8 October 2020

s 7(2)(a) - Privacy
Team Leader: Infrastructure Projects
Tauranga City Council
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Mauao - Additional Works Stability Assessment

2-9b463.03

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1 Introduction

Further to your recent request we have carried out a slope stability assessment for the slope supporting the Pohutukawa tree identified at the western end of the recently repaired section of the base track.

The location of the tree and slope is identified on the appended site plan C73. The purpose of the assessment is to determine the stability of the slope which supports the Pohutukawa tree and track above beyond the repaired section of the track.

This assessment includes:

- Review of existing geologic data and boreholes to produce a geotechnical ground model through a critical section which includes the land supporting the Pohutukawa tree.
- Slope stability analyses to determine the Factor of Safety for various slip circles to evaluate the risk of failure of the land supporting the track and Pohutukawa tree below.

2 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 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 the slope stability outputs which are appended to this report.

2.1 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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2.2 Geotechnical Design Parameters

Geotechnical design parameters have been assumed using, site geological observations, investigation data and back analysis of our original 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')
Interbedded silty sand and sandy silt	17	10	30
Very stiff to hard clay	18	20	34
Very stiff silty clay	16	15	34

2.3 Slope Stability Analyses

A summary of the slope stability outputs is summarised in Table 3 below and the stability outputs are appended. For this analysis we have modelled Section 1 under static and assumed transient conditions to determine the factor of safety (FoS) of potential failures near the tree and track locations. We have also modelled a potential tension crack at the crest of the slope where we noted a potential lobe feature during our previous assessment. The tree and track positions are indicated on the appended slope models.

Table 2: Slope stability analysis summary

Analysis Case	Minimum Factor of Safety (at Pohutukawa tree)	Factor of Safety (slip surface near track)
Section 1 – Static, Normal Groundwater	1.06	1.1 to 1.3
Section 1 – Tension Crack (water filled)	0.69	-
Section 1 – Tension Crack, Normal Groundwater	1.01	-
Section 1 – Static, Transient Groundwater	1.00	1.1 to 1.2
Section 1 – Section 1, Transient Groundwater (Ru method).	1.02	1.1 to 1.2

2.4 Discussion of Results

Our analysis indicates that the track maintains a FoS of 1.1 to 1.2 which is stable (but less than TCC IDC guidelines) under transient groundwater conditions or when excess pore water pressure is experienced within the interbedded silty sand and sandy silt deposits. However, the slope at the location of the tree (near slope edge) shows very marginal stability in vicinity of the tree. The model also indicates that the factor of safety of slip surfaces along the tension crack are marginally stable if the tension crack is dry while if it is full of water then the slope is at failure.

At the location of the track alignment the FoS is improved as it is set back approximately 6m from the edge of the track.

2.5 Tree Stability

It must be noted that we cannot comment on the ongoing stability of the tree which is outside the scope of this report. We have only considered the stability of the slope supporting the tree in this assessment. However, we note previous studies by Oliver (1997) indicate Pohutukawa trees can create a high-density root mass at the edge of the slope which can reduce permeability and increase pore water pressures at the interface of the soil and root mass which can reduce stability. The tree can also apply torques to the slope aiding in production of instability however we cannot model this in the stability analysis.

For assessment of the health, condition and structural integrity of the tree which could affect stability of the slope the Client should engage a professional arborist to undertake an assessment.

2.6 Conclusions and Recommendations

Based on the above results, the portion of the slope near the edge where the tree and potential tension crack is located is marginally stable under normal conditions and at risk of failure under transient conditions.

However, as the current track position is set back from the edge of the slope (approx. 6 metres) the stability is improved and slip circles are less likely to affect the track although there would still be a residual risk of regressive failure of the slope if an initial failure near the crest of the slope were to occur.

Therefore, further stabilisation would then be required at a later stage if an initial slip had occurred. Based on this conclusion and to improve the long-term resilience of the slope to the west of the repair, we would recommend stabilising the slope with additional drainage and soil nails to enhance the stability of the site and to enhance the stability of the slope supporting the lower Pohutukawa tree. This would also allow the opportunity to address any maintenance works from the previous stage.

