THURBER ENGINEERING LTD.

MEMORANDUM

To:	Associated Engineering / ISL Engineering and Land Services Ltd.	Date:	January 15, 2024
Attn:	Priscilla Tsang, P.Eng.	File:	32079
From	Daniel Cohen, P.Eng.		
Reviewer:	Denny Ma, P.Eng.		

FRASER VALLEY HIGHWAY 1 CORRIDOR IMPROVEMENT PROGRAM
264 STREET TO WHATCOM ROAD
GEOTECHNICAL INPUT FOR WASTE BERM AREA

Dear Priscilla,

This memo has been prepared at the request of Associated Engineering and ISL Engineering and Land Services (ISL) and provides the results of our geotechnical analysis and design recommendations for the proposed waste berm situated at the east end of the Mainline West project as part of the Highway 1 Corridor Improvement Program.

It is a condition of this memorandum that the performance of Thurber's professional services is subject to the attached Statement of Limitations and Conditions.

1. BACKGROUND

The proposed waste berm is shown on the 100% Detailed Design drawings prepared ISL Engineering and Land Services Ltd. dated December 1, 2023. The waste berm is situated south of the highway and is approximately 350 m long (between Sta. 1112+85 and Sta. 1116+35). Figure 1 shows the location and configuration of the waste berm.

Based on the provided sections, the berm was provisionally designed by Associated Engineering and ISL with 2.5H:1V slopes on either side with a minimum setback of 2.8 m from the top of the ditch. The maximum height shown is about 3.8 m. We understand that the berm will comprise of waste material derived from the project, similar to the existing material within the current highway median. Further, the berm will be placed on ground that is approximately level to or slightly above the highway grade. The existing median stockpiles are sloped as steep as approximately 1.5H:1V and are up to approximately 4 m high.

2. GEOTECHNICAL ASSESSMENT

The waste berm was added to the project scope after geotechnical investigation was completed. Thurber has not completed any test holes beneath the proposed waste berm. We have assumed

that the waste berm will be constructed on top of stiff, silty clays based on nearby test hole information. These stiff silty clays are predominately encountered throughout the project site. Further, we have assumed that the waste berm material will comprise silts and clay, as well as organic topsoil and may be saturated. Stability assessment of the waste berm was completed using the commercially available Slide2 by Rocscience, Version 9.028.

Selected material parameters for the native, stiff silty clay are based on the Segment 2 (Mt Lehman) Mainline Draft 100% Detailed Design Report by Thurber, dated December 20, 2023 and are summarized in the outputs. The water table is assumed to be at the toe of the highway ditch and then it raises gradually up to near the ground surface below the waste berm. The waste material was assumed to have a unit weight of 18 kN/m^3 and a friction angle of 25°. This friction angle is low because the waste berm will comprise a mixture of soils, may be potentially wet, and it may be difficult to compact.

Our analyses considered pseudo-static stability based on a 1:475 return period seismic hazard, consistent with the Design Criteria which requires at least 50% of the lanes, but not less than one, to be operational following a 1:475 return period seismic hazard. We expect the Glaciomarine Silt and Clay unit will behave as an undrained material during seismic loading.

Based on the provisional design provided, the maximum height of the waste berm is 3.8 m and the smallest setback from the existing crest of ditch is about 2.8 m. As such, we developed a model based on these parameters with the proposed 2.5H:1V slopes. The model produced results that did not meet the minimum requirements for factor of safety. As such, the model was adjusted by flattening the slopes to a 3H:1V angle, which yielded satisfactory results. The results of the analyses are summarized in Table 2.1 and presented in Figures 2 to 5.

Table 2.1: Waste Berm Slope Stability Analysis of Provisional Design by Others

Figure Number	Analysis Condition	Factor of Safety
2	Static towards Highway 1 (exiting through the ditch)	1.95
3	Pseudo-static towards Highway 1 (1:475) $k_h = 0.13$	1.86
4	Static stability for slip surfaces within the waste berm.	1.45
5	Pseudo-static for shallow slip surface (1:475) $k_h = 0.13$	1.03

3. DISCUSSION AND RECOMMENDATIONS

The results indicate that the adjusted waste berm geometry with a minimum setback of 2.8 m and sloped at 3H:1V will achieve a minimum FS of 1.54 for slip surfaces that daylight through the highway ditch or near the highway in accordance with the required Factor of Safety in accordance with the Ministry Supplement to S6-19. The waste was assumed to have a relatively low strength to account for uncertainty of material type and material condition when placed. The strength applied to the waste material is considered conservative because the existing median waste berms were formed at much steeper slopes.

