



Boffa Miskell Limited  
Mauao Base Track Remediation  
Geotechnical Design Report

October 2018

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# 1. Introduction

## 1.1 Introduction

Boffa Miskell Ltd has been engaged by Tauranga City Council to design a southern section of the Mauao (Mount Maunganui) Base Walking Track.

GHD Ltd has been engaged by Boffa Miskell, as a sub consultant, to undertake detailed design associated with re-aligning the track due to a previous slope failure removing a section of the existing track. The re-alignment involves a section of track as a raised boardwalk, remediation of the slip face with soil nails and erosion protection matting, a revetment and an earth worked section of re-aligned track.

This remedial solution was recommended in the previously completed Geotechnical Assessment Report (GAR) also commissioned by Boffa Miskell. The GAR reports on the ground conditions and the remedial options deemed to be less suitable. The report is presented in Appendix B

## 1.2 Purpose and Scope of this Report

- Present the ground model and the geotechnical parameters used for design
- Present the details, design process and format of the final solution
- Identify key construction considerations

## 1.3 Observed Failure

The April 2017 slip has left an exposed un-vegetated very steep slope where existing soil/rock and a large tree overhang the face. The existing track above the slip has been partially removed closing this section of track. The material and the large tree which were part of the slip debris have been partially eroded away by the tides however a small shore platform of slip debris remains as well as the tree roots/stump.

## 1.4 Proposed Works

The proposed works can be best described in three sections and comprise:

- **Section One - Boardwalk:** Cut stable slopes to provide adequate grades in the location of the proposed Design and Construct (D&C) raised boardwalk on screw piles
- **Section Two - Failure Area Remediation:** Trimming of the slip face and edges to remove slip debris and overhanging tree/ disturbed/soft material, installation of soil nails, installation of erosion protection matting reinforced with strong wire netting over the remediation area (MACMAT-R or equivalent), fitting of soil nail bearing plates, hydro seeding remaining face.
- **Section Two & Three - Revetment Design:** Trimming of the face of the existing slope adjacent to the proposed revetment to remove overhanging trees and disturbed/soft material, excavate and construct the revetment structure and ramp to design levels and details provided in the construction drawings.
- **Section Three - Earthworks:** Replace existing culvert for stream, earthwork picnic area and track to design levels and grades as per the design drawings.

## 1.5 Reference Standards and Guidelines

The following standards and guidelines have been referred to during the design process:

1. New Zealand Geotechnical Society 2005 Guidelines for the Field Description of Soil and Rock.
2. MBIE/NZGS (2016) Earthquake geotechnical engineering practice Module 1: Overview of the guidelines.
3. MBIE Acceptable Solutions and Verification Methods For New Zealand Building Code Clause B1 (B1/VM4).
4. AS/NZS 1170.0:2002 - Structural Design Actions, Part 0 - General Principals.
5. NZS 1170.5:2004 - Structural Design Actions, Part 5 - Earthquake Actions, New Zealand.
6. NZTA Bridge Manual (SP/M/022), Third edition, Amendment 2, May 2016.
7. Ciria C637 2005 – Soil Nailing Best Practice Guidance
8. BS EN 14490:2010 Execution of Soil Nails
9. Federal Highway Administration for Soil Nail Walls 2003 guidance

## 2. Investigation Summary

GHD issued a Geotechnical Assessment Report on the 10<sup>th</sup> July 2018 which outlines the subsurface conditions encountered at the site which forms Appendix B. Further investigations for the revetment foundation was assessed during revetment design and due to the limitations in place for completing a more intrusive Geotechnical site investigation on the shoreline in terms of consents, and lack of access, Scala Penetrometer data had to suffice for detailed design. The information from the Scala Penetrometer data was used to assume that the boulder field identified to the northern and eastern extents of the proposed revetment may exist at a shallow depth throughout the foundation locations of the revetment, however the depth, continuity and location remains relatively uncertain until the area is excavated during construction. In order to account for the risk in terms of the unknown and potential variability in ground conditions beneath the revetment, we have provided two design profiles for founding the revetment on either a shallow boulder field or sand at depth. The Engineer at the time of excavation will determine the most suitable foundation design to adopt.

## 3. Geotechnical Model

### 3.1 Cross-Sections

Three different ground models were used for modelling the stability of the revetment structure. The ground models are assumed representative of a typical section through the revetment with only the depth and footing details changing.

The following scenarios were included in the slope stability assessments:

- Full depth revetment design to -3.23MSL (assuming no boulders encountered at depth)
- Alternative revetment toe design to -1.0MSL (assuming boulders encountered approximately 2m below current sand level based on Scala Penetrometer information.)
- Eroded beach profile design (full depth revetment toe at -3.23MSL with sand level eroded to top of primary armour rock -1.6MSL)

Figure 1, 2 and 3 below present the three different ground models.

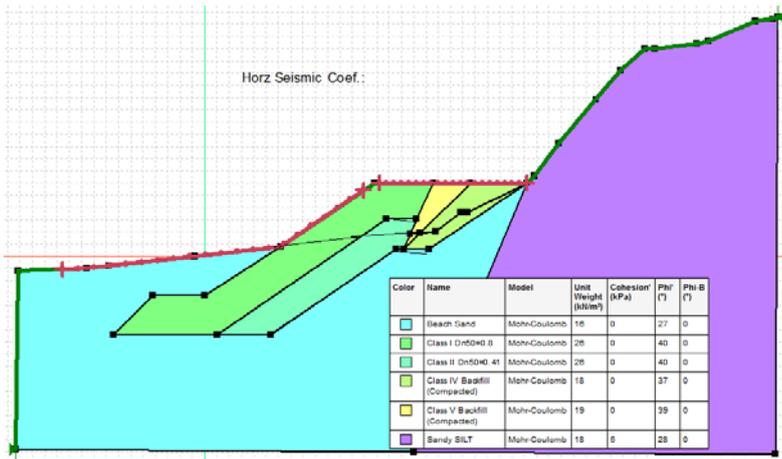


Figure 1 Full Depth Revetment -3.23MSL

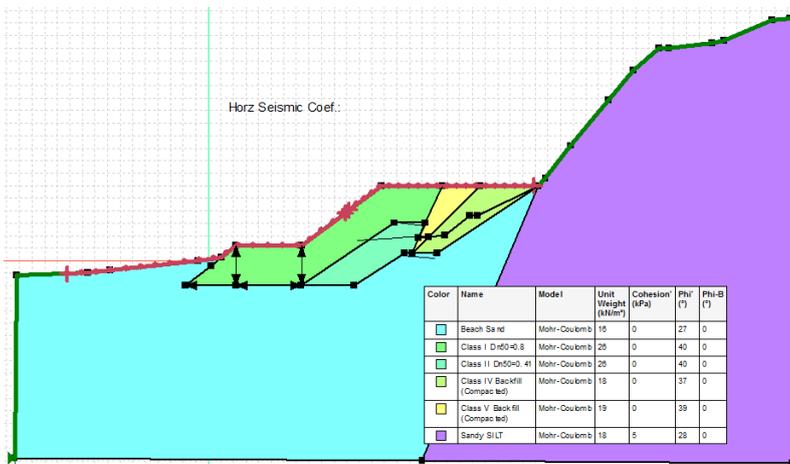


Figure 2 Alternative Revetment design -1.0MSL

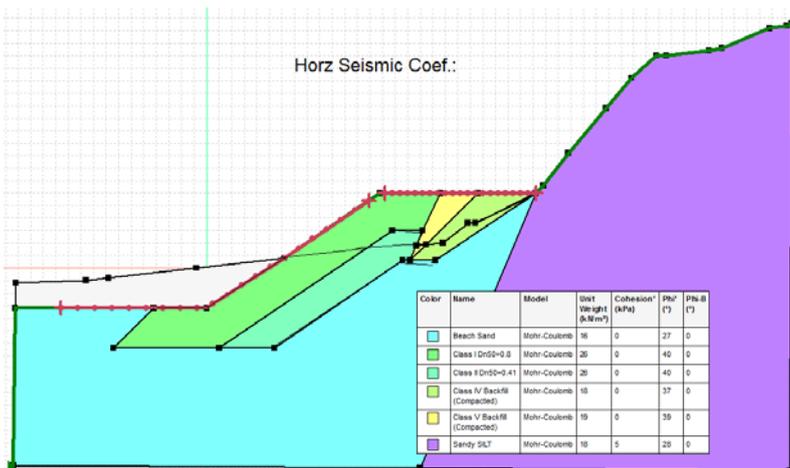


Figure 3 Eroded Beach Profile

### 3.2 Surcharges

A 5 kPa surcharge was applied to model the pedestrian loads on the track.

### 3.3 Geotechnical Parameters

The design parameters used in the analyses are shown in Table 1.

Table 1 Geotechnical Parameters

Geotechnical unit	Bulk unit weight, $\gamma$ (kN/m <sup>3</sup> )	Undrained shear strength, $s_u$ (kPa)	Effective cohesion, $c'$ (kPa)	Effective friction angle, $\phi'$ (°)
Matua Subgroup sandy Silt	18	80	5	28
Beach Sand	16	-	-	27
Revetment Armour Rock Dn50=0.8	26	-	-	40
Revetment Armour Rock Dn50=0.41	26	-	-	40
Class IV Revetment Backfill	18	-	-	37
Class V Revetment Backfill	19	-	-	39

These parameters were determined based on the interpretation of the results of the ground investigation information, in-situ test results, empirical relationships and local experience.

### 3.4 Groundwater

Slope stability was focused on analysing the stability of the revetment structure only and due to the tidal influence two water tables were analysed; High tide and Low tide.

Due to the unknown groundwater levels in the slopes above the revetment (due to the elevation distance between the ground investigation and the revetment) both the High and Low tide cases have been analysed for long term groundwater and have been modelled using SLOPE/W.

Groundwater levels in the low tide case projected through the revetment at -1.1MSL and at high tide at 1.5MSL.

Hand auger data indicated that no groundwater was encountered to a maximum drilled depth of 3.0mbgl.

### 3.5 Seismic Design Criteria

The seismic coefficients for geotechnical design are based on the NZTA Bridge Manual (NZBM). The following assumptions have been made in assessing the peak ground acceleration (PGA):

- Importance level 1
- Annual probability of exceedance:

- $U_{LS_{EQ}} = 1/100$
- Subsoil Class D - (NZS 1170.5:2004 – Deep of soft soil site)

The design PGA is calculated using the following formula:

$$PGA = C_{0,1000} \times \frac{R_u}{1.3} \times f \times g$$

Input parameters are suggested within the NZBM for the location being assessed and underlying subsoil conditions identified. These are summarised in Table 1.

Table 2 Seismic Design Input Parameters (NZBM)

Un-weighted PGA Coefficient for Class D & E Soil	ULS Return Period Factor, $R_u$ (1/100)	Site Subsoil Class Factor for Class C
0.34	0.5	f =1.0

Based on the input parameters in Table 2 above, the PGA for the ultimate limit state design was calculated. The resulting value however fell below the lower bound limit for a 6.5 magnitude earthquake at 20km distance for site subsoil class D (Deep or soft soils) therefore the lower bound limit PGA coefficient of 0.16g stated in the NZTA Bridge Manual has been adopted for design.

