

Rangitaiki River Stopbanks Assessment

Reynold's Bend

Right Bank 3040 to 4700m

Prepared for

Bay of Plenty Regional Council

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1 Introduction

The large bend in the Rangitaiki River between 3.0 and 4.7km upstream of the river mouth is known as Reynold’s Bend due to an early land owner. There is a history of breaches of the right river bank at the bend. The Bay of Plenty Regional Council has been progressively reviewing the security of the flood defence system along the river and has engaged Ice Geo and Civil Ltd to assess whether there could be further problems within this bend.

This report presents the following;

- background information on Reynold’s Bend,
- the results of shallow in situ investigations,
- the results of seepage analyses for the estimated 100 year return period flood allowing for climate change,
- the results of the stability analysis of two cross sections,
- recommendations for some further investigations in one critical area and
- proposed stopbank strengthening measures for two areas.

This report is the property of our client, the Bay of Plenty Regional Council and Ice Geo and Civil Ltd. The comments within relate only to the length of stopbank along the right bank of the Rangitaiki River from 3.04 to 4.70km from the river mouth.

The conclusions of this report are based on the interpretation of historic deep subsurface investigations and recent shallow investigations carried out at isolated points only. There could be ground or other conditions which have an effect on the integrity of the stopbanks that have not been identified. Laboratory testing results from Langdon’s Bend, just upstream of this section and the Thornton School area, just downstream have also been used with the assumption that the soil descriptions and locations in the soil sequence are similar to those at Reynold’s Bend.

2 Background

At Reynold’s Bend a relatively small stopbank has been built on the natural river levee which is 2 to 3m higher than the land within the bend. The land within the bend has been drained and is now as low as 1m below sea level. Water ponded here following the breach of the stopbank upstream of Edgecumbe in 2004 as shown in Figure 1. Prior to the construction of the stopbanks and other river management work, tributaries joined the river at the upstream and downstream ends of this section of stopbank. The levees from these tributaries can be seen in the LIDAR plot (Figure 2).

The most recent breach at Reynold’s Bend occurred at about 4550m (Cross Section 7 in Figure 3) in 1962 when heave occurred in the paddock 50 to 60 yards from the river

and a piping failure progressed back to the river bank. Farmers had previously observed springs in the paddocks and heaving when the river was high¹. The breach was repaired with greywacke rock fill and some rip rap was placed along the river bank. The Catchment Commission carried out investigations and installed 11 piezometers in the area in 1966 and 67. The information gained was used to design an overlay typically 3 to 4ft thick, but up to 5ft thick in the area of the breach. A second overlay was placed in a low area near the top of the bend as shown on drawing R450/11/2 Sheet 1 attached.

The present stopbank was built in the early 1970s. Some of the river berm was used to provide fill for the stopbank construction. The crest width is typically 3.5m and the stopbank batters were designed at 3H:1V. No earthquake damage was recorded along this section in 1987². There is no record of any heave or springs being observed by farmers within the bend since the stopbank was built, although in the 2004 flood the ponded water in the low area may have prevented problems developing during the prolonged high river flow period.

3 Subsurface Investigations and Soil Profile

3.1 Previous Investigations

The earliest subsurface investigations in the area appear to be those carried out after the 1962 breach. The locations of seven bore holes and the bore logs are shown on Drawings R233 S 7/9, included in Appendix A. The holes extended to up to 15m depth and the bore logs give some good descriptions and particle grading information.

Some investigations up to 4.6m deep were carried out along the right bank of the river in 1972 prior to the construction of the stopbank. Three of the investigations were in the Reynold’s Bend area at approximately 3020m, 3500m and 4670m. The bore logs are shown on Drawing R450/11/10.

In 2002 four hand augers to 3m depth were carried out within Reynold’s Bend prior to some work to improve the freeboard on the stopbank³. The bore logs are included in Appendix A. A particle grading test was carried out in a sample from one of these augers and four other grading tests were carried out on samples from just upstream of Reynold’s Bend.

In 1987 three cone penetrometer tests were carried out to about 13m depth in the Morris farm on the opposite side of the river as part of a liquefaction study. These tests showed extensive liquefiable sandy deposits⁴.

¹ Eastern Bay of Plenty Catchment Commission (1968) Scheme Report

² Staff report to Bay of Plenty Catchment Commission (July 1987) Post earthquake flood evaluation of the lower Rangitaiki River.

³ Beca Carter Hollings & Ferner Ltd (2002) Rangitaiki River Stopbank Assessment: Edgecumbe to Thornton (RHS).

⁴ Christensen, S.A. (1995) Liquefaction of cohesionless soils in the March 2, 1987 Edgecumbe Earthquake, Bay of Plenty, New Zealand and other earthquakes, Department of Civil Engineering, University of Canterbury, research report.

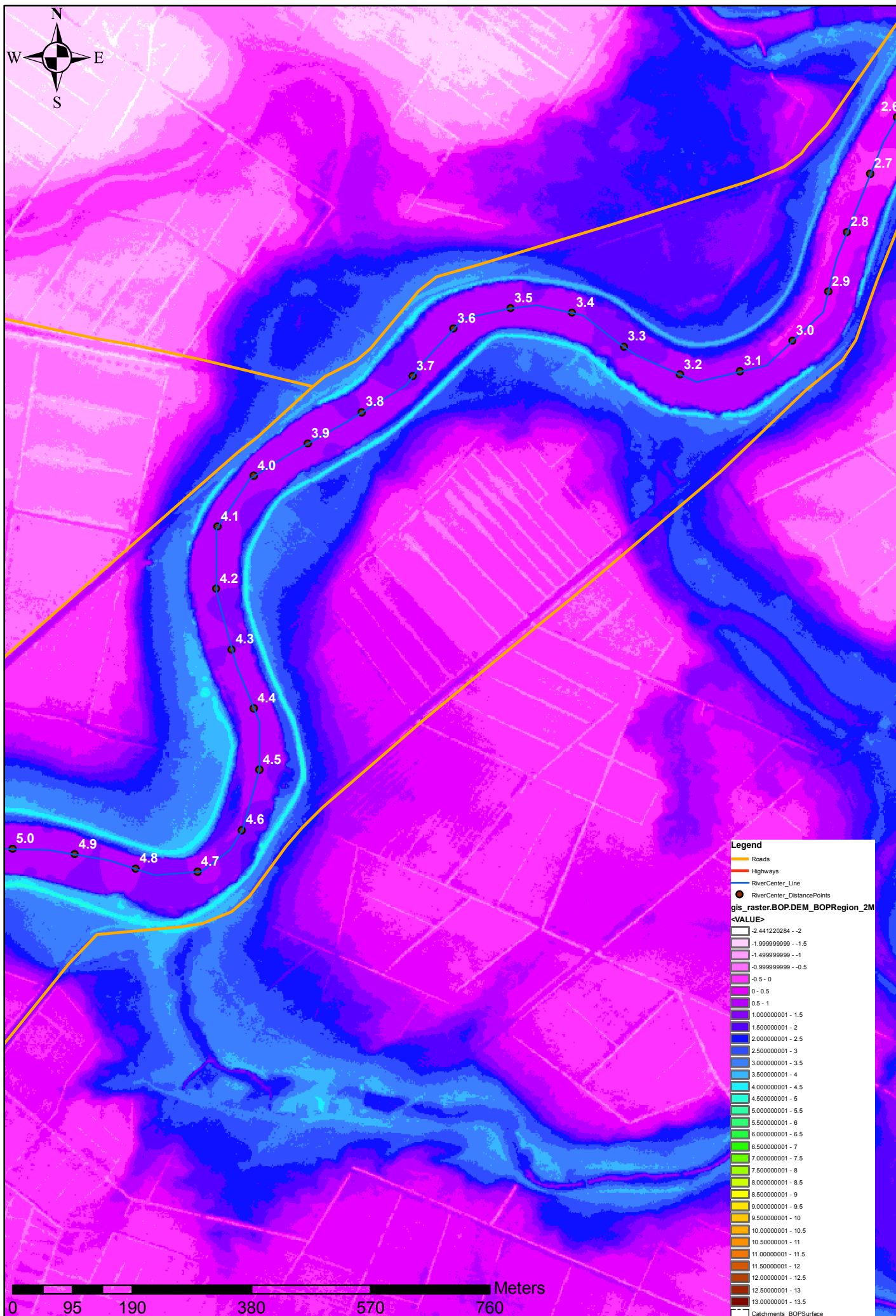


Rangitaiki River Scheme

Appendix 6

July 2004 Flood Damage Locality Plan

Sheet 9





**Rangitaiki River at Reynold's Bend.
Location of hand auger holes**

Dec, 2010
Survey Plan 102

3.2 In Situ Test Programme

The in situ test programme carried out for this report consisted of 30 hand augers to typically 3m depth. These were arranged in nine cross sections around the bend as shown in Figure 3.

The bore logs are included in Appendix B. The soils have been logged generally in accordance with the New Zealand Geotechnical Society Guidelines (December 2005). The cross sections were surveyed by Regional Council staff. The derived sub-surface soil profiles are included in Appendix C

3.3 Stopbank Soil Profile

Hand augers 1, 22 and 26 were carried out through the top of the stopbank. These showed that the stopbank is made predominantly of dense sandy silt and silty fine sand. Some hard gravel was found in HA26 and a thin silty fine to coarse sand layer was found overlying the natural soil at the base of the stopbank foundation in HA22.

The interface between the stopbank soils and the natural ground can be defined by the presence of the natural surface silt although this was not clear in HA1.

3.4 In Situ Soil Profile

The typical natural soil profile of the low lying basin within the bend consists of surface low permeability layers of silt, clayey silt and peat overlying a thin layer fine to coarse pumice sand which is probably a Tarawera ash. This is underlain by further peat and a stiff pumice silt. The Catchment Commission bore logs show that these layers are underlain by silty fine sand, fine sand and a basement medium to coarse sand layer. This basement layer was also found beneath the river levees and at other sites such as near the Thornton School^{5,6} and along Reid’s Canal^{7,8}.

The soil profile in the levee close to the river is much less predictable than in the low lying basin due to cycles of erosion, river meandering, river bank breakout and overtopping causing new deposits to be placed on the levee. Consequently in some areas there is sand at higher levels close to the river compared to within the basin. A highly permeable pumice gravel layer was also found in two of the Catchment Commission boreholes close to the river. Some deep layers of peat were also found.

4 Analysis Method

4.1 Discussion

The in situ investigations carried out provide subsoil profiles at isolated locations only. An effort has been made to build a degree of conservatism into the analysis of the

⁵ Ice Geo & Civil (2009) Rangitaiki River stopbanks assessment, Thornton School Section Right Bank 2300 to 3050m.

⁶ Ice Geo & Civil (2009) Rangitaiki River stopbanks assessment, Section 4, Right Bank 4800 to 6300m.

⁷ Ice Geo & Civil (2012) Reid’s canal floodway widening (1050m to 2900m), Geotechnical assessment.

⁸ Ice Geo & Civil (2013) Reid’s canal floodway upgrading (0m to 970m) Geotechnical assessment.

stopbank cross sections discussed in the following sections; however the subsurface investigations show reasonable variation in the soil layers particularly close to the river. It is therefore possible that in terms of the seepage response to a flood in the river there are worse combinations of soil layers than those assumed.

The computer programme used to analyse the seepage through and under the stopbank, Geo-Slope Seep/W (2012), is a two dimensional programme; therefore three dimensional effects such as seepage across the bend or down old stream paths, cannot be accurately modelled. The seepage analyses carried out must therefore be considered indicative only.

The problems that could arise due to a flood in the river include:

- The removal of soil particles due to high hydraulic gradients through or beneath the stopbank, resulting in piping and collapse of the stopbank.
- Heave of upper soil layers due to high water pressures developing beneath them, leading to the exposure of high permeability soils, rapid piping and stopbank collapse.
- Failure of either face of the stopbank due to high water level or draw down conditions.
- Over-topping of the stopbank causing rapid erosion of the stopbank.

The first three problems are addressed in this report. The Regional Council has designed the stopbank crest levels to allow for a 300mm freeboard in the 100 year return period flood, therefore overtopping should not occur prior to any of the other three failure mechanisms.

The maximum hydraulic exit gradient considered acceptable with the light soils in this area is 0.4 (based on a critical gradient which could initiate piping of 0.7). After a surface low permeability layer has been lifted and cracked, much lower hydraulic gradients can cause the loss of soil particles^{9,10}. The risk of piping can be reduced by preventing heave by the addition of overlays, by lengthening the seepage path, or by installing a drain in the area susceptible to piping to allow flow to the ground surface without the removal of soil particles.

The preferred no maintenance method to reduce the risk of heave and piping is overlays; however when the ground contours and permeability conditions combine to create the need for very wide overlays other options need to be assessed. Along the Rangitaiki River the more recent overlays have been designed to provide a minimum factor of safety against heave of 1.1 using conservative soil models. Around much of Reynold's Bend the river levee acts as an overlay across the soil layers in the basin.

The potential for piping failure following the occurrence of heave just beyond the overlay has been assessed by modelling the soil profile with a hole in the upper layer and estimating of the hydraulic gradient in the exposed high permeability layer. This is then

⁹ Weijers, J.B.A and Sellmeijer, J.B. (1993) A new model to deal with the piping mechanism on filters, Geotechnical and Hydraulic Engineering, Brauns, Herbaum and Schuler (editors) Balkema, Rotterdam

¹⁰ Schertmann, J.H. (2000) The non-filter factor of safety against piping through sands, ASCE Geotechnical Special Publication No. 111

compared to the critical hydraulic gradient for the soil and layer thickness given by the following formula². If the estimated gradient is less than the critical gradient it has been assumed that the risk of piping developing after heave has occurred is very small.

$$H_{crit} = \alpha c (\gamma_p' / \gamma_w) \tan \Theta (0.68 - 0.1 \ln c) L$$

$$\alpha = (D/L)^{(0.28 / ((D/L)^{2.8} - 1))}$$

$$c = c\eta \left((d_{70}^2 / k) (d_{70} / L) \right)^{0.33}$$

H_{crit} = critical value of head differential (m)

γ_w = unit weight of water (kN/m³)

γ_p' = submerged unit weight of soil particles (kN/m³)

Θ = angle of repose of soil particles

η = Whites drag coefficient

d_{70} = sieve size for which 70% by weight of the soil is finer (m)

D = thickness of sand layer (m)

L = seepage length (m)

$K = v k / g$

v = kinematic viscosity (m²/s)

g = gravity (m/s²)

k = hydraulic permeability (m/s)

The computer models allow seepage from the ground surface behind the stopbank as seepage of only small volumes of water from the ground surface can significantly reduce the uplift pressures acting on a low permeability surface layer. It has been assumed that the ends of the soil layers are exposed in the river bank although it is likely that they are covered by silt and vegetation. This is a conservative assumption however in a large flood the silt layer may be removed by erosion.

