Reid's Canal: Right Bank Cross Section 4

Geotechnical Assessment

Prepared for

Environment Bay of Plenty

August 2008

ICE GEO & CIVIL

A division of ICE CONSTRUCTION LTD

Contents

Appendices

1 Introduction

Reid's Canal is designed to take some flood flow from the Rangitaiki River to reduce the pressure on the river's stopbanks. It is proposed to upgrade Reid's Canal so that it can take a bigger proportion of the flood flow from the river. The upgrade will require moving to the west a length of the left stopbank at the lower end of the canal to increase the waterway capacity. There is a very wet area of farmland below the right stopbank in the area of Environment Bay of Plenty Cross Section 4, about 1.5km upstream of the Canal outlet into the river. As there are no plans to rebuild the right stopbank, Ice Geo and Civil has been engaged by Environment Bay of Plenty to investigate the stopbank in this area to confirm its integrity.

This report presents the following information:

- the results of insitu investigations,
- the results of seepage and stability analyses and
- a suitable remediation method.

This report is the property of our client, Environment Bay of Plenty and Ice Geo and Civil. The comments within relate only to the right bank stopbank of Reid's Canal at Cross Section 4.

2 Site Description

Cross Section 4 lies within what was a peat swamp before European occupation. The land has been drained extensively for dairy farming. This has resulted in a drop in the ground level and on going settlement of the peat. At present the paddocks adjacent to Cross Section 4 lie at about RL-0.3 (below mean sea level, Moturiki). These paddocks remain green all year round and are very wet in the winter. The typical water level in the canal is probably RL0.6 to 0.8. This means there is continuous seepage from the canal into the farmland and a need for drainage pumps.

The LIDAR map of the area shows surface and buried coastal fore dunes to just south of State Highway 2. There also appears to be shadows of the most inland buried fore dunes just to each side of Cross Section 4. This suggests that the peat at Cross Section 4 could be reasonably shallow.

The crest of the stopbank is at about RL2.8. There is a berm about 15m wide between the canal side toe of the stopbank and the canal bank at normal flows. This berm is 1.3m higher than the land on the opposite side of the stopbank. The slope of the sides of the stopbank is typically at 2.5-3.0H to 1V (Figure 4).

3 Subsurface Investigations

The subsurface investigations consisted of seven hand augers carried out along the cross section as shown in Figure 1. No hand augers could be carried out through the crest of the stopbank due to a compacted gravel surface. The investigations were carried out a few days after the canal water level had risen across the berm and the day after heavy overnight rain. There appeared to be seepage coming from the inland toe of the stopbank below the water level in the canal. This part of the stopbank and the adjacent paddock were water logged.

The hand auger logs are included in Appendix A.

The subsurface soils found are similar to those identified by Opus in their investigations along the left bank of the canal (Reference1).

The upper stopbank fill was found to consist of silty fine to medium sand and gravel. Some clay was found on the inland side if the stopbank. A fine to medium sand layer was found at RL0.1 on both sides of the stopbank and at RL1.4 within the stopbank. It is considered that the observed seepage was coming through the stopbank in this layer.

It appears from HA7 that the canal berm has been built up since the stopbank was built. A thick layer of ash (from burnt trees?) was found and layers of clay. The first layer that could be identified as being undisturbed was the black coarse sand, Tarawera Ash, at RL-0.15. Although this layer was not found on the land side of the stopbank, the ash was found mixed with the silt at RL-0.5 in HA3. This mixing is consistent with ploughing as the ash is often found at about 0.3m depth below an undisturbed surface. Above the Tarawera Ash in HA7 is the fine to medium sand layer that extends under the stopbank. It is possible that this sand layer is the result of canal cleanings being spread out before the stopbank was built.