In addition, there may be value undertaking a high-level risk assessment and walk over of the complete Mauao base track route to identify areas that may be prone to future slips or are marginally stable. This could be undertaken as an extension to our previous monitoring at the site.

2.7 References

Oliver, C.R, 1997: A Geotechnical Characterisation of Volcanic Soils in Relation to Coastal Landsliding on the Maungatapu Peninsular, Tauranga, New Zealand. University of Canterbury.

If you have any further questions, please don't hesitate to contact us.

Regards,

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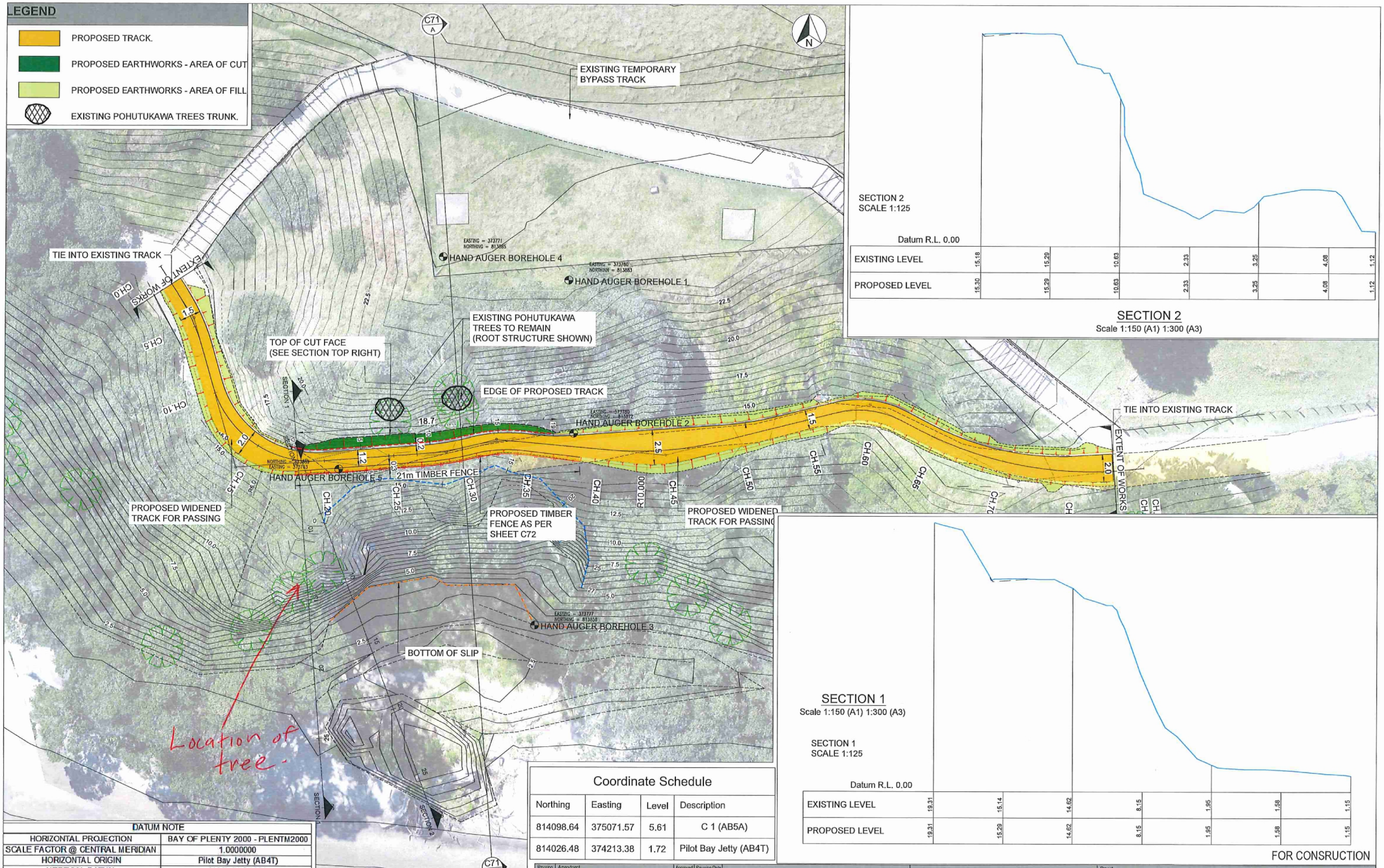
Engineering Geologist