Seepage analyses have been carried out on the nine cross sections shown in Figure 3 plus a modified cross section from HA26 to HA28.

4.2 Flood Hydrograph

The Regional Council has provided a hydrograph for the river for a 100 year return period storm with an allowance for climate change. Figure 4 shows the 14 day

hydrograph. This was adjusted around Reynold’s Bend to allow for the change in stopbank crest level.

The initial water level in the river was assumed to be RL1.0 and the inland ground water level RL-1.0, due to the water level being kept down by pumping. A steady state seepage analysis was carried out to set up the initial conditions for the transient 100 year flood flow analysis. In the transient analysis the boundary conditions were the flood in the river and water ponding in the drains up to the ground surface.

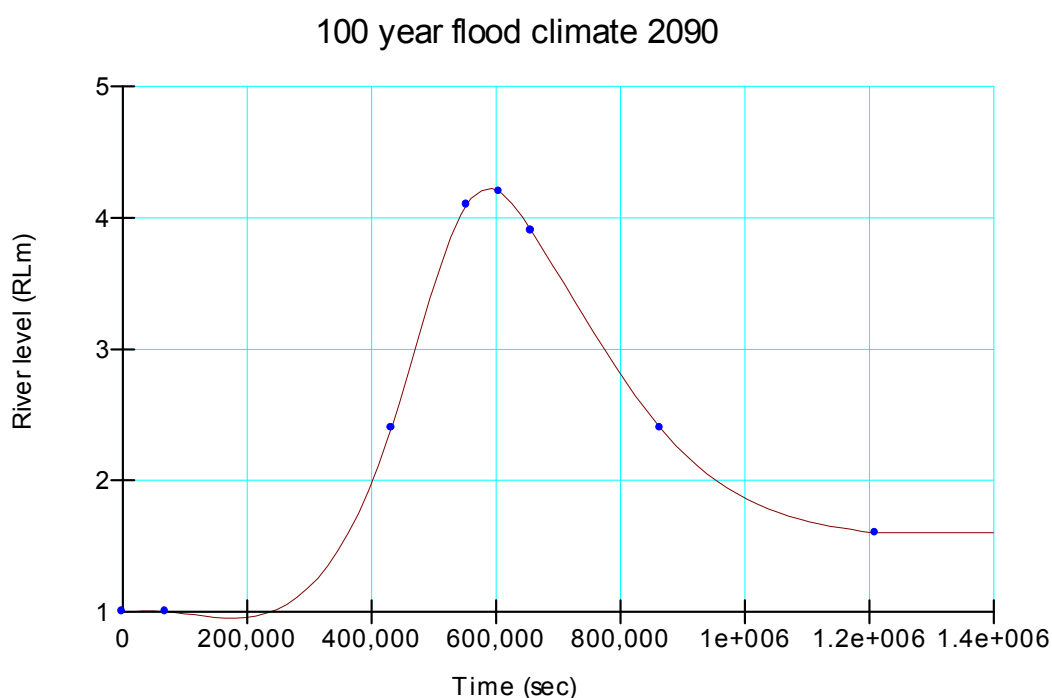


Figure 4: 100 year return period flood flow hydrograph

4.3 Soil Model

The soil layers found in the in situ investigations were simplified to form seepage analysis models for each of the stopbank cross sections. These are discussed in following sections and are shown in Appendix D.

Table 1 summarises the soils types and the permeabilities assumed. The permeabilities were based on the falling head and particle grading tests carried out within this section of stopbank and others near by.

In terms of the assessment of the risk of heave of the soil upper layers, it is conservative to assume a permeability on the low side of that found from tests on the upper silts and on the high side for the more permeable sand layers beneath acting as aquifers. It was assumed that the compaction process in stopbank construction would cause a greater horizontal permeability than vertical.

Table 1: Assumed soil permeabilities

soil	k_h (m/s)	k_v (m/s)
stopbank fill	5×10^{-6}	2.5×10^{-6}
surface silt	2×10^{-7}	2×10^{-7}
peat / organic clay	5×10^{-8}	5×10^{-8}
fine sand	5×10^{-5}	5×10^{-5}
fine to medium sand	1×10^{-4}	1×10^{-4}
medium to coarse sand	3×10^{-4}	3×10^{-4}
pumice gravel	3×10^{-3}	3×10^{-3}
silty fine sand	4×10^{-6}	4×10^{-6}

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 soil descriptions from the in situ tests were compared to those in the Seep library to choose the hydraulic conductivity and water content relationships. Once soils are saturated the water content relationship has no effect on the flow characteristics.

The stopbank cross sections were generally modelled to about 150m to 200m from the river to pick up the low area in the basin and to prevent any boundary effects on seepage patterns in critical areas.

The weight of the upper silt layers was assumed to be 15 kN/m^3 when heave potential was being checked; 14 kN/m^3 has been assumed for pumiceous silt and silty sand, 13 kN/m^3 for pumiceous sand and 12 kN/m^3 for organic clayey silts and peat.

Water is likely to pond in the low lying basin in a large storm. This water would reduce the head difference and relative seepage pressures across the stopbanks in this area. Ponded water has not been allowed for above the top of the drains shown on the cross sections.

5 Seepage Analysis Results

5.1 Cross Section 1

Cross Section 1 is at the down stream end of Reynold's Bend. It crosses the end of the levee from an abandoned stream. The stopbank itself is only about 1.4m high but the ground level drops from RL2.8 to -0.2 inside the stopbank, giving a head differential across the combined stopbank and levee of 4.2m at the peak of the flood.

The soil profile information from hand augers 21, 25, 26 and 27 was augmented by the log of BH 13 from the Eastern Bay of Plenty Catchment Commission's investigations (Drawing R233 S7/9). This log included some silt and peat layers at depth that would greatly reduce the inflows from the river if they extend to the river bed. A sensitivity analysis was carried out replacing these layers near the river with fine sand to determine the effect on the pressures developed inland.

Both transient analyses showed that there is a risk of heave of the base of dips and drains during the flood. A hole down to a medium grained sand in the dip 112m from the river was modelled and the maximum hydraulic gradient in the sand was found to be 0.07 on day seven of the flood. The formula to calculate the critical hydraulic gradient given in Section 4.1 requires d_{70} of the sand layer. A sensitivity analysis was carried out using the d_{70} value from each of the particle grading tests carried out on this layer (0.2 to 1.0mm) and a range of permeabilities for a medium grained sand, to determine the lowest critical hydraulic gradient at which piping could develop. This was found to be 0.09 with a permeability of 1×10^{-4} m/s and a d_{70} size of 5.8×10^{-4} m. It is therefore considered that if heave does occur in the base of the dip at 112m there is a low risk of piping developing. This analysis was repeated for heave at 89m from the river and again it was found that there is a low risk of piping developing.

5.2 Cross Section 1 Downstream

Just down stream from Cross Section 1 there is a dip in the old stream levee. This was probably the old stream bed. HA 28 was augered in this dip and a predominantly sand soil profile was found. Cross Section 1 was modified to reflect a cross section along the old stream bed. A transient flood flow analysis indicated that there should be no problems along the old stream bed as although the soils are sandier than elsewhere, the ground level inside the stopbank is higher.

5.3 Cross Section 2

The soil profile at this cross section was developed from hand augers 21, 22, 23 and 24 plus the log of BH 13, BHB from the Bay of Plenty Catchment Commission's investigations (Drawing R450/11/10) and Beca hand augers 15 and 16. The river levee is quite wide at this cross section and the ground level does not drop to RL0 until 180m from the river. There appears to be a reasonable thickness of silts and clays overlying the silty sands and coarse sands forming the levee.

The transient flood flow analysis shows that due to the sands in the levee the uplift pressure under the silts at the toe of the levee could be as high as the weight of the silts and there could be heave in the base of the drain at 196m and beyond. Holes in the silt layer down to the sand layer were modelled at 160m and 196m as for Cross Section 1. At 160m the highest gradient in the sand was found to be 0.02 and the critical gradient was calculated at 0.20. Similarly at 196m the maximum modelled gradient found was 0.04 and the critical gradient calculated was 0.20. Therefore the development of piping during the flood is not expected. These findings are consistent with observed stopbank failures along the Rangitaiki River which have been recorded as initiating with heave up to about 70m from the stopbank.

5.4 Cross Section 3

Cross Section 3 is through a narrow part of the river levee near the mid point of Reynold's Bend. The ground level drops to RL0 within 80m of the river at this cross section and continues to drop to RL-0.7. There is therefore 4.7m of head differential across this section of stopbank at the flood peak.

The soil profile used in the analysis was derived from hand augers 18, 19, 20 and 21, plus BH10 on the Eastern Bay of Plenty Catchment Commission's Drawing R233 S 7/9 and Beca hand augers 15 and 16. BH10 is a considerable distance from Cross Section 3 therefore a sensitivity analysis was carried out replacing a silt layer at RL-3 in BH10 with a medium grained sand layer open to the river bed. This level is just below the depth of the hand augers carried out for this stopbank assessment.

The transient analysis with the silt layer in place showed no factor of safety against heave in the base of the drain 121m from the river. When the silt was replaced with sand the model showed potential heave at 121m and further out at 200m where the ground level drops to RL-0.7. Further analyses were carried out with a hole down to the medium sand layer at RL-2.0 and a hole down to the layer at RL-3.0. Both of these analyses showed that the maximum hydraulic gradient in the sand layer was about a third of the critical gradient. Piping is therefore not expected to develop should heave occur in a flood.

5.5 Cross Section 4

At Cross Section 4 there is a levee at RL2.5 to 2.8 about 80m wide on the inside of the stopbank. The ground level then drops to as low as RL-0.5 over the next 50m. The inverts of drains within the low basin are as low as RL-1.2.

Information from hand augers 14, 15, 16 and 17, BH10 and Beca hand augers 13 and 14 were used to develop the soil profile. Coarse pumice sand was found beneath silty sand in HA14 on the river side of the stopbank. It was assumed that further away from the river the coarse sand graded into the medium sand found within the peat across most of the basin.

The initial transient flood flow seepage analysis with the lower sand layers opened up to the river bed showed there could be heave problems beyond 130m from the river. Further transient analyses were carried out modelling a hole in the upper silt layers at 132m, 153m and 176m. The critical gradient for the coarse sand was calculated using the d_{70} values from four coarse sand samples from Langdon's Bend, just upstream and two samples from the Thornton School section, just downstream. The permeability of the sand was taken as 3×10^{-4} m/s and the d_{70} value giving the lowest critical hydraulic gradient was found to be 0.4mm. The maximum hydraulic gradients in the sand adjacent to the holes were found to be 50 to 80% of the critical gradient. It is therefore considered that there is a low risk of piping developing following heave.

5.6 Cross Section 5

At Cross Section 5 the river levee is broad and only drops below RL2.0 about 100m from the stopbank and RL0.0 about 160m from the stopbank.

The soil profile here was developed from hand augers 10, 11, 12 and 13, BH10 and Beca hand augers 13 and 14. The soils in the levee seem quite complex with multiple layers of sand, silty sand and lapilli beneath the surface silts. These layers were modelled as a soil with a horizontal permeability of 4×10^{-4} m/s and a vertical permeability of 4×10^{-6} m/s.

It appears from the marker medium grained pumice sand layer across the basin that the levee has grown since this layer was laid down, causing about 0.8m of settlement of the underlying soils at the HA13 location. It was assumed that this sand layer extends under the levee and is connected to the coarse sand found in HA 11. It is considered that the soil model adopted is reasonably conservative in that it promotes the transmission of high water pressures towards the low lying basin.

The initial transient analysis showed that the only area where there could be heave problems was in the drain at 168m. A hole was modelled here and the maximum hydraulic gradients in the sand were found to be 40% of that required to sustain piping. It is therefore considered that there is a low risk of stopbank failure across this cross section.

5.7 Cross Section 6

Cross Section 6 is downstream of the 1962 breach location. The river levee grades steadily down from the stopbank to RL1.0 over 80m and then more gradually to RL-0.1. This cross section intersects several drains with the lowest invert 139m from the stopbank at RL-0.8.

The subsurface soil profile was developed from hand augers 7, 8, 9 and 10 and BH10. The river levee appears to consist predominantly of clayey silt. This may be the downstream end of the surcharge placed during the remedial works of 1963.

The initial transient analysis assuming the sand layers were all open to the river showed that there could be heave problems beyond the toe of the levee/surcharge at 119m from the river. Holes in the upper silt layers down to the sand layers were modelled at each of the drains and it was found that the maximum hydraulic gradients in the sand were 20 to 30% of the critical gradients to sustain piping.

5.8 Cross Section 7

Cross Section 7 is through the 1962 breach repair. The Catchment Commission report¹ states that 0.9 to 1.5m (3 to 5 ft) of silt was placed across the stop of the greywacke rock fill used to close the breach. There are no known records of the how far the hole caused by the breach extended inland from the river. For the purposes of this analysis it was assumed that the hole extended 40m inland at RL-2.0, on top of a peat layer, and tapered up to the general ground level at about 40m from the present stopbank toe.

The soil profile around the rock filled hole was taken from hand augers 4, 5 and 6 and the logs of boreholes 1 and 9 on the Eastern Bay of Plenty Catchment Commission Drawing R233 S 7/9. HA5 was carried out 45m from the stopbank toe and silt surcharge material was found overlying the natural soil profile. BH 1, at the breach site showed layers of fine sands and gravels below the peat at river bed depth.

In the initial transient flood flow analysis of this cross section it was assumed that the permeability of the rock fill is 1×10^{-3} m/s and that it is open to the river. It was found with these assumptions that during the flood there would be heave of the silt overlay over the rock fill and in the paddock beyond the rock fill. A second analysis was carried out assuming the permeability of the rock fill is 1×10^{-4} m/s. It was found that the uplift

pressure approximately balances the weight of the overlay and even though the uplift pressures under the paddock had reduced they could still cause heave. A further analysis was carried out assuming that silty fine sand had washed into the voids in the surface 1m of rock fill. This still showed high uplift pressures. Other analyses were carried out varying the permeabilities of the fine sand and gravel layers in BH1 and BH9. All these analyses indicated potential problems. Therefore it is considered that some deep boreholes are required within and around the rock fill area to confirm the soil profile. In situ permeability tests should be carried out to refine the permeability estimate for the rock fill and the underlying sand and gravel layers.

5.9 Cross Section 8

Cross Section 8 traverses a narrow part of the river levee and East Bank Road and then runs along the edge of the old stream levee at the upstream end of Reynold's Bend. The ground level drops to RL1.0 within 65m of the stopbank toe and then levels out at about RL0.3 along the stream levee. The river bank in this location is particularly steep.

