment are attached (see Figures 1 to 6). The calculated factor of safety for the various analyses are summarized in Table 4-2.

Table 4-2: Slope stability assessment results

Geometry	Loading	Soil Model used in Overburden	Minimum FoS [1] Calculated	*AVERAGE*	Target FoS per MoTI Supplement to CHBDC S6-19 [2]	Figure No.
Existing slope	**Static** + Traffic	Mohr-Coulomb	1.19	*1.10*	1.54	1
		Non-linear	1.02			2
Post-construction with Stabilization	**Static** + Spillway gravity loads + Hydrodynamic	Mohr-Coulomb	1.89	*1.65*	1.54	3
		Non-linear	1.42			4
	Pseudo-Static + Spillway gravity loads	Mohr-Coulomb	1.64	*1.43*	1.3	5
		Non-linear	1.22			6

[1] Factor of Safety

[2] For typical degree of understanding and typical consequences

Two soil strength models were assigned to the embankment overburden to examine sensitivity, including a Mohr-Coulomb strength envelope with a friction angle of 45° and a non-linear strength envelope. The non-linear strength envelope has been used in the past for other similar highway embankment assessments and assumes about a 47° friction angle at lower confining stresses and about a 34° friction angle at higher confining stresses. Loading from the spillway was modelled as a uniform 50 kPa vertical load to represent gravity loading and a 13 kN/metre width point load to represent hydrodynamic forces. The pseudo-static analyses were conducted with a horizontal coefficient of 0.11 g, consistent with the 1 in 475-year PGA for NBCC 2020 Site Class D.

The current slope geometry is oversteepened when assessed against current design guidelines, although it is consistent with the highway corridor and appears to be performing acceptably geotechnically. The calculated slope stability factors of safety for the existing slope geometry ranged from about 1 to 1.2, depending on the soil model applied to the overburden (see Figures 1 and 2). Given that the historical performance of the embankment slope in the project location has been adequate, the Mohr-Coulomb strength model is likely more representative of the soil conditions in this location. The average between the two strength models was used to evaluate the stabilization design.

Our analysis indicated that slope stabilization was required to achieve the required slope stability factors of safety specified in the BC MOTT Supplement to CHBDC S6-19 (see Figures 3 to 6). As the existing slope has performed adequately, we have not evaluated slope stabilization measures away from the spillway location. We expect the proposed stabilization design for the spillway will improve the stability of the adjacent slopes when compared to existing conditions.

4.2.2 Anchor Recommendations

The recommended slope stabilization design includes a row of anchors installed through the lower spillway footing. The anchors were designed to stabilize potential slip surfaces extending from the highway roadway to below the spillway. Our recommended anchor design comprises:

- 16 m long DYWIDAG #18 bar double corrosion protected anchors
- A 12 m long bond zone with a 4 m long free-length zone
- A minimum bond diameter of 150 mm
- Horizontal anchor spacing of 1.5 m
- Anchor inclination of 20 degrees below horizontal
- A 600 kN lock-off load

Our design assumes that the anchors will likely be bonded partially in soil and partially in rock. Field adjustments could be required during construction based on the actual conditions encountered. If rock is encountered within 5 m during drilling for the anchors, the bond zone can likely be reduced to 7 m. We recommend that the anchors be installed with a bond breaker along the free length to facilitate testing. The drill holes should be cased with centralizers installed on the anchor at 3 m spacing with the first centralizer to be placed 0.5 m from the end of the bonded zone.

The anchor facing must be detailed to withstand the recommended lock-off load and the recommended testing loads (up to 1.33WL). We understand that the anchors will be located below the spillway. The anchor heads should not be left exposed to the spillway outflow. Consideration should be given to encasing the anchor heads in concrete after they have been tested, post-tensioned, and approved by Thurber.

Our drilling logs note the presence of cobbles and boulders encountered in the highway embankment during our investigation. We expect boulders and the large void spaces associated with them will be encountered during drilling of the anchors.

We used an unfactored bond resistance of 215 kPa in our anchor design. Each anchor must be tested by the contractor in general accordance with the Post Tensioning Institute (PTI) recommendations in the presence of Thurber. At least two anchors must be performance tested. The testing shall be performed by incrementally loading the anchors in accordance with the schedules provided in Table 4-3. A suitable calibrated hydraulic cylinder, pump and pressure gauge of sufficient capacity to test the anchors is required. In addition, a gauge to record movement of the anchor to the nearest 0.025 mm with respect to an independent fixed reference point must be used. At each increment, the movement of the tendon shall be recorded. The jack load shall be monitored with a pressure gauge or load cell. Both performance and proof tests shall be subject to a creep test. When the anchor is subject to the maximum load, this load shall be held constant for 10 minutes and the anchor movement shall be recorded at 1, 2, 3, 4, 5, 6, and 10 minutes. If the movement between the 1 minute and 10 minute reading is 1 mm or more, the load shall be maintained for an additional 50 minutes and the movement recorded at 15, 20, 30, 40, 50 and 60 minutes. During the creep test, the anchor load shall not deviate from the test load by more than 10%.

Table 4-3: Anchor testing requirements

Proof Testing	Performance Testing
AL[1]	AL, 0.25WL
0.25WL[2]	AL, 0.25WL, 0.50WL
0.50WL	AL, 0.25WL, 0.50WL, 0.75WL
0.75WL	AL, 0.25WL, 0.50WL, 0.75WL, 1.00WL
1.00WL	AL, 0.25WL, 0.50WL, 0.75WL, 1.00WL, 1.20WL
1.20WL	AL, 0.25WL, 0.50WL, 0.75WL, 1.00WL, 1.20WL, 1.33WL (hold for creep test)
1.33WL (hold for creep test)	AL
1.00WL (lock-off)	1.00WL (lock-off)

[1] Alignment Load
[2] Working Load

4.3 Excavations and Temporary Slopes

Excavations must be in accordance with Worksafe BC requirements. Temporary excavations are the responsibility of the contractor. We would consider a mixed open-cut and trench box excavation to be reasonable for construction of the culvert through the roadway. If a trench box is used, it must be appropriate for the proposed depth and dimensions. Ramps may need to be constructed for access to the install the spillway and anchors. We expect that unstabilized temporary slopes of up to 1H:1V may be achievable for slope heights of less than 3 m depending on the season construction is completed. Steeper slopes may require stabilization measures such as shotcrete and soil nails.

4.4 Subgrade Preparation

We expect the headwalls, culvert, and spillway will be founded on granular fill. The subgrade should be prepared such that the surface is as dry as possible, smooth, and free of organics and other soft, wet, or deleterious materials. If the subgrade comprises granular soil, it should be compacted using a vibratory compactor to at least 95% standard Proctor maximum dry density (SPMDD). The prepared subgrade should be reviewed by Thurber to determine if the subgrade conditions conform to those anticipated.

4.5 Backfill

Culvert and headwall fill should comprise bridge end fill (as per the MOTTI Standard Specifications). Fill should be placed in maximum 150 mm thick lifts and compacted to 100% Standard Proctor Maximum Dry Density (SPMDD).

Bedding material should be placed below the culvert and comprise a minimum of 50 mm thick 25 mm minus well graded base course material and compacted to 95% SPMDD.

4.6 Bearing Resistance

The bearing elements of the headwall and spillway can be designed using a bearing resistance of 200 kPa for SLS and 300 kPa for ULS conditions. This assumes that our recommendations for slope stability and subgrade preparation of have been followed. This incorporates a geotechnical resistance factor of 0.5. The bearing surface should have a minimum embedment depth of 0.6 m for frost protection. An interface friction factor of 0.5 can be used between soil and concrete for sliding.

4.7 Earth Pressures

The headwall will have to be designed to resist the lateral pressure of the soil. Provided bridge end fill is used, the wall will not have to be designed to resist hydrostatic pressures. We recommend the earth pressures described below be used for design. Earth pressure diagrams showing our recommendations are provided in Figure 7.

- Static earth pressure against the headwall should be taken as the greater of:
    - a uniform pressure of 20 kPa
    - a triangular pressure distribution where the lateral pressure is equal to 7 times the depth in metres (assumes 2H:1V back slope above the headwall)
- Seismic earth pressure against the headwall should be taken as the sum of:
    - static component - a triangular pressure distribution where the lateral pressure is equal to 6 times the depth in metres
    - seismic component - an inverted triangular distribution where the lateral pressure is equal to 8 times the height measured from the base of the wall in metres for a 1:2,475-year seismic event.