- $PGA_{ULS} = 0.16 \text{ g}$

### 3.6 Liquefaction Potential

Geotechnical investigation was limited to hand augers and Scala penetrometers with site restrictions, access issues and the presence of shallow boulders meant that no CPT's were completed in which a quantitative assessment of liquefaction could be completed. The ground investigation indicated that the stiff to very stiff silt and medium dense to dense sand of the Matua Subgroup was unlikely to be susceptible to liquefaction due to not encountering the water table in the investigation and the presence of some plasticity in the material.

The revetment would likely be founded on Rhyolite boulders from the Matua Subgroup surrounded by beach sands as indicated by the Scala penetrometer results, however it must be noted that site investigation data was sporadic in nature and there could be instances of the revetment founding on beach sands where there are no boulders present.

In the areas where the revetment is founding on Rhyolite boulders and in areas where the revetment could be founded on beach sands without the presence of boulders, the liquefaction risk can be assumed to be reduced due to being in a high-energy marine environment providing for a denser material at depth in comparison to a low energy alluvial deposit.

## 4. Detailed Design

### 4.1 Section One: Boardwalk Foundations

#### 4.1.1 General

The proposed foundations for the boardwalk will comprise steel screw piles, to minimise disturbance to archaeological sites. Detailed pile design will be part of a design and build contract for the boardwalk construction due to the unknown design spans and loads and the requirement for connection detailing and is therefore not specifically designed here.

Screw pile location and design will however have to take into account the proposed vicinity of mature trees as they may encounter obstructions such as tree roots and the distance to the edge of the shoreline as expected boulders were encountered in HA07 at a depth of 1.7mBGL which may need bridging.

Any topsoil or midden material is to be neglected in pile capacity design. Screw piles should be embedded sufficiently into the stiff to very stiff silt and medium dense to dense sand of the Matua Subgroup.

Allowance for corrosion needs to be made for steel piles in this marine environment in line with the specification (Appendix D).

Pile design should follow Engineering New Zealand Practice Note 28 "Screw Piles: Guidelines for design, Construction & Installation (Engineering New Zealand, 2015).

#### 4.1.1 Strength Reduction Factor

As required by Section B1/VM4 of the New Zealand Building Code Handbook (NZBC, 2018), a strength reduction factor ( $\phi_{pc}$ ) must be applied to recommended geotechnical ultimate soil capacities in conjunction with their use in factored design load cases for static and earthquake overstrength conditions respectively. The strength reduction factor depends on the method of assessment of the geotechnical strength and associated uncertainty.

A strength reduction factor of **0.5** may be used for static analysis without specific load testing (Table 4, B1/VM4).

A strength reduction factor in the range of **0.85** may be used for load combinations including earthquake overstrength (Table 4, B1/VM4).

#### 4.1.2 Loss of Material

As the boardwalk piles are located on a steep slope in some locations, it is recommended that piles are designed to account for loss of material as a result of shallow slips. Stabilisation of the side slope in the location of the proposed boardwalk is outside the scope of the project.

### 4.2 Section Two: Failure Area Remediation (Soil Nails)

#### 4.2.1 Stability Analysis

Slope stabilisation of the failure area was not required as part of the scope of this project. However, protection from erosion, rock fall and spalling from the face was required in order to protect users of the walking track below. Numerical slope stability analysis using SLOPE/W was therefore not completed. However, a risk based analysis was completed and can be found in the Geotechnical Assessment Report section 5.1.1 Appendix B. Soil nails and erosion

protection matting has been specified in the design solely to prevent the spalling and erosion of the existing slope face. Due to the steep nature of the failure slope and relatively dense material, soil nails have been specified as opposed to short pins or duckbill anchors as it is unlikely they would provide sufficient embedment to hold the erosion matting.

The soil nails and erosion protection matting will not prevent larger failure of the face. The revetment was chosen as a more robust structure for the track which could be remediated if further localised landslips occur.

#### 4.2.2 Slope Regrading

The slope requires regrading in the location of the failure to remove slip debris, overhangs, trees and soft material to form a consistent slope profile (of approximately 50-60°) suitable for soil nail installations.

The slope remedial extents and details are outlined in the design drawings Appendix A.

#### 4.2.3 Wall Design Calculations

Specific design of the soil nails was not completed as part of this project, nail spacing and embedment provided in the drawings was determined based on off a relatively common grid pattern for soil nailed slopes and the depth deemed necessary to embed the nails sufficiently into stiff natural ground to anchor the erosion control matting to the face.

#### 4.2.4 Slope Facing and Planting

Slope facing is required to provide erosion control support to the slope and is a key component of the design considering the spacing of soil nails in the slope. As specified in the construction drawings in Appendix A and Specification in Appendix D, the sequence of hydro seeding and laying of mat shall be in accordance with the manufacturer's recommended sequence, which is;

1. ProGanics sprayed onto cut slope (to manufactures specification)
2. Flexterra HP-FGM applied over ProGanics (to manufactures specification)
3. MacMat-R Placed over top of hydro-seeding products (to manufactures specification)

Any alternative facing support or hydro-seeding products must be approved by the engineer prior to use. The flexible facing must be pinned to the slope sufficiently utilising the soil nail heads as appropriate.

#### 4.2.5 Soil Nail Performance Testing

Proof loading of soil nails is not required.

#### 4.2.6 Soil Nail Specification

A project specific specification for soil nail works has been prepared to outline various requirements to control quality of soil nail construction. The soil nail specification for this project is attached in Appendix D.

### 4.3 Section Two & Three: Revetment Design

#### 4.3.1 General

Detailed revetment design has been covered in a separate design report "Revetment Detailed Design Report" however the stability of the revetment structure is provided in this report and is to accompany their design report and drawings.

### 4.3.2 Slope stability

Analysis of slope stability was carried out for a section of the revetment using computational software SLOPE/W (Geostudio 2018), with design parameters given in Table 1.

Design has been undertaken based on FoS acceptance criteria for different conditions. These are summarised in Table 3.

Analyses were undertaken based on cross section models described in section 3.1. Results are presented within Table 4 and the outputs are presented in Appendix C.

**Table 3 Factors of Safety for Stability Analysis**

Criteria	Acceptable FoS
Static – effective stress parameters	1.5
Seismic – total stress parameters	1.0
High groundwater – effective stress parameters	1.2

**Table 4 Results of Slope Stability Analysis**

Loading case	Acceptable FoS	FoS achieved		
		Full Depth Revetment (-3.23MSL)	Alternative Revetment Design (-1.0MSL)	Eroded Beach Profile
High Tide	1.5	1.9	1.6	1.5
Low Tide	1.5	1.7	1.5	1.5
Seismic High Tide	1.0	1.4	1.1	1.1
Seismic Low Tide	1.0	1.2	1.1	1.0

FOS was determined based on a number of specified failure surfaces, through the primary and secondary armour rock as well as beneath the revetment armour rock, however only the critical factor of safety has been noted.

## 4.4 Section 1-3: Earthworks

### 4.4.1 General

All earthworks should be in line with the detailed design drawings (Appendix A) and the specification (Appendix D).

### 4.4.2 Excavation

Excavation is required across all sections of track in some form and we recommend that cuts on the upper side of the track where required should be battered at a cut angle specific to the material they are cut into. Batter angles are summarised in Table 5.

Material Type	Batter Cut Angle
---------------	------------------

Matua Subgroup Rock	2 V in 1 H
Matua Subgroup Soil	1 V in 1 H
Midden Material	Seek engineering/heritage advice

**Table 5** Batter Angle of Track Cuts

Extensive cut faces along the track should be revegetated as per the design drawings (Appendix A) and the specification (Appendix D) to prevent erosion of the face, however if required they can have MacMat, DuraMAT or other similar approved product installed onto them and held in place with suitably designed anchors.

#### 4.4.3 Filling

All earthworks should be carried out to the specification (Appendix D).

It has been noted however that the material in the flat low lying areas of Section 3 of the track in the location of the picnic area was fill won from site from existing slope failures and placed in an uncontrolled manner. Therefore, track construction and earthworks in these areas may be prone to settlement. The client has accepted this risk of settlement and the potential ongoing maintenance required for the track and slopes adjacent to the track and therefore requested that fill is placed directly over this material, rather than excavating to natural ground.

#### 4.5 Safety in Design

A designer's risk assessment is included within Appendix E and should be reviewed and added to by the contractor.

## 5. References

- Engineering New Zealand. (2015). *Practice Note 28 Screw Piles: Guidelines for Design, Construction & Installation*. Engineers New Zealand.
- GHD. (July 2018 Revision 2). *Mauao Base Track Remediation Geotechnical Assessment*. GHD.
- NZBC. (2018). *Acceptable Solutions and Verification Methods For New Zealand Building Code Clause B1 Structure*. Ministry of Business, Innovation & Employment.

## 6. Limitations

This report has been prepared by GHD Limited (GHD) for Boffa Miskell Limited and may only be used and relied on by Boffa Miskell Limited for the purpose agreed between GHD and Boffa Miskell Limited as set out in this report.

GHD otherwise disclaims responsibility to any person other than Boffa Miskell Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible. GHD accepts no responsibility for other use of the data. This report presents the results of a geotechnical investigation prepared for the purpose of this commission. The data and advice provided relate only to the proposed development described herein.

The advice tendered in this report is based on information obtained from the investigation locations tests points and sample points and is not warranted in respect to the conditions that may be encountered across the site at other than these locations. It is emphasised that the actual characteristics of the subsurface materials may vary significantly between adjacent test points and sample intervals and at locations other than where observations, explorations and investigations have been made. Subsurface conditions, including groundwater levels and contaminant concentrations can change with time. This should be borne in mind when assessing the data. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

Ground conditions are inferred if no subsurface investigations have been conducted as part of this commission. Future investigations and/or construction may reveal different ground conditions.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Data queried from the New Zealand Geotechnical Database (NZGD) may have been considered in the preparation of this report. Where drill hole or test pit logs, cone tests, laboratory tests, geophysical tests and similar work have been performed and recorded by others, the Data are included and used in the form provided by others to the NZGD. No warranty or representation whatsoever (including as to its accuracy, adequacy, completeness, or fitness for any purpose) is provided by GHD in connection with the Data; and neither the Data Provider, the Data Owner nor any other Person providing Data to the NZGD accepts any liability (including in negligence) in relation to it.

Where drill hole or test pit logs, cone tests, laboratory tests, geophysical tests and similar work have been performed and recorded by others under a separate commission, the data is included and used in the form provided by others. The responsibility for the accuracy of such data remains with the issuing authority, not with GHD.

An understanding of the geotechnical site conditions depends on the integration of many pieces of information, some regional, some site specific, some structure specific and some experienced based. Hence this report should not be altered, amended or abbreviated, issued in part and issued incomplete in any way without prior checking and approval by GHD. GHD accepts no responsibility for any circumstances which arise from the issue of the report which have been modified in any way as outlined above.