The soil profile used in the analyses was based on hand augers 1, 2 and 3, and Catchment Commission boreholes 2, 3 and 18. The river levee appears to consist predominantly of silt and overlies a peat layer found in all the boreholes. Near the river the lower soils are mainly sands and gravels, whereas further inland the sand immediately below the peat becomes silty.

An initial transient flood analysis with the pumice gravel found in BH18 indicated there could be heave problems below the edge of the road fill. If the gravel layer is replaced with a fine sand as found in BH2 heave is unlikely when the ground level is above RL0.3.

The initial analysis assuming the gravel layer extends under the stopbank and is overlain by fine sand, as shown in the BH18 log, was repeated with a hole due to heave down to the fine sand layer modelled at the toe of the road fill, about 20m from the stopbank toe. It was found that the maximum hydraulic gradients in this sand layer exceed the critical gradient for the development of piping. This analysis was repeated with a hole 60m from the stopbank toe. It was found that piping could also develop from this location. This is consistent with the observations of the initiation of the breach in 1962.

It was found that if the gravel layer under the levee was replaced with fine sand the risk of piping initiating 60m from the stopbank toe is greatly reduced. It is therefore considered that boreholes are required through the stopbank at this location and inland near the toe of the road fill to confirm the presence and permeability of the various high permeability layers.

5.10 Cross Section 9

Cross Section 9 is at the upstream end of Reynold's Bend and runs along the adjacent old stream levee. The ground level inside the stopbank therefore does not drop below RL2.0. A subsurface soil profile was developed from hand augers 29 and 30 and BH18.

A transient flood analysis showed that the ground water level inside the stopbank does not rise to the ground surface and the water pressures below the surface would not be sufficient to cause heave.

6.0 Stopbank Stability

There is no berm along the river bank at cross sections 1 and 8, therefore stability analyses were carried out on these cross sections for low river, high river and drawdown conditions. The stability analyses were carried out using the Geo-Slope / W programme linked to the Seep / W programme.

The low river level was assumed to be RL1.0 and the high river level was taken as the peak of the flood. The pore water pressure and flow regimes throughout the transient seepage analyses were assessed to find the worst drawdown condition and these pressures were transferred to the stability model.

The soil models are shown in Appendix E and the assumed soil strength parameters are given in Table 2.

Table 2: Soil strength parameters

soil	density ρ_b (kN/m ³)	cohesion c' (kPa)	friction ϕ' (°)
stopbank fill	16	2	30
surface silt	15.5	2	28
pumice silt	14	0	26
peat / organic clay	12	5	20
fine sand	13	0	35
fine to medium sand	13	0	38
medium to coarse sand	13	0	38
pumice gravel	12	0	38
silty fine sand	14	0	30
rock	20	0	35

An analysis of Cross Section 1 with a low river level showed that the factor of safety against slope failure was only 1.1. The critical failure surface was about 2m deep and extended to the stopbank crest. In this situation a factor of safety of 1.5 would be considered acceptable. When the river is high the water buttresses the face of the stopbank and the factor of safety against failure of the river side face increases to 1.8. The water level within the stopbank is not sufficiently developed to cause problems for the 3H:1V inland face of the stopbank. The worst drawdown conditions were found to occur 9.7 days into the flood and the factor of safety against failure drops to 1.1.

It is considered that a berm is required at Cross Section 1 to bring the low water level factor of safety up to 1.5 and the drawdown factor of safety up to 1.3. The addition of a 5m wide rock berm at RL2.0, with a 2H:1V batter in the river, was found to increase the factors of safety to the required values.

The same stability analyses as for Cross Section 1 were repeated for Cross Section 8. The low river level factor of safety was found to be less than 1.1, the high river level, 2.5 and the drawdown factor of safety 12.5 days into the flood, 1.1. The addition of a rock berm as at Cross Section 1 improves the low water level factor of safety to 1.5.

7 Conclusions

1. The geology along Reynold’s Bend is quite complicated due to the presence of stream levees at each end of the bend, previous breach repairs and surcharges.
2. A reasonably conservative approach to assessing seepage related problems along the stopbank has been taken by assuming there is no silt covering the ends of sand layers exposed in the river bank, deep sand layers are not sealed by low permeability layers in the river bed and there is no ponding above typical ground level in the low lying basin.
3. Some deep investigations and in situ permeability tests are required in the area of the 1962 breach (Cross Section 8) and Cross Section 9 to confirm the soil profile and possible heave and piping problems.
4. Rock berms are required in the areas of cross sections 1 and 8, the downstream and upstream extents of Reynold’s Bend, to provide adequate factors of safety against failure of the stopbank face. These berms should be 5m wide at RL2.0 and have batters no steeper than 2H:1V.

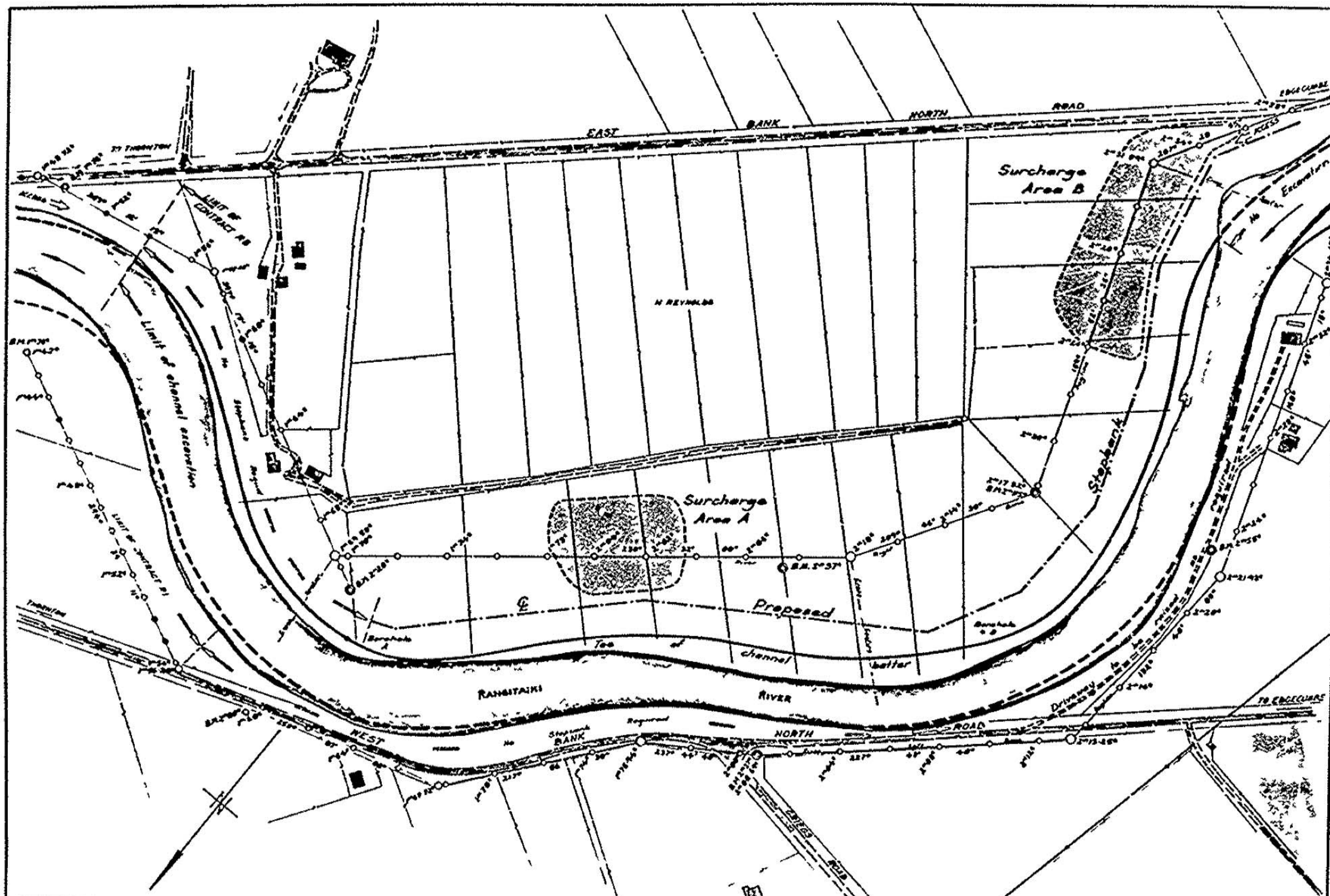
M. O’Halloran

BE, PhD, Dip BA, MIPENZ (Geotechnical), CPEng IntPE

30 June 2014

Appendix A

Previous Subsurface Information



BAY OF PLENTY CATCHMENT COMMISSION

RANGITAIKI-TARANERA RIVERS MAJOR SCHEME
 RANGITAIKI RIVER WIDENING STAGE II
 1" 50' - 2" 38'

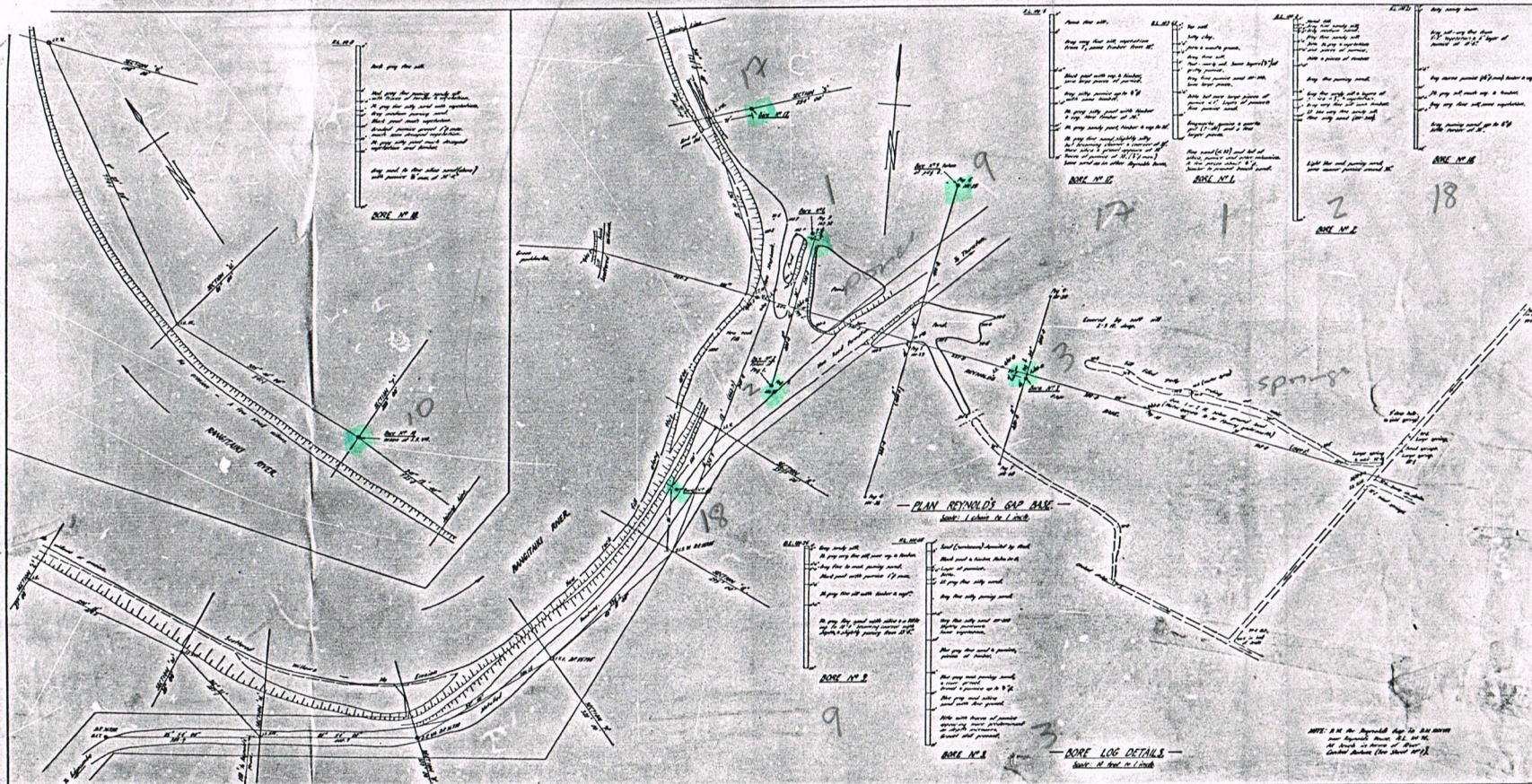
SURVEYED	1/50	1/50
DRAWN	1/50	1/50
DESIGNED	1/50	1/50
TRACED	1/50	1/50
DESIGNED	1/50	1/50
BY CHECK	1/50	1/50

APPROVED
P. O. Reynolds
 CHIEF ENGINEER

SCALE
 2 chains to an inch
 (approx)

REFERENCES
 Aerial Photographs
 taken 19/3/60.
 Nos. 14

PLAN NO.
RA50/11/2
 Sheet 1 of 12



RANGITIKI RIVER INVESTIGATION.

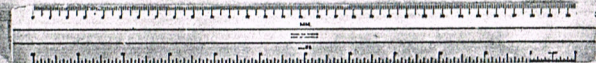
EASTERN BAY OF PLENTY CATCHMENT COMMISSION.