Attachments: Site Plan & Sections
Slope Stability Analysis Outputs
Borelogs



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)

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:

1:150 @ A1
1:300 @ A3
0 2 4 6 8 10 12 14 m

Revision	Amendment	Approved	Revision Date
1	ISSUED FOR CONSRUCTION	s 7(2)(a) - Priv	2019-11-22

Tauranga City

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Designed	Approved	Approved Date
s 7(2)(a) - Privacy		2020-09-21
Drawn	Scales	
s 7(2)(a) - Privacy	AS SHOWN	

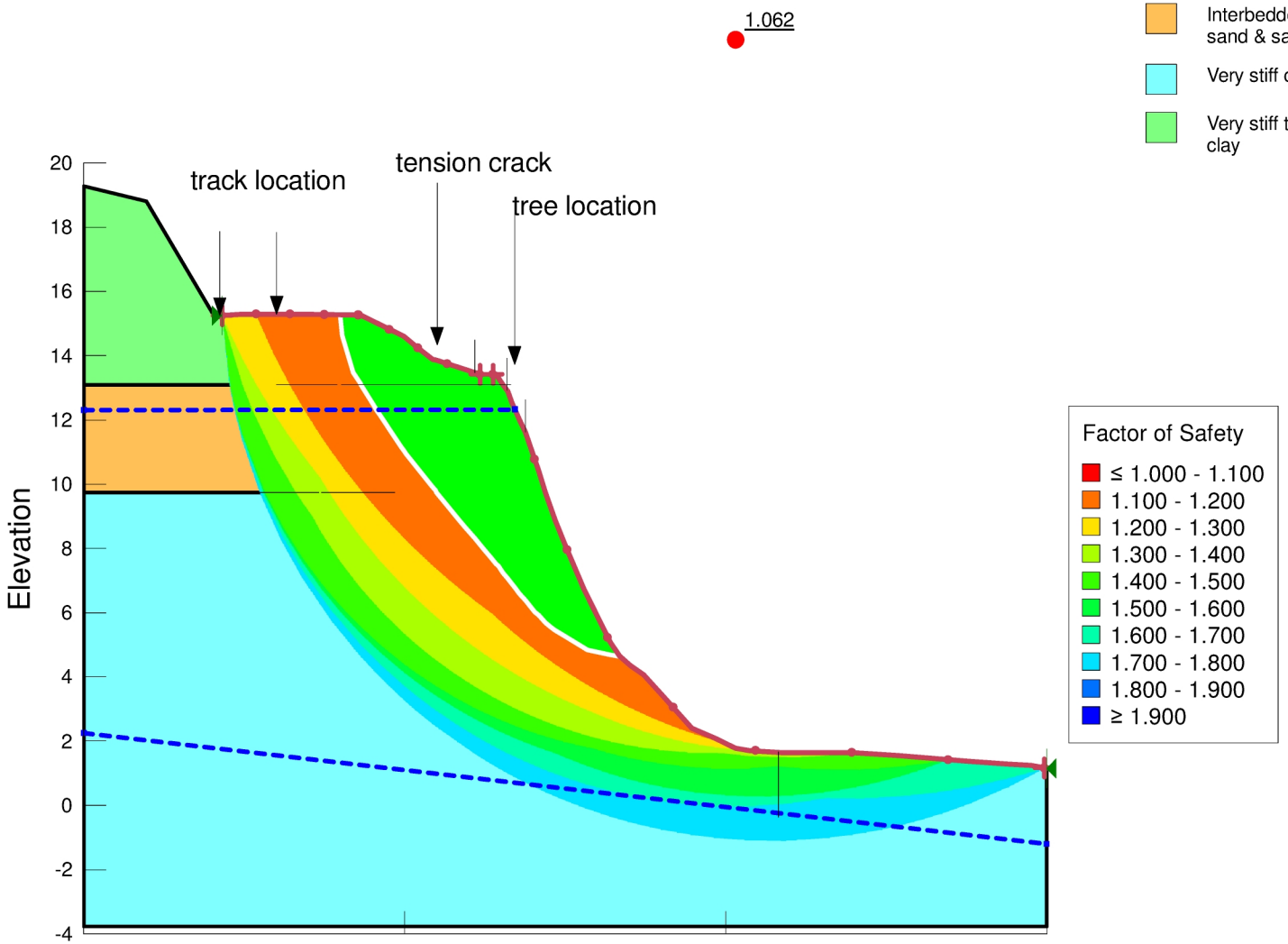
Project
TAURANGA CITY COUNCIL
MAUAO BASE TRACK REINSTATEMENT
MOUNT MAUNGANUI, TAURANGA

