29 January 2021

[redacted]
Tauranga City Council

Mauao Base Track Soil Nail Addendum Design Report

2-9b497.00

Dear [redacted]

1 Introduction

Tauranga City Council (TCC) has engaged WSP to undertake the design of further slope stability improvement works to a section of the Mauao Base Track immediately west of the existing slip repair on the southern side of Mauao (refer sheet C01). The existing repair involved retreating the slope above the track and installing soil nails and bored drains along with erosion protective matting on the cut face above the track and on the slip face below the track.

Further to a request from Mr [redacted] from TCC, WSP carried out a slope stability assessment for the slope promontory supporting a twin trunked Pohutukawa tree at the western end of the initial repair site in October 2020.

The geotechnical assessment concluded that there was no immediate risk to the track above, however the report identified that the slope below the Pohutukawa tree was marginally stable as the geomorphology suggested there was a potential tension crack above a lobe feature which supports the tree.

The geotechnical assessment then concluded that there was the potential for regressive failure of the slope if an initial failure near the crest of the slope were to occur which could affect the track in the future.

Based on this conclusion WSP recommended to stabilise the lobe feature with additional soil nails and drainage which was accepted by TCC.

This addendum design report describes the additional soil nail design and should be read in conjunction with the original reports titled “Mauao Base Track Reinstatement – Design Report by WSP dated 18 December 2018” and Mauao Base Track Reinstatement – Geotechnical Completion Report dated 24 June 2020.

2 Site Location

The site location is depicted on the appended plans C01 & C02. For a detailed description refer to the above referenced reports.

3 Geology

The site geology is described as follows taken from our Geotechnical Completion Report.

The geology encountered at the site (Figure 3, borehole logs 1 – 5, Appendix B) comprised a sequence of colluvium and air fall tephra units (above the level of the base track), alluvial deposits of the Matua Subgroup (directly below the base track) and a weakly welded ignimbrite (near the toe of the slope).

The weakly welded ignimbrite encountered at the base of the slope has characteristics similar to the Te Puna Ignimbrite described by Briggs et al. (1996)[1] *i.e. a non-welded to partially-welded, buff brown ignimbrite which weathers to a firm clay. It is plausible that Te Puna Ignimbrite could exist at this site given that sections have been described at Matakana Island, Pahoia, and Omokoroa (Briggs et al., 1996).*

The materials encountered in HA02 and HA05 are typical of the Matua Subgroup; interbedded, volcanic tephra derived clays, silts and sands (Briggs et al., 1996). The Matua Subgroup encompasses all sediment deposited in fluvial, estuarine and lacustrine regimes between approximately 2 million to 50 thousand years ago (Briggs et al., 1996). Shear vane readings indicate that some of the silts and clays are highly sensitive, meaning that these materials lose a significant amount of strength when the peak strength is overcome. Sensitive materials are typically wet to saturated due to the ability of the unique halloysite clay minerals to bind with pore water (Kluger et al., 2018[2]*).*

Ashes interbedded with colluvium were encountered above the Matua Subgroup. The lack of horizontal marker beds make it difficult to place these ashes within the Matua Subgroup or Hamilton Ashes, which typically overlies the Matua Subgroup in the wider Tauranga area. The colluvium encountered at the site is typified by the presence of rhyolite gravel and mottled colours. The thick sequence of colluvium (~3.5m) indicates that slope instability above the site has been an historically active process."

4 Geotechnical Ground Model

For this assessment, we have produced a ground model from our existing borehole information and observations. The geology of the slope comprises stiff brown clay from track level (possibly Hamilton Ashes) underlain by interbedded silty sand and sandy silt deposits (Matua Subgroup) to very stiff to hard clay (un-welded Te Puna Ignimbrite) at depth. The geotechnical ground model is presented in C02 and was used for the slope stability analysis presented in this report.

4.1 Groundwater

Groundwater was modelled as a perched water table within the interbedded silty sand and sandy silt deposits based on the groundwater levels measured in the original boreholes for normal (static) conditions and the levels were raised to simulate transient conditions.

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[1] Briggs, R.M., Hall, G.J., Harmsworth, G.R., Hollis, A.G., Houghton,B.F., Hughes, G.R., Morgan, M.D., Whitbread-Edwards, A.R. (1996). Geology of the Tauranga Area. Occasional Report No. 22, Department of Earth Sciences, University of Waikato.

[2] Kluger, M.O., Moon, V.G., Krieter, S., Lowe, D.J., Churchman, G.J., Hepp, D.A., Seibel, D., Jorat, E., Morz, T. (2016). A new attraction-detachment model for explaining flow sliding in clay-rich tephras. Geology, 45(2):131-134.

4.2 Geotechnical Design Parameters

Geotechnical design parameters have been assumed using, site geological observations, investigation data and back analysis of the slope models. The geotechnical design parameters are summarised in Table 1 below.

Table 1: Geotechnical design parameters

Material Type	Design Parameters		
	Unit Weight (γ) kN/m³	Effective Cohesion (C') kPa	Effective Friction Angle (ϕ')
Silty sand with some clay (Matua Subgroup)	15	4	30
Very stiff clay (TePuna Ignimbrite)	16	15	34
Very stiff to hard clay	18	20	34
Very stiff to hard clayey silt (Matua Subgroup)	16	10	32

5 Remediation Design

5.1 Seismicity

For derivation of seismic loads, the site is categorised as subsoil class C – shallow soil according to NZS 1170.5.2004. We have selected Class C as opposed to D as the underlying depth to rock on the southern side of Mauao is not well understood and therefore we have conservatively assumed Class C soils for seismic design.

Peak ground accelerations for the design have been derived from the NZTA Bridge Manual and NZS1170.5 as recommended in Section 5.1 of the New Zealand Geotechnical Society Module 1, Earthquake geotechnical engineering practice.

A summary of the seismic inputs used for the calculation of design accelerations is given below in Table 2.

Table 2: Seismic inputs derived from NZTABM and NZS1170.5

Site subsoil class	C
Importance level	2
Unweighted peak ground acceleration coefficient (C0,1000) for subsoil class C site in Tauranga	0.34
Design Life (used to derive the PGA)	50
Annual probability of exceedance for ULS earthquake design actions for cut slopes	1/100
Return period factor, (Ru)	0.5

ULS peak ground acceleration $PGA = C_{0,1000}\frac{R_u}{1.3}fg$	0.17

5.2 Design Standards and Method

Slope stability analysis has been determined using the computer program GeoStudio 2019 Slope W. The assessment was carried out using the widely accepted Morgenstern- Price limit equilibrium slope stability method. The slope model has been created using the geological profile determined from the survey and investigation data. Soil parameters were assessed using back analysis of the slope in conjunction review of the soil logs, prior to failure using assumed groundwater conditions.

Design of the soil nail reinforcement followed the method described in the Soil Nail Wall Reference Manual, FHWA-NHI-14-007 using a combination of Allowable Stress Design (ASD) and Load Resistance Factored Design (LRFD). Slope W software was used to perform the ASD.

The degree of stability of a slope is expressed as the factor of safety (FoS). A minimum factor of safety of 1.5 is often adopted for typical civil engineering projects where consequence of failure is high. For this design TCC has agreed to reduced target FoS for static and seismic design cases. The adopted FoS criteria is given below which is in accordance with FHWA-NHI-14-007 for non-critical structures.

Slope stability results are summarised in Table 3 below and the stability outputs are contained in Appendix C.

Table 3: Slope stability analysis summary

Analysis Case	Factor of Safety Achieved	Target Factor of Safety (as agreed with TCC)
Static (back analysis)	1.06	-
Static with soil nails installed	1.35	1.35
Static with soil nails installed + 6kPa maintenance vehicle surcharge	1.34	-
Static with transient groundwater conditions (Ru Method)	1.25	1.25
Static with saturated groundwater conditions	1.20	-
Seismic	1.06	1.00

The soil nails will be installed in a grid pattern below the track within the natural slope. The soil nails will be installed in a nail staggered pattern. The soil nail design is summarised in Table 4 below. Further details can be found in the appended design drawings in Appendix A and specification in Appendix D.