We recommend that the waste berm is to be sloped no steeper than 3H:1V and does not exceed 4 m high. The waste berm should be setback at least 3 m from the crest of the highway ditch. We anticipate that the waste berm could potentially experience some deformation during a 1:475 return period seismic event. However, it is our opinion that seismic deformation of the berm would likely result in local infilling the ditch adjacent to the berm, and potentially some deposition of material onto the bus on shoulder. The lane and ditch could both easily be cleared to resume operation.

The waste berm may be susceptible to shallow instability and may slough due to inclement weather, particularly before vegetation growth occurs on the berm.

We recommend that the waste berm is constructed and compacted to 92% standard Proctor maximum dry density using compaction equipment suitable for fine grained fills (pad foot, sheepsfoot or similar). The material that is disposed within the waste berm will need to be handled with some care by the contractor. It would not be suitable for the contractor to allow the material to become too wet before disposing of it within the waste berm. It will be critical for waste berm construction for the material to not be too wet of optimum or else placement and compaction will be very challenging.

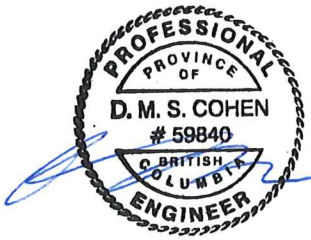
We recommend that the waste berm is constructed with wick drains placed horizontally in layers as follows:

- Drains oriented perpendicular to the highway alignment and sloped down nominally 3% away from the highway,
- Wick drains layers are spaced vertically about 1.2 m,
- Within each layer, individual wick drains should be spaced horizontally about 3 m,
- Successive layers should be staggered nominally 1.5 m so they are offset from adjacent layers.

Erosion and sediment control plans should account for potential seepage from the waste berm. We recommend hydroseeding or similar on the slopes as soon as practical to establish vegetation and minimize risk of shallow sloughing.

Attachments

- Statement of Limitations and Conditions (1 page)
- Figures (5 pages)



01/15/2024

Thurber Engineering Ltd.
Permit to Practice #1001319

THURBER

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

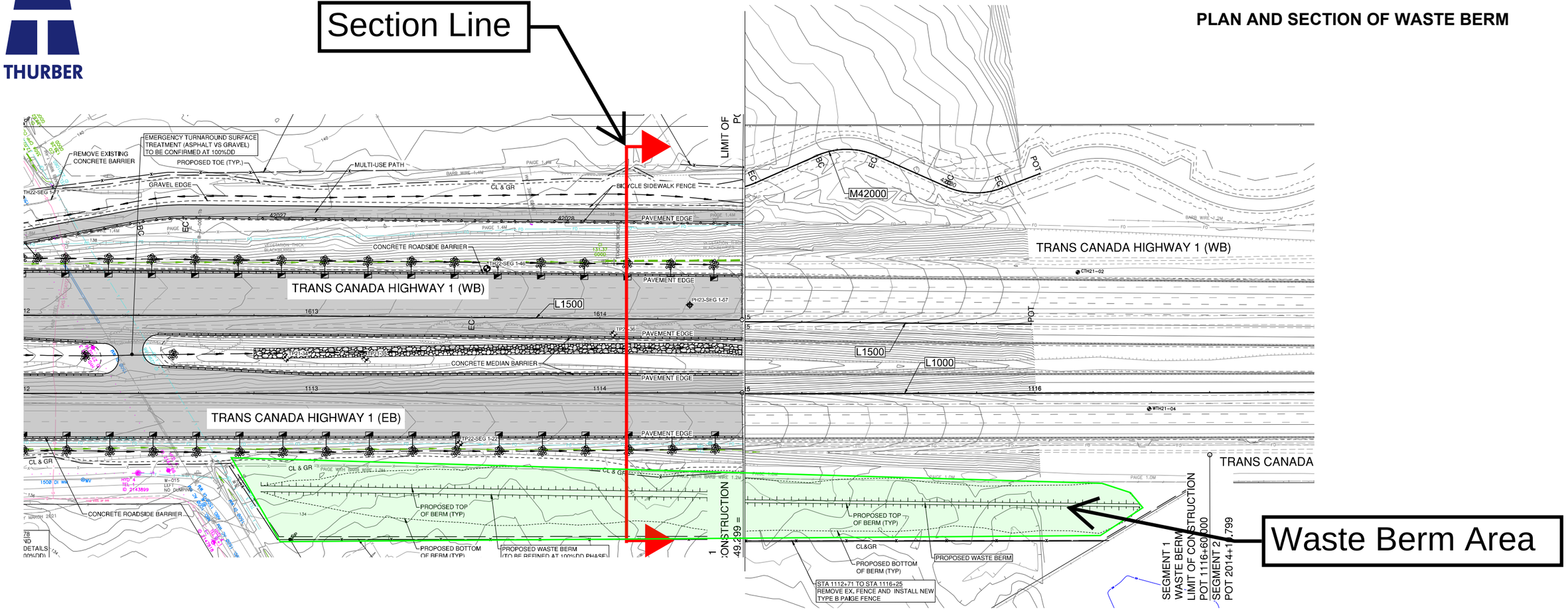
Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, 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.