Sheet
SLIP LAYOUT PLAN - EXTRA SECTIONS
SHEET 1 OF 1

Project No.	Sheet No.	Revision
2-9B463.00	C73	A

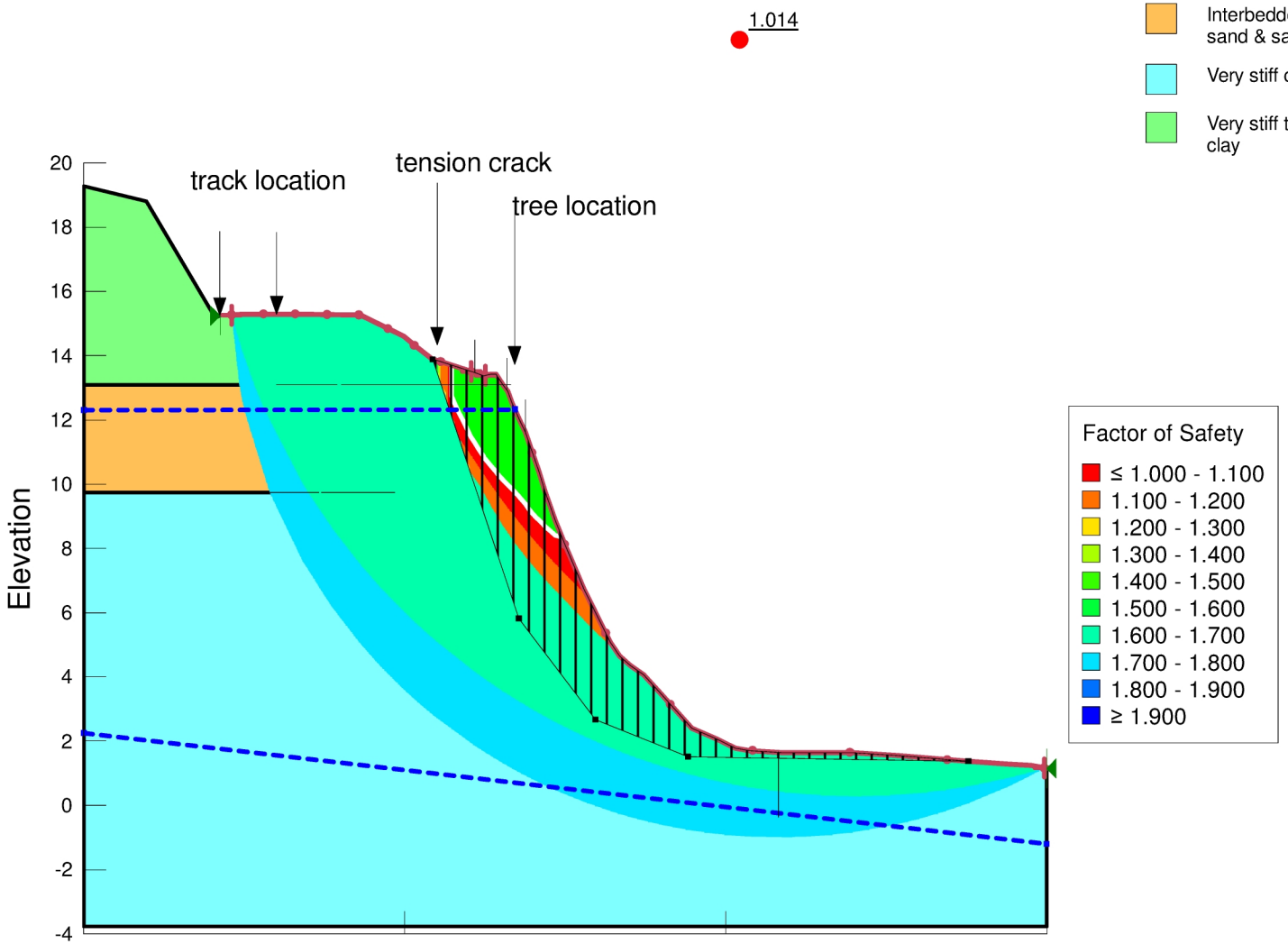
Original Sheet Size A1 [841x594] Plot Date 2020-09-24 at 11:08:07 AM Path U:\Projects\NZ\29\02-9B463.00 Mount Base Track Investigations\Home\4. Design\Drawings\(C) Civil\+AutoCAD\2-9B463.00_GEOTECH-EXTRA SECTION.dwg C73[1]