Table 4: Soil nail design summary

Soil Nails Below Track (Slip Face)	
Number of rows	9
Vertical spacing	1.5m
Horizontal spacing	1.5m
Nail Pattern	Staggered
Hole diameter	100mm
Hole inclination	15° from horizontal
Nail Bar	Treaded RB25, grade 500 steel, galvanised
Bar length	8m
Nail head	200x200x12 Grade 250mm steel plate, galvanised, with 25mm diameter bevelled washer and nut.
Grout strength	30MPa
Facing	Macmat R or equivalent
Factored nail tensile strength*	$\phi f_y A = 0.75 \times 500MPa \times 491mm^2 = 184.1kN/m$
Factored pull out resistance*	4.89kN/m/m (from slope W)

*Load factors taken from FHWA-NHI-14-007

5.3 Bored Horizontal Drains

Bored horizontal drains will be installed to tap seepages/ groundwater springs. The general positions are shown on the design drawings and may be adjusted to suit site conditions at the discretion of the geo professional. The bored horizontal drains will help to reduce water pressures in the slope and improve stability. Drains should be installed so they do not conflict with the installation of the soil nails. A summary of the proposed drains is shown in Table 5 below. Further drainage details can be found on the drawings and in the specification.

Table 5: Bored horizontal drains design summary

Number of drains	Estimated 2
Level	Refer to design drawings (Appendix A)
Horizontal spacing	3.0m (spaced to avoid soil nails)
Hole diameter	100mm
Hole inclination	Min 1/20 gradient
Pipe	65mm diameter PN9 (AS/NZS 1477:2006) PVC slotted as per specification
Drain length	10m

5.4 Verification and Proof Testing

Verification and proof testing should be undertaken as per the appended Geotechnical Specification contained in Appendix D.

5.5 Safety in Design

In accordance with the Health & Safety at Work Act 2015 safety in design has been considered for construction, maintenance, and decommissioning of the proposed works. Our safety in design register is contained in our original design report.

5.6 Slips from Slope Above Track

As we have not nailed the entire slope above the track, there is a remaining risk of slips and/ or erosion from areas outside those nailed. In the event of small failures from above the track then clearing of the debris would be required as part of the ongoing track maintenance and remedial repairs if necessary.

5.7 Stability of Trees

It must be noted that although the trees appeared stable at the time of our investigations we cannot comment on the ongoing stability of the trees which is outside the scope of this design. It must also be noted that failure of these trees could have a detrimental effect on the track or slope. We therefore recommend that on-going inspections by an arborist are undertaken to assess the condition, health and stability of the trees.

5.8 Coastal Erosion

Based on our recent monitoring to date at the site it is apparent that there has not been any notable coastal erosion at the toe of the slope. Therefore, we don't believe there is an immediate risk of coastal erosion however this may be an issue with future sea level rise and mitigation may need to be implemented as the need arises.

5.9 Limitations

This report ('**Report**') has been prepared by WSP exclusively for [Tauranga City Council] ('**Client**') in relation to this soil nail design report ('**Purpose**') and in accordance with the OOS referenced "Mauao Base track – Stage 2 Design and MSQA Services dated 30 October 2020. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

Prepared By: Reviewed By:

[redacted]

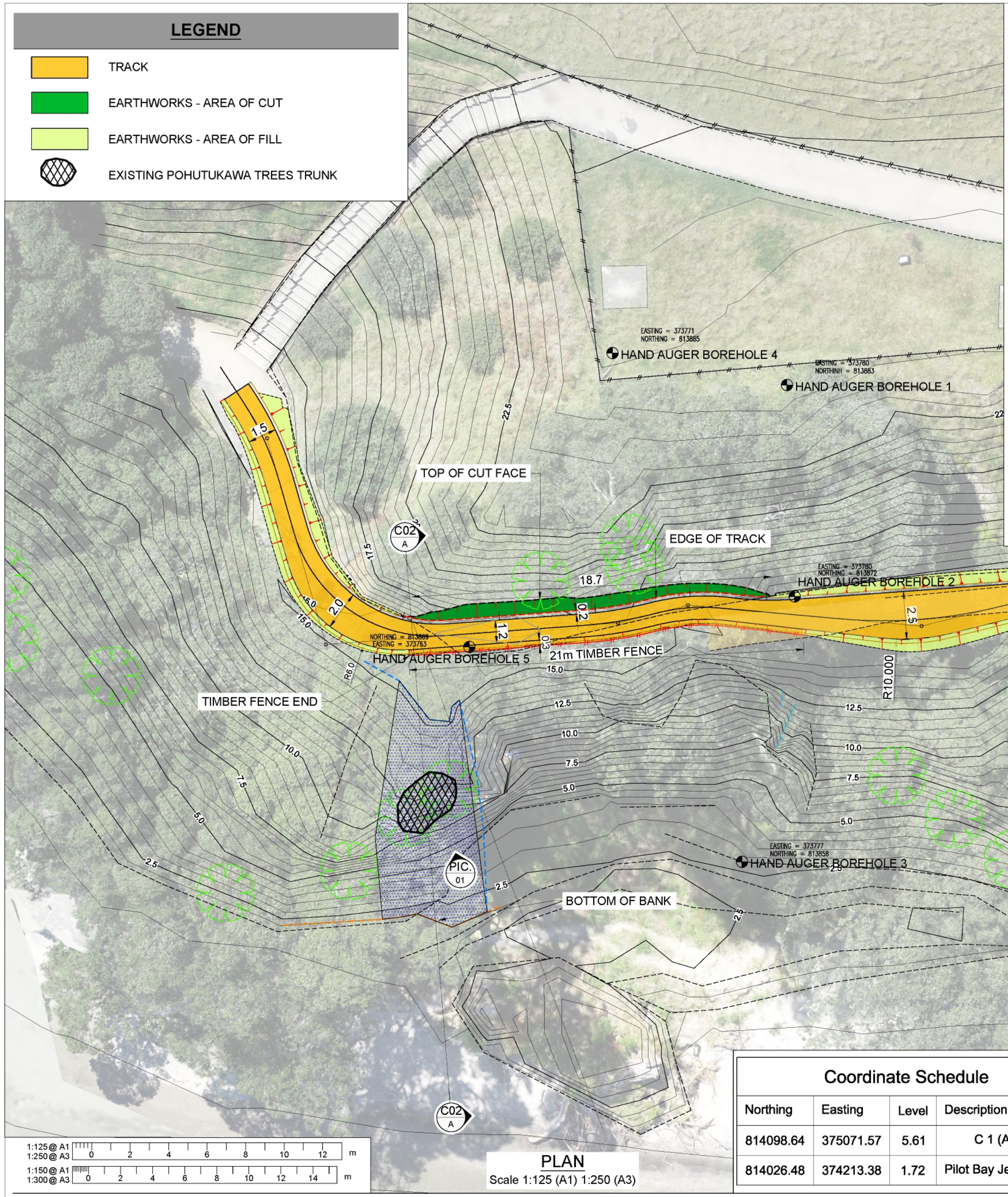
s 7(2)(a) ... Privacy

Appendix A - Drawings

TAURANGA CITY COUNCIL
MOUNT MAUNGANUI, TAURANGA
MAUAO BASE TRACK - STAGE 2 WORKS

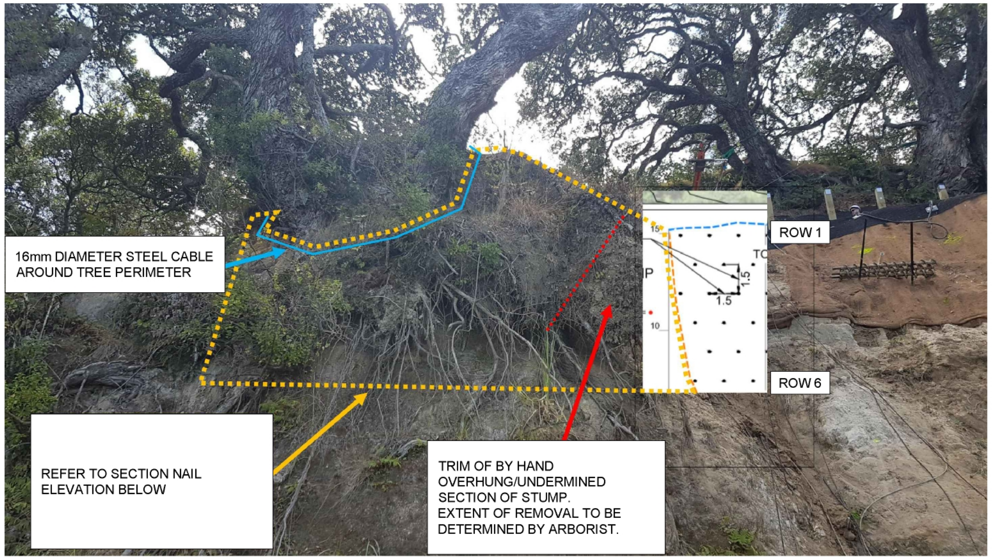
GEOTECHNICAL
SOIL NAIL DESIGN

Project No: 2-9B497.00
Date: 2020-12-22



PLAN

Scale 1:125 (A1) 1:250 (A3)