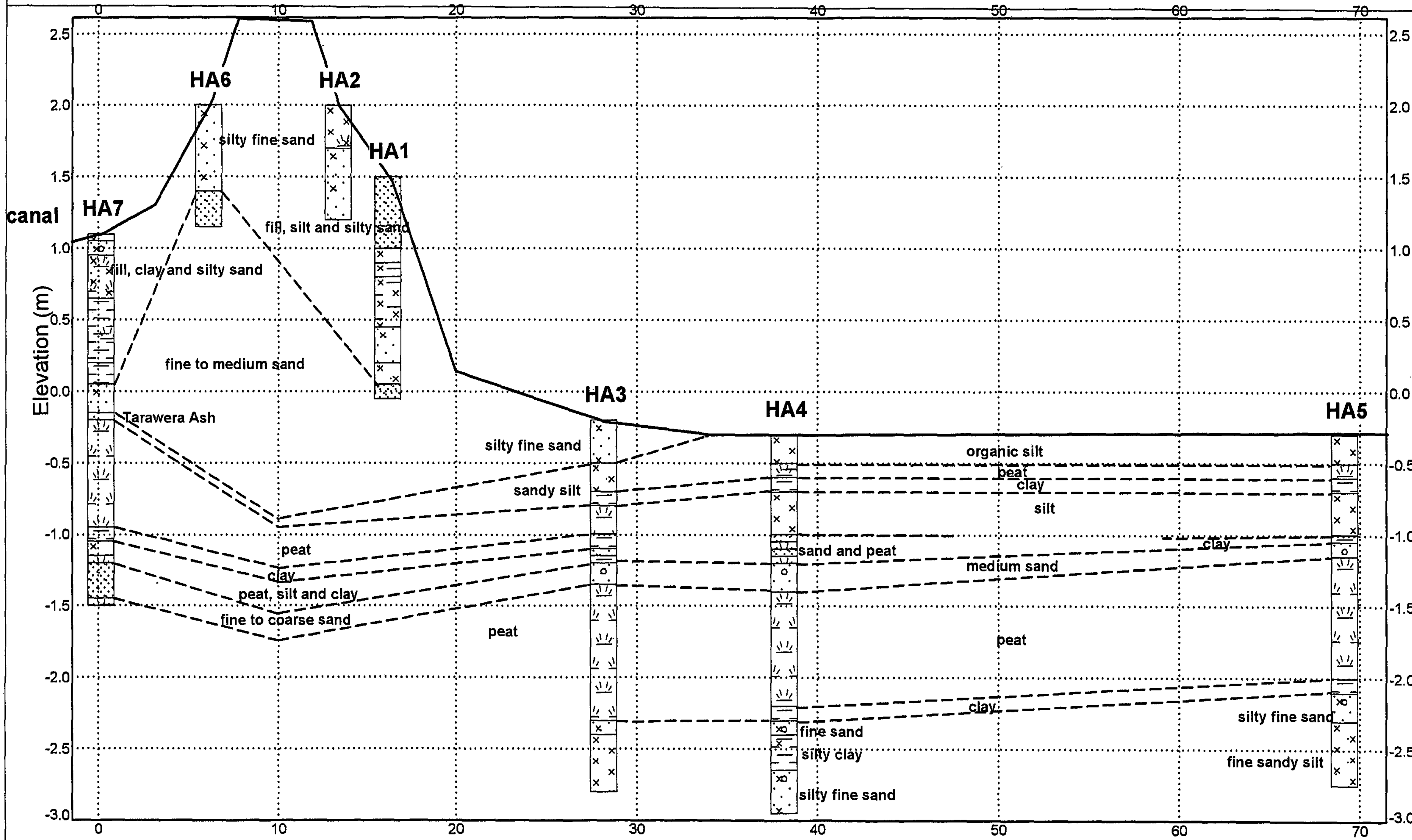
Below the Tarawera Ash in HA7 is a 0.75m layer of peat then thinner layers of clay, silt and peat. A 0.25m thick medium grained pumice sand layer was found at RL-1.2. Further peat was found below this.

It is expected that the natural soil layers will dip below the stopbank due to the compressibility of the peat. The machine investigations carried out through the stopbank by Opus suggest about 1.5m of settlement has occurred in similar soils to those found at Cross Section 4.