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Interbedded silty sand & sandy silt	Mohr-Coulomb	16	10	30
	Very stiff clay	Mohr-Coulomb	16	15	34
	Very stiff to hard clay	Mohr-Coulomb	18	20	34



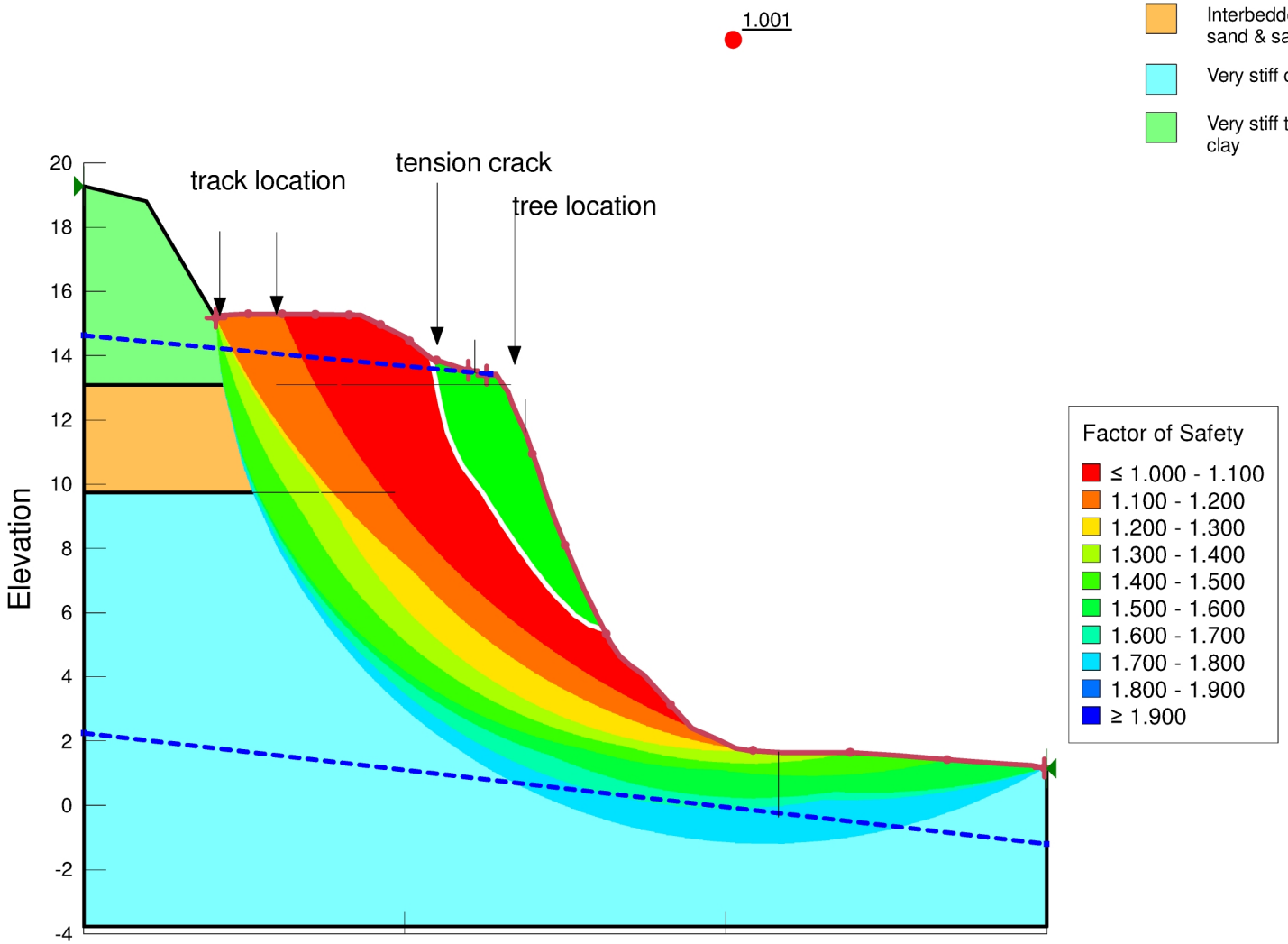
Project:	**Mauao Base Track**	Model	SLOPE/W	Proj No.	2-9B463.00
Analysis:	Section 1_Static	Method	Morgenstern-Price	Date:	02/10/2020
		PGA	g	Scale	1:150
Modelled By:	s 7(2)(a) - Privacy	FOS	1.062	Sheet No.	
Checked By:	Name				