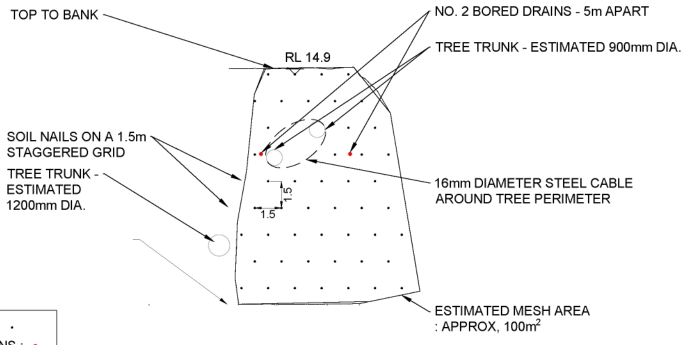
PICTURE 01 - TREE PROTECTION WORK (EARTH STABILITY)

N.T.S

DATUM NOTE	
HORIZONTAL PROJECTION	BAY OF PLENTY 2000 - PLENTM2000
SCALE FACTOR @ CENTRAL MERIDIAN	1.0000000
HORIZONTAL ORIGIN	Pilot Bay Jetty (AB4T)
VERTICAL DATUM	MOTURIKI 1953
VERTICAL ORIGIN	Pilot Bay Jetty (AB4T)

COMMENTS:

THIS WORK INCLUDES DATA WHICH IS LICENSED BY LAND INFORMATION NEW ZEALAND (LINZ) FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.



Coordinate Schedule

Northing	Easting	Level	Description
814098.64	375071.57	5.61	C 1 (AB5A)
814026.48	374213.38	1.72	Pilot Bay Jetty (AB4T)

LOCATION OF SOIL NAILS : ·
LOCATION OF BORED DRAINS : •
NO. OF SOIL NAILS = 48

SECTION - NAIL ELEVATION

Scale 1:150 (A1) 1:300 (A3)

REVISION	AMENDMENT	APPROVED	DATE
A	SOIL NAIL DESIGN	s 7(2)(a) – Privacy	2020-12-22

Tauranga City

wsp
Tauranga Office
+64 7 578 2089

PO Box 646
Tauranga 3140
New Zealand

GEOTECHNICAL

SCALES
AS NOTED

ORIGINAL SIZE
A1

DRAWN
s 7(2)(a)

DESIGNED
s 7(2)(a) – Privacy

APPROVED

DRAWING VERIFIED

DESIGN VERFIED

APPROVED DATE
2020-12-22

SOIL NAIL DESIGN

PROJECT
TAURANGA CITY COUNCIL
MOUNT MAUNGANUI, TAURANGA
MAUAO BASE TRACK - STAGE 2 WORKS

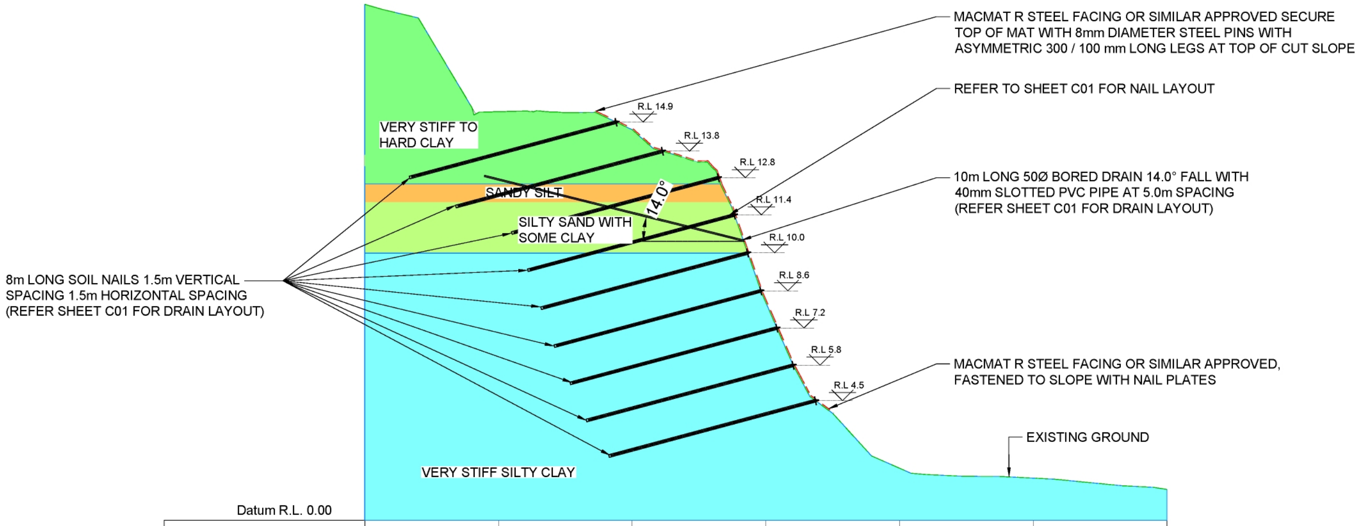
TITLE
STAGE 2 WORKS
PLAN & SECTION

WSP PROJECT NO. (SUB-PROJECT)
2-9B497.00

SHEET NO.
C01

REVISION
A

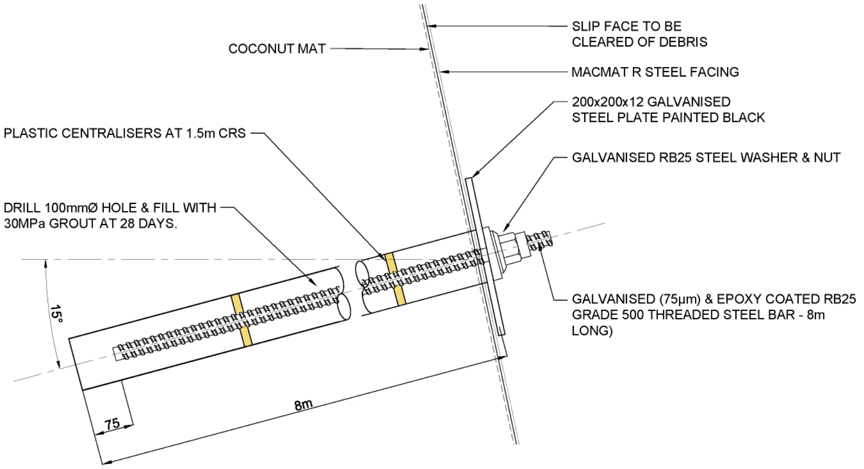
Original sheet size A1 (841x594) Plot Date 2020-12-22 at 11:34:22 AM \\corp.pbwan.net\ANZ\ProjectsNZ\29\2-9B497.00 Mauao Base Track - Stage 2 Detailed Desi\Home\05 Drawings\+Civil3D\2-9B463.00_GEOTECH-EXTRA SECTION.dwg C01



EXISTING LEVEL	19.31	15.14	14.62	8.15	1.95	1.58	1.15
PROPOSED LEVEL	19.31	15.29	14.62	8.15	1.95	1.58	1.15

SECTION A

Scale 1:100 (A1) 1:200 (A3)



TYPICAL SOIL NAIL DETAIL

Scale 1:5 (A1) 1:10 (A3)

NOTES

1. SOIL NAIL WORKING LOAD VARIES REFER TO SPECIFICATION FOR TESTING REQUIREMENTS.
2. LEVEL OF SOIL NAIL SHOWN IS APPROXIMATE ONLY.
3. BORED DRAINS TO BE LOCATED TO AVOID CONFLICT WITH NAILS.
4. NAILS TO BE LOCATED TO AVOID CONFLICT WITH EXISTING NAILS

1:5 @ A1 1:10 @ A3 0 50 100 150 200 250 300 350 400 450 500 mm
1:100 @ A1 1:200 @ A3 0 1 2 3 4 5 6 7 8 9 10 m

REVISION	AMENDMENT	APPROVED	DATE
A	SOIL NAIL DESIGN	s 7(2)(a) – Privacy	2020-12-22

Tauranga City

wsp
Tauranga Office
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Tauranga 3140
New Zealand