THURBER

PLAN AND SECTION OF WASTE BERM



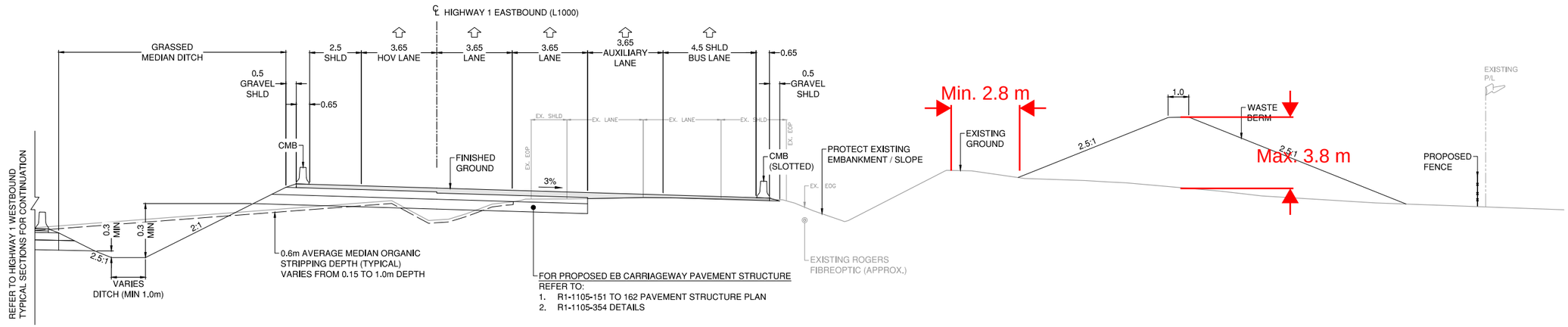
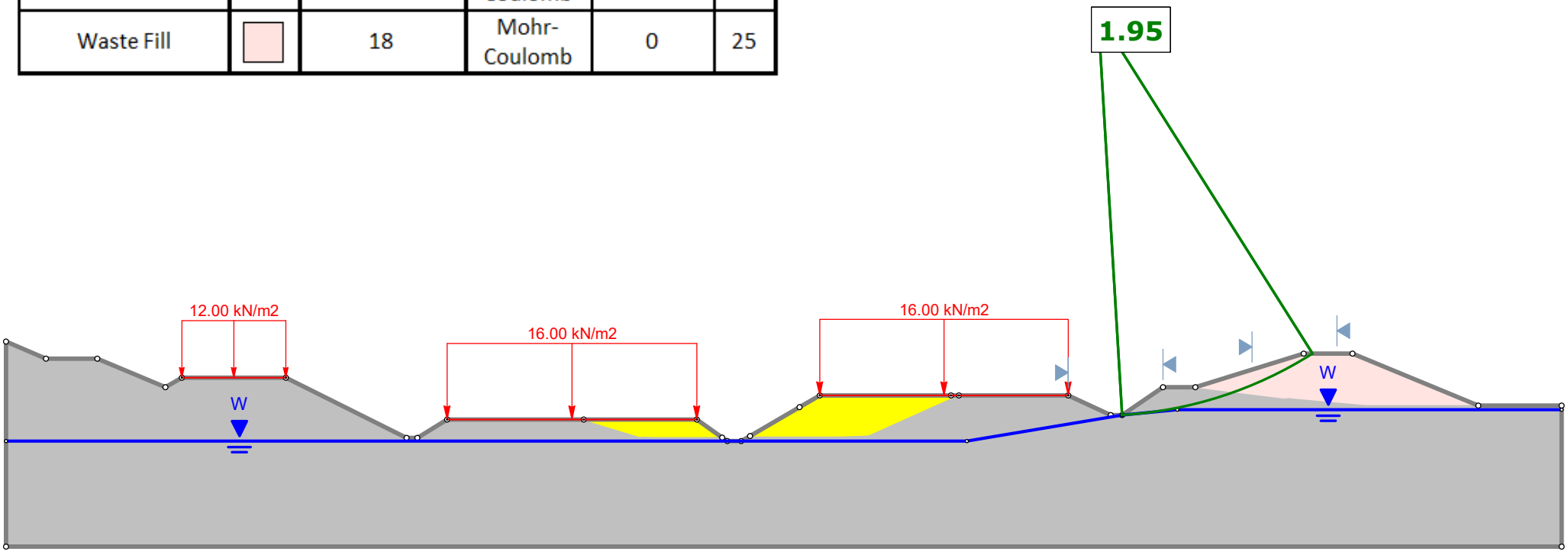