On the inland side of the stopbank hand augers 3, 4 and 5 showed surface layers of organic silts, peat and clay. Hand augers 4 and 5 show a layer of silt not found in HA3. This variation in layers is not uncommon in alluvial situations. The deep medium sand layer found in HA7 is also found at a similar depth in hand augers 3, 4 and 5. Due to its consistent presence it is considered that this layer could be an airfall deposit, rather than an alluvial deposit, and is possibly an earlier Tarawera or Kaharoa Ash. This sand layer was also found sandwiched between peat layers along the Eastern Drain.

Project: Reid's Canal
Client: Environment Bay of Plenty
Location: Reid's Canal CS1
Number: 1

Figure 1: Subsurface Cross Section Reid's Canal
Cross Section 4



Ice Geo & Civil

16/08/08

The subsurface cross section in Figure 1 suggests that this sand layer could be exposed in the side of the canal and may form another permeable seepage path under the stopbank.

Another peat layer was found below the medium sand layer and further inconsistent silty sand, sand, silt and clay layers below this.

No laboratory tests were carried out due to the difficulties in obtaining clean samples in the conditions and because the soils found were similar to those found along the Eastern Drain and elsewhere.

4 Analyses

4.1 Introduction

The subsurface cross section shown in Figure 1 was simplified slightly for the seepage and stability analyses. The computer programmes Geo-Slope Seep/W and Slope/W(Version 6.19) were used in the two dimensional analysis of the stopbank. An initial steady state seepage analysis was carried out to model the normal flow conditions towards the paddocks, assuming the canal water level was at RL0.8. A transient analysis was superimposed on the steady state analysis to assess the effects of a flood in the canal. The seepage pressure conditions at the peak flow in the canal were then imported into the stability analysis of the inland face of the stopbank. Seepage from the ground surface was allowed for.

4.2 Flood Hydrograph

EBoP have estimated a flood flow hydrograph for the canal after it has been widened (Figure 2). This includes an allowance for climate change.

For the purposes of the transient seepage analysis this hydrograph has been simplified and extended to about 80 hours to allow for the estimated time that the Rangitaiki River would be high enough for water to flow down the canal. It can be seen from the hydrographs that the stopbank will have to be raised to provide some freeboard in the design flood.