GEOTECHNICAL

SCALES
AS NOTED
ORIGINAL SIZE
A1
DRAWN | DESIGNED | APPROVED
s 7(2)(a) – Privacy
DRAWING VERIFIED | DESIGN VERIFIED | APPROVED DATE
2020-12-22

SOIL NAIL DESIGN

PROJECT
TAURANGA CITY COUNCIL
MOUNT MAUNGANUI, TAURANGA
MAUAO BASE TRACK - STAGE 2 WORKS

TITLE
STAGE 2 WORKS
LONG SECTION AND DETAIL

WSP PROJECT NO. (SUB-PROJECT): 2-9B497.00
SHEET NO.: C02
REVISION: A

0 10 mm 50 100 200 300 mm

Original sheet size A1 (841x594) Plot Date 2020-12-22 at 11:35:14 AM \\corp.pbwan.net\ANZ\ProjectsNZ\29\2-9B497.00 Mauao Base Track - Stage 2 Detailed Desi\Home\05 Drawings\+Civil3D\2-9B463.00_GEOTECH-EXTRA SECTION.dwg C02

Appendix B – Borehole Records

Auger Scala No. HA01

Project: Mount Base Track Investigations
Client: Tauranga City Council
Contractor:
Project No.: 2-9B463.00

Location: Mauao
Coordinates: Not established
Ref. Grid: n/a
R.L.: Not established

SOIL TESTS

DEPTH (m)	DESCRIPTION	SHEAR STRENGTH (kPa)
	Topsoil with trace rootlets and trace pipi shells up to 15mm	
	SILT, trace sand and rootlets, orange brown	80/16
	SILT, minor sand, trace gravel: moist	67/13
1	SILT, some clay: orange brown, moist, moderately plastic	113/16
	Silty CLAY, trace sand; orange brown, moist, moderately plastic becoming sandy	
2	becoming brown, moisture increasing, becoming wet	63/16
		80/27
	Sandy SILT; brown, wet, moderately plastic, trace pyrite flecks	
	SAND; brown, wet, fine to medium, loose	
	Silty SAND, trace fine gravel; brown with orange mottles	
3	SILT, some sand: brown with orange and black mottles trace medium ryholite gravel, angular	
	Clayey SILT, trace sand; brown mottled orange, moist, high plasticity becoming light brown	188/87
	CLAY, trace sand; light brown with orange mottles, moist, high plasticity	188+
4	becoming wet	188+
	CLAY, trace silt; orange brown, moist, high plasticity	188+
	Silty CLAY; brown, black mottles, wet, high plasticity	188+

GRAPHIC LOG | WATER LEVEL | R.L. (m) | DEPTH (m) | SCALA PENETROMETER (Blows per mm) | OTHER TESTS | SAMPLES

0 2 4 6 8 10 12 14 16 18 20

0 4 8 13 18 23 28 33 38 43 48
Inferred CBR (%)

END OF AUGER AT 5m - Target Depth Reached

Test Methods:
Field Description of Soil and Rock, NZ Geotechnical Soc., 2005

Notes:

Date Tested:
Tested by: [redacted]
Date Reported:

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Approved by

Signed by:
Designation:
Date: 18/12/2019

Auger Scala No. HA02

Project:	Mount Base Track Investigations	*Location:*	Mauao
Client:	Tauranga City Council	*Coordinates:*	Not established
Contractor:		*Ref. Grid:*	n/a
Project No.:	2-9B463.00	*R.L.:*	Not established

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	WATER LEVEL	R.L. (m)	DEPTH (m)	SOIL TESTS SCALA PENETROMETER (Blows per mm) 0 2 4 6 8 10 12 14 16 18 20	SOIL TESTS SHEAR STRENGTH (kPa)	SOIL TESTS OTHER TESTS	SOIL TESTS SAMPLES
	CLAY; orange brown with brown streaks, moist, high plasticity								
	CLAY; light brown, moist, high plasticity becoming wet						112/12		
							129/16		
1	SILT, some sand and clay; brown, wet, high plasticity				1				
	Sandy CLAY; brown, wet, high plasticity, soft						121/20		
							188+		
	black specs with limonite staining								
2	SAND with minor silt; light greyish brown, wet				2		90/32		
	with black flecks						80/32		
	Sandy SILT; light brown with black specs, saturated , pumiceous						94		
3					3				
	becoming wet saturated, very soft, highly sensitive - possible perched water table		▼ 3.3m				43/12		
							123/21		
4					4		76/12		
							124/32		
	Sandy SILT; light brown, sturated, very soft, highly sensitive					0 4 8 13 18 23 28 33 38 43 48 Inferred CBR (%)			

END OF AUGER AT 5m - Target Depth Reached

Test Methods:

Field Description of Soil and Rock, NZ Geotechnical Soc., 2005

Notes:

Date Tested:

Tested by: s 7(2)(a) ... Privacy

Date Reported:

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Signed by:

Designation:

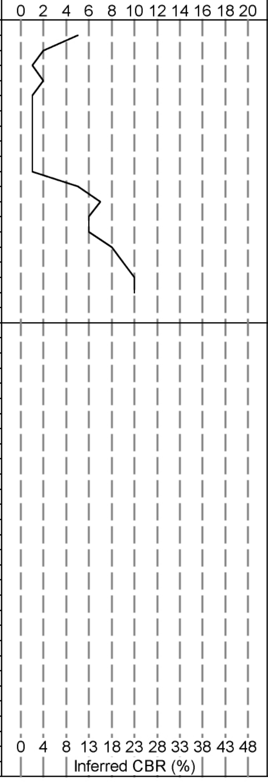
Date: 18/12/2019

Auger Scala No. HA03

Project: Mount Base Track Investigations
Client: Tauranga City Council
Contractor:
Project No.: 2-9B463.00

Location: Mauao
Coordinates: Not established
Ref. Grid: n/a
R.L.: Not established

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	WATER LEVEL	R.L. (m)	DEPTH (m)	SCALA PENETROMETER (Blows per 100mm)	SHEAR STRENGTH (kPa)	OTHER TESTS	SAMPLES
	Sandy SILT; gey mottled, wet highly plastic (slip debris)								
	Clayey sandy SILT; dark brown, mottled, wet high plasticity (slip debris)						60/11 62/5		
1	SAND; grey, wet				1				
	SAND; dark grey, trace fine gravel becoming moist. (beach sand)								
	SAND, fine to coarse; grey, moist with trace shells becoming wet/ saturated								
2	water table encountered at 1.8m tidaly controlled END OF AUGER AT 2m - No Sample Recovery		2m		2				
3					3				
4					4				



Test Methods:

Field Description of Soil and Rock, NZ Geotechnical Soc., 2005
Determination of the Penetration Resistance of a Soil, NZS 4402 Test 6.5.2:1988
Inferred CBR values taken from AustRoads Pavement Design Manual, 2004

Notes:

Date Tested:
Tested by: s 7(2)(a) ... Privacy
Date Reported:

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Signed by:
Designation:
Date: 18/12/2019

Auger Scala No. HA04

Project:	Mount Base Track Investigations	*Location:*	Mauao
Client:	Tauranga City Council	*Coordinates:*	Not established
Contractor:		*Ref. Grid:*	n/a
Project No.:	2-9B463.00	*R.L.:*	Not established

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	WATER LEVEL	R.L. (m)	DEPTH (m)	SOIL TESTS SCALA PENETROMETER (Blows per 100mm) 0 2 4 6 8 10 12 14 16 18 20	SHEAR STRENGTH (kPa)	OTHER TESTS	SAMPLES
	Topsoil, rootlets								
	SILT, trace sand and gravel with some clay						148/32		
1	becoming orange brown, no clay, moist				1		188+ 80/16		
	Sandy SILT; orange brown, moist, moderately plastic						64/16		
2	minor sand				2		105/27		
	Sand, minor silt; light brown, moist, becoming wet								
	fine sand						78/20		
3	Clayey SILT, trace sand and gravel, brown with orange mottles, moist, moderately plastic				3				
	CLAY, with minor silt and trace medium gravel, angular, moist, highly plastic. limonite gravel. (coluvium)						188+		
	CLAY, trace sand; orange brown, mottled, moist, high plasticity						188+		
4	with grey streaks				4		188+		
	becoming wet						188+		
	unable to auger - too hard END OF AUGER AT 4.65m - Unable to Advance Auger - Too Hard					0 4 8 13 18 23 28 33 38 43 48 Inferred CBR (%)			