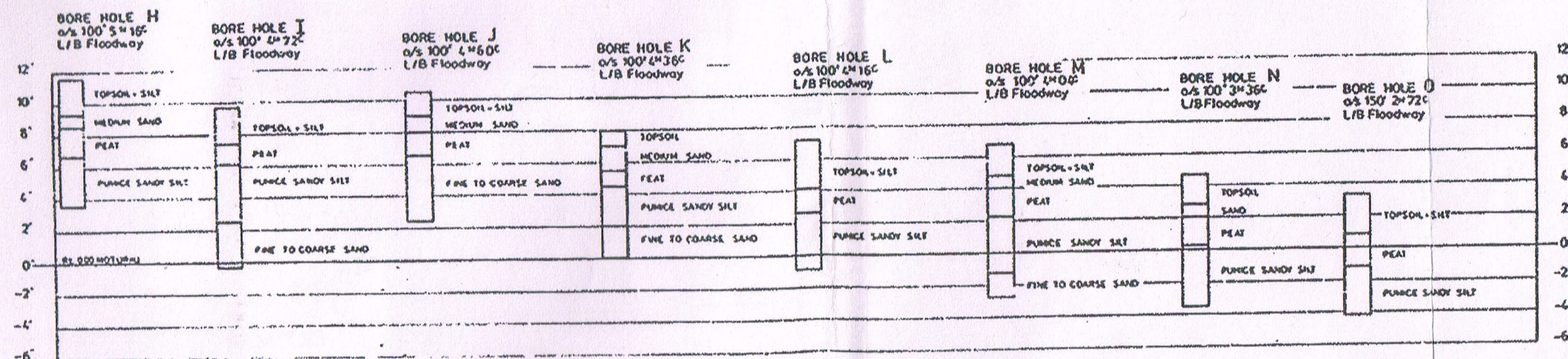
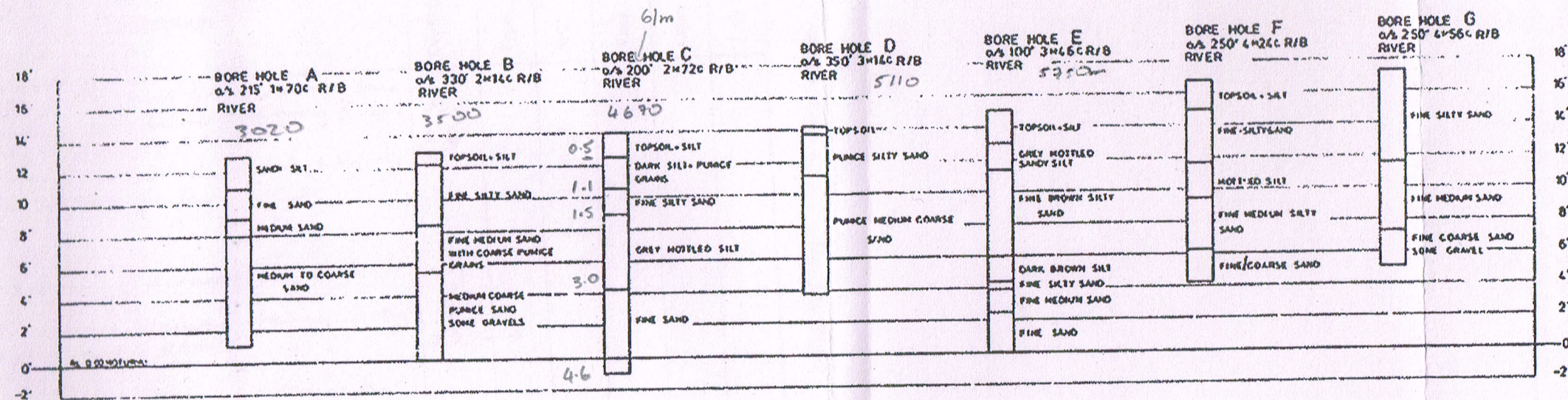
PLANS AND SECTIONS

Sheet 7 of 8 sheets

ARTHUR HARRISON & PARTNERS
 ENGINEERS, SURVEYORS & ARCHITECTS
 11, ADELAIDE STREET, AUCKLAND, N.Z.

1/2077





BAY OF PLENTY CATCHMENT COMMISSION

RANGITAHI TARAWERA RIVERS MAJOR SCHEME
RANGITAHI RIVER WIDENING STAGE II
BORELOGS

SURVEYED	D.C.A.	8/70
DRAWN	-	-
DESIGNED	-	-
TRACED	D.F.A.	8/75
DESIGN CHECK	-	-
ON CHECK	Q.P.	7/78

APPROVED
R. S. King
CHIEF ENGINEER

SCALES
4 feet to an inch vertical

REFERENCES
DATUM
NOTED

PLAN NO
R450/III/10
Sheet 1 of 1 Sheets

RECORD OF BOREHOLE

JOB NAME: Rangitikei Shapbank

Sheet 1 of

BH 13

CLIENT: EBOF

Location: 2000m R.H.S

JOB NO.: 9301739 / 010

Coords: 23990m

Elev.: Datum:

Strata

Sample

Field Tests

Depth (m)

LGD

SYM

Description

Depth (m)

Type

SPT

Vane

Other

Lab Test

brown silty SAND, some pumice
lenses to 5mm

0.6 orange brown mottled grey
silt, some sand & clay, plastic, lumpy
1.0 orange brown mottled grey fine
sandy silt/silty SAND grey fine
1.2 some fine lumps & pumice to 20mm

1.7 orange brown mottled grey
fine silty SAND, moist

2.3 orange brown mottled grey fine silt

2.65 orange/yellow grey well graded
fine sand, some fine gravel
2.8 EBOF

OBSERVATIONS:

SAMPLES

- * Small disturbed sample
- ↔ Large disturbed sample
- ⊕ undisturbed core sample
- ⌋ SPT Split spoon sample

FIELD TESTS

SPT = Standard penetration Test
(blows/150mm, N=blows/300mm)
C = Cohesion as measured direct with shear
vane (kPa)
CR = Remoulded C
CC = Corrected Reading (kPa)

PILCON VANE

Dial No.

DATE STARTED: 22/3/01

CORE DIA:

DATE FINISHED:

LOGGED BY: D.O.H

RIG:

CONTRACTOR: A.H

Beca Carter Hollings & Ferner

Ph: (07) 578-0896

RECORD OF BOREHOLE

Sheet 1 of

BH 14

JOB NAME: Rangitikei Stopbank

Location: 2000m R.H.S.

CLIENT: EBOF

12m from p.p.

Coords: ~ 3990m

JOB NO.: 9301739 / 010

Elev.: Datum:

Depth (m)	Strata			Sample		Field Tests			Lab Test
	LGD	SYM	Description	Depth (m)	Type	SPT	Vane	Other	
0.0 - 0.6	X X								

OBSERVATIONS:

SAMPLES

- * Small disturbed sample
- ↔ Large disturbed sample
- € undisturbed core sample
- ↓ SPT Split spoon sample

FIELD TESTS

SPT = Standard penetration Test (blows/150mm, N=blows/300mm)
C = Cohesion as measured direct with shear vane (kPa)
CR = Remoulded C
CC = Corrected Reading (kPa)

CON VANE

Dial No.

DATE STARTED: 27/3/02

CORE DIA:

RIG:

DATE FINISHED:

LOGGED BY: JCH

CONTRACTOR: A.H.

Beca Carter Hollings & Ferner

Ph: (07) 578-0896

RECORD OF BOREHOLE

JOB NAME: Rangitiki Stopbank

CLIENT: E80P

JOB NO.: 9301239 / 010

Sheet 1 of

BH 15

Location: 1450m A.H.S.

1m from per
23440m

Coords:

Elev.:

Datum:

Strata

Sample

Field Tests

Depth (m)

IGD

SYM

Description

Depth (m)

Type

SPT

Vane

Other

Lab Test

0.3 orange brown mottled grey fine sandy silt / silty SAND
0.5 orange brown mottled light grey fine SAND, fluffy

0.6 - *

1.7 becoming darker grey, & moist
2.05 orange brown stained grey med - coarse SAND

2.2 - *

2.7 black iron stained layer on top of coarse pum SAND
2.85 2.85

OBSERVATIONS:

SAMPLES

- * Small disturbed sample
- ↔ Large disturbed sample
- € undisturbed core sample
- ↓ SPT Split spoon sample

FIELD TESTS

SPT = Standard penetration Test (blows/150mm, N=blows/300mm)
C = Cohesion as measured direct with shear vane (kPa)
CR = Remoulded C
CC = Corrected Reading (kPa)

PILCON VANE

Dial No.

DATE STARTED:

22/3/02

CORE DIA:

LOGGED BY: R.O.H

RIG:

CONTRACTOR: A.H

DATE FINISHED:

Ph: (07) 578-0896

Beca Carter Hollings & Ferner

RECORD OF BOREHOLE

Sheet 1 of

BH 16

JOB NAME: Rangitikei Stopbanks

Location: 1450m AHS
19.2m from peg

CLIENT: E BOP

Coords: 23440m

JOB NO.: 9301739

Elev.: Datum:

		Strata		Sample		Field Tests			Lab Test
Depth (m)	LGD	SYM	Description	Depth (m)	Type	SPT	Vane	Other	
0.0	x		brown silty fine SAND/sandy SILT						
1.0			0.3 orange mottled light gray fine SAND, fluff						
2.0			2.1 gray med - coarse SAND						
3.0		7	3.1 wet						
4.0		5	3.2 gray coarse SAND						
OBSERVATIONS									

OBSERVATIONS:

SAMPLES

- * Small disturbed sample
- ↔ Large disturbed sample
- € undisturbed core sample
- ↓ SPT Split spoon sample

FIELD TESTS

SPT = Standard penetration Test
(blows/150mm, N=blows/300mm)
C = Cohesion as measured direct with shear vane (kPa)
CR = Remoulded C
CC = Corrected Reading (kPa)

PILCON VANE

Dial No.

DATE STARTED: 27/3/02

CORE DIA:

RIG:

DATE FINISHED:

LOGGED BY: DOW

CONTRACTOR:

AN

Beca Carter Hollings & Ferner

Ph: (07) 578-0896

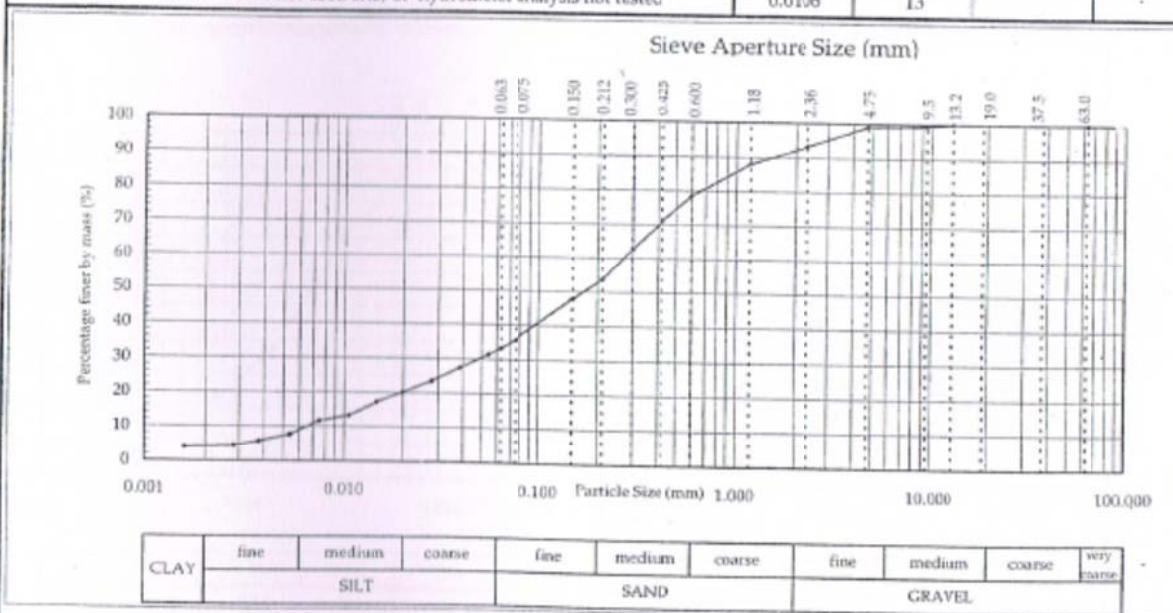
PARTICLE SIZE ANALYSIS TEST REPORT

Project : Rangitaiki Stopbanks
 Location: Unknown
 Client : Beca Carter Hollings and Ferner Ltd
 Client/Sample Ref : -
 Contractor : -
 Bore/Test Pit No: BH1 Depth: 0.30 metres 2850m
 Sampled by : Unknown 4840
 Date received : 03/04/02
 Sampling method : Unknown
 Sample condition : As received
 Sample description : Light brown silty fine SAND
 Solid Particle Density (t/m^3): 2.65 assumed
 Water Content (as received): 8.3 %



Project No: 2-55545.04
 Lab Ref No: 02/326/001
 Client Ref: 10138

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	99	0.300	63	0.0541	31	0.0075	12
37.5	--	2.36	93	0.212	54	0.0389	27	0.0054	8
19.0	--	1.18	88	0.150	48	0.0279	23	0.0038	6
13.2	100	0.600	79	0.075	36	0.0199	20	0.0028	4
9.5	99	0.425	71	0.063	33	0.0147	17	0.0016	4
Note: "--" denotes sieve not used and/or hydrometer analysis not tested						0.0106	13		



Test Methods	Notes
Particle Size Analysis: NZS 4402 1986 Test 2.8.1 (Wet Sieve)	Fraction Tested: Whole soil
Particle Size Analysis: NZS 4402 1986 Test 2.8.4 (Hydrometer)	pH of suspension : 8.0

Date Tested: 09/04/02

Date Reported: 10/04/02

IANZ Approved Signatory *SA*
 Designation : Senior Civil Engineering Technician
 Date : 10/04/02

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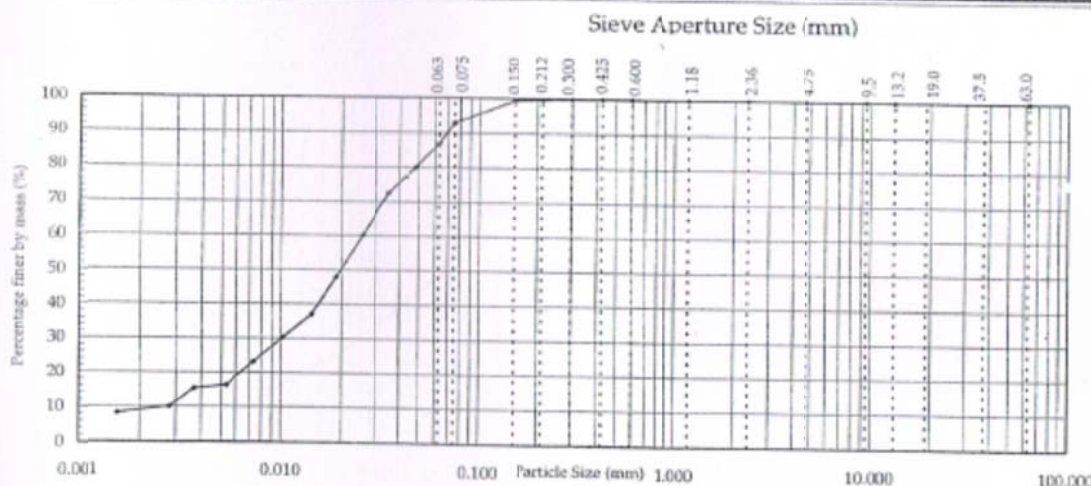
PARTICLE SIZE ANALYSIS TEST REPORT