FIGURE # 1

Client: BC Ministry of Transportation and Infrastructure
File No.: 32079
E-File: Thurber_20231109_Waste Berm Area Memo_32079

January 10, 2024

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)
Glaciomarine Silt/ Clay (FLc)		19.5	Mohr-Coulomb	0.5	30
Fill-Silty Sand		20	Mohr-Coulomb	0	32
Waste Fill		18	Mohr-Coulomb	0	25



REV	DATE	REVISION	BY
1	YYYY-MM-DD	-	-

LEGEND / NOTES

SEAL

PERMIT TO PRACTICE

THURBER

CLIENT NAME: BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

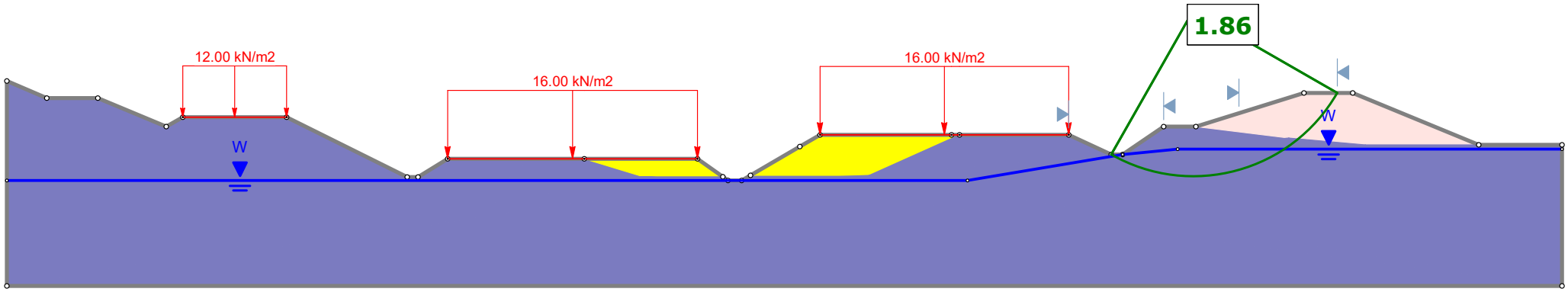
DRAWING TITLE: WASTE BERM - STATIC STABILITY TOWARDS HIGHWAY 1

PROJECT NAME AND LOCATION: FRASER VALLEY HIGHWAY 1 CORRIDOR IMPROVEMENT PROGRAM - 264th STREET TO WHATCOM ROAD

DRAWN BY	DATE
DMC	2024-01-15
DESIGNED BY	SCALE
OTHERS	-
APPROVED BY	PROJECT No.
-	32079
DRAWING / FIGURE No.	REV.
2	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)
Fill-Silty Sand		20	Mohr-Coulomb	0	32
Softened Glaciomarine Silt/ Clay (Undrained)		19.5	Undrained	32	
Waste Fill		18	Mohr-Coulomb	0	25

Seismic Coefficient: 0.13



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LEGEND / NOTES

SEAL

PERMIT TO PRACTICE

THURBER

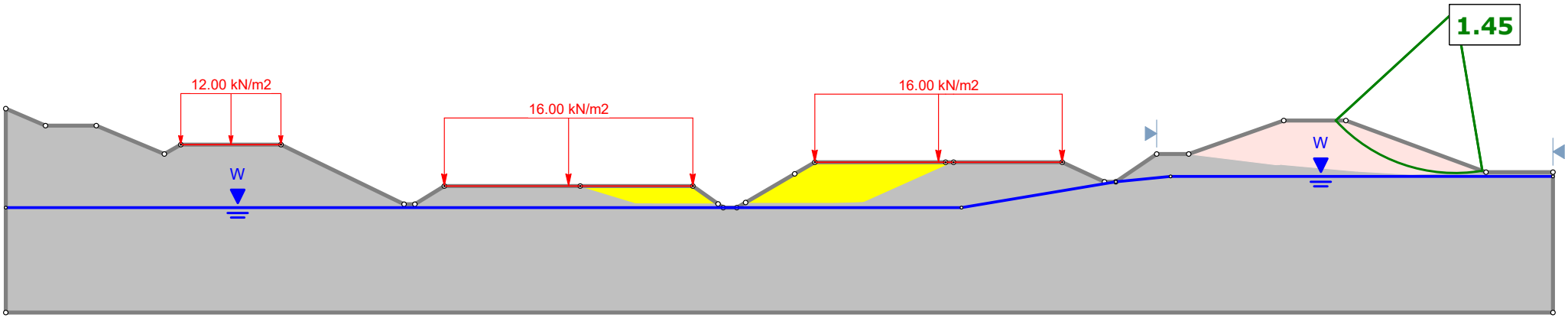
CLIENT NAME: BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