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Interbedded silty sand & sandy silt	Mohr-Coulomb	16	10	30
	Very stiff clay	Mohr-Coulomb	16	15	34
	Very stiff to hard clay	Mohr-Coulomb	18	20	34



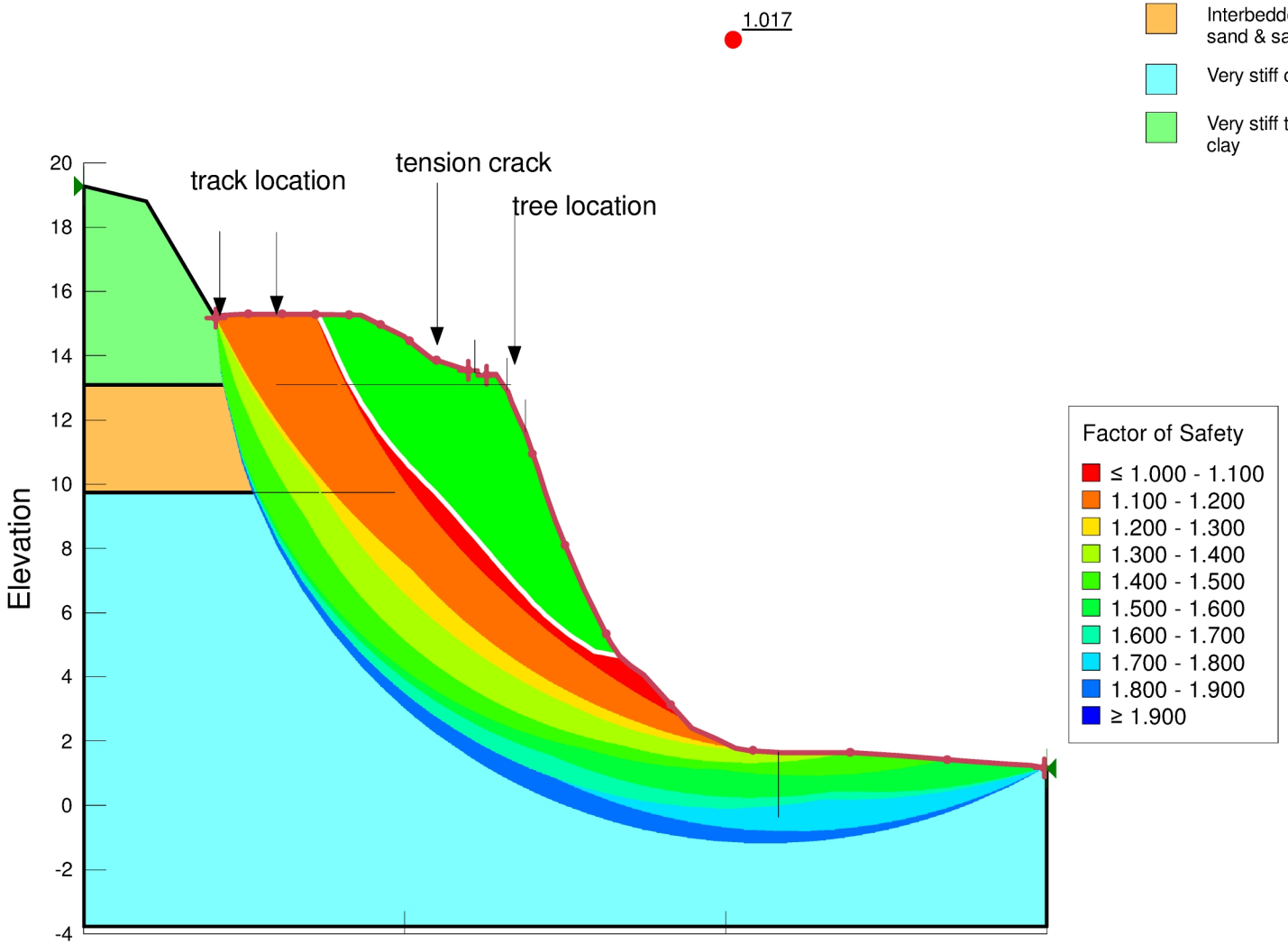
Project:	**Mauao Base Track**	Model	SLOPE/W	Proj No.	2-9B463.00
Analysis:	Section 1_Tension crack	Method	Morgenstern-Price	Date:	02/10/2020
		PGA	g	Scale	1:150
Modelled By:	s 7(2)(a) - Privacy	FOS	1.014	Sheet No.	
Checked By:	Name				

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Interbedded silty sand & sandy silt	Mohr-Coulomb	16	10	30
	Very stiff clay	Mohr-Coulomb	16	15	34
	Very stiff to hard clay	Mohr-Coulomb	18	20	34



Project:	**Mauao Base Track**	Model	SLOPE/W	Proj No.	2-9B463.00
Analysis:	Section 1 Transient Piezo	Method	Morgenstern-Price	Date:	02/10/2020
		PGA	g	Scale	1:150
Modelled By:	s 7(2)(a) - Privacy	FOS	1.001	Sheet No.	
Checked By:	Name				

Color	Name	Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Ru
	Interbedded silty sand & sandy silt	Mohr-Coulomb	16	10	30	0.3
	Very stiff clay	Mohr-Coulomb	16	15	34	0
	Very stiff to hard clay	Mohr-Coulomb	18	20	34	0.3



Project:	**Mauao Base Track**	Model	SLOPE/W	Proj No.	2-9B463.00
Analysis:	Section 1_Transient Ru method	Method	Morgenstern-Price	Date:	02/10/2020
		PGA	g	Scale	1:150
Modelled By:	s 7(2)(a) - Privacy	FOS	1.017	Sheet No.	
Checked By:	Name				