- Static earth pressure against the upslope face of the lower footing and against the spillway side walls should be taken as:
    - a triangular pressure distribution where the lateral pressure is equal to 7 times the footing or wall depth in metres.
- Seismic earth pressure against the upslope face of the lower footing and against the spillway side walls should be taken as:
    - static component – a triangular pressure distribution where the lateral pressure is equal to 6 times the footing or wall depth in metres
    - seismic component – an inverted triangular distribution where the lateral pressure is equal to 8 times the height measured from the base of the footing or wall in metres for a 1:2,475-year seismic event.
- Passive earth pressures should not be relied on for the upslope or downslope footings. The lateral forces should be resolved through the pre-tensioned anchors at the lower footing. The spillway structure must be sufficiently stiff to transfer the lateral loading to the lower footing.

4.8 Sulphate Exposure

Surficial samples of native colluvium were taken from the project site and submitted for suplhate ion testing. The results show that the samples had very low levels of sulphate. We recommend that the culvert be designed considering a ‘low’ sulphate exposure class per MOTT’s implementation of CSA 23.A Table 3.

4.9 Climate Change Resilience

The geotechnical discipline design criteria sheet for climate change resilience per Technical Circular T-04/19 is included in Appendix D.

We anticipate that the most significant effect of climate change as it relates to the geotechnical design of the culvert replacements at Cooper’s Corner Pullout and Slide locations is increases in intense precipitation events. These increases will likely produce greater peak culvert flows and increase surficial erosion of loose soils both upstream and downstream of the culvert.

We do not anticipate that climate change will have a significant effect on the geotechnical performance of the proposed slope stability measures and culvert replacements, provided that erosion downslope of the spillways is monitored. Additionally, we do not anticipate that climate change will meaningfully affect the ground water table regime for these highway sites.

5. CLOSURE

We trust this information meets your present needs. If you have any questions, please contact the undersigned at your convenience.

Yours truly,
Thurber Engineering Ltd.
Paul Evans, P.Eng.
Review Principal

PROFESSIONAL
PROVINCE OF
A. T. M. SILVESTER
55384
BRITISH COLUMBIA
ENGINEER

Thurber Engineering Ltd.
Permit to Practice #1001319

Adam Silvester, P.Eng.
Geotechnical Engineer

2025-01-31

Attachments

- Statement of Limitations and Conditions
- Dwg. 34041-2 Test Hole Location Plan
- Test Hole Logs
- Slope Stability Assessment Output (Figures 1-6)
- Earth Pressure Diagrams (Figure 7)
- Climate Change Resilience Sheet

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client, the BC Ministry of Transportation and Infrastructure (MoTI) and Authorized Users as defined in the MoTI Special Conditions Form H0461d. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Any use which an unauthorized third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any unauthorized third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

Plotted: October 30, 2024

LEGEND:

⌖ TEST HOLE

NOTES:

1. BASE TAKEN FROM CAD FILE "SURVBASE_COG.DWG." PROVIDED BY THE MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE ON SEPTEMBER 15, 2022.
2. TEST HOLES WERE SURVEYED USING HANDHELD GPS. TEST HOLE LOCATIONS ARE APPROXIMATE .

THURBER ENGINEERING LTD.

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

TEST HOLE LOCATION PLAN

HIGHWAY 1
LOWER FRASER CANYON FLOOD REPAIRS
BOSTON BAR, BC

DESIGNED	DRAWN	APPROVED	DATE	SCALE	PROJECT No.	DWG. NO.	REV.
JAW	MOM	ATMS	MAY 01, 2024	1:300	34041 -	**2**	0

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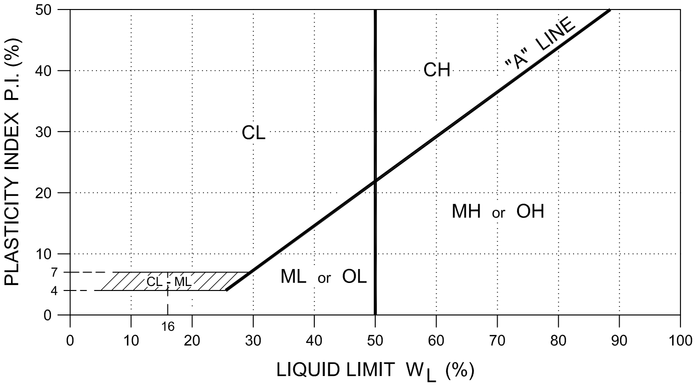
THURBER

UNIFIED CLASSIFICATION SYSTEM FOR SOILS (ASTM D2487)

MAJOR DIVISION			SYMBOLS		TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA
			GROUP	GRAPH		
COARSE-GRAINED SOILS (MORE THAN 50% BY WEIGHT RETAINED ON No. 200 SIEVE)	GRAVELS MORE THAN 50% COARSE FRACTION RETAINED ON No. 4 SIEVE	CLEAN GRAVELS (< 5% FINES)	**GW**		WELL GRADED GRAVEL and WELL GRADED GRAVEL with SAND.	$C_U = \frac{D_{60}}{D_{10}} \geq 4$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$
			GP		POORLY GRADED GRAVEL and POORLY GRADED GRAVEL with SAND.	NOT MEETING ABOVE REQUIREMENTS
		GRAVELS WITH FINES (> 12% FINES)	**GM**		SILTY GRAVEL, GRAVEL - SAND - SILT MIXTURES.	FINES CLASSIFY AS ML or MH (3)
			GC		CLAYEY GRAVEL, GRAVEL - SAND - CLAY MIXTURES.	FINES CLASSIFY AS CL or CH (3)
	SANDS MORE THAN 50% COARSE FRACTION PASSES No. 4 SIEVE	CLEAN SANDS (< 5% FINES)	**SW**		WELL GRADED SAND and WELL GRADED SAND with GRAVEL	$C_U = \frac{D_{60}}{D_{10}} \geq 6$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$
			SP		POORLY GRADED SAND and POORLY GRADED SAND with GRAVEL.	NOT MEETING ABOVE REQUIREMENTS
		SANDS WITH FINES (> 12% FINES)	**SM**		SILTY SAND, SAND - SILT MIXTURES.	FINES CLASSIFY AS ML or MH (3)
			SC		CLAYEY SAND, SAND - CLAY MIXTURES.	FINES CLASSIFY AS CL or CH (3)
FINE-GRAINED SOILS (MORE THAN 50% BY WEIGHT PASSES No. 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	W_L < 50%	**ML**		INORGANIC SILTS, SILTS with SAND and SILTS with GRAVEL and SANDY or GRAVELLY SILTS.	P.I. < 4 or PLOTS BELOW THE "A" LINE
		W_L > 50%	**MH**		INORGANIC SILTS, SILTS with SAND & SILTS with GRAVEL & SANDY or GRAVELLY SILTS, FINE SANDY or SILTY SOILS.	P.I. PLOTS BELOW THE "A" LINE
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	W_L < 50%	**CL**		INORGANIC CLAYS of LOW PLASTICITY, GRAVELLY, SANDY, or SILTY CLAYS, LEAN CLAYS.	P.I. > 7 and PLOTS ON OR ABOVE THE "A" LINE
		W_L near 50%	**CL-CH**		BORDERLINE INORGANIC CLAYS and SILTY CLAYS with LIQUID LIMITS NEAR 50%.	(only used for visual identification)
		W_L > 50%	**CH**		INORGANIC CLAYS of HIGH PLASTICITY, FAT CLAYS.	P.I. PLOTS ON OR ABOVE THE "A" LINE
	ORGANIC SILTS and CLAYS	W_L < 50%	**OL**		ORGANIC SILTS and ORGANIC SILTY CLAYS of LOW PLASTICITY.	$\frac{W_L \text{ (oven dried)}}{W_L \text{ (not dried)}} < 0.75$
		W_L > 50%	**OH**		ORGANIC CLAYS OF HIGH PLASTICITY.	$\frac{W_L \text{ (oven dried)}}{W_L \text{ (not dried)}} < 0.75$
HIGHLY ORGANIC SOILS			**PT**		PEAT and other HIGHLY ORGANIC SOILS.	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE.