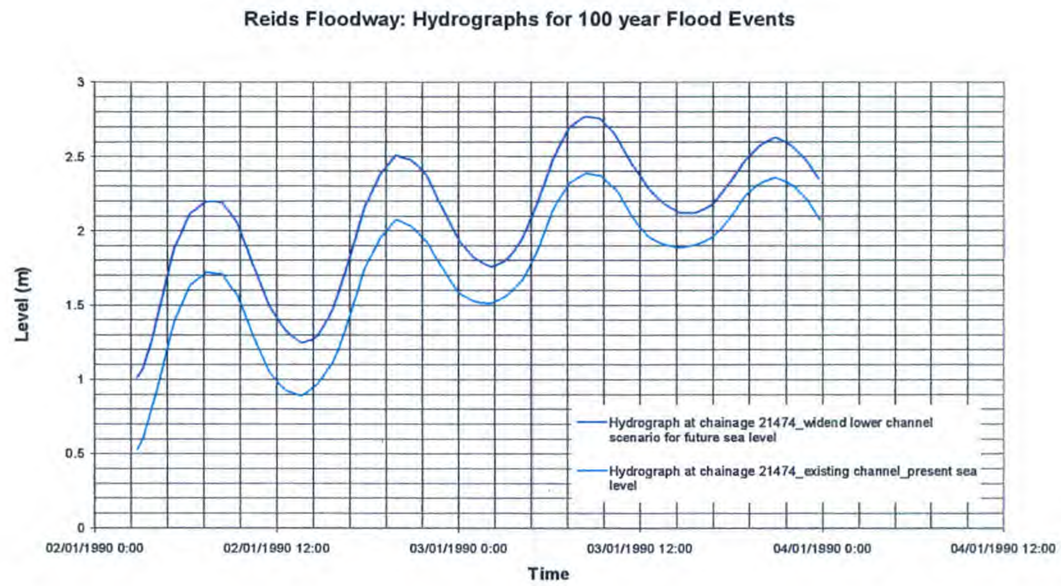


Figure 2: EBoP hydrograph

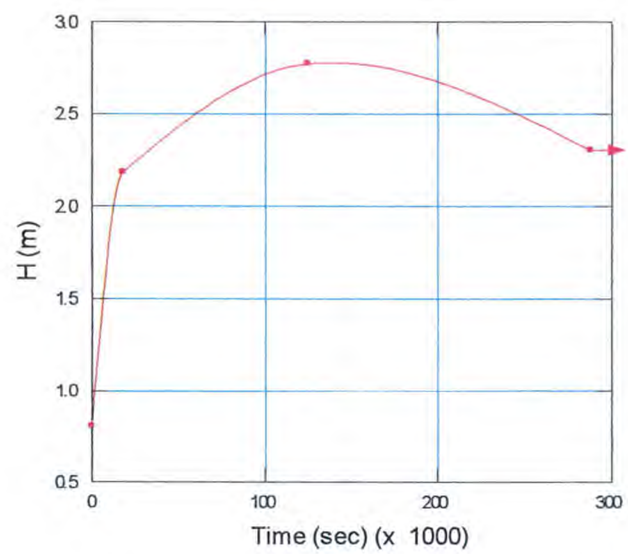


Figure 3: Assumed hydrograph

4.3 Soil Model

The soil permeabilities used in the analyses have been based on laboratory permeability and grading test results for similar soils from other sites within the Rangitaiki Plains. Table 1 summarises the seepage and strength parameters used.

soil	k_h (m/s)	k_v (m/s)	ρ_b (kN/m^3)	ø' (degrees)	c' (kPa)
stopbank fill	1×10^{-5}	5×10^{-6}	17	0	33
fine to medium sand	3×10^{-5}	3×10^{-5}	14	0	35
upper silts	5×10^{-7}	5×10^{-7}	15.5	2	24
peat	7×10^{-9}	7×10^{-9}	10.5	2	20
banded peat, clay and sand	5×10^{-6}	1×10^{-8}	14	1	22
medium to coarse sand	5×10^{-4}	5×10^{-4}	14	0	35
lower sands, silts and clays	5×10^{-7}	1×10^{-7}	14	1	22

Table 1: Assumed soil properties

Where the soils are banded due to compaction or natural placement processes the vertical permeability has been assumed to be less than the horizontal.

The Geo-Slope Seep/W computer package used for the seepage analyses contains a library of soil grading curves with corresponding hydraulic conductivity and water content versus water pressure relationships. The particle gradings observed on site were compared to those in the Seep library and the closest fit chosen as the soil model to be used in the seepage analysis. The library does not include any relationships for peat. As the peat is mostly saturated the water content relationship is not too critical and a relationship for a clay with a similar low permeability was used.

4.4 Seepage Analysis

Flow from the fine to medium sand layer at the base of the stopbank under normal canal water level conditions was considered to be unacceptable. A clay cut-off through this layer was therefore modelled at the inland toe of the stopbank. The inland toe was chosen as the depth of excavation here would be less here than on the canal side.

In the transient analysis is was found that the factor of safety against heave of the peat and silt layers above the medium to coarse sand was less than 1.0. The clay cut-off was therefore extended into this layer (Figure 4). This improved the factor of safety against heave of the upper layers to approximately 1.0.

Due to the light nature of the peat and pumiceous soils the heave potential of approximately the top 2m of soil was also checked. The factor of safety was again found to be just below 1.0. A deeper cut off into the deep sandy, silty layers was not considered practical. At this stage the thickness of these layers is not know and they may lie on top of the old fore dunes. An overlay option was therefore considered.

An analysis was carried out with a 600mm overlay from the inland toe of the stopbank to 20m from the toe, then tapering to ground level 40m from the toe (Figure 4). The minimum factors of safety against heave were found to be between 1.1 and 1.2.