Project : Rangitaiki Stopbanks
 Location: Unknown
 Client : Beca Carter Hollings and Ferner Ltd
 Client/Sample Ref : -
 Contractor : -
 Bore/Test Pit No: BH1 Depth: 1.20 metres 2850 mm
 Sampled by : Unknown 4840
 Date received : 03/04/02
 Sampling method : Unknown
 Sample condition : As received
 Sample description : Light brown sandy SILT
 Solid Particle Density (t/m^3): 2.65 assumed
 Water Content (as received): 38.8 %



Project No: 2-55545.04
 Lab Ref No: 02/326/001
 Client Ref: 10138

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	100	0.0482	80	0.0074	23
37.5	--	2.36	100	0.212	100	0.0350	72	0.0053	16
19.0	--	1.18	100	0.150	99	0.0257	60	0.0037	15
13.2	100	0.600	100	0.075	93	0.0189	48	0.0028	10
9.5	100	0.425	100	0.063	87	0.0142	37	0.0016	8
Note: "--" denotes sieve not used and/or hydrometer analysis not tested						0.0102	30		



CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	very coarse
	SILT			SAND			GRAVEL			

Test Methods	Notes
Particle Size Analysis: NZS 4402 1986 Test 2.8.1 (Wet Sieve)	Fraction Tested: Whole soil
Particle Size Analysis: NZS 4402 1986 Test 2.8.4 (Hydrometer)	pH of suspension : 8.0

Date Tested: 09/04/02

Date Reported: 10/04/02

NZ Approved Signatory *[Signature]*
 Designation : Senior Civil Engineering Technician
 Date : 10/04/02

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PARTICLE SIZE ANALYSIS TEST REPORT

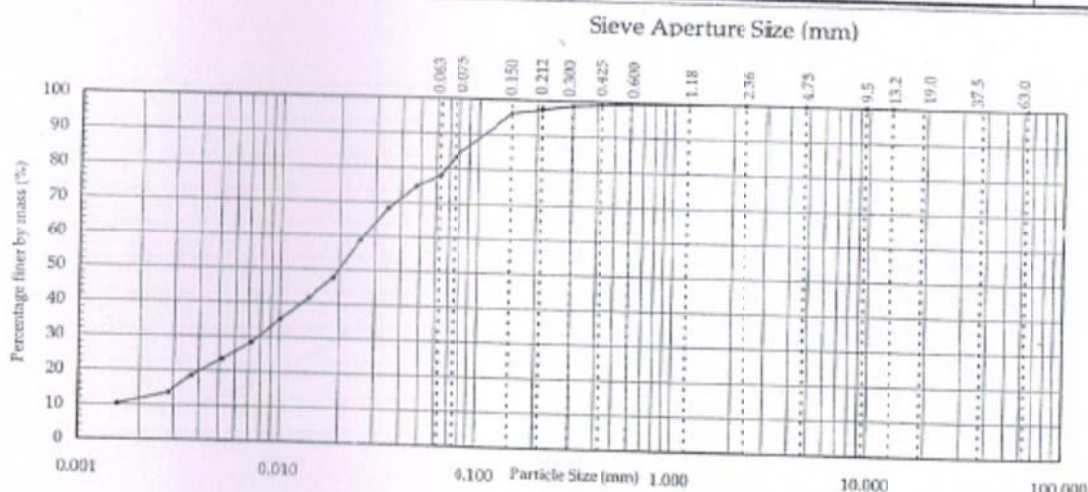
Project : Rangitaiki Stopbanks
 Location: Unknown
 Client : Beca Carter Hollings and Ferner Ltd
 Client/Sample Ref : -
 Contractor : -
 Bore/Test Pit No: BH2 Depth: 0.30 metres 2.850m
 Sampled by : Unknown 3.9.0.0.0
 Date received : 03/04/02
 Sampling method : Unknown
 Sample condition : As received
 Sample description : Light brown sandy SILT
 Solid Particle Density (t/m^3): 2.65 assumed
 Water Content (as received): 14.9 %



Project No: 2-55545.04
 Lab Ref No: 02/326/001
 Client Ref: 10138

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	99	0.0475	75	0.0072	28
37.5	--	2.36	100	0.212	97	0.0347	68	0.0052	23
19.0	--	1.18	100	0.150	96	0.0254	59	0.0037	18
13.2	100	0.600	100	0.075	83	0.0186	48	0.0028	14
9.5	100	0.425	99	0.063	78	0.0139	41	0.0016	10
						0.0100	35		

Note: "--" denotes sieve not used and/or hydrometer analysis not tested



CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	very coarse
	SILT			SAND			GRAVEL			

Test Methods	Notes
Particle Size Analysis: NZS 4402 1986 Test 2.8.1 (Wet Sieve)	Fraction Tested: Whole soil
Particle Size Analysis: NZS 4402 1986 Test 2.8.4 (Hydrometer)	pH of suspension : 8.0

Date Tested: 09/04/02

Date Reported: 10/04/02

IANZ Approved Signatory *Sh*
 Designation : Senior Civil Engineering Technician
 Date : 10/04/02

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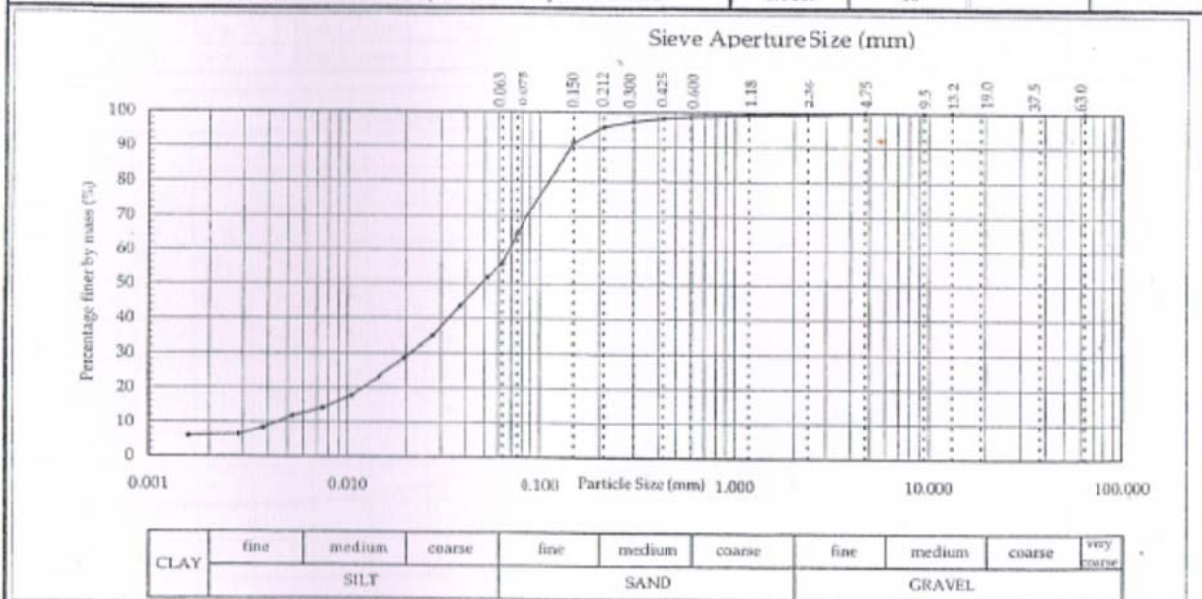
PARTICLE SIZE ANALYSIS TEST REPORT

Project : Rangitaiki Stopbanks
 Location : Unknown
 Client : Beca Carter Hollings and Ferner Ltd
 Client/Sample Ref : -
 Contractor : -
 Bore/Test Pit No : BH3 Depth: 0.50 metres 2900-4000
 Sampled by : Unknown
 Date received : 03/04/02
 Sampling method : Unknown
 Sample condition : As received
 Sample description : Light brown sandy SILT
 Solid Particle Density (t/m^3): 2.65 assumed
 Water Content (as received): 10.4 %



Project No: 2-55545.04
 Lab Ref No: 02/326/001
 Client Ref: 10138

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	97	0.0515	52	0.0075	14
37.5	--	2.36	100	0.212	96	0.0375	44	0.0053	12
19.0	--	1.18	99	0.150	91	0.0273	35	0.0038	8
13.2	100	0.600	99	0.075	65	0.0197	29	0.0028	6
9.5	100	0.425	98	0.063	56	0.0145	23	0.0016	6
Note: "--" denotes sieve not used and/or hydrometer analysis not tested						0.0105	18		



Test Methods	Notes
Particle Size Analysis: NZS 4402 1986 Test 2.8.1 (Wet Sieve)	Fraction Tested: Whole soil
Particle Size Analysis: NZS 4402 1986 Test 2.8.4 (Hydrometer)	pH of suspension : 8.0

Date Tested: 09/04/02

Date Reported: 10/04/02

IANZ Approved Signatory *[Signature]*
 Designation : Senior Civil Engineering Technician
 Date : 10/04/02

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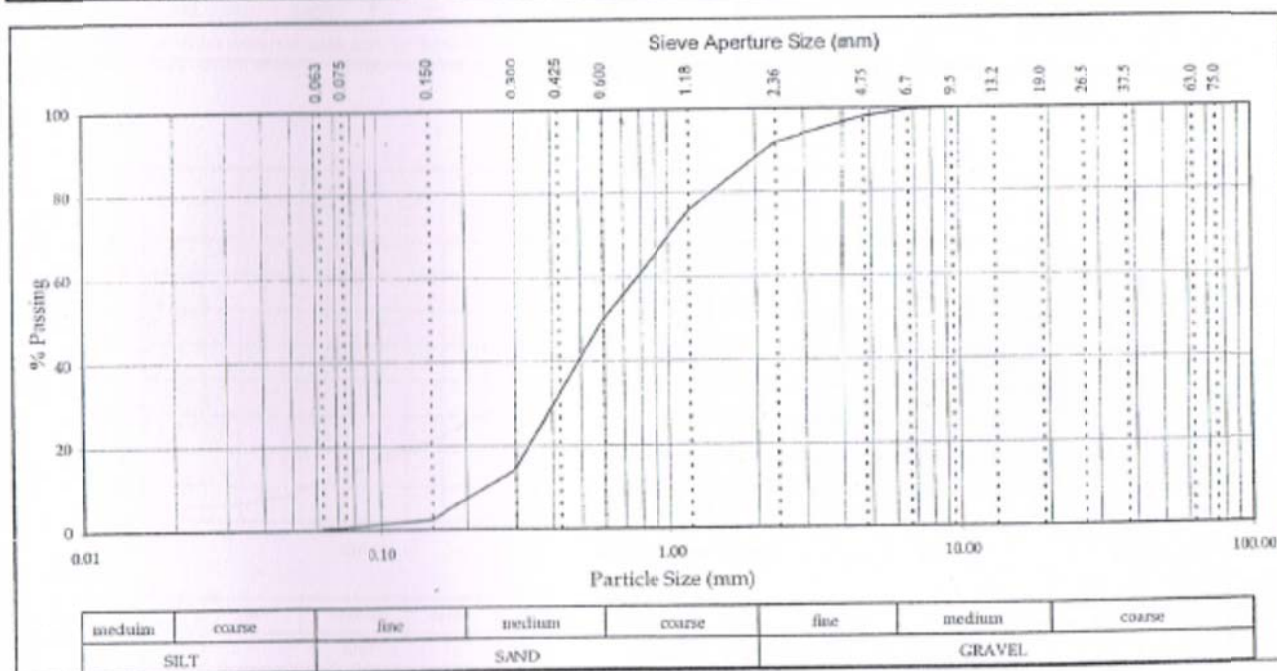
WET PARTICLE SIZE DISTRIBUTION TEST REPORT



Project : Rangitaiki Stopbanks
Location : Unknown
Client : Beca Carter Hollings and Ferner
Contractor : N/A
Sampled by : Beca Carter Hollings and Ferner
Date sampled : Unknown
Sampling method : Unknown
Sample description : Gravelly SAND
Sample condition : Natural State
Bore hole no : 14 2000-
Depth (m) : 3.4m 3990

Project No : 25545.04/OTL
Lab Ref No : 10138
Client Ref No : -

Particle Size Distribution					
Size (mm)	% Passing	Size (mm)	% Passing	Size (mm)	% Passing
75.00	-	13.20	-	2.36	92
63.00	-	9.50	100	1.18	76
37.50	-	6.70	100	0.600	50
19.00	-	4.75	98	0.425	33
				0.300	15
				0.150	2
				0.075	1
				0.063	0



Test method
NZS 4407 : 1991 Test 3.8.1

Notes
History : Natural State
Fraction tested : Whole Soil
Dispersant : Sodium Hexametaphosphate
History : Natural State

Date tested : 16 April 2002
Date reported : 16 April 2002

Percentage passing finest sieve obtained by difference.
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IANZ Approved Signatory

M.B. [Signature]

Designation :
Date :

Laboratory Manager
16 April 2002



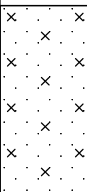

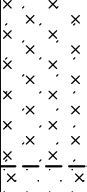
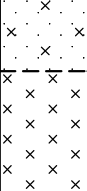
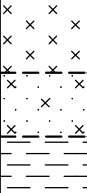
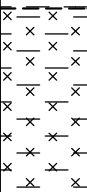


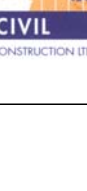

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Appendix B

Hand Auger Logs

Project: **Rangitaiki River Stopbank Assessments** Test: **HA1**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 4.46
 Number: Date: 06/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	3.86		fine to medium silty SAND , some pumice gravel to 5mm, orange brown, dry, dense	
1.0			fine sandy SILT , some hard angular gravel to 15mm, brown	
1.5	2.76		silty fine SAND , grey with orange staining, damp, med. dense	
2.0	2.46		SILT , grey with orange staining, moist, firm	
2.5	1.86		silty fine SAND , grey with orange staining, moist	
3.0	1.66		CLAY , some fine roots, grey with orange staining, firm, moist	
	1.46		clayey SILT , grey with orange staining, moist	
3.5	0.76		CLAY , some fibrous organic material, green grey, soft, moist	
4.0				
4.5	-0.04			



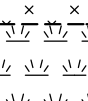
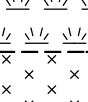
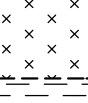
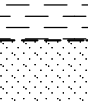