PLASTICITY CHART FOR SOILS PASSING No. 40 SIEVE



NOTES:

1. ALL SIEVE SIZES ARE U.S. STANDARD, A.S.T.M. E11-04.
2. COARSE GRAINED SOILS WITH 5 TO 12% FINES REQUIRE DUAL SYMBOLS (GW-GM, GW-GC, GP-GM, GP-GC, SW-SM, SW-SC, SP-SM, SP-SC).
3. IF FINES CLASSIFY CL-ML USE DUAL SYMBOL (GC-GM or SC-SM).
4. WHERE TESTING IS NOT CARRIED OUT, THE IDENTIFICATIONS ARE DETERMINED BY VISUAL-MANUAL PROCEDURES DESCRIBED IN ASTM D2488-06.

Client: TEL Standard Detail
File No.: n/a
E-File: UCSFS-20140807.dwg

Revised: August 07, 2014

British Columbia | Ministry of Transportation and Infrastructure

SUMMARY LOG

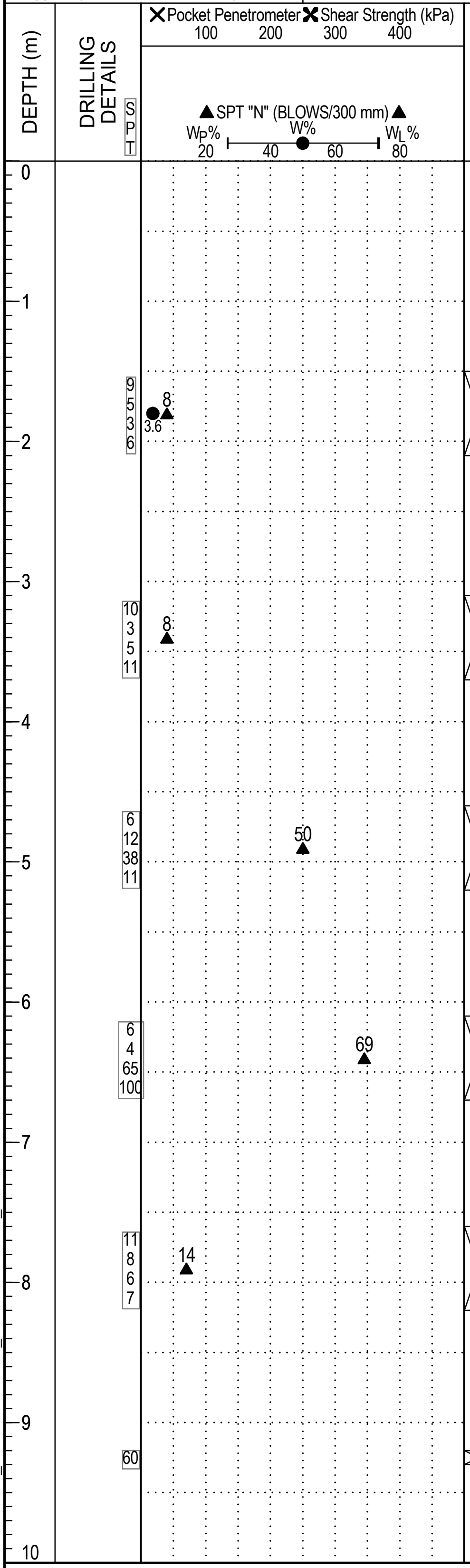
Drill Hole #: TH24-01

Project: **Highway 1 Lower Fraser Canyon Flood Repairs**
Location: Boston Bar

Date(s) Drilled: April 23, 2024
Company: On Track Drilling Inc.
Driller: Brady Yeo
Drill Make/Model: MPP Geopower Track Rig
Drilling Method: ODEX

Prepared by: 34041
Thurber Engineering Ltd.
Logged by: JAW Reviewed by: ATMS

Datum: UTM NAD 83 ZONE 10U
Northing/Easting: 5513038 , 613808
Elevation: 282.50 m
Alignment:
Station/Offset:
Coordinates taken with GPS



SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	CLASSIFICATION
S	SPT1	25	GW-GM
S	SPT2	25	GP-GM
S	SPT3	29	GP-GM
S	SPT4	8	
S	SPT5	17	GP
S	SPT6	4	

SOIL DESCRIPTION

ASPHALT (100 mm thick). 0.1m

GP/SP - GRAVEL and SAND to sandy GRAVEL, trace to some silt; coarse to medium sand, angular, 40 mm max. size gravel, grey-brown, damp, loose to very dense.

- occasional cobbles between 7.6 and 9.2 m depth

- occasional boulders below 9.2 m depth

COMMENTS TESTING
Drillers Estimate
{G % S % F %}

ELEVATION (m): 282, 281, 280, 279, 278, 277, 276, 275, 274, 273

Legend Sample Type: A-Auger, B-Becker, C-Core, G-Grab, V-Vane, L#-Lab Sample, S-Split Spoon, O-Odex (air rotary), W-Wash (mud return), T-Shelby Tube

Legend Installation: Sand, Grout, Cement, ■ Bentonite, Drill Cuttings, Slotted, Slough, Piezometer

Final Depth of Hole: 18.3 m
Depth to Top of Rock:

Ministry of Transportation and Infrastructure
BRITISH COLUMBIA

SUMMARY LOG

Drill Hole #: **TH24-01**

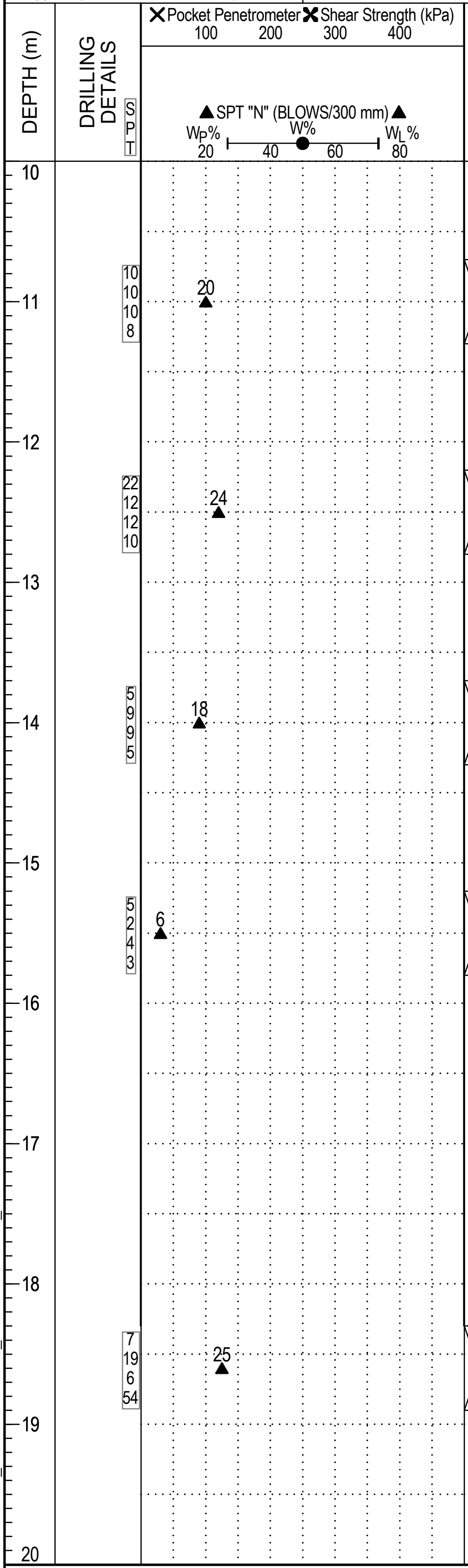
Project: **Highway 1 Lower Fraser Canyon Flood Repairs**
Location: Boston Bar

Prepared by: 34041
Thurber Engineering Ltd.