Test Methods:

Field Description of Soil and Rock, NZ Geotechnical Soc., 2005
Determination of the Penetration Resistance of a Soil, NZS 4402 Test 6.5.2:1988
Inferred CBR values taken from AustRoads Pavement Design Manual, 2004

Notes:

Date Tested:

Tested by: [redacted]

Date Reported:

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Approved by

Signed by:

Designation:

Date: 18/12/2019

Auger Scala No. HA05

Project: Mount Base Track Investigations
Client: Tauranga City Council
Contractor:
Project No.: 2-9B463.00

Location: Mauao
Coordinates: Not established
Ref. Grid: n/a
R.L.: Not established

DEPTH (m)	DESCRIPTION	WATER LEVEL	R.L. (m)	SCALA PENETROMETER (Blows per mm)	SHEAR STRENGTH (kPa)	OTHER TESTS	SAMPLES
	Sandy CLAY; orange brown, dry, friable						
	CIAY, with minor sand; orange brown, moist, highly plastic				166		
					164/24		
	CLAY, minor sand; light brown with black flecks				105/16		
1							
	CLAY, with some silt, and minor sand; orange brown, moist, highly plastic				185/32		
					188+		
	with black streaks						
2	CLAY, with some sand; orange brown, moist, high plasticity				188+		
	Clayey SILT, with some sand and trace gravel; light brown, moist, high plasticity, appears soft				102/19		
	becoming wet						
	Clayey sandy SILT; light brown, wet, high plasticity, soft				188+		
3							
	Sandy SILT, minor clay, light brown, moist, moderately plastic				164/24		
	Silty SAND; light brown, moist						
	Sandy SILT				118/35		
	Silty SAND						
	Sandy SILT; light whitish brown, moist, pumicieous						
4	SAND; light whitish brown, moist pumiceous				86/56		
	Silty fine SAND, with some clay; light brown and grey, wet, highly plastic, very soft						

SOIL TESTS

0 2 4 6 8 10 12 14 16 18 20

0 4 8 13 18 23 28 33 38 43 48
Inferred CBR (%)

END OF AUGER AT 5m - Target Depth Reached

Test Methods:
Field Description of Soil and Rock, NZ Geotechnical Soc., 2005

Notes:

Date Tested:
Tested by: s 7(2)(a) … Privacy
Date Reported:

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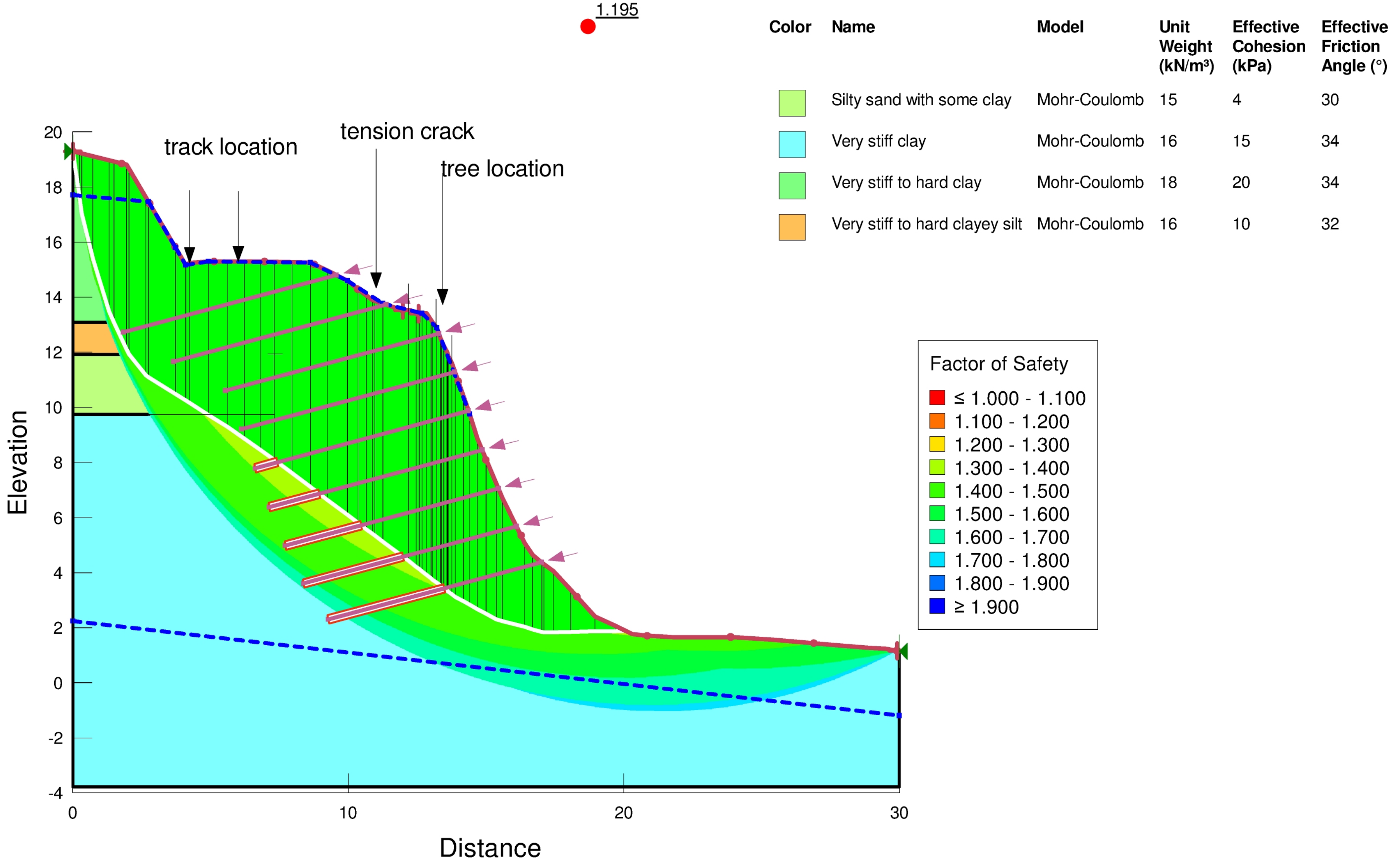
Approved by

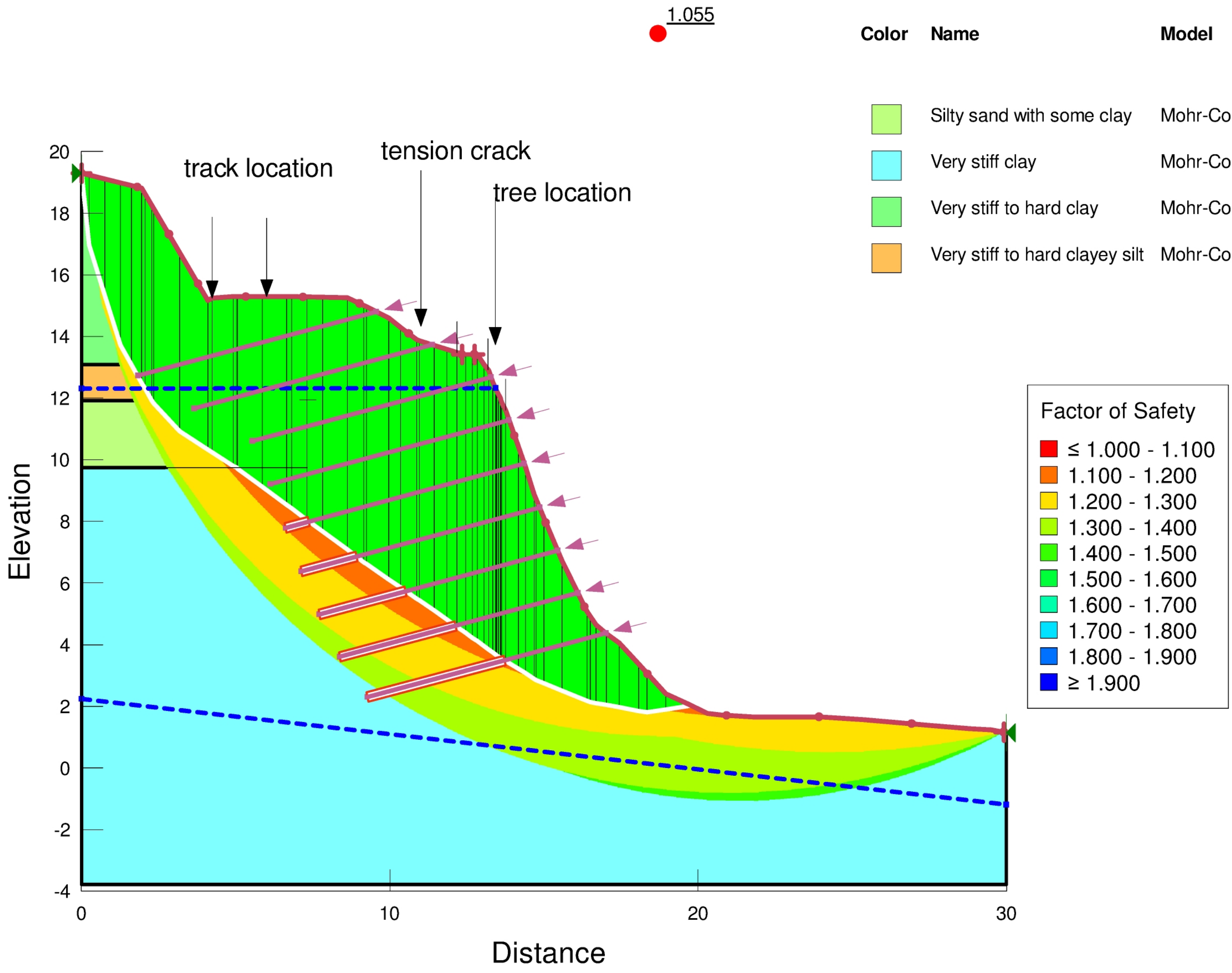
Signed by:
Designation:
Date: 18/12/2019