It should be noted that because of the inherent uncertainties in subsurface evaluations, changed or unanticipated ground and groundwater conditions may occur that could affect total project cost and/or execution. GHD does not accept responsibility for the consequences of significant variances

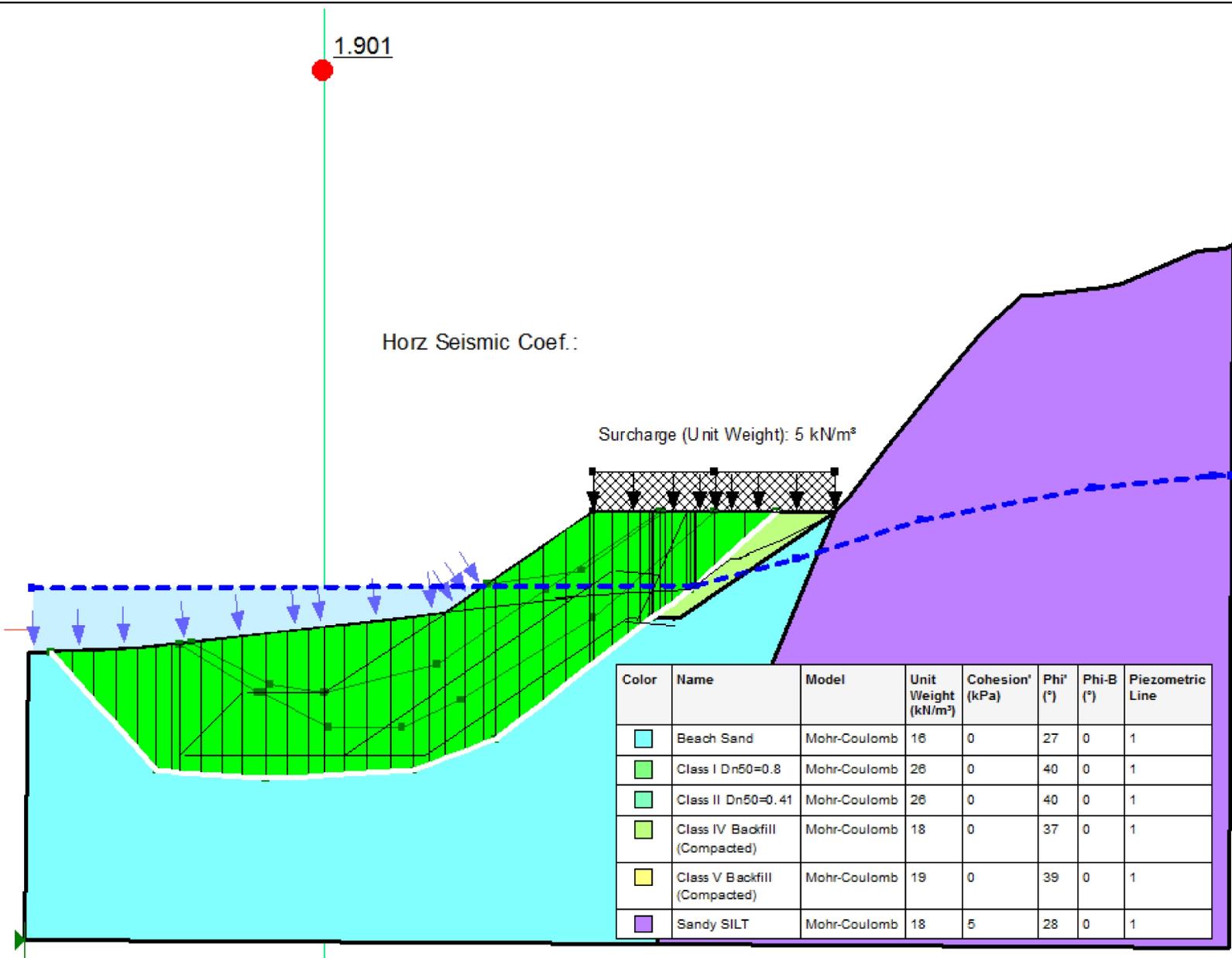
in the conditions and the requirements for execution of the work. If the revealed conditions do not accord with those assumed in this report the matter should be referred back to GHD.

# Appendices

# Appendix A – Drawings

# Appendix B – Geotechnical Assessment Report

# Appendix D – Slope/W Outputs



Horz Seismic Coef.:

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>

Notes:

- Showing critical slip circle

Color	Name	Model	Unit Weight (kN/m <sup>3</sup> )	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Beach Sand	Mohr-Coulomb	18	0	27	0	1
	Class I Dn50=0.8	Mohr-Coulomb	28	0	40	0	1
	Class II Dn50=0.41	Mohr-Coulomb	26	0	40	0	1
	Class IV Backfill (Compacted)	Mohr-Coulomb	18	0	37	0	1
	Class V Backfill (Compacted)	Mohr-Coulomb	19	0	39	0	1
	Sandy SILT	Mohr-Coulomb	18	5	28	0	1

Issue	Description	Date	Approved	Designed	Name	Date
01	SlopeW	Aug18		Designed		August 18
				Drawn		August 18
				Checked	s 7(2)(a) – Private	August 18
				Approved		August 18
				Scale @ NTS	Projection: -	

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Fax: (09) 370 8001

Project:

### Mauao Base Track Remediation

Section C' – Full Revetment Design  
Static - High Tide

Issued For: Revetment Design	Project Number: 51-37691	Sheet Number: GEO 01	Issue: 01
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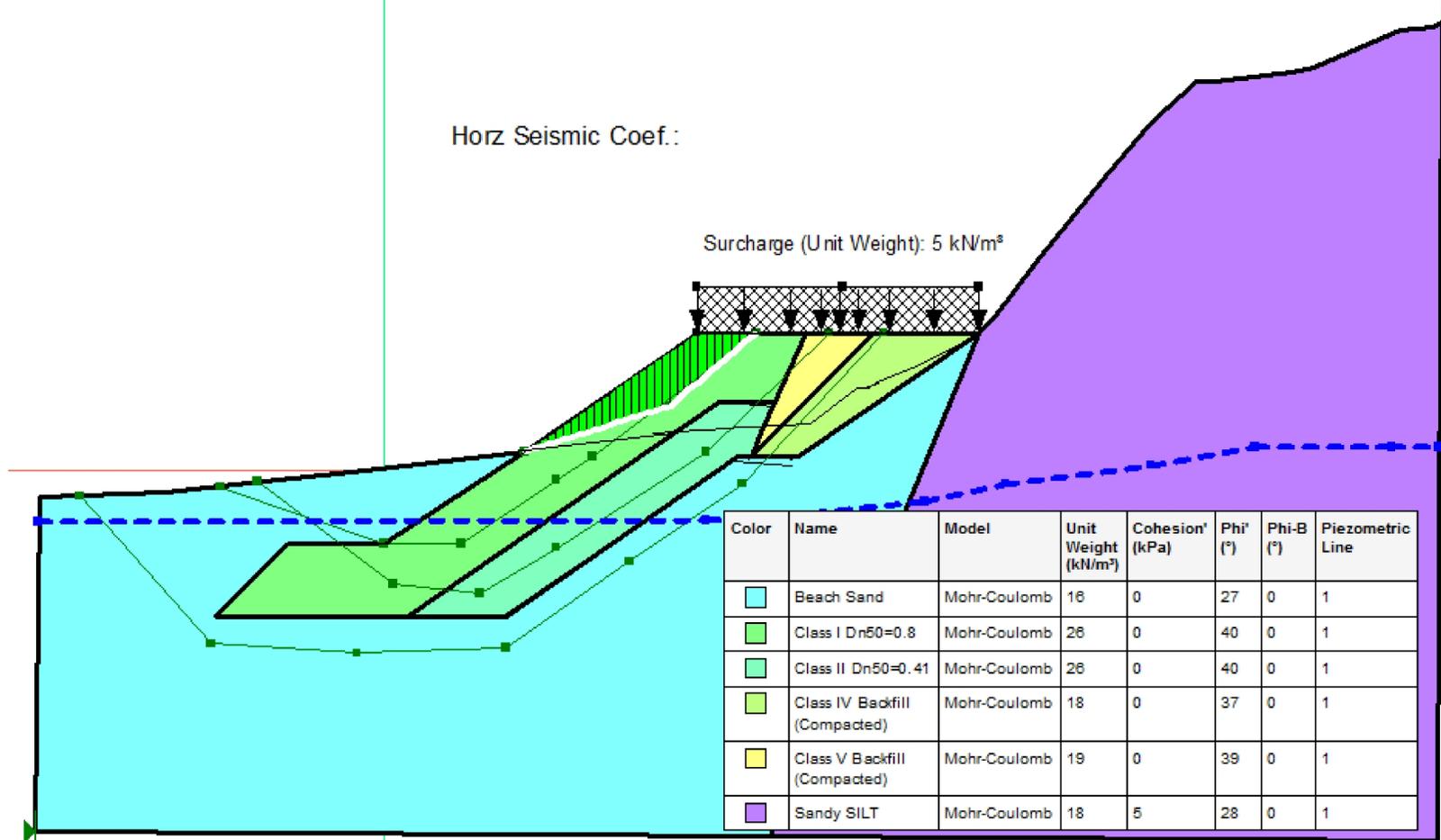
Notes:

- Showing critical slip circle

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Horz Seismic Coef.:

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>



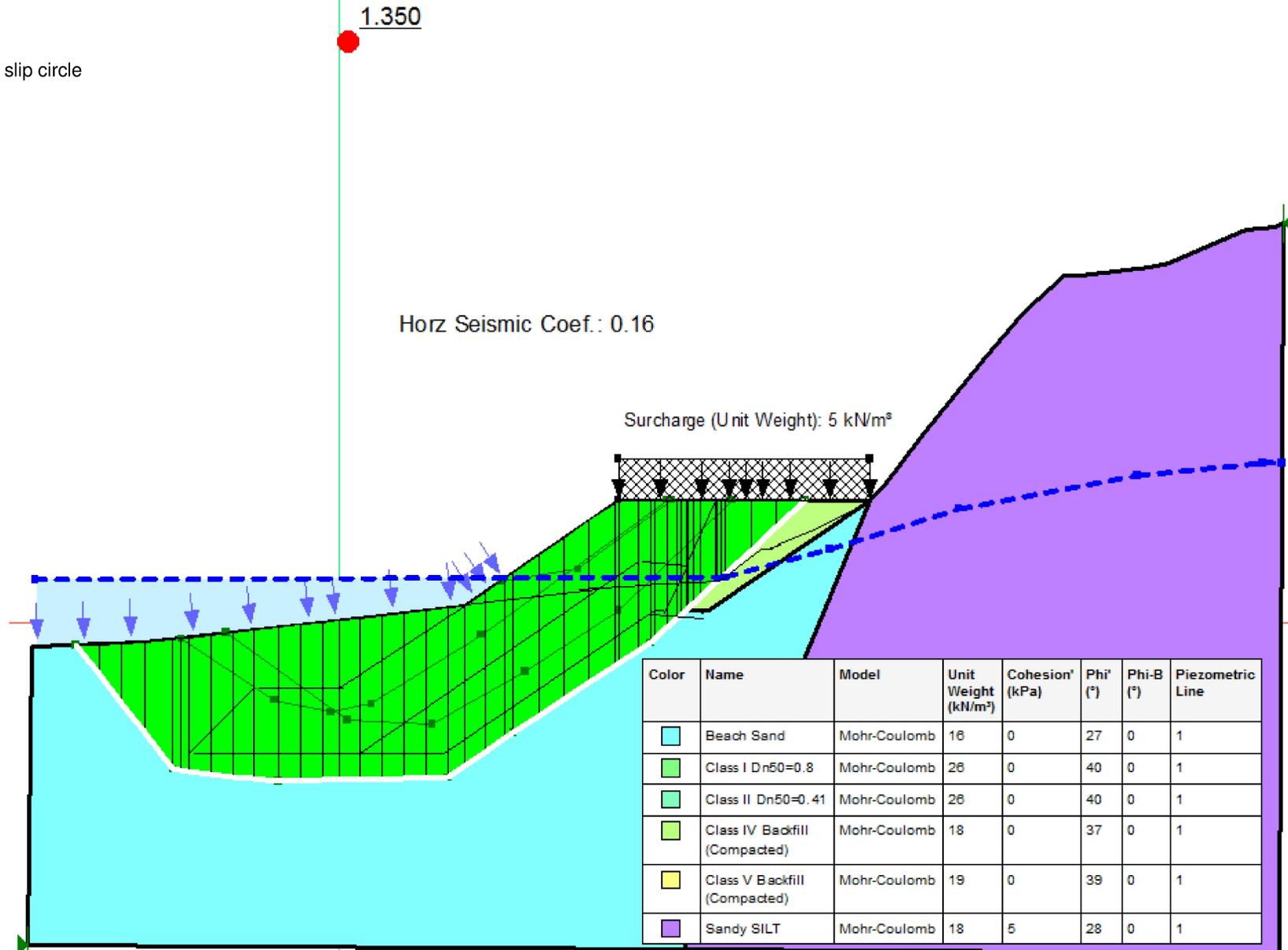
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				Drawn	August 18
				Checked	August 18
				Approved	August 18
				Scale @ NTS	Projection: -

Client:	  <p>GHD Centre Level 3 27 Napier Street Freemans Bay Auckland 1011 Ph: (09) 370 8000 Fax: (09) 370 8001</p>	Project:
		<p><b>Mauao Base Track Remediation</b> Section C' – Full Revetment Design Static – Low Tide</p>
Issued For:	Project Number:	Sheet Number:
Revetment Design	51-37691	GEO 02
		Issue:
		01

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Notes:

- Showing critical slip circle



Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18		Designed	August 18
				Drawn	August 18
				Checked	August 18
				Approved	August 18
				Scale @ NTS	Projection: -

Client:			GHD Centre Level 3 27 Napier Street Freemans Bay Auckland 1011 Ph: (09) 370 8000 Fax: (09) 370 8001	Project:	<b>Mauao Base Track Remediation</b> Section C' – Full Depth Revetment Earth Quake – High Tide				
		Issued For:	Revetment Design	Project Number:	51-37691	Sheet Number:	GEO 03	Issue:	01

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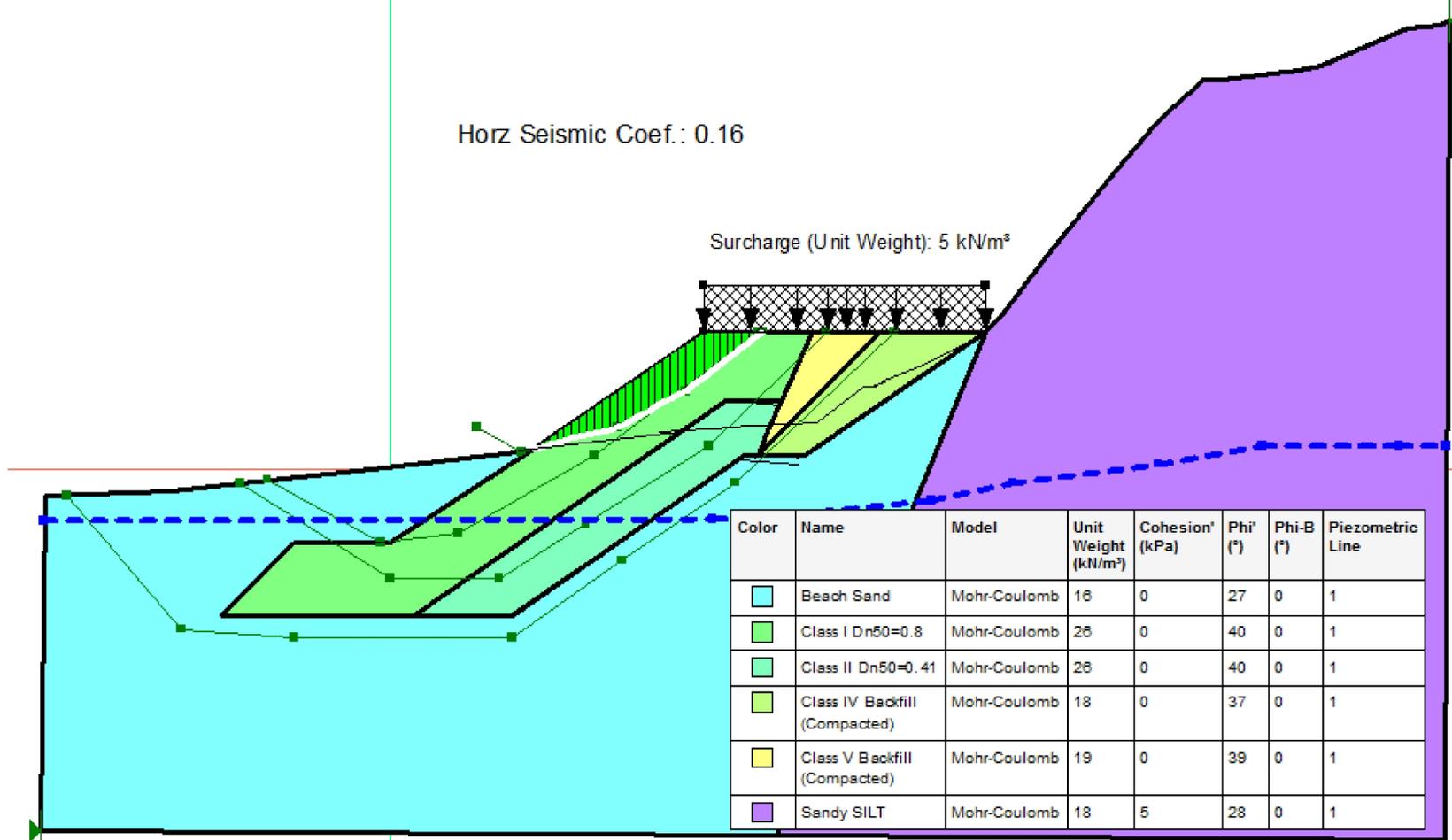
Notes:

- Showing critical slip circle

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Horz Seismic Coef.: 0.16

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>



Color	Name	Model	Unit Weight (kN/m <sup>3</sup> )	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Beach Sand	Mohr-Coulomb	16	0	27	0	1
	Class I Dn50=0.8	Mohr-Coulomb	26	0	40	0	1
	Class II Dn50=0.41	Mohr-Coulomb	26	0	40	0	1
	Class IV Backfill (Compacted)	Mohr-Coulomb	18	0	37	0	1
	Class V Backfill (Compacted)	Mohr-Coulomb	19	0	39	0	1
	Sandy SILT	Mohr-Coulomb	18	5	28	0	1

Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18			August 18
					August 18
					August 18
					August 18
			Scale @ NTS	Projection: -	

Client:			GHD Centre Level 3 27 Napier Street Freemans Bay Auckland 1011 Ph: (09) 370 8000 Fax: (09) 370 8001	Project:	<b>Mauao Base Track Remediation</b> Section C' – Full Revetment Earth Quake – Low Tide		
		Issued For:	Project Number:	Sheet Number:	Issue:		
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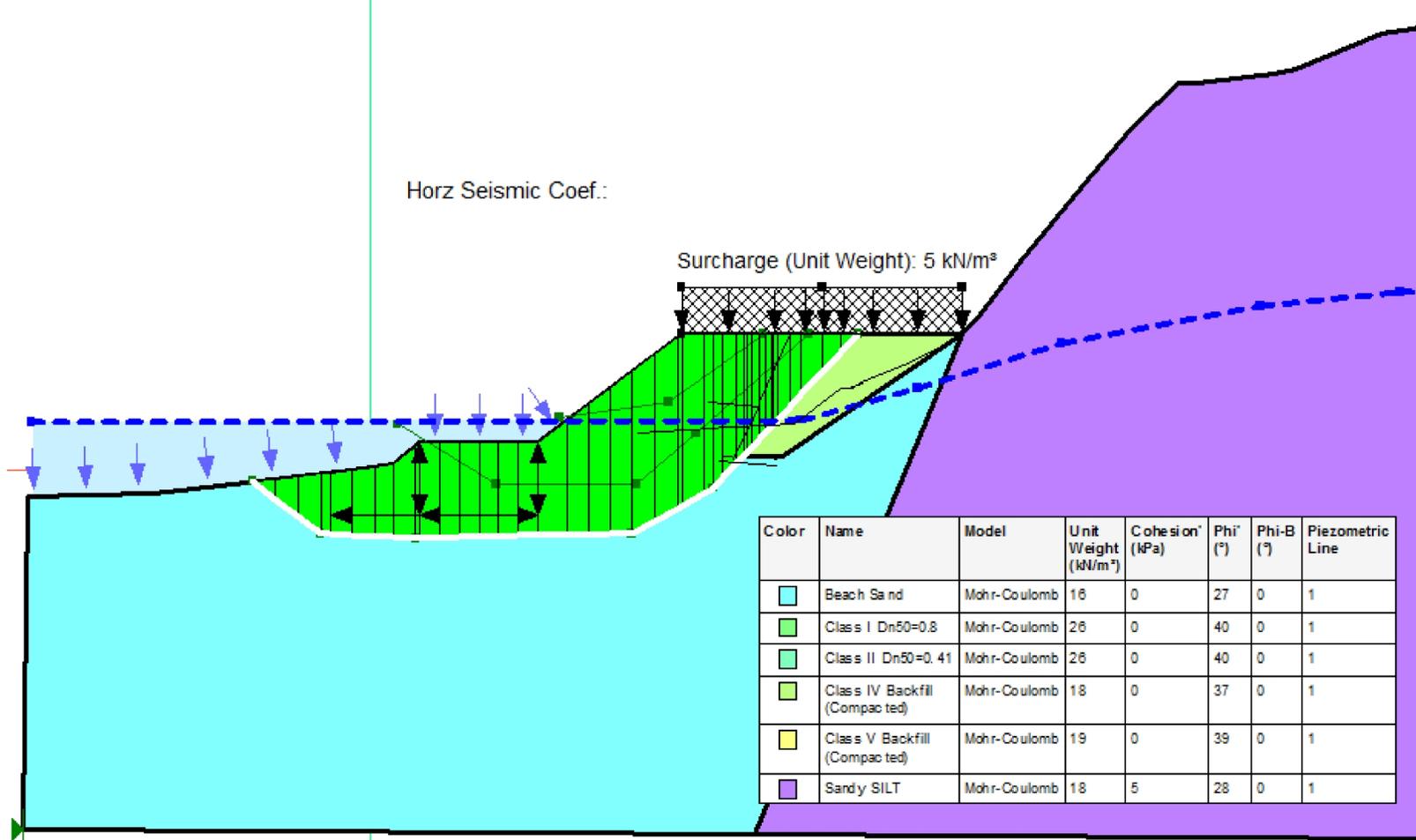
Notes:

- Showing critical slip circle

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Horz Seismic Coef.:

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>



Color	Name	Model	Unit Weight (kN/m <sup>3</sup> )	Cohesion (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
Light Blue	Beach Sand	Mohr-Coulomb	16	0	27	0	1
Green	Class I Dn50=0.8	Mohr-Coulomb	26	0	40	0	1
Light Green	Class II Dn50=0.41	Mohr-Coulomb	26	0	40	0	1
Yellow-Green	Class IV Backfill (Compacted)	Mohr-Coulomb	18	0	37	0	1
Yellow	Class V Backfill (Compacted)	Mohr-Coulomb	19	0	39	0	1
Purple	Sandy SILT	Mohr-Coulomb	18	5	28	0	1

Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18	s 7(2)(a)	Designed	August 18
				Drawn	August 18
				Checked	August 18
				Approved	August 18
				Scale @ NTS	Projection: -

Client:



GHD Centre  
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Freemans Bay  
Auckland 1011

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Fax: (09) 370 8001

Project:

**Mauao Base Track Remediation**  
Section C' – Alternative Revetment Design  
Static – High tide

Issued For: Revetment Design	Project Number: 51-37691	Sheet Number: GEO 05	Issue: 01
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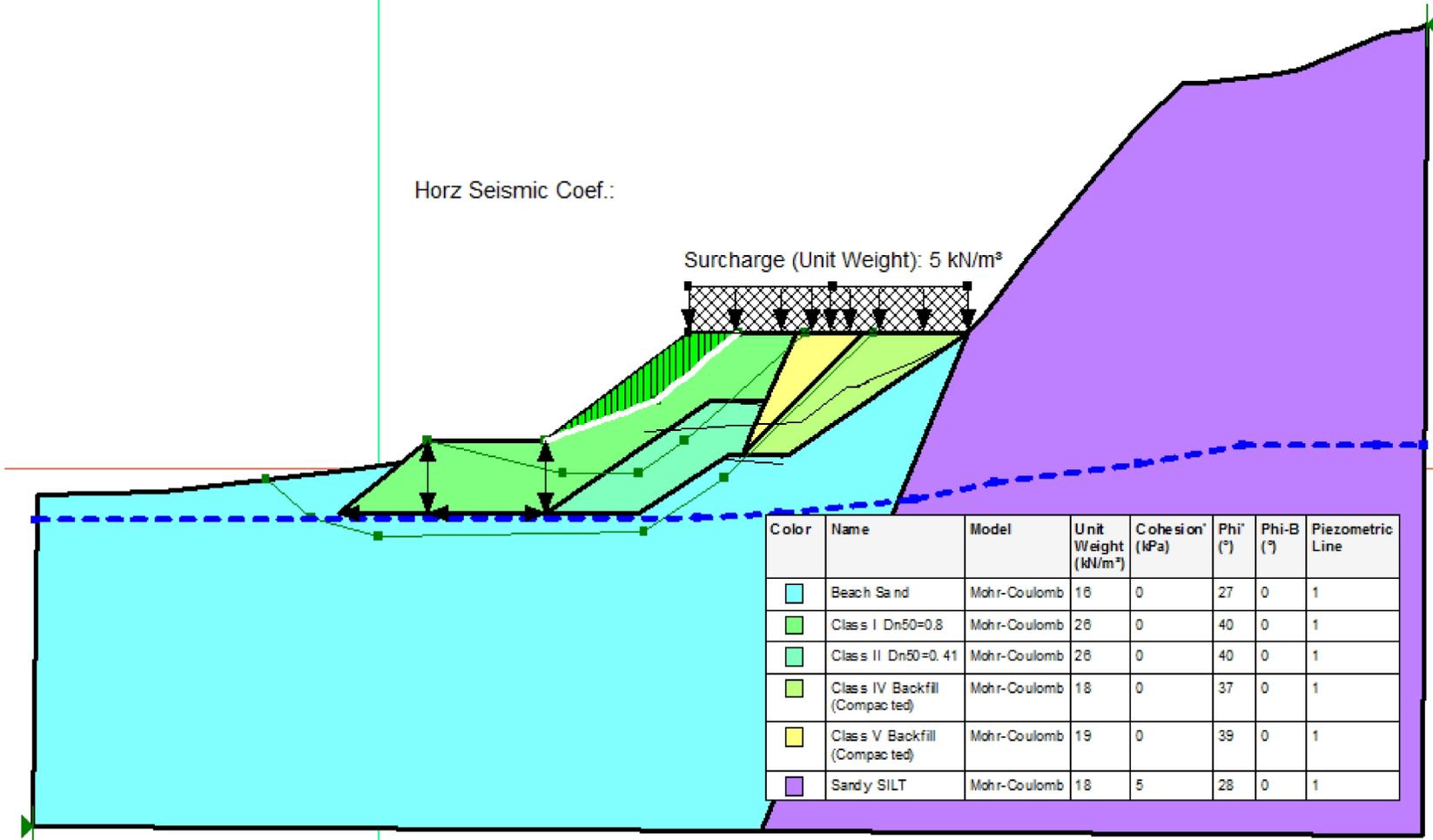
Notes:

- Showing critical slip circle

1.498

Horz Seismic Coef.:

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>



Color	Name	Model	Unit Weight (kN/m <sup>3</sup> )	Cohesion (kPa)	Phi (°)	Phi-B (°)	Piezometric Line
Light Blue	Beach Sand	Mohr-Coulomb	18	0	27	0	1
Green	Class I Dn50=0.8	Mohr-Coulomb	26	0	40	0	1
Light Green	Class II Dn50=0.41	Mohr-Coulomb	26	0	40	0	1
Light Yellow	Class IV Backfill (Compacted)	Mohr-Coulomb	18	0	37	0	1
Yellow	Class V Backfill (Compacted)	Mohr-Coulomb	19	0	39	0	1
Purple	Sandy SILT	Mohr-Coulomb	18	5	28	0	1

Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18	s 7(2)(a)	Designed	August 18
				Drawn	August 18
				Checked	August 18
				Approved	August 18
				Scale @ NTS	Projection: -

		GHD Centre Level 3 27 Napier Street Freemans Bay Auckland 1011  Ph: (09) 370 8000 Fax: (09) 370 8001	Project:	
			Mauao Base Track Remediation Section C' – Alternative Revetment Design Statci – Low Tide	
Issued For: Revetment Design		Project Number: 51-37691	Sheet Number: GEO 06	Issue: 01

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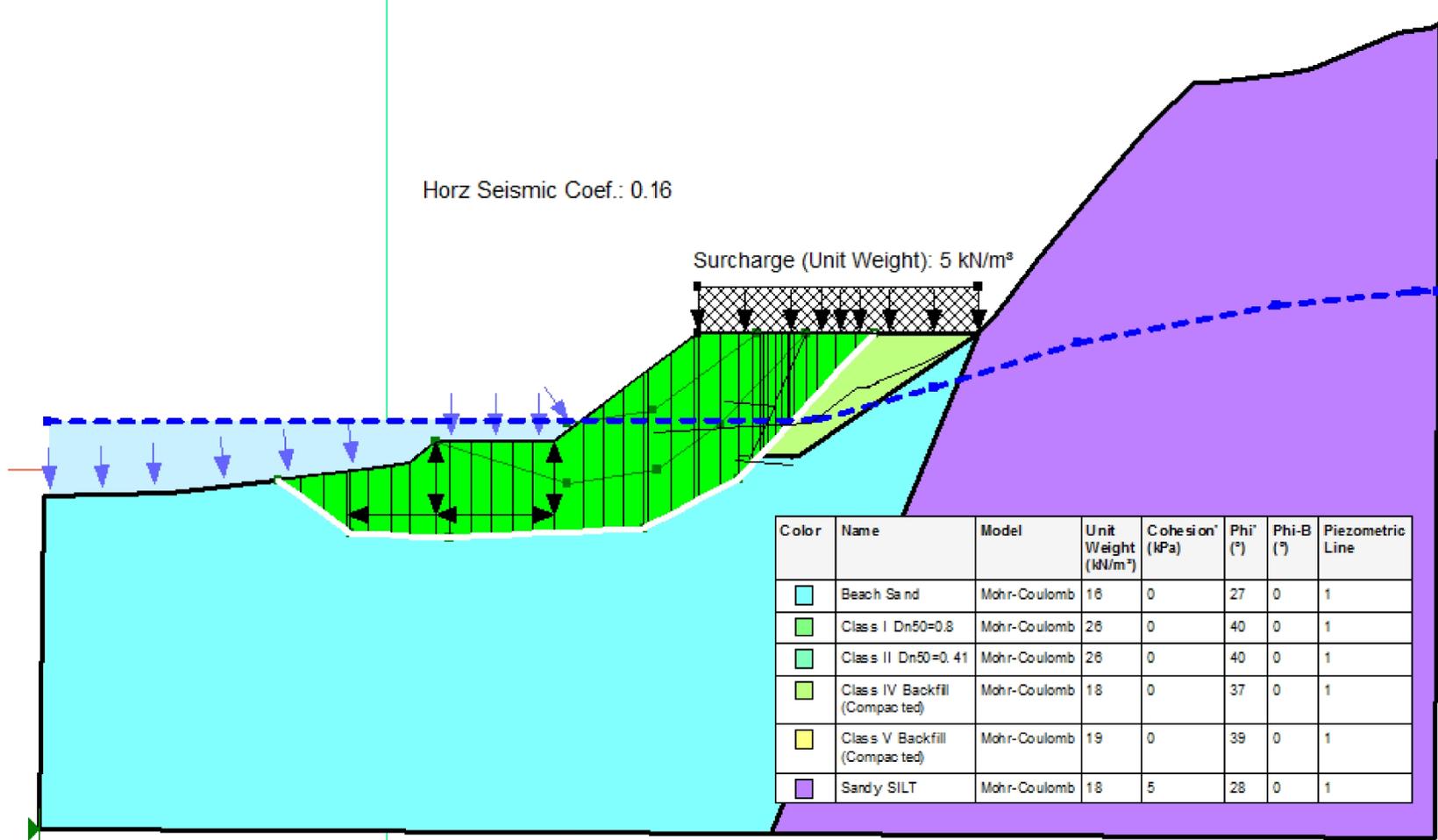
Notes:

- Showing critical slip circle

1.050

Horz Seismic Coef.: 0.16

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>



Color	Name	Model	Unit Weight (kN/m <sup>3</sup> )	Cohesion (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
Light Blue	Beach Sand	Mohr-Coulomb	16	0	27	0	1
Green	Class I Dn50=0.8	Mohr-Coulomb	26	0	40	0	1
Light Green	Class II Dn50=0.41	Mohr-Coulomb	26	0	40	0	1
Yellow-Green	Class IV Backfill (Compacted)	Mohr-Coulomb	18	0	37	0	1
Yellow	Class V Backfill (Compacted)	Mohr-Coulomb	19	0	39	0	1
Purple	Sandy SILT	Mohr-Coulomb	18	5	28	0	1

Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18	s 7(2)(a)	Designed	August 18
				Drawn	August 18
				Checked	August 18
				Approved	August 18
				Scale @ NTS	Projection: -

Client:



GHD Centre  
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Project:

**Mauao Base Track Remediation**  
Section C' – Alternative Revetment Design  
Earth Quake – High Tide

Issued For:	Project Number:	Sheet Number:	Issue:
Revetment Design	51-37691	GEO 07	01

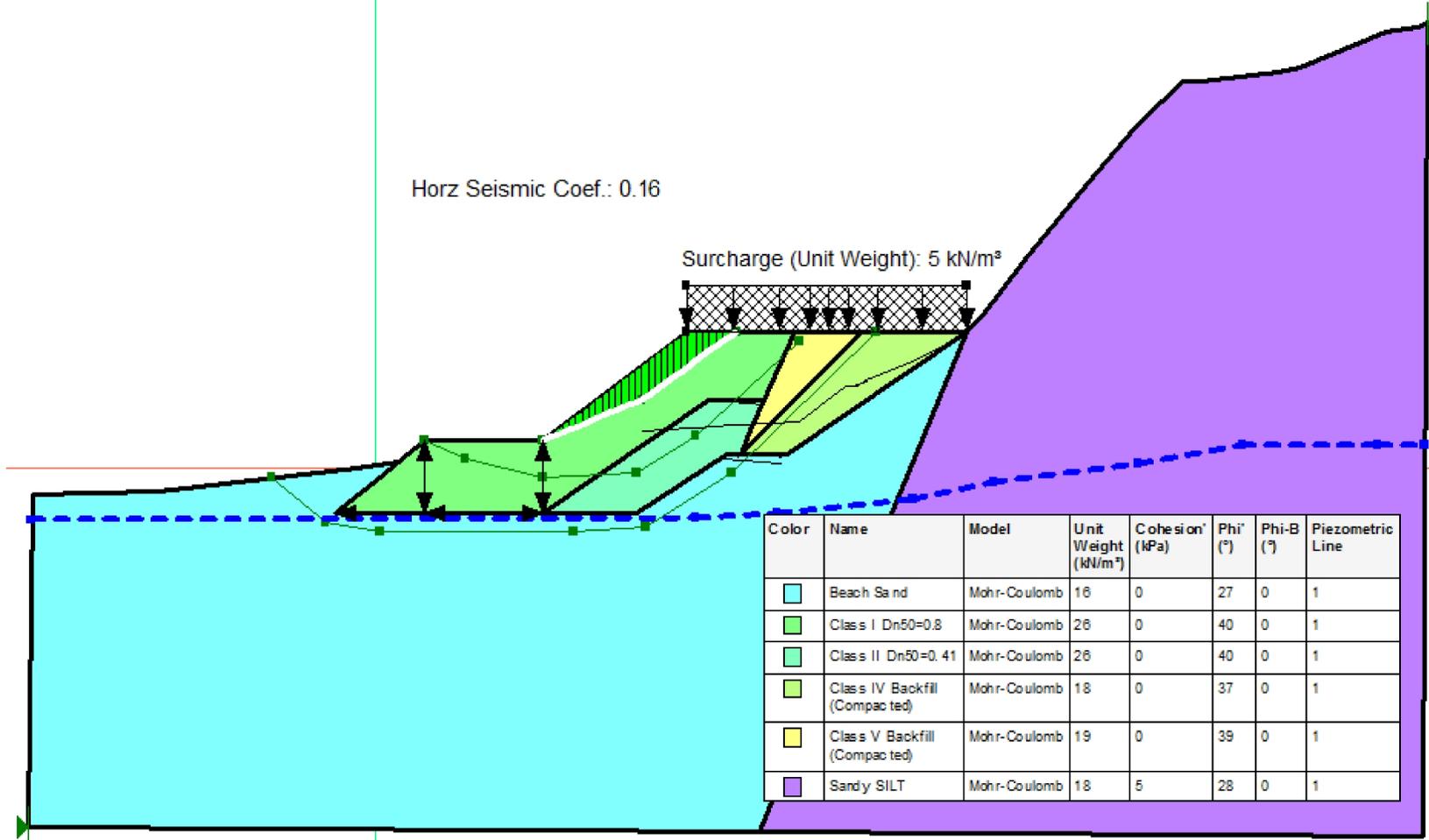
Notes:

- Showing critical slip circle

1.082

Horz Seismic Coef.: 0.16

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>



Color	Name	Model	Unit Weight (kN/m <sup>3</sup> )	Cohesion (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
Light Blue	Beach Sand	Mohr-Coulomb	16	0	27	0	1
Green	Class I Dn50=0.8	Mohr-Coulomb	26	0	40	0	1
Light Green	Class II Dn50=0.41	Mohr-Coulomb	26	0	40	0	1
Yellow-Green	Class IV Backfill (Compacted)	Mohr-Coulomb	18	0	37	0	1
Yellow	Class V Backfill (Compacted)	Mohr-Coulomb	19	0	39	0	1
Purple	Sandy SILT	Mohr-Coulomb	18	5	28	0	1

Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18	s 7(2)(a)	Designed	August 18
				Drawn	August 18
				Checked	August 18
				Approved	August 18
				Scale @ NTS	Projection: -

Client:



GHD Centre  
Level 3  
27 Napier Street  
Freemans Bay  
Auckland 1011

Ph: (09) 370 8000  
Fax: (09) 370 8001

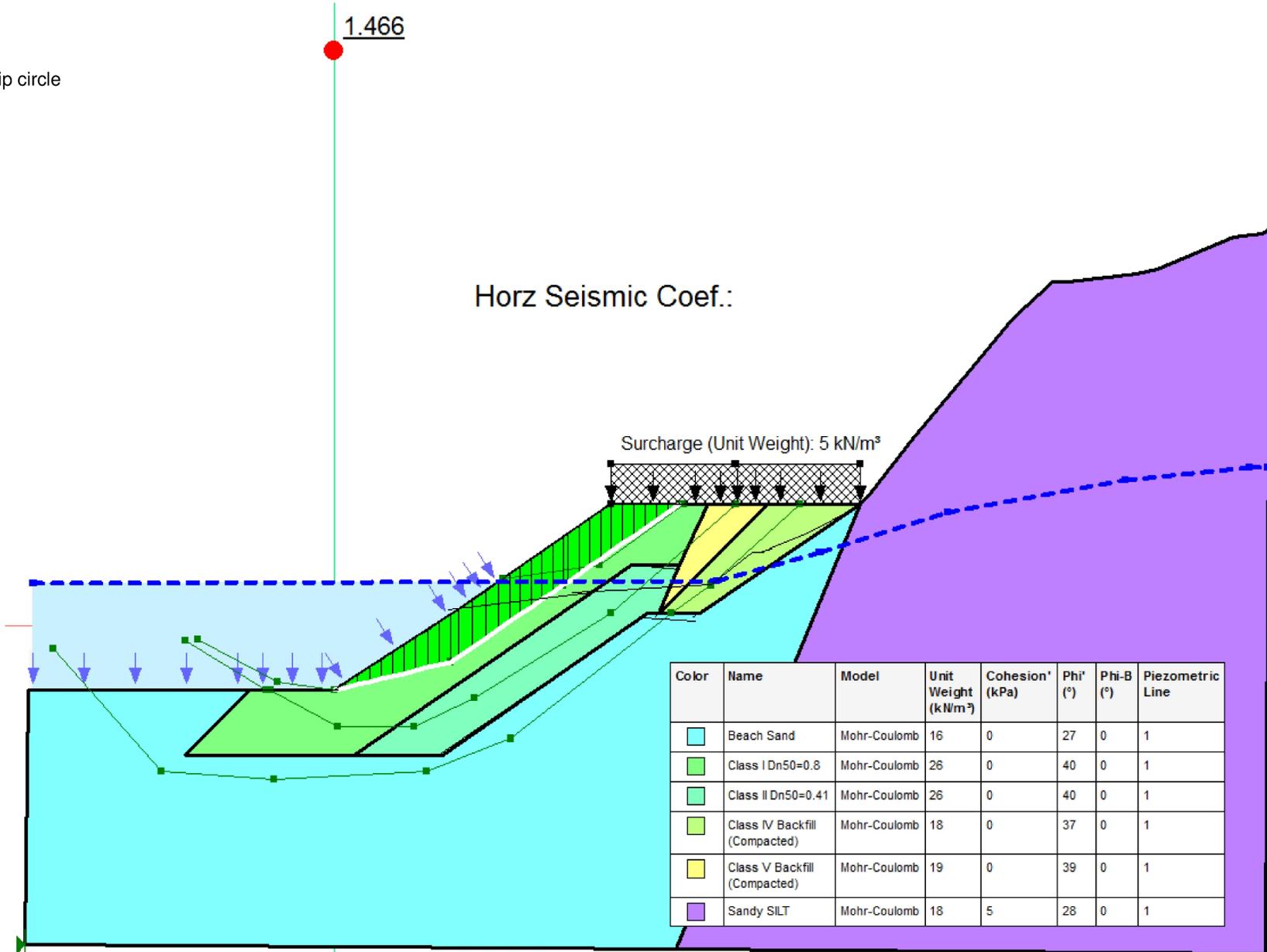
Project:

**Mauao Base Track Remediation**  
Section C' – Alternative Revetment Design  
Earth Quake – Low tide

Issued For: Revetment Design	Project Number: 51-37691	Sheet Number: GEO 08	Issue: 01
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Notes:

- Showing critical slip circle



Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18	<span style="background-color: black; color: white;">s 7(2)(a)</span>	<span style="background-color: black; color: white;">s 7(2)(a) – Privac</span>	August 18
					August 18
					August 18
					August 18
				Scale @ NTS	Projection: -