Project: **Rangitaiki River Stopbank Assessments** Test: **HA1**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 4.46
 Number: Date: 06/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
4.5			EOB	
5.0				
5.5				
6.0				
6.5				
7.0				
7.5				
8.0				
8.5				
9.0				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA2**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 1.93
 Number: Date: 06/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
			fine sandy SILT , brown, damp, firm	
0.5	1.53		silty fine SAND , grey, loose, light, fluffy, damp	
	1.33		fine sandy SILT , grey with orange mottles, firm, moist	
1.0	1.03		clayey SILT , grey with orange staining, plastic, med. strength, moist	
1.5	0.38		clayey fibrous organic material and rotten timber, PEAT , brown	
	0.13		CLAY with some fibrous material, green grey, plastic, soft, moist	
2.0				
2.5	-0.67		pumiceous SILT , light brownish grey, sensitive, dilatant, wet	
	-0.97		medium pumice SAND , grey	
3.0	-1.17		PEAT , dark brown, sand washing in, EOB	
	-1.27			
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA3**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 0.36
 Number: Date: 06/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
	0.06		fine sandy SILT , brown, damp, firm	
0.5	-0.34		SILT , grey with orange staining, damp, firm	
1.0	-0.74		organic clay with fibres, PEAT , brown, firm, damp	
1.5	-1.14		pumiceous SILT , light brownish grey, moist	
	-1.34		CLAY , some fibres, green grey, soft, wet	
	-1.54		fine to medium pumice SAND	
2.0			fibrous clayey PEAT , dark brown	
2.5	-2.24			
3.0			EOB squeezing	
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA4**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.39
 Number: Date: 13/01/2011
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0	2.29		rock fill	
0.5				
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				
4.5				

Test: **HA5**
Elevation: 1.45
Date: 13/01/2011
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5				
1.0	0.45		SILT , brown, dense, dry, surcharge fill	
1.5	-0.1		clayey SILT , grey, firm, damp	
2.0	-0.4		clayey SILT , some organic fibres, green grey, med. strength, plastic, moist	
2.5			EOB, timber	
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA6**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 0.35
 Number: Date: 13/01/2011
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	-0.15	x x x x x	SILT , brown, damp, firm	
	-0.25	x x x x x	clayey SILT , grey with orange staining, plastic, damp	
		x x x x x	pumiceous SILT , light orangy grey, moist	
1.0	-0.55	x x x x x	organic clay PEAT , brown, soft	
	-0.65	x x x x x	fine to medium pumiceous SAND , grey, moist	
	-0.95	x x x x x	PEAT , fibrous, amorphous, brown, soft	
1.5		x x x x x		
	-1.55	x x x x x	pumiceous SILT , grey, stiff, hard	
2.0	-1.6	x x x x x	EOB	
2.5				
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA7**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.47
 Number: Date: 13/01/2011
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	1.97	x x	SILT , brown, stiff, dense, dry	
1.0	1.47	x x	SILT , blue grey, dense, damp	
1.5	0.87	x x	SILT , grey with orange staining, dense, damp	
2.0	0.67	x x	silty fine SAND , grey, damp to moist	
2.5	0.47	x x	SILT , grey, moist	
3.0	0.27	x x	silty fine to medium SAND , grey, moist	
3.5	-0.83	x x	SILT , grey	
4.0	-1.23	x x	SILT , brown	
4.5	-1.33	x x	pumiceous SILT , light grey EOB squeezing	

Project: **Rangitaiki River Stopbank Assessments** Test: **HA8**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.11
 Number: Date: 11/01/2011
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
		x x x x	SILT , brown, dense, dry	
	1.81	x x x x		
		x x x x	SILT , grey with orange staining, dry	
0.5	1.61	x x x x		
		x x x x	clayey SILT , grey brown, damp	
		x x x x		
1.0	1.01	x x x x		
		x x x x	SILT , grey with orange staining, damp	
	0.71	x x x x		
1.5		x x x x	clayey SILT , grey with orange staining, med. strength, plastic, damp	
	0.31	x x x x		
2.0	0.11	x x x x	silty fine SAND , grey, moist	
		x x x x	SILT , grey brown, moist	
		x x x x		
2.5	-0.49	x x x x	SILT , grey, moist	
	-0.69	x x x x	clayey SILT , blue grey, organic smell, moist	
3.0		x x x x		
	-1.29	x x x x	clayey pumice SILT , light grey	
3.5	-1.49	x x x x		
	-1.59	x x x x	pumice SILT , light grey, dense	
	-1.69	x x x x	CLAY , green grey, soft	
	-1.79	x x x x	organic CLAY / PEAT , brown	
4.0	-1.89	x x x x	medium to coarse SAND , EOB	
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA9**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 0.3
 Number: Date: 23/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.1		x x x x x	SILT , brown, firm, damp	
0.5		x x x x x	clayey SILT , grey with orange staining, firm, damp	
1.0		x x x x x		
-0.8		x x x x x	pumiceous clayey SILT , light brown grey	
-1		x x x x x		
-1.1		x x x x x	medium to coarse pumiceous SAND	
1.5		PEAT, dark brown, amorphous		
2.0				
-1.9		x x x x x	pumiceous SILT , grey, rare fine pumice, firm to stiff	
2.5		x x x x x		
-2.3		x x x x x	EOB	
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA10**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 0.02
 Number: Date: 23/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
		x x x x	SILT , brown, damp, firm	
	-0.28	x x x x		
		x x x x	SILT , some clay, grey with orange staining, firm	
0.5	-0.48	x x x x		
		x x x x	pumiceous SILT , light brown grey, damp	
	-0.68	x x x x		
	-0.78	x x x x	clayey SILT , grey with Fe staining, moist	
		x x x x	fine to medium pumice SAND , wet	
1.0	-0.98			
		\\ \\ \\ \\	PEAT , amorphous, remnant fibres, some pockets fine to medium	
		\\ \\ \\ \\	sand, dark brown, soft	
1.5		\\ \\ \\ \\		
		\\ \\ \\ \\		
		\\ \\ \\ \\		
		\\ \\ \\ \\		
	-1.88	x x x x		
2.0	-1.98	x x x x	gravelly SILT , grey, pumice gravel to 30mm in pumice silt matrix,	
			stiff	
			EOB	
2.5				
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA11**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.64
 Number: Date: 11/01/2011
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	2.04		SILT , dry, firm, grey	
1.0	1.34		silty fine SAND , firm, dry, grey	
1.5	1.24		fine to coarse SAND , orange stained grey, dry	
1.5	0.94		silty fine SAND , firm, dry, grey	
2.0	0.74		bands silty fine SAND and LAPILLI to 3mm, bands 20mm	
2.5	0.14		coarse SAND , some lapilli to 10mm, grey	
2.5	-0.11		fine LAPILLI to 4mm	
3.0			EOB washing in	
3.5				
4.0				
4.5				

Test: **HA12**
Elevation: 2.83
Date: 11/01/2011
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	2.33		SILT , brown, dry, firm	
1.0			SILT , orange stained grey, damp, firm	
1.5				
2.0	0.63		silty fine SAND , orange stained grey, moist	
2.5	0.23		SILT , blue grey, moist	
3.0				
3.5	-0.77		fine sandy SILT , grey 3.8 some organic content	
4.0	-1.07		silty fine SAND , grey	
	-1.17		fine sandy SILT , grey	
	-1.27		EOB	
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA13**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 0.46
 Number: Date: 23/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.26		x x x x	SILT , brown, firm, damp	
0.5		x x x x	clayey SILT , orange stained grey, damp, firm	
1.0		x x x x		
1.5		x x x x		
1.64		x x x x	clayey SILT , some organic content, green grey, soft	
2.0		x x x x		
2.14		x x x x	pumice SILT , light brown grey, soft	
2.174		x x x x	organic CLAY/PEAT , brown, soft	
2.5		x x x x	fine to medium pumice SAND , grey	
2.14		x x x x	PEAT , fibrous, amorphous, dark brown with pockets coarse pumice	
3.0		x x x x	SAND/fine LAPILLI	
2.59		x x x x	EOB washing in	
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA14**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.63
 Number: Date: 11/01/2011
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
	2.53	x x x x x	fine sandy SILT , brown, dry	
		x x x x x	silty fine SAND , brown stained grey	
	2.33	x x x x x	SILT , grey, damp, firm	
0.5		x x x x x		
		x x x x x		
		x x x x x		
		x x x x x		
1.0	1.63	x x x x x	silty fine SAND , orange stained grey, damp	
		x x x x x		
		x x x x x		
		x x x x x		
1.5		x x x x x		
		x x x x x		
		x x x x x		
		x x x x x		
2.0	0.73	x x x x x	SILT , grey, moist	
	0.63	x x x x x	silty fine SAND , grey, moist	
		x x x x x		
		x x x x x		
2.5		x x x x x		
		x x x x x		
		x x x x x		
		x x x x x		
	-0.02	x x x x x	coarse pumice SAND / fine LAPILLI to 1.5mm	
	-0.17		EOB washing in	
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA15**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.26
 Number: Date: 23/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
		x x x x x	SILT , brown, firm, damp	
	1.96	x x x x x		
0.5		x x x x x	clayey SILT , orange stained grey, firm, damp	
	1.66	x x x x x		
		x x x x x	SILT , orange stained grey, firm, damp	
1.0		x x x x x		
		x x x x x		
1.5		x x x x x	1.5m wet	
		x x x x x		
2.0		x x x x x		
		x x x x x		
	-0.04	x x x x x		
2.5		x x x x x	silty fine SAND , grey	
	-0.44	x x x x x		
			EOB washing in	
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA16**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: -0.23
 Number: Date: 16/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
	-0.43	x x x x x	SILT , brown, damp, firm	
0.5		x x x x x	clayey SILT , orange stained grey, damp, firm	
	-1.03	x x x x x	clayey SILT with some organic fibres, green grey, soft	
1.0		x x x x x		
	-1.63	x x x x x	clayey pumiceous SILT , light brown grey, soft	
1.5		x x x x x		
	-1.83	x x x x x	PEAT , dark brown, fibrous amorphous, soft with pockets fine to medium pumice SAND , grey	
2.0		x x x x x		
	-2.53	x x x x x	UTP - grey silt?	
2.5				
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA17**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: -0.24
 Number: Date: 23/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
		x x x x	SILT , brown, firm, damp	
	-0.54	x x x x		
0.5		x x x x	clayey SILT with organics, brown and grey, plastic, firm	
	-0.84	x x x x		
		x x x x	pumiceous SILT , light brown grey, damp	
	-1.04	x x x x		
	-1.19	x x x x	organic CLAY / PEAT , brown, soft, moist	
1.0		x x x x	fine to medium pumice SAND , grey, wet	
	-1.44	x x x x		
		x x x x	PEAT , amorphous, remnant fibres, some pockets fine to medium sand, dark brown, soft	
1.5		x x x x		
		x x x x	rotten timber?	
2.0		x x x x		
	-2.34	x x x x		
	-2.44	x x x x	pumiceous SILT , grey	
	-2.54	x x x x	gravelly SILT , grey, pumice gravel to 30mm in pumice silt matrix, stiff	
2.5			EOB	
3.0				
3.5				
4.0				
4.5				

Test: **HA18**
Elevation: 2.10
Date: 21/12/2010
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	1.6		SILT , brown, moist	
1.0	1.3		SILT , orange stained grey, moist	
1.5			silty fine SAND , orange stained grey, moist	
2.0	-0.1		EOB washing in	
2.5				
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA19**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.25
 Number: Date: 21/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	1.75		SILT , brown, moist	
1.0	1.25		SILT , orange stained grey, moist	
1.5	0.95		silty fine SAND , orange stained grey	
2.0			clayey SILT , brown grey, moist, plastic	
2.5	-0.1		clayey SILT , some fibrous organic material, green grey, soft	
3.0	-0.25		silty fine SAND , grey	
3.5	-0.55		SILT , grey	
4.0	-0.85		clayey SILT and fibrous organic material, green grey	
4.5	-1.85		EOB	

Project: **Rangitaiki River Stopbank Assessments** Test: **HA20**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: -0.61
 Number: Date: 21/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0			SILT , brown, damp, firm	
0.5	-0.91		clayey SILT , orange stained grey, damp, firm	
	-1.31		0.5m bands dark brown fibrous organic material, PEAT approx. 50mm thick	
1.0	-1.61		clayey SILT and fibrous organic material, green grey, soft	
	-1.96		clayey SILT , light brown grey, soft	
1.5	-2.06		pumiceous SILT , light brown grey	
	-2.31		fine to medium pumice SAND becoming coarse / fine LAPILLI , light grey	
	-2.51		fibrous PEAT , dark brown	
2.0			EOB washing in	
2.5				
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA21**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: -0.63
 Number: Date: 21/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
		x x x x	SILT , brown, firm, damp	
	-0.93	x x x x		
0.5		x x x x	layers SILT , green grey, / SILT , brown, fibrous PEAT	
	-1.23	x x x x		
		x x x x	pumiceous SILT , some organic content / timber, light brown grey	
1.0		x x x x		
	-1.78	x x x x		
	-1.93	x x x x	fine to medium pumice SAND , light grey	
1.5		x x x x	PEAT , dark brown, fibrous	
	-2.43	x x x x		
2.0			EOB washing in	
2.5				
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA22**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 4.11
 Number: Date: 21/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
		x x x x x	SILT , brown, damp	
	3.81	x x x x x		
0.5		x x x x x	silty fine SAND , brown, damp, dense	
		x x x x x		
	3.21	x x x x x		
1.0	3.11	x x x x x	silty fine to coarse SAND , brown, damp, dense	
		x x x x x	fine sandy SILT , brown, dense, damp	
	2.91	x x x x x		
1.5		x x x x x	SILT , orange stained grey, dense, damp	
		x x x x x		
	2.41	x x x x x		
2.0		x x x x x	silty fine SAND , grey, damp	
		x x x x x		
2.5		x x x x x		
		x x x x x		
3.0	1.21	x x x x x	coarse pumice SAND , grey	dis.
		x x x x x		
3.5	0.76	x x x x x	fine LAPILLI to 1.5mm, bands medium to coarse SAND	dis.
	0.51	x x x x x		
			EOB washing in	
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA23**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.53
 Number: Date: 13/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
		x x x x x	SILT , brown, dense, dry	
	2.28	x x x x x	SILT , orange stained grey, damp	
0.5		x x x x x		
	1.83	x x x x x	silty fine SAND , light brown grey, light, fluffy, dry	
	1.63	x x x x x	SILT , grey, damp	
1.0		x x x x x		
	1.33	x x x x x	clayey SILT , orange stained grey, damp, plastic	
1.5		x x x x x		
	1.03	x x x x x	SILT , orange stained grey, damp	
2.0		x x x x x		
	0.53	x x x x x	clayey SILT , orange stained grey, plastic, moist, firm	
		x x x x x		
2.5		x x x x x	fine sandy SILT , grey, dilatant, wet	
	0.13	x x x x x		
	-0.12	x x x x x	silty fine SAND , grey	
	-0.17	x x x x x	fine sandy SILT , grey, dilatant, wet	
	-0.37	x x x x x	clayey SILT , green grey, some tree roots	
3.0		x x x x x		
	-0.77	x x x x x	EOB squeezing	
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA24**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 0.38
 Number: Date: 13/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
	0.18	x x x x x	SILT , brown, dry, firm	
		x x x x x	clayey SILT orange stained grey, plastic , damp	
0.5		x x x x x		
	-0.32	x x x x x	SILT , orange stained grey, moist	
1.0		x x x x x		
	-0.72	x x x x x	clayey SILT orange stained grey, plastic , damp	
	-0.92	x x x x x	clayey PEAT , dark brown, fibrous, moist	
1.5		x x x x x		
	-1.32	x x x x x	CLAY and fibrous materials, green grey	
2.0		x x x x x		
	-1.62	x x x x x	pumiceous SILT , light brown grey	
	-1.92	x x x x x		
	-2.02	x x x x x	clayey PEAT , dark brown, fibrous, moist	
2.5		x x x x x	fine to medium pumice SAND , light grey	
	-2.07	x x x x x	EOB washing in	
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA25**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 0.02
 Number: Date: 13/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
		x x x x	SILT , brown, dense, dry	
	-0.23	x x x x		
		x x x x	SILT , grey, light, dry	
	-0.38	x x x x		
0.5		x x x x	clayey SILT , brown and grey, damp, firm	
	-0.53	x x x x		
		x x x x	silty fine SAND , orange stained grey	
		x x x x		
1.0		x x x x		
	-1.08	x x x x		
		x x x x	silty fine SAND , grey, moist	
		x x x x		
1.5		x x x x		
	-1.48	x x x x		
		x x x x	CLAY , some organic material and rotten timber, green grey and brown, soft	
	-1.68	x x x x		
		x x x x	pumiceous SILT , light brown grey, moist	
	-1.88	x x x x		
2.0		x x x x	organic CLAY and organic material, brown, soft	
	-1.98	x x x x		
		x x x x	fibrous PEAT with thin layers fine to medium pumice SAND (20mm thick), dark brown, soft	
		x x x x		
2.5		x x x x	EOB hard timber ?	
	-2.38	x x x x		
3.0				
3.5				
4.0				
4.5				