Appendix C – Slope Stability Results



Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
🟩	Silty sand with some clay	Mohr-Coulomb	15	4	30
🟦	Very stiff clay	Mohr-Coulomb	16	15	34
🟩	Very stiff to hard clay	Mohr-Coulomb	18	20	34
🟧	Very stiff to hard clayey silt	Mohr-Coulomb	16	10	32

Project: **Mauao Base Track**	Model	SLOPE/W	Proj No.	2-9B463.00
Analysis: Section 1_Saturated	Method	Morgenstern-Price	Date:	22/12/2020
	PGA	g	Scale	1:150
Modelled By: s 7(2)(a) ... Privacy / Checked By: Name	FOS	1.195	Sheet No.	



Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
🟩	Silty sand with some clay	Mohr-Coulomb	15	4	30
🟦	Very stiff clay	Mohr-Coulomb	16	15	34
🟩	Very stiff to hard clay	Mohr-Coulomb	18	20	34
🟧	Very stiff to hard clayey silt	Mohr-Coulomb	16	10	32

Factor of Safety

- 🟥 ≤ 1.000 - 1.100
- 🟧 1.100 - 1.200
- 🟨 1.200 - 1.300
- 🟩 1.300 - 1.400
- 🟩 1.400 - 1.500
- 🟩 1.500 - 1.600
- 🟩 1.600 - 1.700
- 🟦 1.700 - 1.800
- 🟦 1.800 - 1.900
- 🟦 ≥ 1.900

Project: **Mauao Base Track**

Analysis: Section 1_Seismic_Anchors

Modelled By: s 7(2)(a) … Privacy

Checked By: Name

Model	SLOPE/W	Proj No.	2-9B463.00
Method	Morgenstern-Price	Date:	22/12/2020
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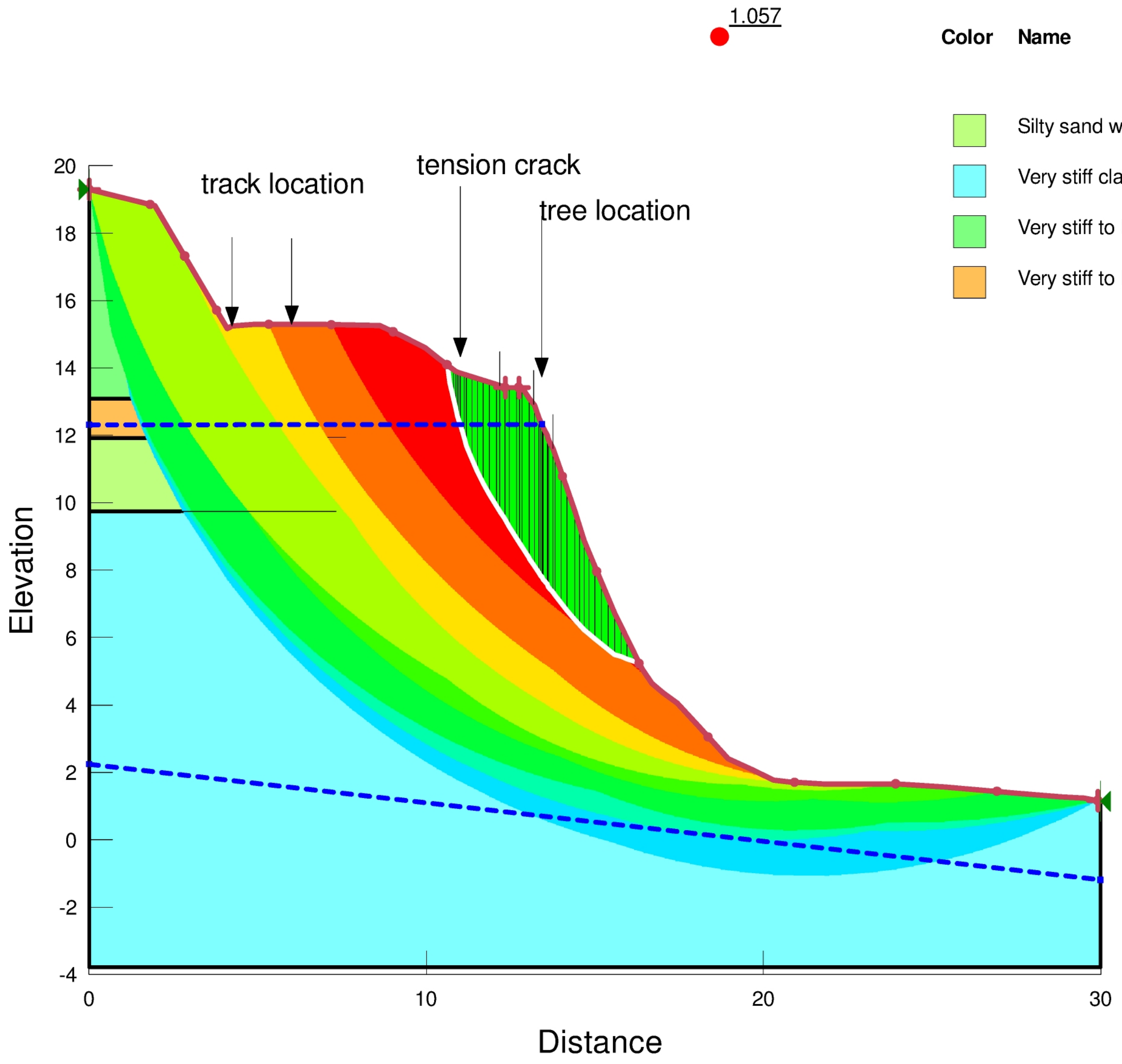
FOS	1.055	Sheet No.	



Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
🟩	Silty sand with some clay	Mohr-Coulomb	15	4	30
🟦	Very stiff clay	Mohr-Coulomb	16	15	34
🟩	Very stiff to hard clay	Mohr-Coulomb	18	20	34
🟧	Very stiff to hard clayey silt	Mohr-Coulomb	16	10	32

Factor of Safety

- 🟥 ≤ 1.000 - 1.100
- 🟧 1.100 - 1.200
- 🟨 1.200 - 1.300
- 🟩 1.300 - 1.400
- 🟩 1.400 - 1.500
- 🟩 1.500 - 1.600
- 🟩 1.600 - 1.700
- 🟦 1.700 - 1.800
- 🟦 1.800 - 1.900
- 🟦 ≥ 1.900

Project: **Mauao Base Track**

Analysis: Section 1_Static

Modelled By: s 7(2)(a) … Privacy

Checked By: Name

Model	SLOPE/W	Proj No.	2-9B463.00
Method	Morgenstern-Price	Date:	22/12/2020
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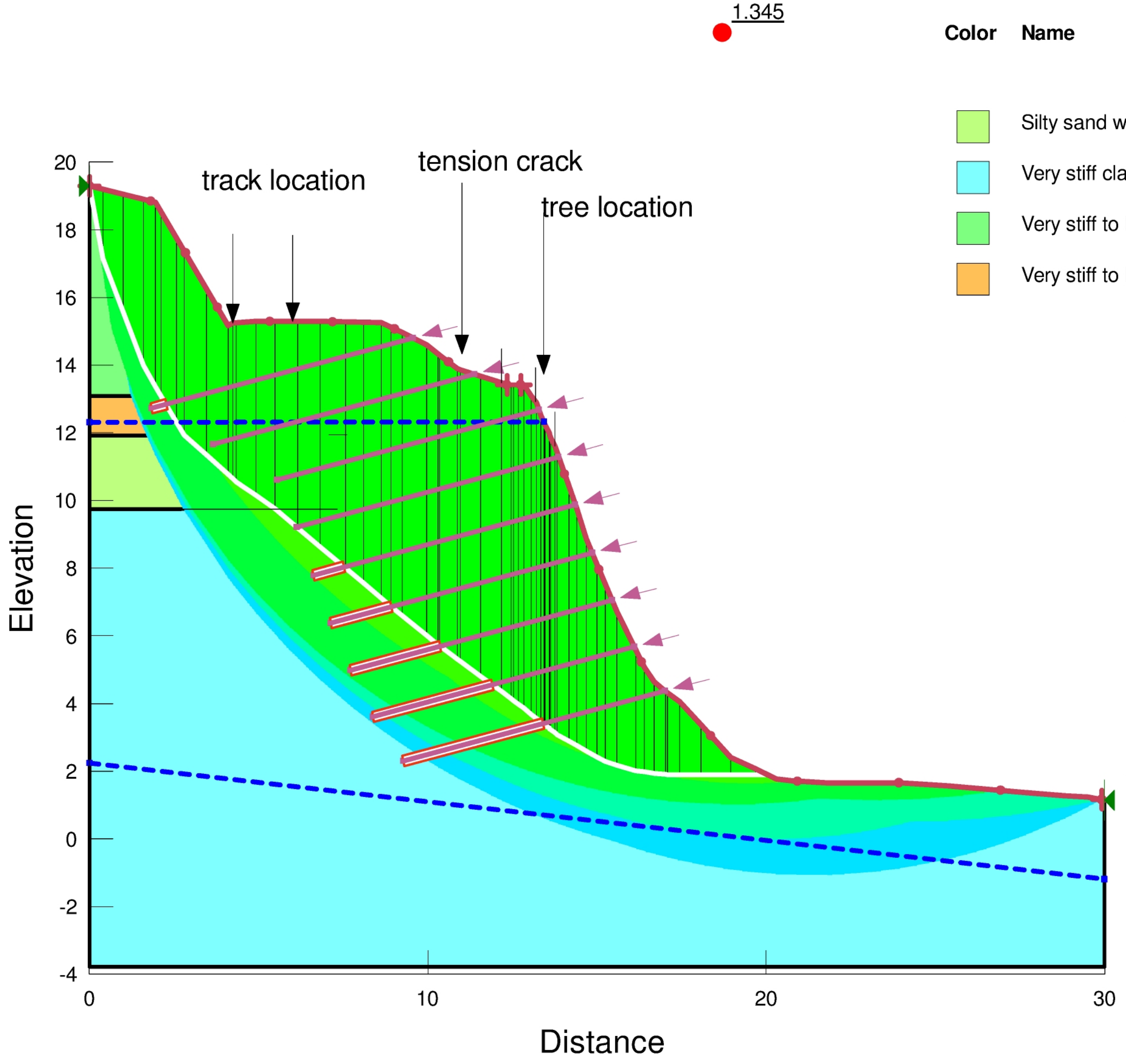
FOS	1.057	Sheet No.	



Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
🟩	Silty sand with some clay	Mohr-Coulomb	15	4	30
🟦	Very stiff clay	Mohr-Coulomb	16	15	34
🟩	Very stiff to hard clay	Mohr-Coulomb	18	20	34
🟧	Very stiff to hard clayey silt	Mohr-Coulomb	16	10	32

Factor of Safety	
🟥	≤ 1.000 - 1.100
🟧	1.100 - 1.200
🟨	1.200 - 1.300
🟩	1.300 - 1.400
🟩	1.400 - 1.500
🟩	1.500 - 1.600
🟩	1.600 - 1.700
🟦	1.700 - 1.800
🟦	1.800 - 1.900
🟦	≥ 1.900

Project: **Mauao Base Track**

Analysis: Section 1_Static_Anchors

Modelled By: s 7(2)(a) ... Privacy

Checked By: Name

Model	SLOPE/W	Proj No.	2-9B463.00
Method	Morgenstern-Price	Date:	22/12/2020
PGA	g	Scale	1:150
FOS	1.345	Sheet No.	

Appendix D - Specification

Mauao Base Track – Stage 2 Works – Project Specification

This specification relates to the Mauao Base Track stage two works using soil nailing, with geosynthetic facing and installation of bored horizontal drains as shown on the drawings:

- C01 & C02 Revision A.

1 General

1.1 Setting Out

The Contractor shall be responsible for the correct set-out of all works based on coordinates supplied by the Engineer. The Engineer shall provide the Contractor with a reference point for set-out.

On completion of the set-out of the works at the site, the Contractor shall immediately advise the Engineer for the purposes of checking the set-out. No other works shall be carried out until this has been checked and approved by the Engineer.

If the set out is found to be incorrect, the works shall again be set out by the Contractor and re-checked by the Engineer.

1.2 Service Locate and Protection

The Contractor shall familiarise themselves with all underground services prior to start of any site works and adequately mark and identify underground services within the site works.

2 Soil Nail Requirements

2.1 Documents

The documents listed below and cited in the Clauses that follow are part of this specification. However, this specification takes precedence in the event of it being at variance with the cited document:

- NZS 3109:1997 Concrete construction
  NZS 3112.4:1986 Tests relating to grout
  NZS 3112.2:1986 Tests relating to determination of strength of concrete. FHWA0-IF-03-017 Pull-out tests
  AS/NZS 1477:2006 PVC pipes and fittings for pressure applications
  MacMat® and MacMat® R Installation Guidelines Int / IG / MMR / Rev: 02, Nov 2010

3 Materials

3.1 Soil Nail Reinforcing Bar

Soil nail bars shall be those stated in the design drawings or an equivalent as approved by the Engineer. Soil nail bars shall be properly labelled and shall be kept protected from dirt, rust and any deleterious substances prior to and during installation. Soil nail bars shall be rejected if damaged as a result of abrasion, cuts, nicks, welds, and weld splatter, handling, placing and fabrication. Soil nail bars shall be galvanised (75μm) to the requirement stated in the design drawings.

3.2 Soil Nail Grout

The grout shall be neat cement grout or similar as approved by the Engineer. The grout shall achieve a minimum characteristic strength as stated in the design drawings after 28 days.

The Contractor shall engage an IANZ accredited laboratory to undertake two compressive strength tests for every batch of grout at 1, 7 and 28 days in accordance with NZS 3112.4. Grout test results shall be supplied to the Engineer within 24 hours of testing.

The grout water/cement ratio by weight shall be below 0.45 and bleed at 20˚C shall be less than 2% after 3 hours from mixing. No admixtures shall be permitted without the Engineer's prior approval. Standard flow cone tests for the grout shall be carried out in accordance with NZS 3112 at the Contractor's expense.

3.3 Soil Nail Hole Drilling

The inclination and spacing of drill holes shall be those as shown on the drawings. The Contractor may vary the inclination and spacing as approved by the Engineer to avoid conflicts such as tree roots or to suit the drilling rig. The soil nails in adjacent rows shall be offset in a staggered drill pattern as shown on the design drawings.

3.4 Soil Nail Bar Installation

Each soil nail bar shall be centralised in the drill hole using centralizers as shown on the drawings. The centralizers shall be installed at an approximate spacing as shown on the drawings.

If necessary, geotextile grout socks should be utilised to minimise loss of grout. Socks shall be pre-assembled prior to installation of soil nail bars.

The drill hole shall be checked to ensure that it is clear of debris prior to installation of the soil nail bar. The soil nail bar shall be inserted in the drill hole to the minimum design length but shall not be pushed beyond the drill hole length.