Client:	  <p>GHD Centre Level 3 27 Napier Street Freemans Bay Auckland 1011</p> <p>Ph: (09) 370 8000 Fax: (09) 370 8001</p>	Project:	
<p><b>Mauao Base Track Remediation</b> Section C' – Eroded Beach Profile Static - HT</p>			
Issued For:	Project Number:	Sheet Number:	Issue:
Revetment Design	51-37691	GEO 09	01

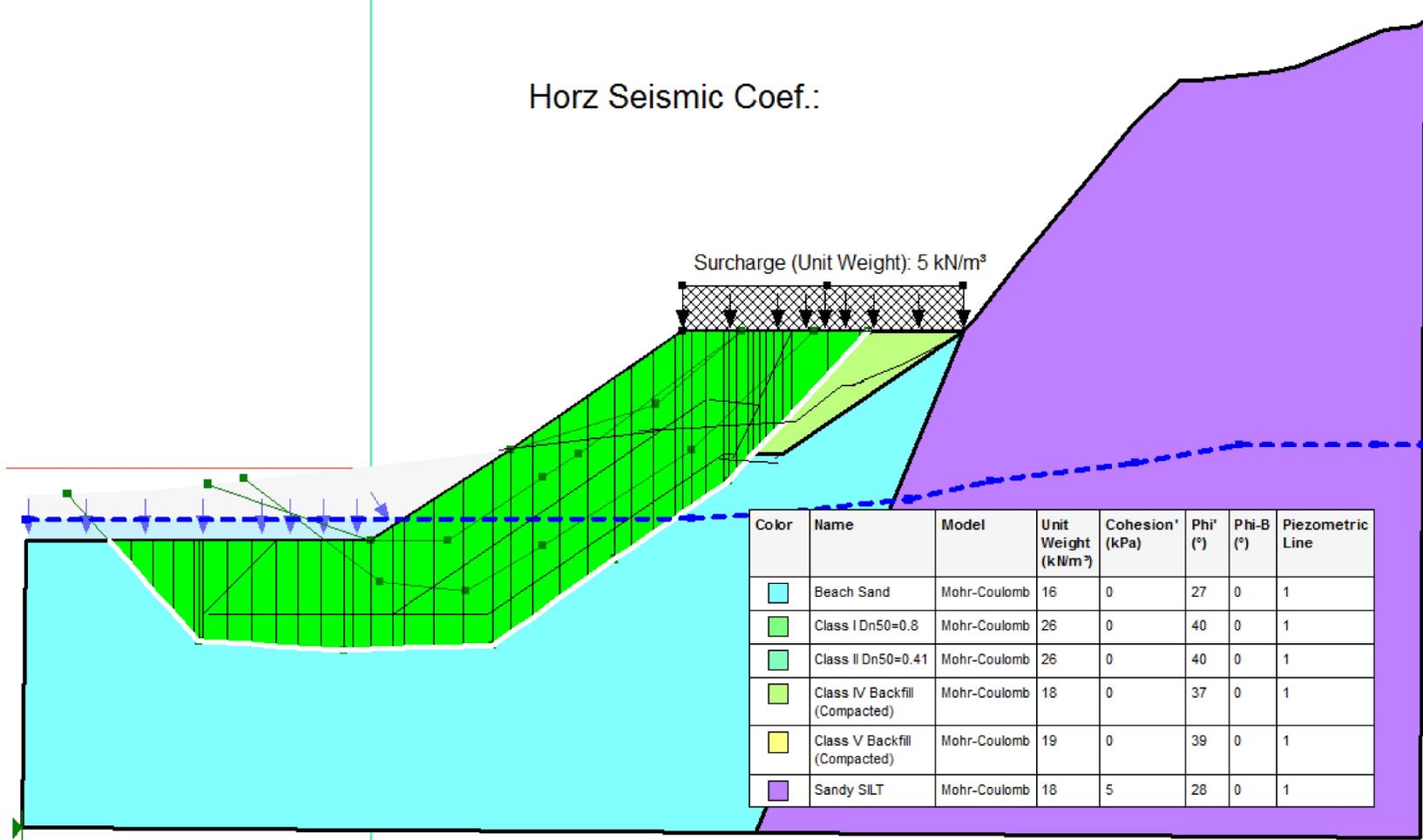
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Notes:

- Showing critical slip circle

1.447

Horz Seismic Coef.:



Color	Name	Model	Unit Weight (kN/m <sup>3</sup> )	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Beach Sand	Mohr-Coulomb	16	0	27	0	1
	Class I Dn50=0.8	Mohr-Coulomb	26	0	40	0	1
	Class II Dn50=0.41	Mohr-Coulomb	26	0	40	0	1
	Class IV Backfill (Compacted)	Mohr-Coulomb	18	0	37	0	1
	Class V Backfill (Compacted)	Mohr-Coulomb	19	0	39	0	1
	Sandy SILT	Mohr-Coulomb	18	5	28	0	1

Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18			August 18
			Designed		August 18
			Drawn		August 18
			Checked		August 18
			Approved		August 18
			Scale @ NTS	Projection: -	

		GHD Centre Level 3 27 Napier Street Freemans Bay Auckland 1011 Ph: (09) 370 8000 Fax: (09) 370 8001		Project: <b>Mauao Base Track Remediation</b> Section C' – Eroded Beach Profile Static - LT	
		Issued For: Revetment Design	Project Number: 51-37691	Sheet Number: GEO 10	Issue: 01

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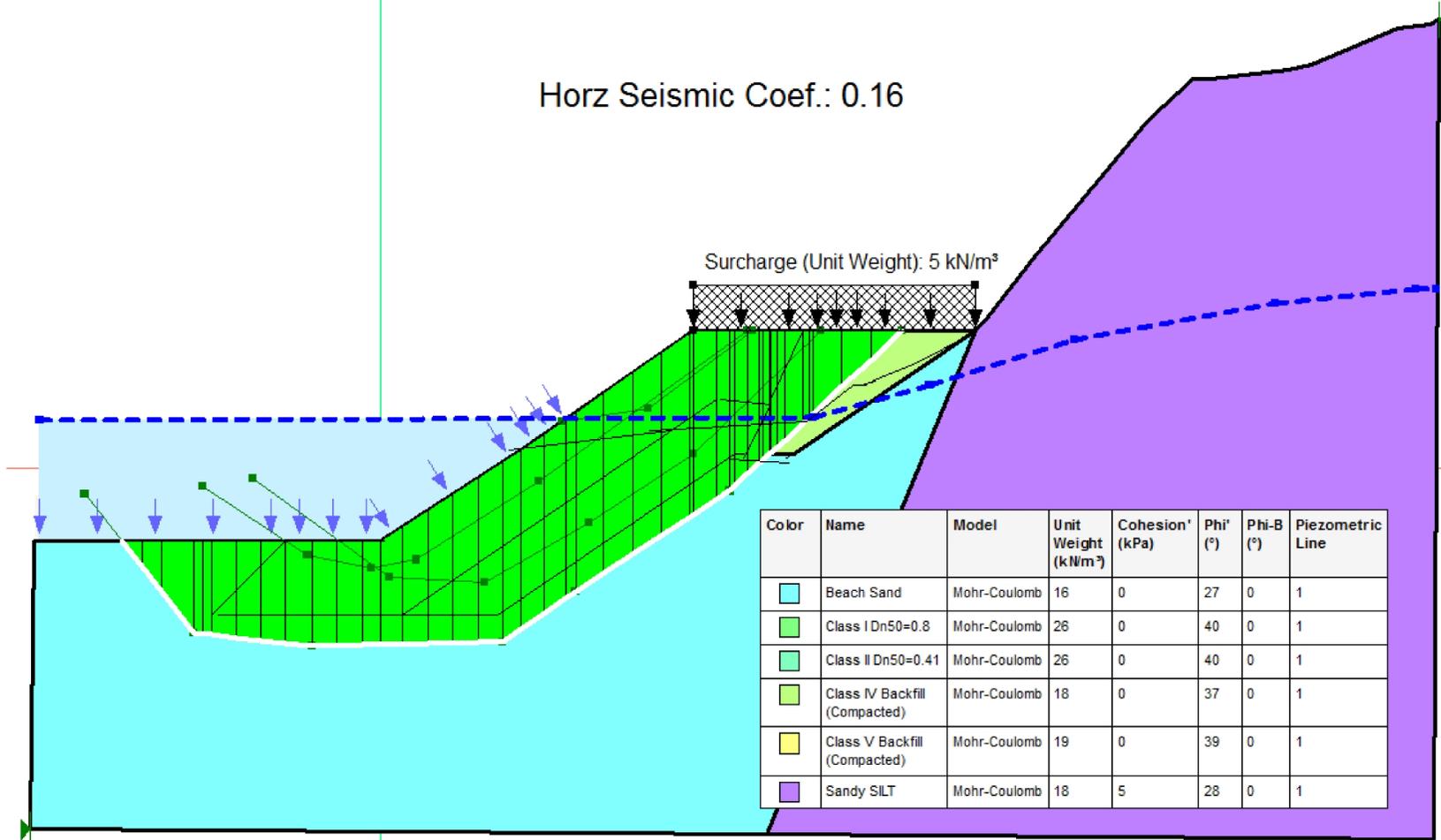
Notes:

- Showing critical slip circle

1.128

Horz Seismic Coef.: 0.16

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>



Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18	s 7(2)(a)	Designed	August 18
				Drawn	August 18
				Checked	August 18
				Approved	August 18
				Scale @ NTS	Projection: -

Client:	Boffa Miskell	GHD Centre Level 3 27 Napier Street Freemans Bay Auckland 1011 Ph: (09) 370 8000 Fax: (09) 370 8001	Project:
<b>Mauao Base Track Remediation</b> Section C' – Eroded Beach Profile Earth Quake – High Tide			
Issued For:	Revetment Design	Project Number:	51-37691
Sheet Number:	GEO 11	Issue:	01