Test: **HA26**
Elevation: 4.21
Date: 10/12/2010
Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	3.71		fine sandy SILT , brown, dry, firm	
1.0	3.11		silty fine SAND , brown, dense, dry	
1.1	3.01		0.9m some hard gravel	
1.2			SILT , brown, dense, dry	
1.3			SILT , grey, damp, firm	
1.5				
2.0				
2.5	1.81		silty fine SAND , grey, damp, light, fluffy	
3.0				
3.5	0.71		fine to medium SAND , grey, moist	
4.0	0.31		medium to coarse SAND / fine LAPILLI grey, wet	
4.1	0.21		EOB	
4.5				

Project: **Rangitaiki River Stopbank Assessments**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend
 Number:

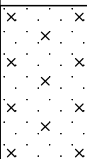
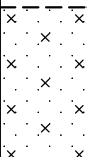
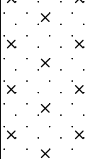
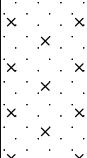
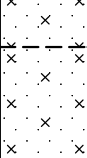
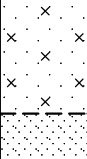

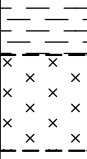
Test: **HA27**
 Elevation: 1.53
 Date: 10/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
	1.33	x x x x x	SILT , brown, damp, firm	
		x x x x x	clayey SILT , grey, firm, plastic, damp to moist	
0.5	1.03	x x x x x		
		x x x x x	SILT , grey and bands clayey SILT , damp, firm	
1.0		x x x x x		
		x x x x x		
1.5	0.03	x x x x x	bands SILT , grey and silty fine SAND	
		x x x x x		
2.0		x x x x x		
		x x x x x		
	-0.67	x x x x x	SILT , grey	
2.5		x x x x x		
		x x x x x	2.7m fine roots	
3.0		x x x x x		
		x x x x x		
3.5		x x x x x		
		x x x x x		
	-2.17	x x x x x	EOB suction	
4.0				
4.5				


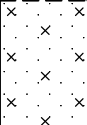

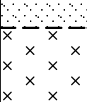
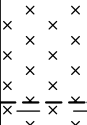
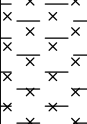
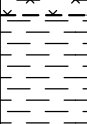

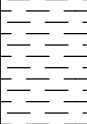

Project: **Rangitaiki River Stopbank Assessments** Test: **HA28**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 1.65
 Number: Date: 10/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
	1.45	x x x x	SILT , brown, moist, firm	
		x x x x	SILT , grey, moist, firm	
0.5	1.15	x x x x	silty fine to medium SAND , grey, damp, mod. dense	
	0.95	x x x x	medium to coarse pumice SAND , trace silt, damp, loose	
	0.85	x x x x	medium SAND , dark grey, damp	
1.0				
	0.55	x x x x	medium to coarse SAND , rare fine gravel, dark grey, moist to wet	
1.5				
	-0.2	x x x x	EOB washing in	
2.0				
2.5				
3.0				
3.5				
4.0				
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA29**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 3.62
 Number: Date: 13/12/2010
 Logged by: M. O'Halloran

Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
0.5	3.12		silty fine to medium SAND , some gravel, brown, dry	
1.0			silty fine SAND / sandy SILT , brown, dry to damp	
1.5				
2.0	1.52		silty fine SAND , brown, moist	
2.5				
3.0	0.82		fine to medium SAND , some silty bands and organic material, grey	
3.5	0.22		CLAY , green grey, plastic, soft	
	0.02		SILT , some organics, grey	
4.0	-0.28		EOB squeezing	
4.5				

Project: **Rangitaiki River Stopbank Assessments** Test: **HA30**
 Client: Bay of Plenty Regional Council
 Location: Reynold's Bend Elevation: 2.42
 Number: Date: 13/12/2010
 Logged by: M. O'Halloran

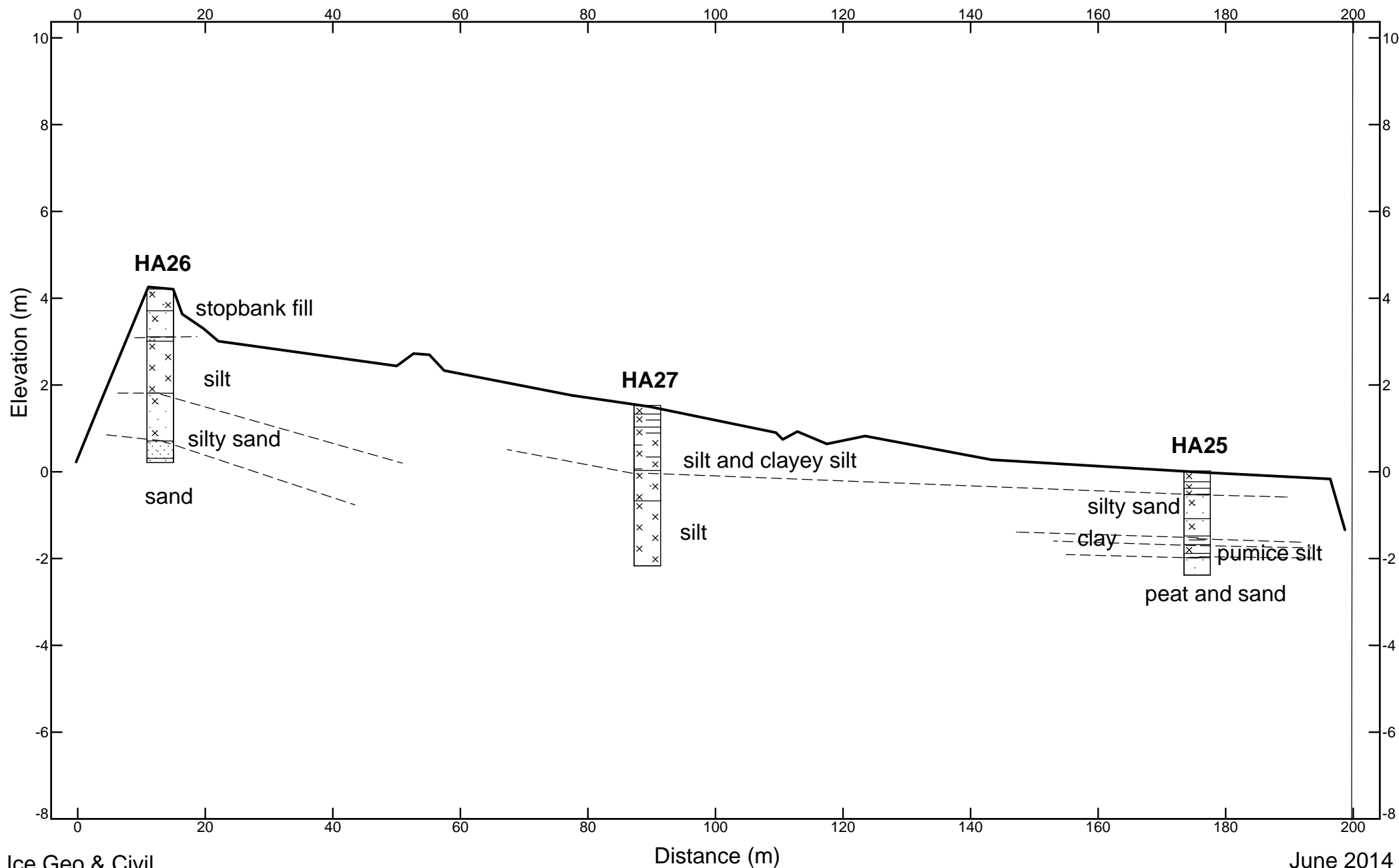
Depth (m)	Elev(m)	Graphic Log	Description	Sample
0.0				
	2.12		SILT , brown, firm, dry	
0.5			silty fine SAND/ sandy SILT , brown, damp, dense	
	1.62		fine to medium pumice SAND , some silt, brown, dry	
1.0	1.47		SILT , orange stained grey, damp, firm	
1.5	0.92		clayey SILT , grey, moist, plastic, firm	
2.0	0.42		CLAY , some organic material, rotten timber, green grey, soft, plastic, moist	
2.5				
3.0	-0.58		pumiceous SILT , light grey brown	
	-0.68		CLAY , some organic material, rotten timber, green grey, soft, plastic, moist	
	-0.88		medium pumice SAND , light grey	
3.5	-0.98		EOB	
4.0				
4.5				

Appendix C

Cross Sections

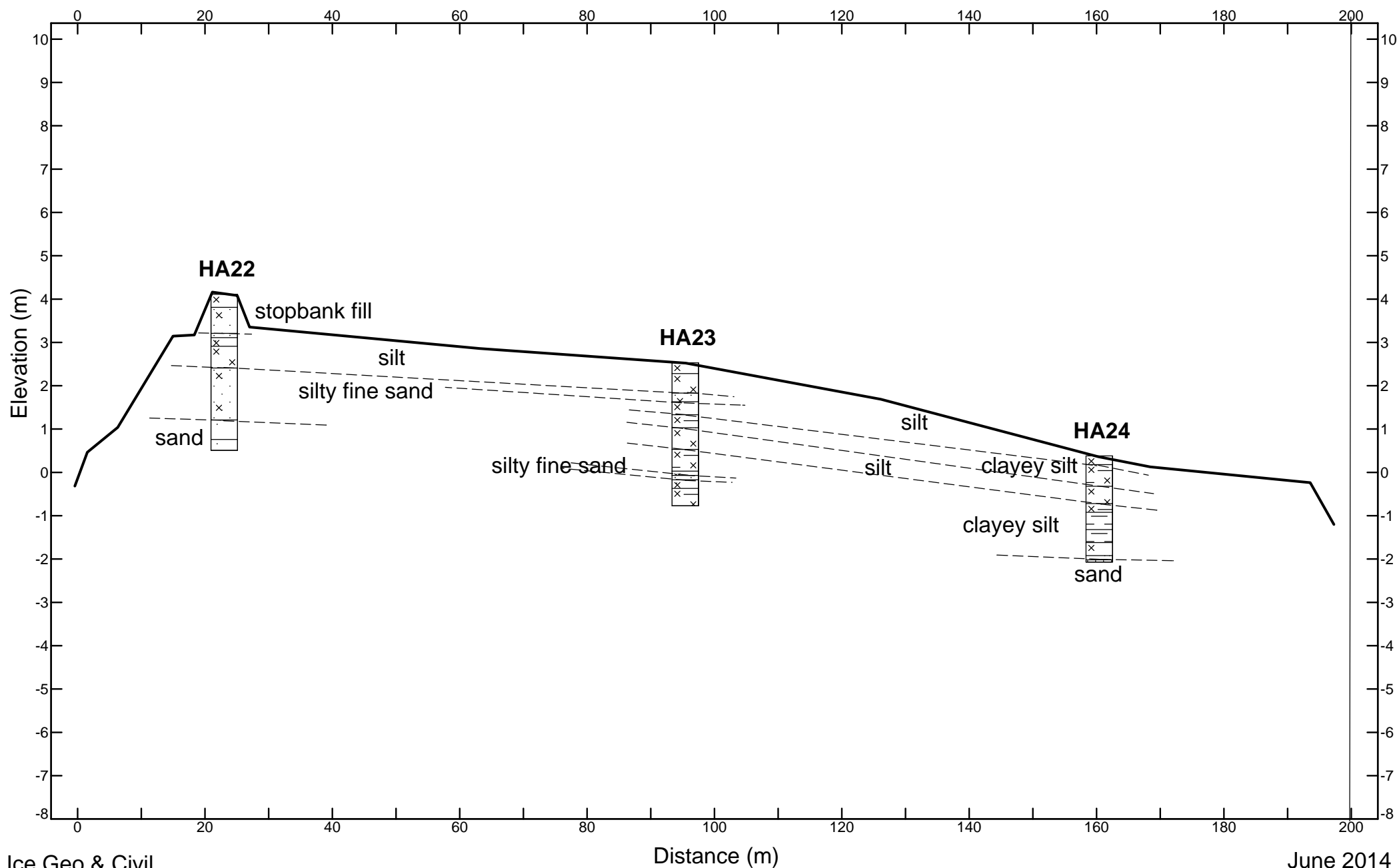
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Regional Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 1