Logged by: JAW Reviewed by: ATMS

Datum: UTM NAD 83 ZONE 10U
Northing/Easting: 5513038 , 613808
Elevation: 282.50 m
Alignment:
Station/Offset:
Coordinates taken with GPS

Date(s) Drilled: April 23, 2024
Company: On Track Drilling Inc.
Driller: Brady Yeo
Drill Make/Model: MPP Geopower Track Rig
Drilling Method: ODEX



DRILLING DETAILS SPT	SPT "N"	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	CLASSIFICATION
10 10 10 8	20	☒	SPT7	42	GW-GM
22 12 12 10	24	☒	SPT8	42	GW-GM
5 9 9 5	18	☒	SPT9	33	GW-GM
5 2 4 3	6	☒	SPT10	0	
7 19 6 54	25	☒	SPT11	0	

SOIL SYMBOL

SOIL DESCRIPTION

GP/SP - GRAVEL and SAND to sandy GRAVEL, trace to some silt; coarse to medium sand, angular, 40 mm max. size gravel, grey-brown, damp, loose to very dense. *(continued)*

- low ODEX resistance, minimal return below 13.7 m depth

18.3m

End of hole at 18.3 m depth.
No water observed.

COMMENTS TESTING

Drillers Estimate
{G % S % F %}

SPT sampler bent on boulder or bedrock.

ELEVATION (m)
272
271
270
269
268
267
266
265
264
263

Legend Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Legend Installation:
Sand
Grout
Cement
Bentonite
Drill Cuttings
Slotted
Slough
Piezometer

Final Depth of Hole: 18.3 m
Depth to Top of Rock:

Ministry of Transportation and Infrastructure
BRITISH COLUMBIA

SUMMARY LOG

Drill Hole #: **TH24-02**

Project: **Highway 1 Lower Fraser Canyon Flood Repairs**
Location: Boston Bar

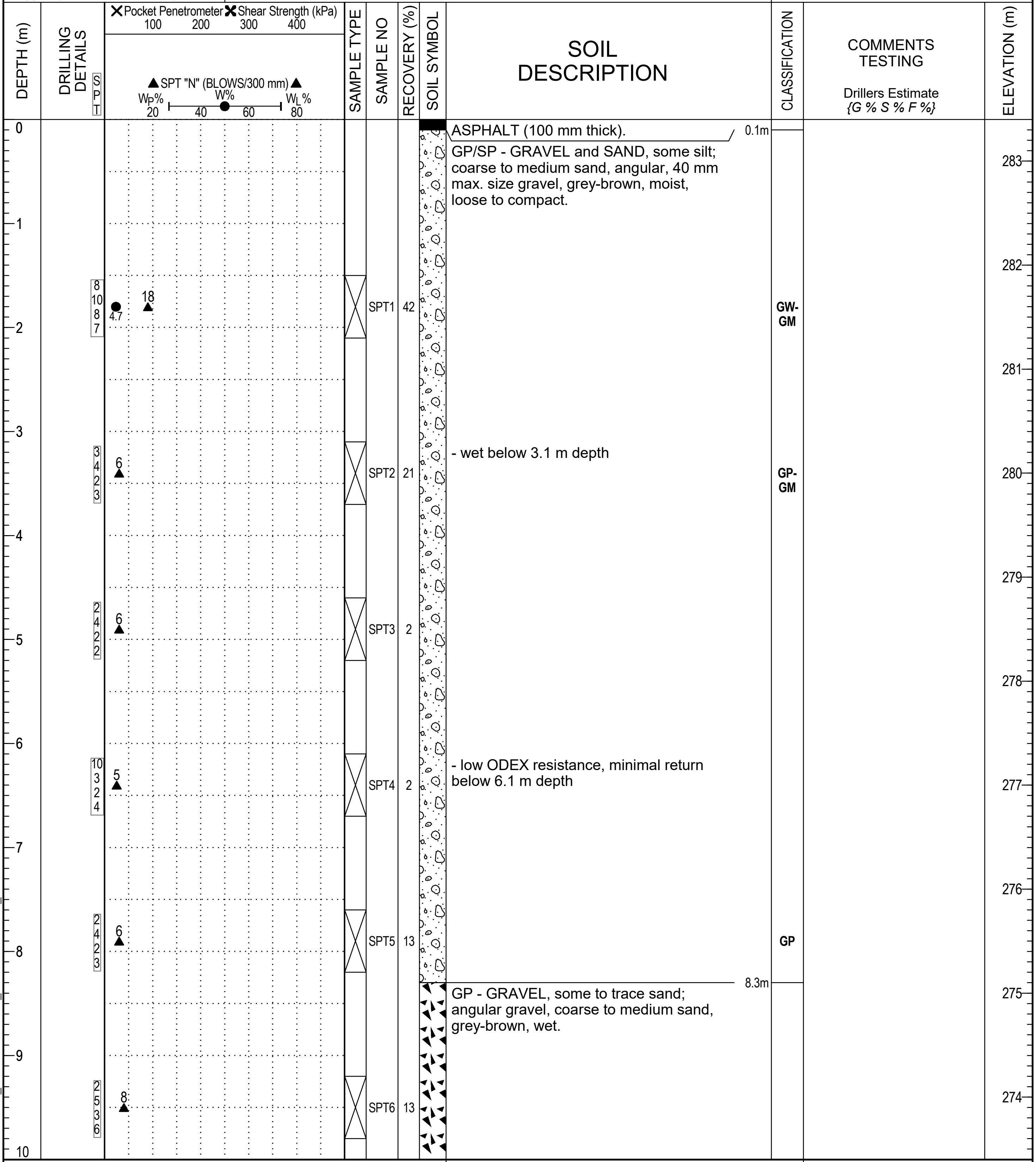
Prepared by: 34041
Thurber Engineering Ltd.

Logged by: JAW Reviewed by: ATMS

Datum: UTM NAD 83 ZONE 10U
Northing/Easting: 5512991 , 613803
Elevation: 283.40 m

Alignment:
Station/Offset:
Coordinates taken with GPS

Date(s) Drilled: April 24, 2024
Company: On Track Drilling Inc.
Driller: Brady Yeo
Drill Make/Model: MPP Geopower Track Rig
Drilling Method: ODEX



Sample No	SPT	SPT "N"	W%	Recovery (%)
SPT1	8 10 8 7	18	4.7	42
SPT2	3 4 2 3	6		21
SPT3	2 4 2 2	6		2
SPT4	10 3 2 4	5		2
SPT5	2 4 2 3	6		13
SPT6	2 5 3 6	8		13

Soil Description	Depth	Classification
ASPHALT (100 mm thick).	0.1m	
GP/SP - GRAVEL and SAND, some silt; coarse to medium sand, angular, 40 mm max. size gravel, grey-brown, moist, loose to compact. - wet below 3.1 m depth - low ODEX resistance, minimal return below 6.1 m depth	8.3m	GW-GM GP-GM GP
GP - GRAVEL, some to trace sand; angular gravel, coarse to medium sand, grey-brown, wet.		

Legend Sample Type: A-Auger B-Becker C-Core G-Grab V-Vane L#-Lab Sample S-Split Spoon O-Odex (air rotary) W-Wash (mud return) T-Shelby Tube

Legend Installation: Sand Grout Cement Bentonite Drill Cuttings Slotted Slough Piezometer

Final Depth of Hole: 16.2 m
Depth to Top of Rock: 10.4 m

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SUMMARY LOG

Drill Hole #: **TH24-02**

Project: **Highway 1 Lower Fraser Canyon Flood Repairs**
Location: Boston Bar

Prepared by: 34041
Thurber Engineering Ltd.
Logged by: JAW Reviewed by: ATMS

Datum: UTM NAD 83 ZONE 10U
Northing/Easting: 5512991 , 613803
Elevation: 283.40 m
Alignment:
Station/Offset:
Coordinates taken with GPS

Date(s) Drilled: April 24, 2024
Company: On Track Drilling Inc.
Driller: Brady Yeo
Drill Make/Model: MPP Geopower Track Rig
Drilling Method: ODEX

DEPTH (m)	DRILLING DETAILS	SPT	✕ Pocket Penetrometer ✖ Shear Strength (kPa) 100 200 300 400 ▲ SPT "N" (BLOWS/300 mm) ▲ W$_P$% W% W$_L$% 20 40 60 80	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*	ELEVATION (m)
10.4m								BEDROCK (Possible GRANODIORITE).			
16.2m								End of hole at 16.2 m depth. No water observed.			