An analysis was run with the overlay but without the clay cut-off. It was found that without the cut-off heave of the upper layers was still possible. An assessment was made to see if a thicker overlay would be more cost effective than a clay cut off. However without a cut-off the overlay would have to be very thick to counteract the uplift pressure due to over 3.5m head of water in the sand layer.

The hydraulic exit gradients were checked to see if there could be significant piping potential. The gradients were found to be acceptable in the sand and silt soils (less than 0.4).

4.5 Stability Analysis

A stability analysis of the inland face was carried out with the highest seepage pressures from the seepage analysis of the canal in flood and the soil strength and density parameters given in Table 1. The lowest factor of safety against a failure which includes the crest of the stopbank was found to be 1.2. This surface is shown in Appendix B. This factor of safety is considered to be on the low side of acceptable under these extreme conditions. Increasing the overlay thickness at the toe of the stopbank would improve this factor of safety.

An analysis with the canal water level at a normal level showed a factor of safety against slope failure towards the canal of 2.1.

5 Construction

It may not be possible to form the clay cut-off with conventional earthworks techniques due to the base of the trench being at about RL-1.5. Rapid inflows of sand and water into an excavated trench would be expected. A method which mixes bentonite with the existing soils in situ may be required. This could be done using Colmix type plant such as that owned by Hiway Stabilisers. However this could be very expensive if it is required over a long length of stopbank. Alternatively, as the cut-off is less than 2m deep, it may be possible to mix in bentonite by turning the in situ soils over with an excavator. If this is done across say a 3m wide trench, there could be reasonable confidence in the result. It is suggested that trials be carried out before work is done on the stopbank.

The overlay should be made of a silty sand or sandy silt with topsoil spread across the surface if necessary. Drain cleanings may be suitable.

6 Conclusions

1. A clay cut-off to about RL-1.5 is required to restrict the seepage through sand layers under the stopbank. This will probably have to be formed by mixing bentonite with the in situ soils in place.

2. A 40m wide, 600mm thick, overlay is required at the inland toe of the stopbank.

3. The stopbank will need to be raised to provide some freeboard above the design level flood. Extra height should be added to allow for the settlement of the peat due to the increased stopbank load.

4. Further investigations are required to confirm the lateral extent that the remedial works are required along the stopbank.

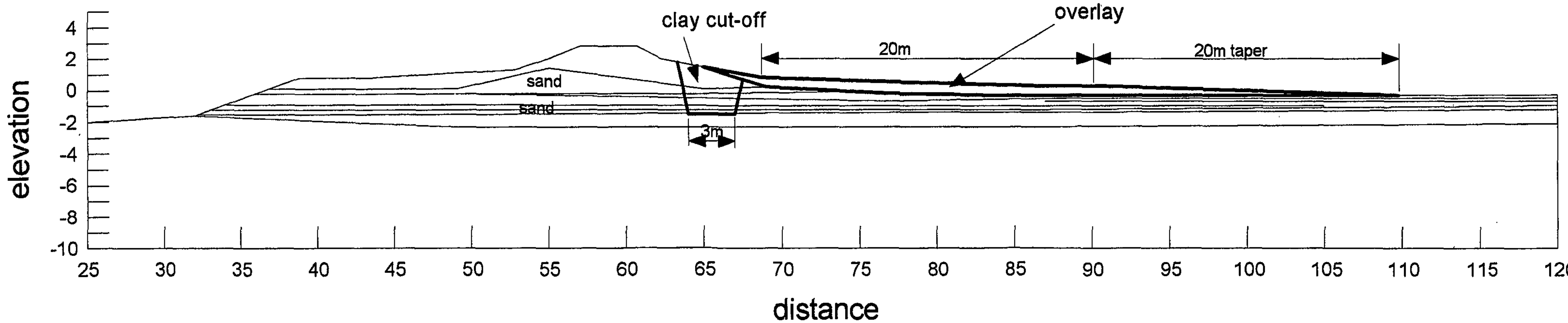
M. O'Halloran

M. O'Halloran 22 August 2008
BE, PhD, Dip BA, MIPENZ (Geotechnical), CPEng IntPE

References

1. Opus International Consultants Ltd (August 2006) Reids central floodway stopbank stability assessment, Geotechnical Report No 2447.