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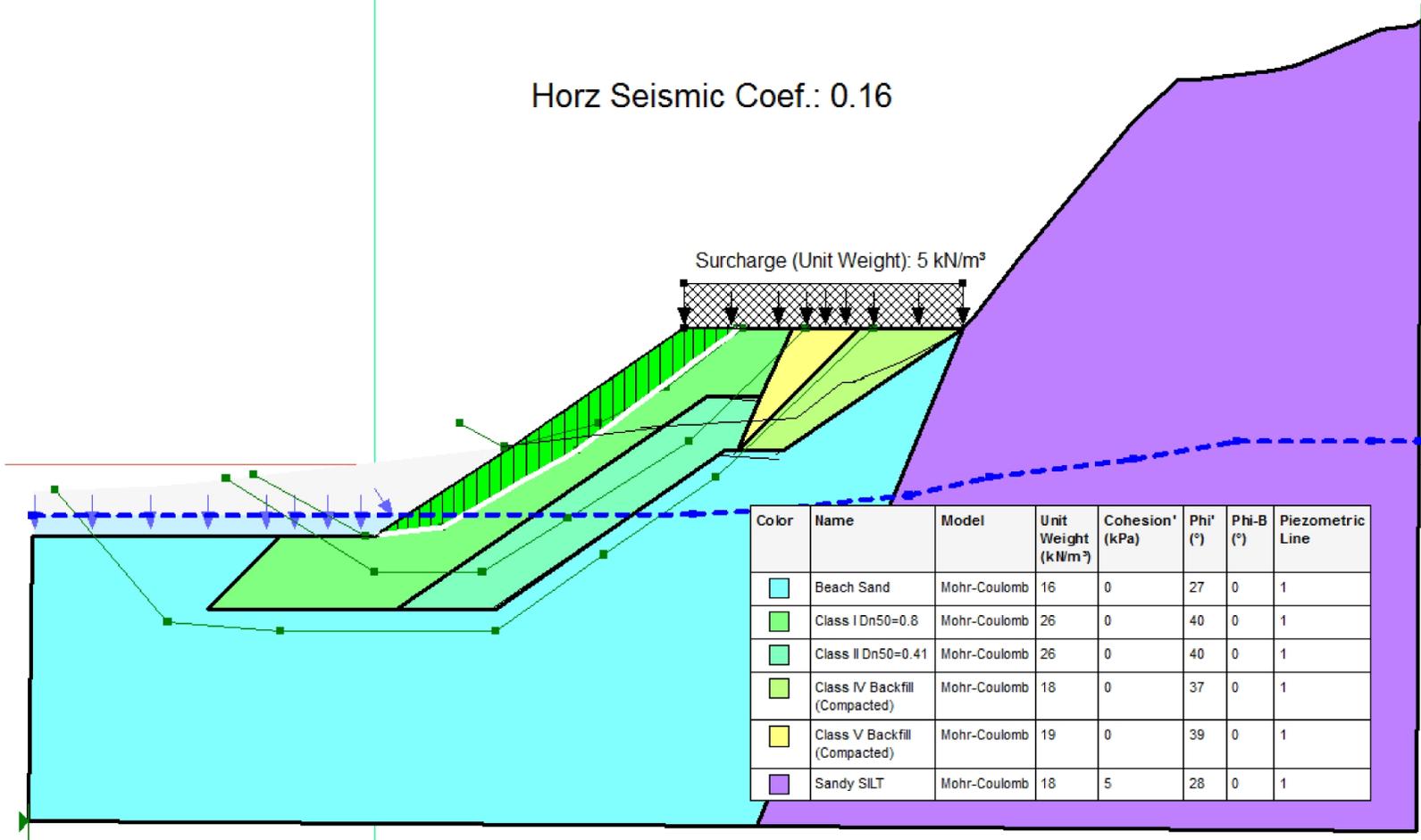
Notes:

- Showing critical slip circle

1.025

Horz Seismic Coef.: 0.16

Surcharge (Unit Weight): 5 kN/m<sup>3</sup>



Color	Name	Model	Unit Weight (kNm <sup>-3</sup> )	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Beach Sand	Mohr-Coulomb	16	0	27	0	1
	Class I Dn50=0.8	Mohr-Coulomb	26	0	40	0	1
	Class II Dn50=0.41	Mohr-Coulomb	26	0	40	0	1
	Class IV Backfill (Compacted)	Mohr-Coulomb	18	0	37	0	1
	Class V Backfill (Compacted)	Mohr-Coulomb	19	0	39	0	1
	Sandy SILT	Mohr-Coulomb	18	5	28	0	1

Issue	Description	Date	Approved	Name	Date
01	SlopeW	Aug18		Designed	August 18
				Drawn	August 18
				Checked	August 18
				Approved	August 18
				Scale @ NTS	Projection: -

		GHD Centre Level 3 27 Napier Street Freemans Bay Auckland 1011  Ph: (09) 370 8000 Fax: (09) 370 8001	Project:			
			Mauao Base Track Remediation Section C' – Eroded Beach Profile Earth Quake – Low Tide			
			Issued For: Revetment Design	Project Number: 51-37691	Sheet Number: GEO 12	Issue: 01

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# Appendix E – Safety in Design



## HSE040 Safety in Design Risk Assessment



Notes: \* Designs with significant quantities of dangerous goods may require detailed risk assessments under Dangerous Goods or Major Hazard legislation

\* Most industrial processes will require an industry specific assessment, e.g. HAZOP and/or Quantitative Risk Assessment for facilities that have chemical or high-pressure processes under Dangerous Goods or Major Hazard legislation.

Design Life Cycle:	Investigation and Design	Setup, Construction and Commissioning	Operation	Maintenance	Disposal		Date:	1/10/2018	Revision No:	1					
Job Name:	Mauao Base Track Remediation		Job No:	5137691	Client	Boffa Miskell		Design:	Soil Nail Wall/Revetment Construction						
People involved in Risk Assessment:		s 7(2)(a) – Private													
Design Ref	Design Life Cycle Stage <small>(Select from Drop Down Box)</small>	Hazards <small>What could cause injury or ill health, damage to property or damage to the environment</small>	Risk <small>What could go wrong and what might happen as a result</small>	Existing Control Measures	Initial Risk Rating			Potential Control Measures <small>(Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)</small>	Responsibility	By When	Decision / Status	Residual Risk Rating			Comments
					Severity	Likelihood	Risk Rating					Severity	Likelihood	Risk Rating	
5137691	Setup, Construction and Commissioning	Mobile plant & equipment	Moving plant - Poor site planning	Nil	C - Severe	3 - Possible	Moderate	Detailed programming and the use of zoned areas for different operations	Contractor	Prior to / during construction	Contractor to provide appropriate measures	C - Severe	1 - Very Unlikely	Low	
5137691	Setup, Construction and Commissioning	Instability	Overturning of plant - Poor working platform	Nil	C - Severe	2 - Unlikely	Low	Control platform construction and maintenance using working platform certification system	Contractor	During construction	Contractor to provide appropriate measures. Use of piling platform if required	C - Severe	1 - Very Unlikely	Low	
5137691	Setup, Construction and Commissioning	Excavation	Collapse of temporary slope - Change in ground conditions, over-excavation or excavation to the wrong profile	Nil	D - Critical	3 - Possible	Significant	Control the excavation process and provide continuous geotechnical assessment	Contractor	During construction	Contractor to provide appropriate measures	D - Critical	1 - Very Unlikely	Moderate	
5137691	Setup, Construction and Commissioning	Slips/Trips/Falls	Falls - Working on a slope during drilling	Nil	D - Critical	2 - Unlikely	Moderate	Use carousel to minimise work on the slope during drilling or provide rig protection system	Contractor	During construction	Contractor to provide appropriate measures	D - Critical	1 - Very Unlikely	Moderate	
5137691	Setup, Construction and Commissioning	Working at heights	- Working on a slope and crest to slope during facing and head plate fixing	Nil	C - Severe	2 - Unlikely	Low	Fix facing and head plates from cherry-picker or use harness. Comply with all relevant health and safety legislation and plans, including those related (but not limited) to edge protection and height ("Best practice guidelines for working at height in New Zealand" published by MBIE, April 2012).	Contractor	During construction	Contractor to provide appropriate measures	C - Severe	1 - Very Unlikely	Low	
5137691	Setup, Construction and Commissioning	Slips/Trips/Falls	Trips - Projecting soil nail elements	Nil	B - Major	3 - Possible	Low	Paint, highlight or cap projecting elements	Contractor	During construction	Contractor to provide appropriate measures	B - Major	1 - Very Unlikely	Negligible	
5137691	Operation	Ground water	Slope movement or failure due to elevated ground water	Nil	D - Critical	3 - Possible	Significant	Check design for onerous condition and invoke monitoring and maintenance regime	Contractor	During construction	Contractor to monitor groundwater. Advise GHD if seepages are noted. GHD to undertake regular site visits.	E - Catastrophic	1 - Very Unlikely	Moderate	Post-construction risks - Long-term slope stability
5137691	Setup, Construction and Commissioning	Hazardous substances/ Dangerous goods	Substances hazardous to health - Contaminated ground	Nil	D - Critical	3 - Possible	Significant	Control excavation process, protect or minimise runoff from site. PPE and other measures	Contractor /Owner	Prior to / during construction	Contractor to provide appropriate measures	C - Severe	1 - Very Unlikely	Low	Post-construction risks - Contaminated ground
5137691	Setup, Construction and Commissioning	Manual handling	Many components on site, such as the flexible facing and soil nails, will require manual handling.	Nil	B - Major	3 - Possible	Low	Ensure personnel are appropriately trained for manual handling on site. Develop safe work method statements for these procedures.	Contractor	Prior to / during construction	Contractor to provide appropriate measures	B - Major	2 - Unlikely	Negligible	

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment.	Risk What could go wrong and what might happen as a result.	Existing Control Measures	Initial Risk Rating			Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating			Comments
					Severity	Likelihood	Risk Rating					Severity	Likelihood	Risk Rating	
5137691	Setup, Construction and Commissioning	Access/egress, access ways, entrances/gates	Worksite includes an existing public track. Contractors plant may interact with the public during the construction phase.	Nil	A - Minor	2 - Unlikely	Negligible	Elimination: barricade work area to prevent public access.	Contractor	During Construction	Contractor to provide appropriate barricading	A - Minor	1 - Very Unlikely	Negligible	
5137691	Setup, Construction and Commissioning	Overhead/Underground Services	Existing underground and overhead utilities may exist within the worksite.	Nil	E- Catastrophic	3 - Possible	Extreme	Identify existing services. Locate services on site prior to undertaking any excavations. Coordinate with Utilities Owners. Design relocated services away from other buried structures where possible. Coordinate construction activities to avoid below ground works near to buried services and to remove overhead services as early as possible. Include relocated services on As-Built drawings.	Contractor	Prior to / during construction	Contractor to provide appropriate measures	E- Catastrophic	2 - Unlikely	Significant	
5137691	Setup, Construction and Commissioning	Ground conditions	Presence of unknown ground conditions below the footprint of the revetment structure, i.e shallow boulder field or sand to founding depth. Could lead to design changes with increased costs and delays to programme.	Nil	B - Major	4 - Likely	Low	Due to the limitations in place for completing a more intrusive Geotechnical site investigation on the shoreline in terms of resource consent, and lack of access, Scala Penetrometer data had to suffice for detailed design. The information from the Scala Penetrometer data was used to assume that a shallow boulder field may exist at a shallow depth. In order to account for this risk we have designed an alternative toe profile for the occurrence of either a shallow boulder field or a sand foundation to account for the variability in ground conditions. During excavation shallow obstructions such as boulders at depth should be assessed to determine the appropriate foundation design to apply.	The Engineer	During Construction	The Engineer to assess the ground conditions when foundations excavated and decide on the most appropriate design to apply.	A - Minor	4 - Likely	Low	
5137691	Setup, Construction and Commissioning	Tides, rough waves, storm surges	Swept into water, drowning	Nil	E- Catastrophic	2 - Unlikely	Significant	Contractor plan work around low tides and weather, working in pairs and having life jackets if working near water	Contractor	During construction	Contractor to provide appropriate measures	C- Severe	2 - Unlikely	Low	

GHD

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Document5

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	s 7(2)(a) ... Privacy					1/10/2018

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