Depth scale (m): 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20
Elevation scale (m): 273, 272, 271, 270, 269, 268, 267, 266, 265, 264

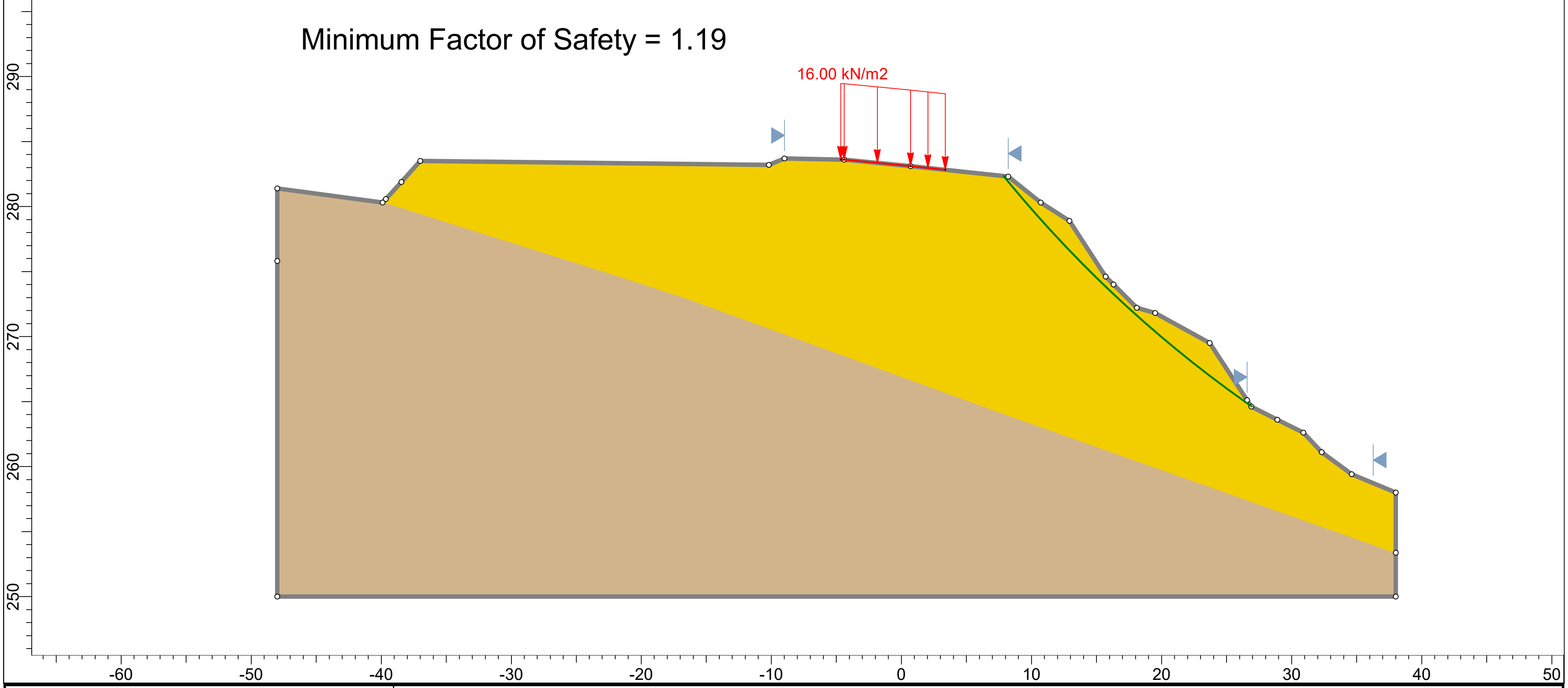
Legend
Sample Type:
- A-Auger
- B-Becker
- C-Core
- G-Grab
- V-Vane
- L#-Lab Sample
- S-Split Spoon
- O-Odex (air rotary)
- W-Wash (mud return)
- T-Shelby Tube

Legend
Installation:
- Sand
- Grout
- Cement
- Bentonite
- Drill Cuttings
- Slotted
- Slough
- Piezometer

Final Depth of Hole: 16.2 m
Depth to Top of Rock: 10.4 m

FIGURE 1

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	UCS (intact) (kPa)	Parameters vary with depth	GSI	mi	D	Water Surface	Ru Value
Overburden (sand & gravel) - MC	🟨	20	Mohr-Coulomb	1	45						None	0
Bedrock	🟫	30	Generalized Hoek-Brown			175000	No	50	32	0.7	None	0


Minimum Factor of Safety = 1.19

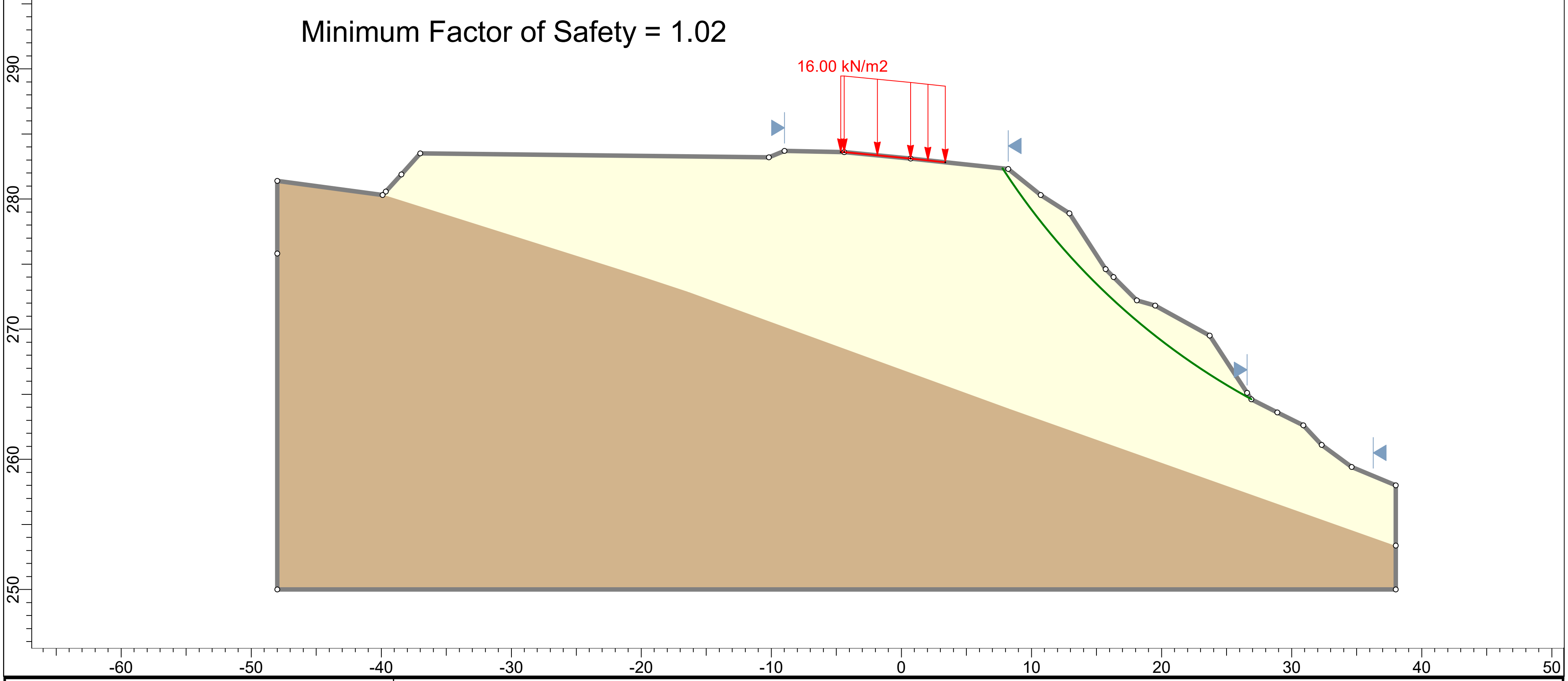
THURBER

Cooper's Corner Pullout Culvert

Client	BC MoTI	*Title*	Culvert Location - Existing Geometry
Project Number	34041		
Date	10/30/2024	*Scale*	1:450

FIGURE 2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Shear/Normal Function	UCS (intact) (kPa)	Parameters vary with depth	GSI	mi	D	Water Surface	Ru Value
Overburden (sand & gravel) - non-linear	🟨	20	Shear/Normal Function	Non Linear Strength Envelope						None	0
Bedrock	🟫	30	Generalized Hoek-Brown		175000	No	50	32	0.7	None	0