3.5 Soil Nail Grouting

Grout shall be injected through a grout pipe from the lowest point upwards. The grout shall flow continuously as the casing is withdrawn. The withdrawal rate shall be controlled to ensure that the end of the casing is always below the grout. The Contractor shall record the grout volume and grout consistency. The grout tube shall be removed from the drill hole after the grouting is completed.

3.6 Reinforced Mat Facing

The Contractor shall use MACMAT R (steel) or equivalent facing. If the Contractor proposes an alternative, the proposed alternative reinforced mat facing material should be submitted to the Engineer for approval before construction. The reinforced mat facing shall be installed in accordance with manufacturer’s instructions and guidelines.

Prior to installing MACMAT R, coconut matting shall be installed below the MACMAT R to prevent migration of fines. Refer to drawings for details.

3.7 Soil Nail Head Installation

Bearing plates shall be placed firmly against the new slope/wall facing with bevelled washers. Nuts shall be tightened by using a large hand wrench.

3.8 Bored Horizontal Drains

The Contractor shall construct bored horizontal drains in the locations and at the grades shown on the Construction Drawings and to the requirements set out below.

The work shall be carried out by persons who have the equipment and a proven track record to carry out this type of work.

The outlet of the pipes shall be terminated a minimum distance of 500mm beyond the face of the slope. Details are given in the Construction Drawings. The bored diameter in the ground shall not exceed 50mm.

PVC pipes for bored drains shall be Class PN9 pressure pipes complying with AS/NZS 1477:2006. Circumferential slots, 2.0mm wide, shall be machine cut and have a length of at least 20mm each on the 40mm pipe. The slots shall be located in pairs in the upper half of the pipe on the same circumferential section. The pair of slots shall be spaced to give 10 pairs every 100mm length. The maximum length of pipe without slots shall be 100mm. The slots shall be machined and free of swarf or burred edges. Hacksaw slots are unacceptable. Pipes shall be unslotted from the discharge point to 1m into the bored hole. The outer anulus between the borehole and the drain pipe OD should be blocked with a grout plug at the slip face to prevent weeping at the face and ensure water drains to the end of the pipe.

The bored drains shall be inclined a minimum gradient above the horizontal of 1/100 to give drainage towards the outlet, as shown on the Construction Drawings.

The Contractor shall clean out the bored drains using low pressure water flushing within three months of completion.

4 Soil Nail Testing

4.1 General Requirements

The Contractor shall perform a minimum of one 'Verification' test for each different anchor length to be used in the design. Bare rods may be used for the sacrificial verification test anchors.

'Proof' tests shall be undertaken for at least 5% of the proposed soil nails. The Engineer may require extra tests based on the results of the testing results. Installation of additional soil nails may also be required if the testing results are unsatisfactory.

Soil nail testing shall not be performed until the grout has reached a minimum compressive strength of 70% of the design strength.

The Engineer shall be given a minimum of 24-hour notice prior to the first 'Verification' or 'Proof' test. The Engineer or his representative shall be present during the above tests. The Contractor shall be responsible for recording, analysing and interpreting all test results and reporting the data to the Engineer for review and approval.

4.2 Testing Equipment

The Contractor shall design the test frame and reaction system, which should be submitted to the Engineer for approval at least 48 hours before commencing the testing. All testing equipment shall be calibrated and checked to be in good working condition prior to each test.

The maximum jack force and pressure gauge shall not be less than 150% of the required test load with an accuracy of ±1% of the required test load. Dial gauges shall have an accuracy of ±0.02mm to measure deformation during creep test and shall have an accuracy of ±0.2mm to measure deformation during other load increments. The dial gauges shall have sufficient travel to allow the test to be completed without having to reset the gauges. The gauges shall be supported independently of the jack, reaction frame or wall local to the test site.

During testing, the jacking equipment shall be placed over the nail in such a manner that the jack, bearing plates, load cell, and jacking anchorage are all aligned. The jack shall be positioned at the beginning of the test such that unloading and repositioning of the jack during the test is not required.

4.3 Verification Test

The Verification Test shall be undertaken as per the load increments given in the following table in accordance with section 9.4 of FHWA-NHI-14-007, FHWA GEC 007, February 2015 or otherwise stated in this document.

The verification test anchors shall have a 4m bonded zone.

- The Verification Test Load is 33kN.

Verification test anchors shall be incrementally loaded as per the following schedule.

Load increment (Verification Test Load)	Hold Time (min)
Alignment load (AL)	1
0.13 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.25 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.38 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.50 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.63 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.75 VTL (Creep Test)	60 (recorded at 1, 2, 4, 5, 6, 10, 20, 30, 50, 60)
0.88 VTL	10
1.00 VTL	10
Alignment load (AL)	1

Notes: (1) AL = alignment load, which is commonly less than or equal to 0.025 VTL.

(2) Soil movement must be measured after each load increment has been achieved and at each time step.

(3) Permanent soil nail movement must also be recorded.

The Contractor must record soil nail movements at each load increment. As noted above, each load increment is held for at least 10 minutes. Creep tests are performed at 0.75 VTL. Test loads excess of this minimum and preferably to pullout failure are recommended.

Test acceptance criteria require that:

- Pullout does not occur at loads less than 1.00 VTL.
- The total movement (Δ_{VTL}) measured at VTL must exceed 80 percent of the theoretical elastic elongation of the unbonded length (L_{UB}), as defined below.
- The creep movement does not exceed the criteria presented in section 4.4.1.

4.4 Proof Test (Acceptance)

The Proof Test shall be undertaken as per the load increments given in the following table in accordance with section 9.4 of FHWA-NHI-14-007, FHWA GEC 007, February 2015.

The proof test Anchors shall have a 4m bonded zone.

- The Proof Test Load is 25kN.

Proof test anchors shall be incrementally loaded as per the following schedule.

Load increment (Proof Test Load)	Minimum period of observation (min)
Alignment load (AL)	1
0.17 PTL	Until Movement Stabilises
0.33 PTL	Until Movement Stabilises
0.50 PTL	Until Movement Stabilises
0.67 PTL	Until Movement Stabilises
0.83 PTL	Until Movement Stabilises
1.00 PTL (Creep Test)	10 recorded at 1, 2, 4, 5, 6 and 10
Alignment load (AL)	1

Notes: (1) AL = alignment load, which should be AL≤0.0025 PTL.

(2) If the soil nail movement measured between 1 and 10 minutes exceeds 0.04 in., PTL must be

maintained for 50 additional minutes and movements must be recorded at 20, 30, 50 and 60 minutes. The permanent soil movement must also be recorded.

(3) Times are measured after the target load had been achieved in each increment.

(4) If the soil reinforced with nails are relatively susceptible to deformation of creep, it is

recommended to hold each load increment for 10 minutes and to record the soil nail movement at 1, 2, 5 and 10 minutes.

4.4.1 *Details of Creep Tests*

Creep test, which are part of the verification and proof tests are conducted at a specified, constant test load, with displacement recorded at specified time intervals. The deflection-versus-log-time results are plotted om a semi-log graph, and are compared with the acceptance criteria presented in the construction specifications.

Acceptance criteria for the creep movement require that:

Verification Tests

- The creep movement between the 1- and 10- minutes readings at 0.75 VTL is less than 1.016mm.
- The creep movement between the 6- and 60- minute readings at 0.75 VTL is less than 2.032mm.
- The creep rate is linear or decreasing throughout the creep test load-hold period.

Proof Tests

- The creep movement is less than 1.016mm. Between the 1- and 10- minute readings.
- If the movement is exceeded, PTL must be maintained for an additional 50 minutes with readings recorded at 20, 30, 50 and 60 minutes.
- If the creep test is extended, the creep movement between the 6- and 60- minute readings is less than 2.032mm.

4.5 Hydroseeding

Following installation of MacMat and soil nails the site shall be hydroseeded with a seed mix approved by TCC. The hydroseed area shall include the stage 1 batter and slip face.

5 Construction Records

The contractor shall keep construction records for every nail and bored drain constructed. The construction records shall contain the following information as a minimum:

- Nail/drain number, location, and dimensions
- A drilling record showing date and time of drilling, the drilling method, the type of materials encountered and the location at which the materials were encountered, water loss/seepage during drilling, problems during drilling.
- Nominal and actual volumes of grout placed.
- Soil nail test records.c

6 Engineers Inspections

The Contractor shall give a minimum 24 hour notice to the Designer for the minimum inspection scheduled as follows:

- Setting out details.
- Inspection of slope.
- Installation of the first soil nail.
- First Verification and Acceptance Test.
- Installation of bored drains.
- Completion of soil nail slopes.