DRAWING TITLE: WASTE BERM - 1:475 PSEUDO-STATIC STABILITY TOWARDS HIGHWAY 1

PROJECT NAME AND LOCATION: FRASER VALLEY HIGHWAY 1 CORRIDOR IMPROVEMENT PROGRAM - 264th STREET TO WHATCOM ROAD

DRAWN BY	DATE
DMC	2024-01-15
DESIGNED BY	SCALE
OTHERS	-
APPROVED BY	PROJECT No.
-	32079
DRAWING / FIGURE No.	REV.
3	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)
Glaciomarine Silt/ Clay (FLc)		19.5	Mohr-Coulomb	0.5	30
Fill-Silty Sand		20	Mohr-Coulomb	0	32
Waste Fill		18	Mohr-Coulomb	0	25



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LEGEND / NOTES

SEAL

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THURBER

CLIENT NAME: BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

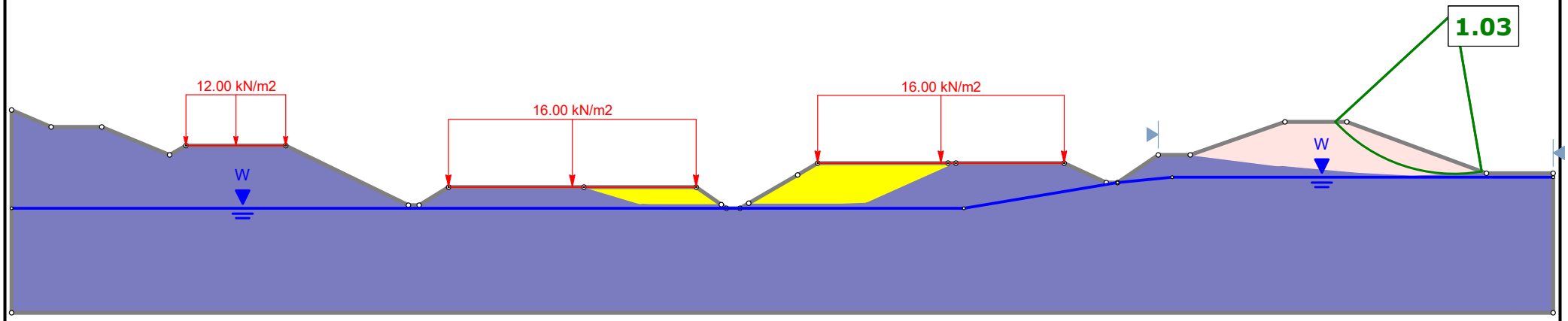
DRAWING TITLE: WASTE BERM - STATIC STABILITY FOR SLIP SURFACES WITHIN WASTE BERM

PROJECT NAME AND LOCATION: FRASER VALLEY HIGHWAY 1 CORRIDOR IMPROVEMENT PROGRAM - 264th STREET TO WHATCOM ROAD

DRAWN BY	DATE
DMC	2024-01-15
DESIGNED BY	SCALE
OTHERS	-
APPROVED BY	PROJECT No.
-	32079
DRAWING / FIGURE No.	REV.
4	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)
Fill-Silty Sand		20	Mohr-Coulomb	0	32
Softened Glaciomarine Silt/ Clay (Undrained)		19.5	Undrained	32	
Waste Fill		18	Mohr-Coulomb	0	25

Seismic Coefficient: 0.13



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LEGEND / NOTES

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CLIENT NAME: BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

DRAWING TITLE: WASTE BERM - 1:475 PSEUDO-STATIC FOR SLIP SURFACES WITHIN WASTE BERM

PROJECT NAME AND LOCATION: FRASER VALLEY HIGHWAY 1 CORRIDOR IMPROVEMENT PROGRAM - 264th STREET TO WHATCOM ROAD

DRAWN BY	DATE
DMC	2024-01-15
DESIGNED BY	SCALE
OTHERS	-
APPROVED BY	PROJECT No.
-	32079
DRAWING / FIGURE No.	REV.
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