THURBER

Cooper's Corner Pullout Culvert

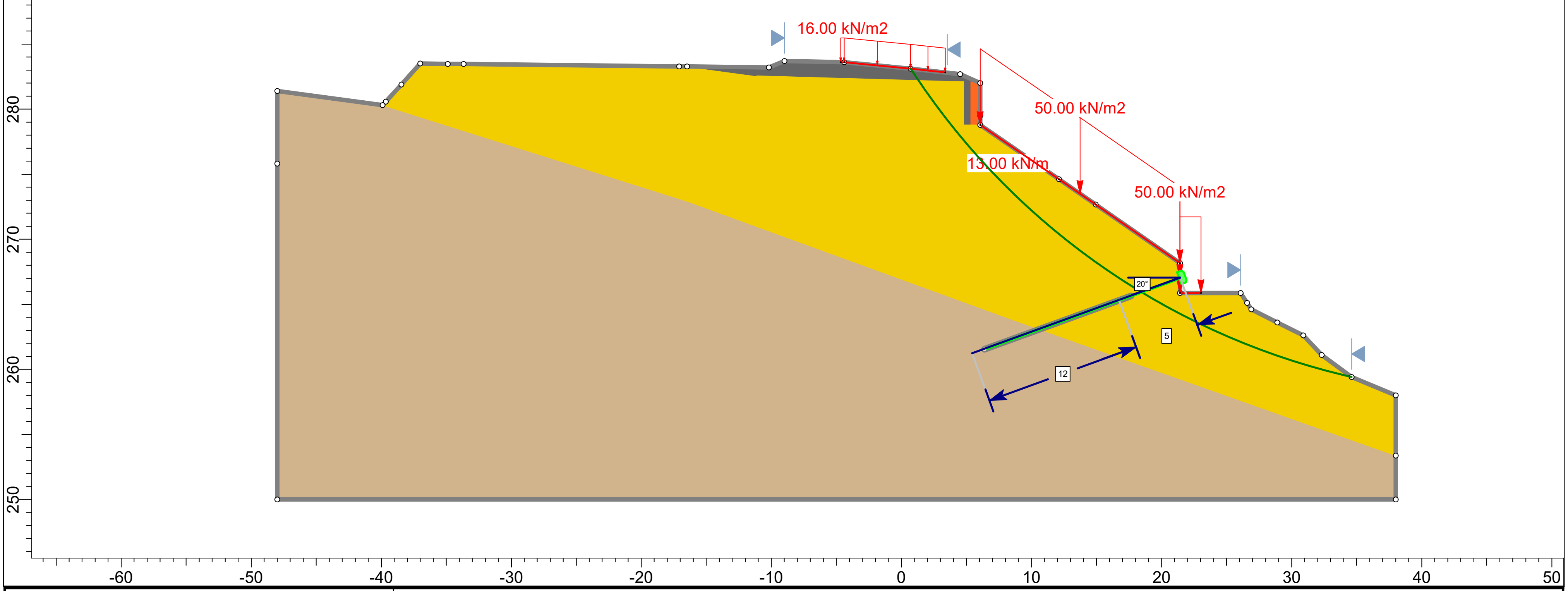
Client	BC MoTI	*Title*	Culvert Location - Existing Geometry
Project Number	34041		
Date	10/30/2024	*Scale*	1:450

FIGURE 3

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	UCS (intact) (kPa)	Parameters vary with depth	GSI	mi	D	Water Surface	Ru Value
Overburden (sand & gravel) - MC	🟨	20	Mohr-Coulomb	1	45						None	0
Bedrock	🟫	30	Generalized Hoek-Brown			175000	No	50	32	0.7	None	0
Concrete	🟧	24	Mohr-Coulomb	5000	0						None	0
Granular Fill	⬛	25	Mohr-Coulomb	0	38						None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Shear Capacity (kN)	Compression Capacity (kN)	Bond Length (m)	Bond Strength (kN/m)	Material Dependent	Force Orientation
DYWIDAG #18 Bar	🟩	Grouted Tieback	Active (Method A)	1.5	850	600	0	0	12	60	No	Parallel to Reinforcement

Minimum Factor of Safety = 1.89



THURBER

Cooper's Corner Pullout Culvert

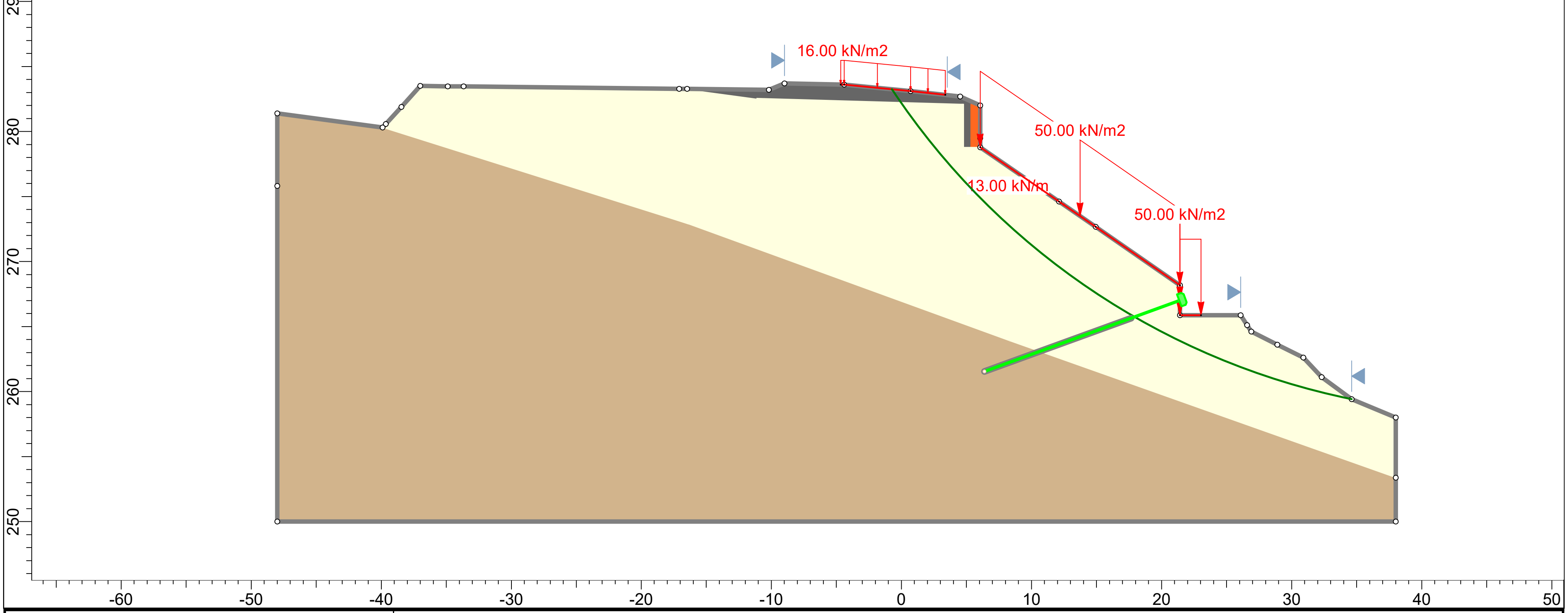
Client	BC MoTI	*Title*	Culvert Location - Post-Construction Geometry with Stabilization
Project Number	34041		
Date	10/30/2024	*Scale*	1:450

FIGURE 4

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	UCS (intact) (kPa)	Parameters vary with depth	GSI	mi	D	Water Surface	Ru Value
Overburden (sand & gravel) - MC	🟨	20	Mohr-Coulomb	1	45						None	0
Bedrock	🟫	30	Generalized Hoek-Brown			175000	No	50	32	0.7	None	0
Concrete	🟧	24	Mohr-Coulomb	5000	0						None	0
Granular Fill	⬛	25	Mohr-Coulomb	0	38						None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Shear Capacity (kN)	Compression Capacity (kN)	Bond Length (m)	Bond Strength (kN/m)	Material Dependent	Force Orientation
DYWIDAG #18 Bar	🟩	Grouted Tieback	Active (Method A)	1.5	850	600	0	0	12	60	No	Parallel to Reinforcement