Figure 4: Reid's Canal Cross Section 4 remedial measure



Appendix A

Hand Auger Logs

Project:	**Reid's Canal**
Client:	Environment Bay of Plenty
Location:	Reid's Canal CS1
Number:	1
Test:	**HA1**
Elevation:	1.5
Date:	08/08/2008
Logged by:	M. O'Halloran

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

Elev(m)	Description	Sample
1.5	brown **silty fine to medium SAND, some fine gravel**	
1	brown **fine sandy SILT**	
0.9	brown **fine GRAVEL**, wet	
0.8	mixed grey and brown **clayey SILT**, soft (water level ▼)	
0.45	brown / grey **silty fine to medium SAND**	
0.2	brown / grey **fine sandy SILT**, fill	
0.05	grey **fine to medium SAND**	
-0.05	EOB - collapsing, grey SILT??	

HAND AUGER REIDS CANAL.GPJ HAND AUGER BASIC.GDT 22/8/08

Project:	**Reid's Canal**	Test:	**HA2**
Client:	Environment Bay of Plenty	Elevation:	2.0
Location:	Reid's Canal CS1	Date:	08/08/2008
Number:	1	Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			brown **organic SILT**, topsoil	
	1.7		brown silty fine to medium SAND, some gravel to 3mm	
0.5				
	1.2		**GRAVEL**	
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				

ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

HAND AUGER REIDS CANAL.GPJ HAND AUGER BASIC.GDT 22/8/08

Project:	**Reid's Canal**	Test:	**HA3**
Client:	Environment Bay of Plenty	Elevation:	-0.2
Location:	Reid's Canal CS1	Date:	08/08/2008
Number:	1	Logged by:	M. O'Halloran

Elev(m)	Description	Sample
	brown **silty fine SAND**, fill, firm	
-0.5	brown **organic fine sandy SILT**, some grit (Tarawera Ash)	
-0.7	brown **organic CLAY**,soft	
-0.8	brown / black fibrous **PEAT**	
-1		
-1.1	light brown / grey **CLAY**, plastic, firm	
-1.15	grey **silty fine SAND**	
-1.2	brown **organic CLAY**, soft	
-1.35	grey **medium to coarse pumice SAND and fine LAPILLI**	
	dark brown / black fibrous **PEAT**, very soft	
-2.3	grey pumice **silty fine SAND**	
-2.4	grey pumice SILT, dilatant	
-2.8	EOB	

Depth (m): 0.0 – 4.0

ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

HAND AUGER REIDS CANAL.GPJ HAND AUGER BASIC.GDT 22/8/08

Project:	**Reid's Canal**	Test:	**HA4**
Client:	Environment Bay of Plenty	Elevation:	-0.3
Location:	Reid's Canal CS1	Date:	08/08/2008
Number:	1	Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			black **organic SILT**, some clay	
	-0.5			
	-0.6		black fibrous **PEAT** and brown **CLAY**, plastic, soft	
	-0.7		light grey with Fe staining **CLAY**, soft	
0.5			light grey with Fe staining **SILT**, soft	
	-1			
	-1.05		grey silty **fine to medium SAND**	
	-1.1		brown fine fibrous **PEAT**	
1.0	-1.15		grey **fine to medium pumice SAND**	
	-1.2		brown fine fibrous **PEAT**	
	-1.4		grey **medium pumice SAND**, some fine lapilli	
			brown fine fibrous **PEAT**	
1.5				
	-2.2			
2.0	-2.3		green grey **CLAY**, plastic, soft	
	-2.4		grey pumice **silty fine SAND with some lapilli** to 3mm	
			light greenish brown / grey **silty CLAY**, soft, some fibres	
	-2.65			
2.5			grey **silty fine SAND with some lapilli** to 3mm	
	-2.95			
			EOB squeezing	
3.0				
3.5				
4.0				

ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

HAND AUGER REIDS CANAL.GPJ HAND AUGER BASIC.GDT 15/8/08

Project: **Reid's Canal**
Client: Environment Bay of Plenty
Location: Reid's Canal CS1
Number: 1

Test: **HA5**

Elevation: -0.3
Date: 08/08/2008
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			black **organic SILT, some clay**	
	-0.5		black fibrous **PEAT**	
	-0.6		grey with Fe staining **CLAY**, soft, plastic	
0.5	-0.7		grey with Fe staining **SILT**	
	-1		light brown **organic CLAY**	
	-1.05		grey **medium pumice SAND, some fine lapilli**	
1.0	-1.15		black fibrous **PEAT**	
1.5				
	-2		green grey **CLAY**, plastic, soft	
	-2.1		light grey brown **pumice silty fine SAND, some rounded pumice** to 10mm	
2.0	-2.3		grey pumice **fine sandy SILT**	
2.5	-2.75		EOB - losing sample	
3.0				
3.5				
4.0				

ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

HAND AUGER REIDS CANAL.GPJ HAND AUGER BASIC.GDT 15/8/08

Project:	**Reid's Canal**	Test:	**HA6**
Client:	Environment Bay of Plenty	Elevation:	2.0
Location:	Reid's Canal CS1	Date:	08/08/2008
Number:	1	Logged by:	M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			brown **silty fine SAND**	
0.6	1.4		grey **fine to medium SAND**	
0.85	1.15		EOB - hole collapsing	

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

HAND AUGER REIDS CANAL.GPJ HAND AUGER BASIC.GDT 15/8/08

Project: **Reid's Canal**
Client: Environment Bay of Plenty
Location: Reid's Canal CS1
Number: 1

Test: HA7
Elevation: 1.1
Date: 08/08/2008
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0	1.05		brown **organic SILT**, topsoil	
	0.95		grey with Fe staining **silty fine to medium SAND and fine GRAVEL** (placed berm?)	
			grey and black **ASH**, hard, gritty	
0.5	0.65		grey **organic CLAY** with fibres	
	0.2		light grey/brown **CLAY**, plastic, soft	
1.0	0.05		grey **fine to medium SAND**	
	-0.15		black **coarse SAND**, Tarawera Ash	
	-0.2		dark brown/black **fibrous PEAT**	
1.5				
2.0	-0.95		light grey / brown **CLAY**	
	-1.05		light grey **SILT**	
	-1.15		dark brown / black **fibrous PEAT**	
	-1.2		light grey fine to medium pumice **SAND**	
2.5	-1.45		brown **clayey PEAT**	
	-1.5			
3.0				
3.5				
4.0				

ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

HAND AUGER REIDS CANAL.GPJ HAND AUGER BASIC.GDT 15/8/08

Appendix B

Stability Analysis

Name: CS4trans overlay.gsz
Title: Reid's Canal Cross Section 4
Comments: Transient Analysis
Date: 21/08/2008 Time: 6:49:01 p.m.

Material #: 1 Description: fill Model: MohrCoulomb Wt: 17 Cohesion: 0 Phi: 33
Material #: 2 Description: sand Model: MohrCoulomb Wt: 14 Cohesion: 0 Phi: 35
Material #: 3 Description: silts Model: MohrCoulomb Wt: 15.5 Cohesion: 2 Phi: 24
Material #: 4 Description: peat Model: MohrCoulomb Wt: 10.5 Cohesion: 2 Phi: 20
Material #: 5 Description: banded Model: MohrCoulomb Wt: 14 Cohesion: 1 Phi: 22
Material #: 6 Description: sand Model: MohrCoulomb Wt: 14 Cohesion: 0 Phi: 35
Material #: 7 Description: sands and silt Model: MohrCoulomb Wt: 14 Cohesion: 1 Phi: 22