Auger Scala No. HA01

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	SHEAR STRENGTH (kPa)	OTHER TESTS	SAMPLES
	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				1		113/16		
	Silty CLAY, trace sand; orange brown, moist, moderately plastic becoming sandy								
2	becoming brown, moisture increasing, becoming wet				2		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								
	SILT, some sand: brown with orange and black mottles trace medium ryholite gravel, angular								
3	Clayey SILT, trace sand; brown mottled orange, moist, high plasticity becoming light brown				3				
	CLAY, trace sand; light brown with orange mottles, moist, high plasticity						188/87		
							188+		
4	becoming wet				4		188+		
	CLAY, trace silt; orange brown, moist, high plasticity						188+		
	Silty CLAY; brown, black mottles, wet, high plasticity					0 4 8 13 18 23 28 33 38 43 48 Inferred CBR (%)	188+		
	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:

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
0	CLAY; orange brown with brown streaks, moist, high plasticity		
	CLAY; light brown, moist, high plasticity becoming wet		
1	SILT, some sand and clay; brown, wet, high plasticity		
	Sandy CLAY; brown, wet, high plasticity, soft		
	black specs with limonite staining		
2	SAND with minor silt; light greyish brown, wet		
	with black flecks		
	Sandy SILT; light brown with black specs, saturated , pumiceous		
3	becoming wet saturated, very soft, highly sensitive - possible perched water table		3.3m
4			
	Sandy SILT; light brown, sturated, very soft, highly sensitive		
	END OF AUGER AT 5m - Target Depth Reached		

SOIL TESTS

R.L. (m)	DEPTH (m)	SCALA PENETROMETER (Blows per mm) 0 2 4 6 8 10 12 14 16 18 20	SHEAR STRENGTH (kPa)	OTHER TESTS	SAMPLES
	0				
			112/12		
			129/16		
	1				
			121/20		
			188+		
	2		90/32		
			80/32		
			94		
	3		43/12		
			123/21		
	4		76/12		
			124/32		
		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

Notes:

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

Approved by

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

Auger Scala No. HA03

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
0	Sandy SILT; gey mottled, wet highly plastic (slip debris)		
	Clayey sandy SILT; dark brown, mottled, wet high plasticity (slip debris)		
1	SAND; grey, wet		
	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
3			
4			

SOIL TESTS

R.L. (m)	DEPTH (m)	SCALA PENETROMETER (Blows per 100mm)	SHEAR STRENGTH (kPa)	OTHER TESTS	SAMPLES
	0	0 2 4 6 8 10 12 14 16 18 20			
	1		60/11 62/5		
	2				
	3				
	4	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: s 7(2)(a) - Privacy

Date Reported:

Approved by

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+		
	Sandy SILT; orange brown, moist, moderately plastic						80/16		
							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: s 7(2)(a) - Privacy

Date Reported:

Approved by

Signed by:

Designation:

Date: 18/12/2019

Auger Scala No. HA05

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)	SHEAR STRENGTH (kPa)	OTHER TESTS	SAMPLES
	Sandy CLAY; orange brown, dry, friable								
	CIAY, with minor sand; orange brown, moist, highly plastic						166		
	CLAY, minor sand; light brown with black flecks						164/24		
1					1		105/16		
	CLAY, with some silt, and minor sand; orange brown, moist, highly plastic						185/32		
	with black streaks						188+		
2	CLAY, with some sand; orange brown, moist, high plasticity				2		188+		
	Clayey SILT, with some sand and trace gravel; light brown, moist, high plasticity, appears soft						102/19		
	becoming wet						188+		
3	Clayey sandy SILT; light brown, wet, high plasticity, soft				3		164/24		
	Sandy SILT, minor clay, light brown, moist, moderately plastic						118/35		
	Silty SAND; light brown, moist						86/56		
	Sandy SILT								
	Silty SAND								
4	Sandy SILT; light whitish brown, moist, pumicieous				4				
	SAND; light whitish brown, moist pumiceous								
	Silty fine SAND, with some clay; light brown and grey, wet, highly plastic, very soft								
	END OF AUGER AT 5m - Target Depth Reached								

SCALA PENETROMETER (Blows per mm): 0 2 4 6 8 10 12 14 16 18 20

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

Test Methods:

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

Notes:

Date Tested:

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

Date Reported:

Approved by

Signed by:

Designation:

Date: 18/12/2019