Minimum Factor of Safety = 1.42



THURBER

Cooper's Corner Pullout Culvert

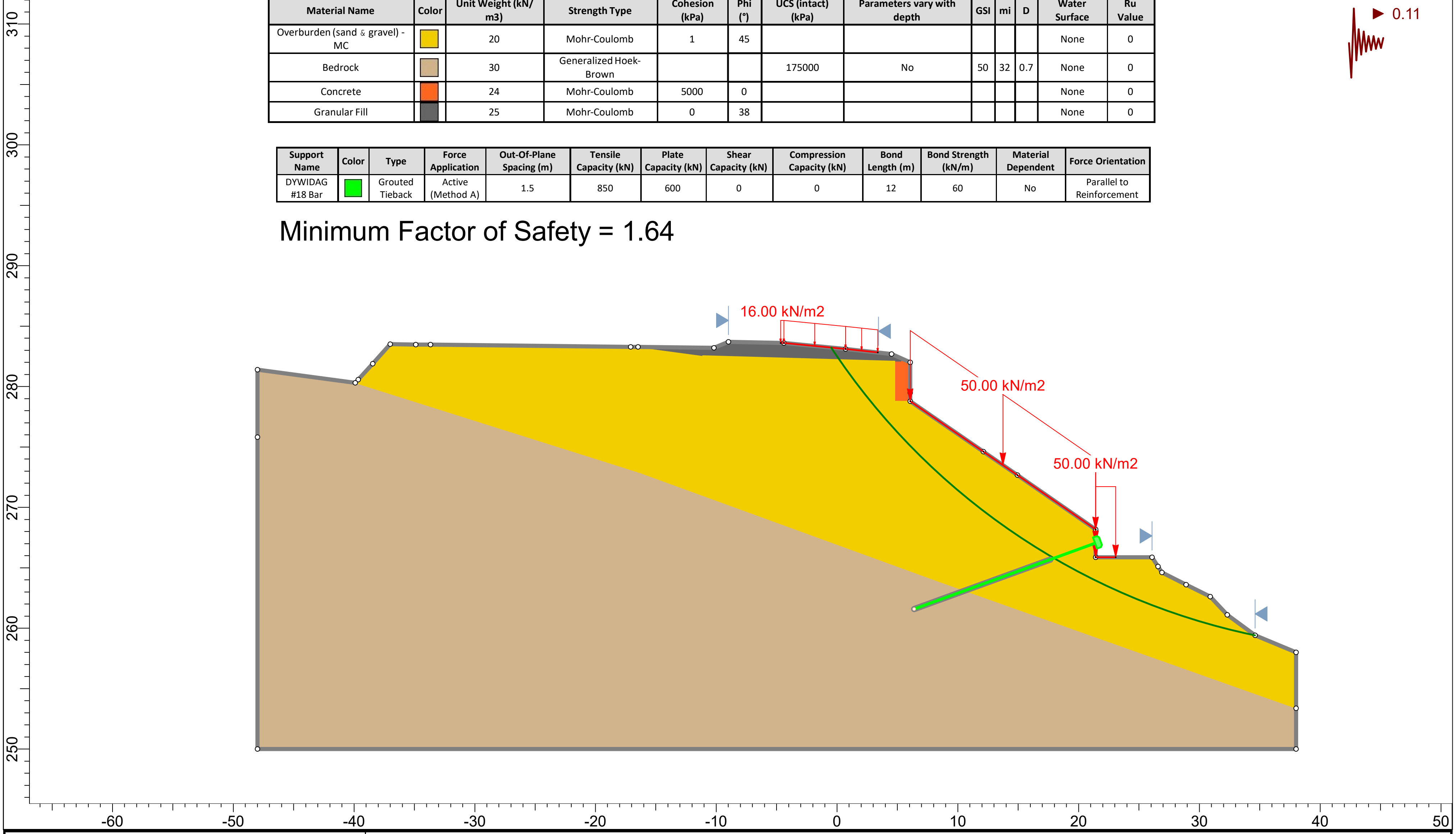
Client	BC MoTI	*Title*	Culvert Location - Post-Construction Geometry with Stabilization
Project Number	34041		
Date	10/30/2024	*Scale*	1:450

FIGURE 5

Material Name	Color	Unit Weight (kN/ m3)	Strength Type	Cohesion (kPa)	Phi (°)	UCS (intact) (kPa)	Parameters vary with depth	GSI	mi	D	Water Surface	Ru Value
Overburden (sand & gravel) - MC	🟨	20	Mohr-Coulomb	1	45						None	0
Bedrock	🟫	30	Generalized Hoek-Brown			175000	No	50	32	0.7	None	0
Concrete	🟧	24	Mohr-Coulomb	5000	0						None	0
Granular Fill	⬛	25	Mohr-Coulomb	0	38						None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Shear Capacity (kN)	Compression Capacity (kN)	Bond Length (m)	Bond Strength (kN/m)	Material Dependent	Force Orientation
DYWIDAG #18 Bar	🟩	Grouted Tieback	Active (Method A)	1.5	850	600	0	0	12	60	No	Parallel to Reinforcement

Minimum Factor of Safety = 1.64



THURBER

Cooper's Corner Pullout Culvert

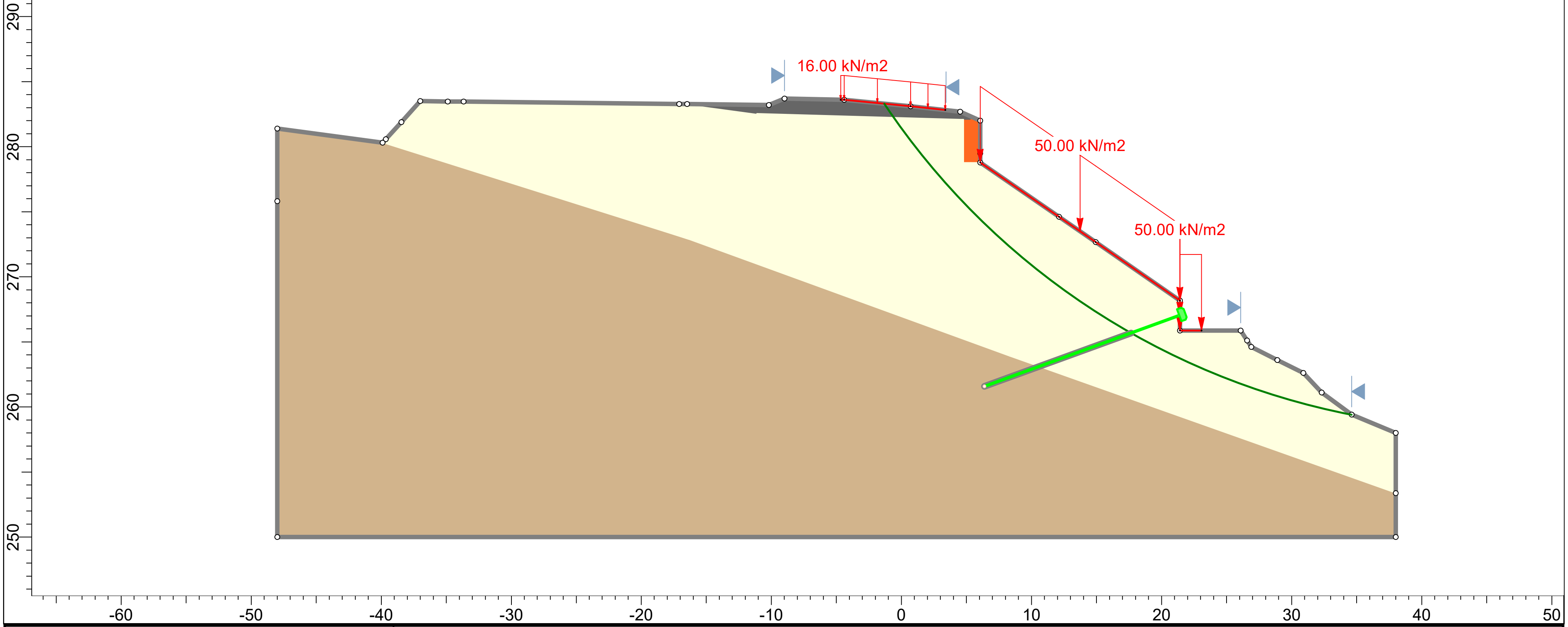
Client	BC MoTI	*Title*	Culvert Location - Post-Construction Geometry with Stabilization
Project Number	34041		
Date	10/30/2024	*Scale*	1:450

FIGURE 6

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	UCS (intact) (kPa)	Parameters vary with depth	GSI	mi	D	Water Surface	Ru Value
Overburden (sand & gravel) - MC	🟨	20	Mohr-Coulomb	1	45						None	0
Bedrock	🟫	30	Generalized Hoek-Brown			175000	No	50	32	0.7	None	0
Concrete	🟧	24	Mohr-Coulomb	5000	0						None	0
Granular Fill	⬛	25	Mohr-Coulomb	0	38						None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Shear Capacity (kN)	Compression Capacity (kN)	Bond Length (m)	Bond Strength (kN/m)	Material Dependent	Force Orientation
DYWIDAG #18 Bar	🟩	Grouted Tieback	Active (Method A)	1.5	850	600	0	0	12	60	No	Parallel to Reinforcement

Minimum Factor of Safety = 1.22



THURBER

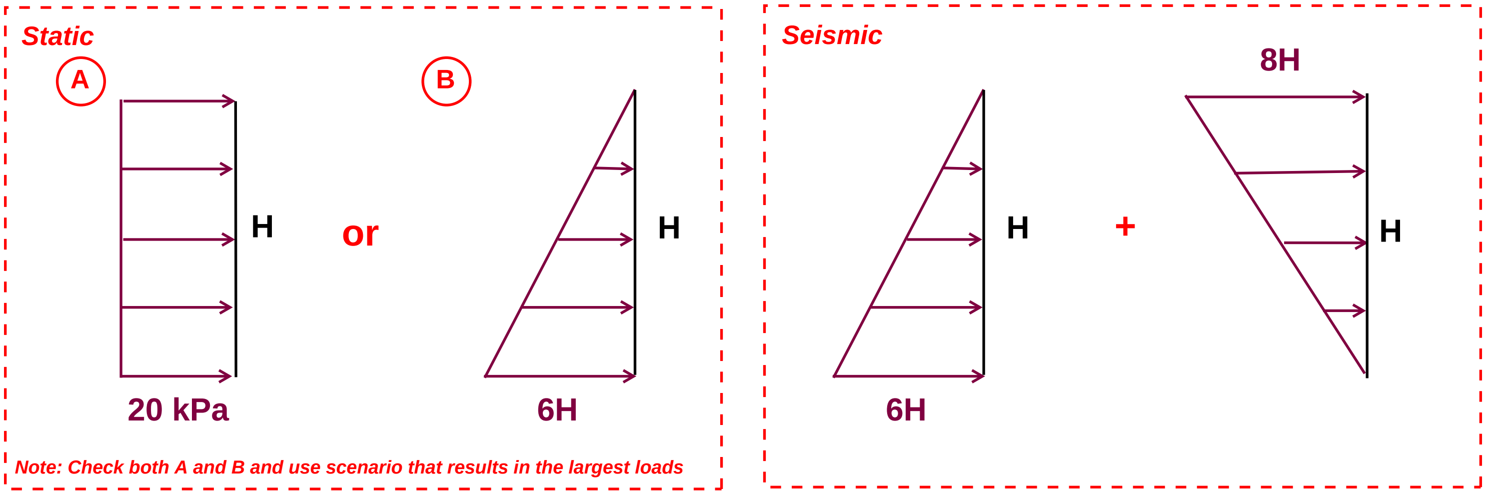
Cooper's Corner Pullout Culvert

Client	BC MoTI	*Title*	Culvert Location - Post-Construction Geometry with Stabilization
Project Number	34041		
Date	10/30/2024	*Scale*	1:450

THURBER

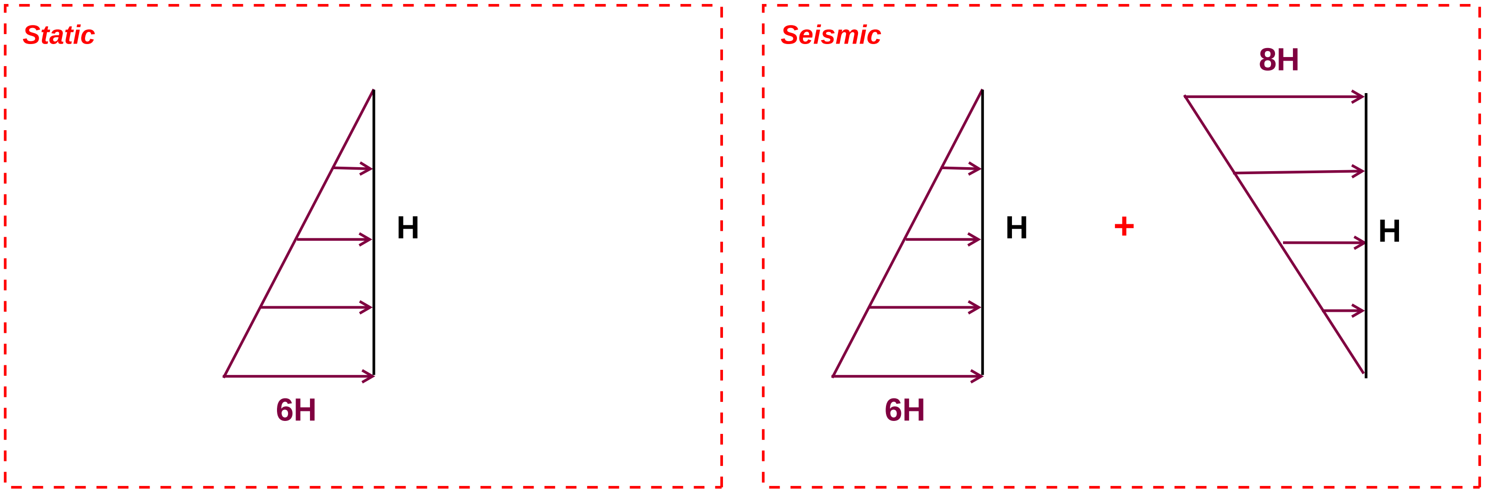
Figure 7 - Earth Pressure Diagram Sketches

Headwalls



Note: Check both A and B and use scenario that results in the largest loads

Footings



Note: Units of height (i.e., H) is in metres and pressure (i.e., 6H) is in kPa

BC MOTT Design Criteria Sheet for Climate Change Resilience (as per Technical Circular T-04/19)

Highway Infrastructure Design Engineering and Climate Change Resilience
Ministry of Transportation and Transit

Project: *Cooper's Corner Pullout and Slide Culvert Replacements [Thurber Project No. 34041]*
Type of work: *Slope Retention Design and Culvert Replacement Design*
Location: *Boston Bar, BC*
Discipline: **Geotechnical**

Design Component	Design Life or Return Period (Years)	Design Criteria + (Units)	Design Value Without Climate Change	Change in Design Value from Future Climate	Design Value Including Climate Change	Comments / Notes / Deviations / Variances
Geotechnical Design	75	N/A	N/A	N/A	N/A	- See Discussion Below

Responses to Screening Questions & Further Explanatory Notes / Discussion:

Based on the Pacific Climate Impacts Consortium Plan2Adapt tool for the Fraser Valley Region, in the next 75 years, climate change is predicted to result in a median increase of 4.6% in annual precipitation and a rise in mean annual temperature of 2.5 degrees Celsius (median prediction). Furthermore, 36 additional frost-free days are anticipated and, in general, climate change is expected to increase the frequency and intensity of severe precipitation events.

We anticipate that the most significant effect of climate change as it relates to the geotechnical design of the culvert replacements at Cooper's Corner Pullout and Slide locations is increases in intense precipitation events. These increases will likely produce greater peak culvert flows and increase surficial erosion of loose soils both upstream and downstream of the culvert.

Hotter temperatures in this region may increase wear and tear on pavement surfaces during the summer months. However, conversely warmer temperatures could reduce frost-related pavement damage.

We do not anticipate that climate change will have a significant impact on the geotechnical performance of the proposed slope stability measures and culvert replacements, provided that erosion downslope of the spillways is monitored. Additionally, we do not anticipate that climate change will meaningfully affect the ground water table regime for these highway sites.

Recommended by: Engineer of Record: Adam Silvester, P.Eng.

Date: January 27, 2025

Engineering Firm: Thurber Engineering Ltd.

Accepted by BC MOTT Consultant Liaison: ____________________
(For External Design)

Deviations and Variances Approved by the Chief Engineer: ____________________
Program Contact: Scott Cosman, P.Eng.