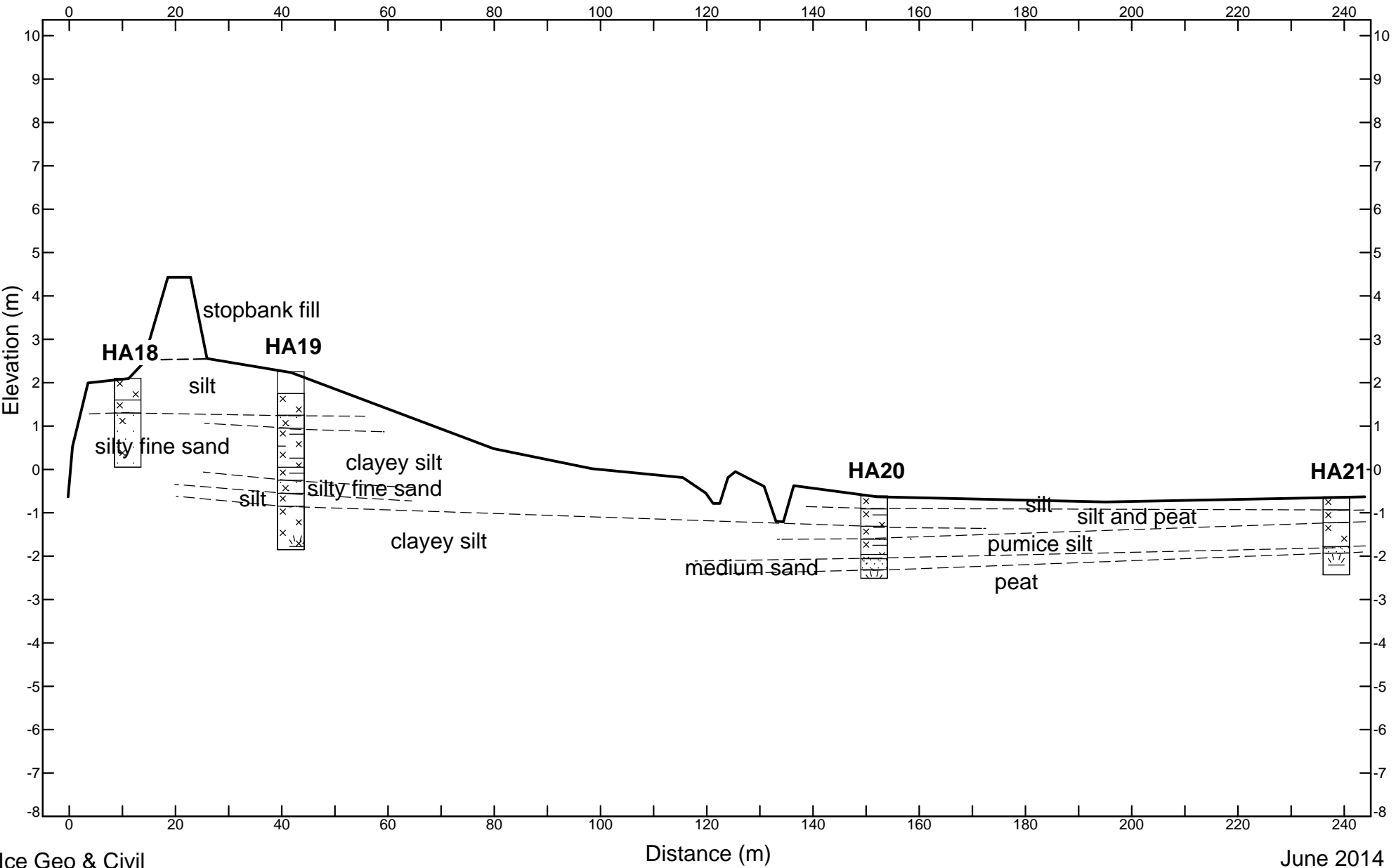
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Regional Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 2



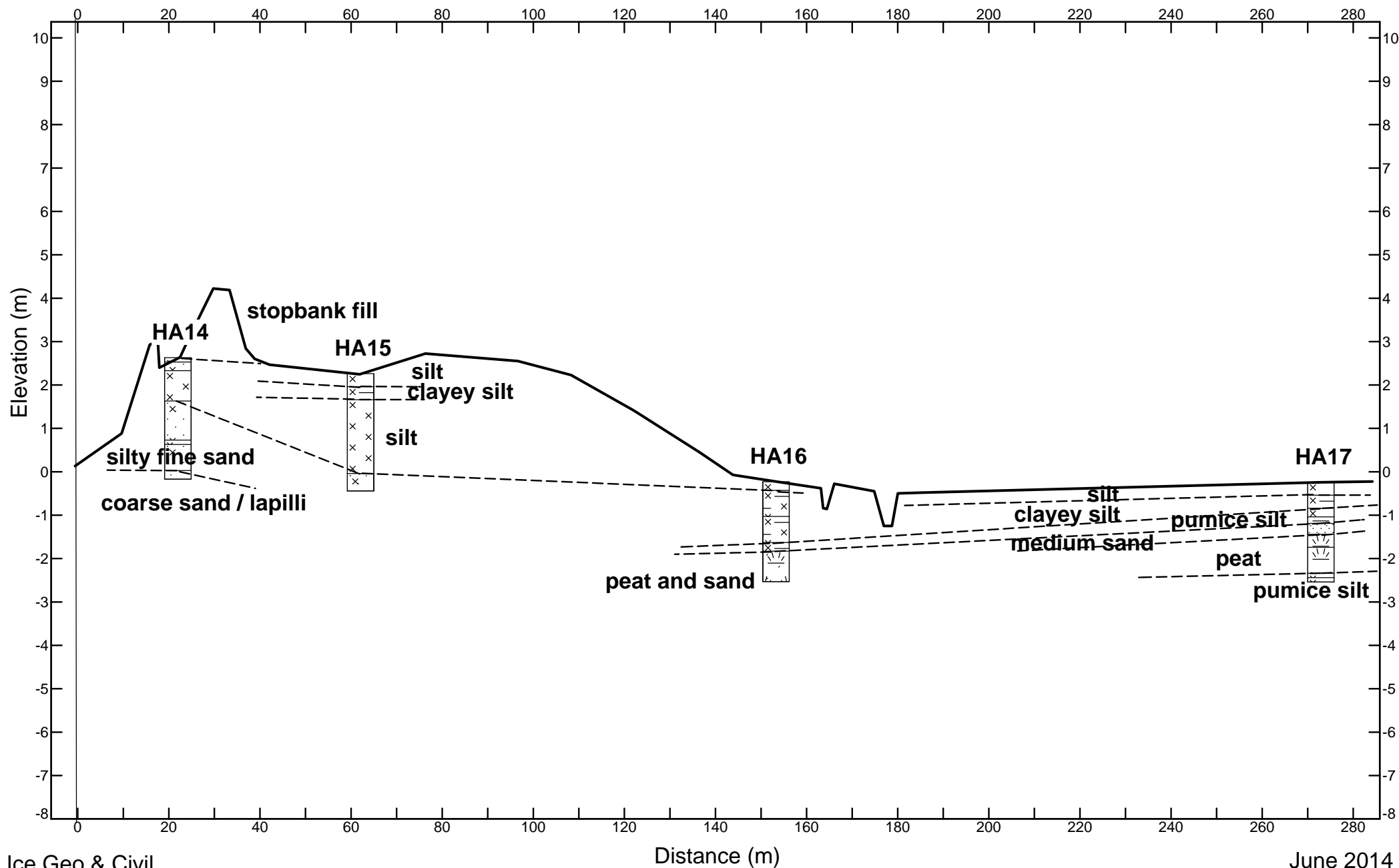
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Regional Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 3



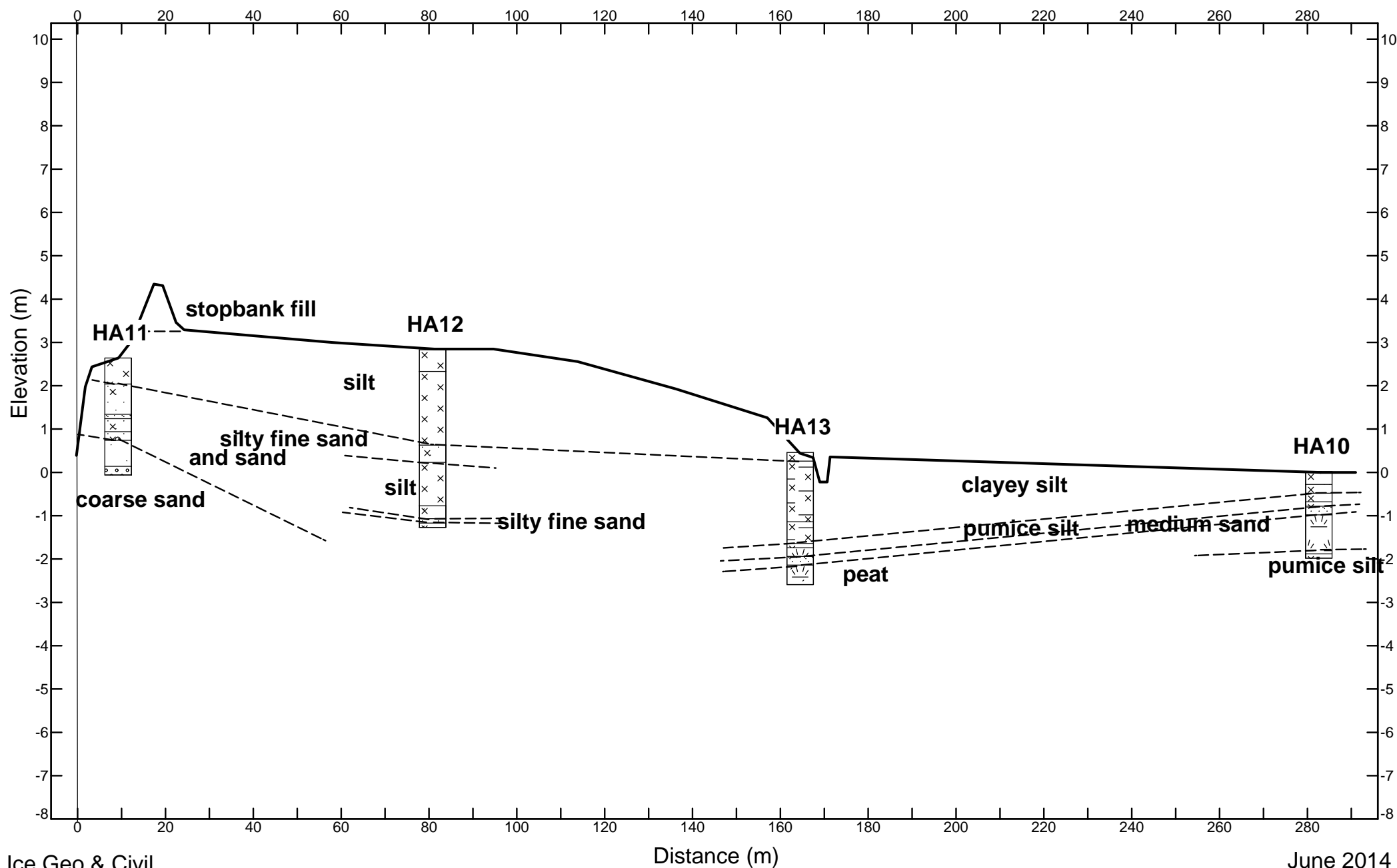
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Regional Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 4



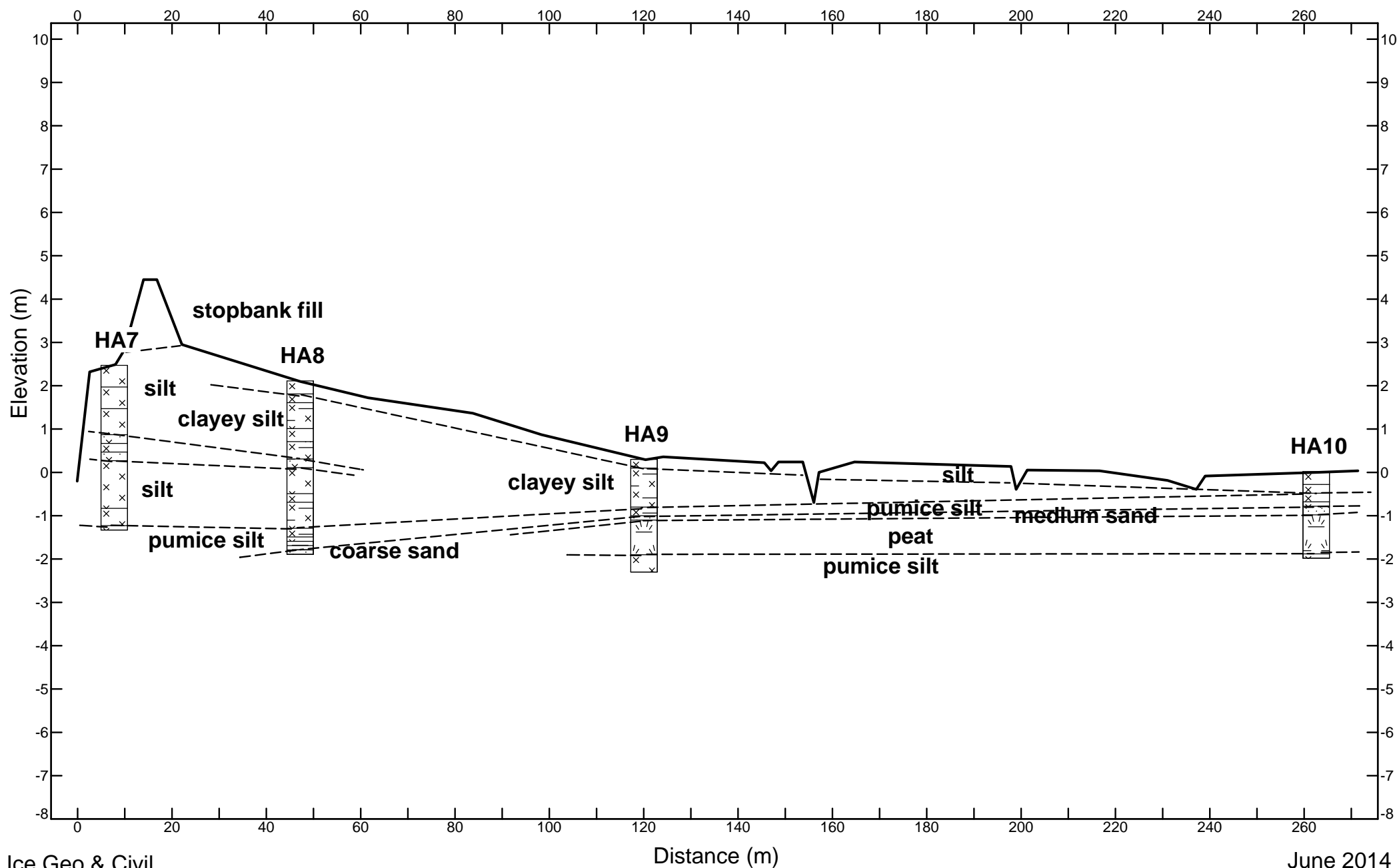
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Regional Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 5



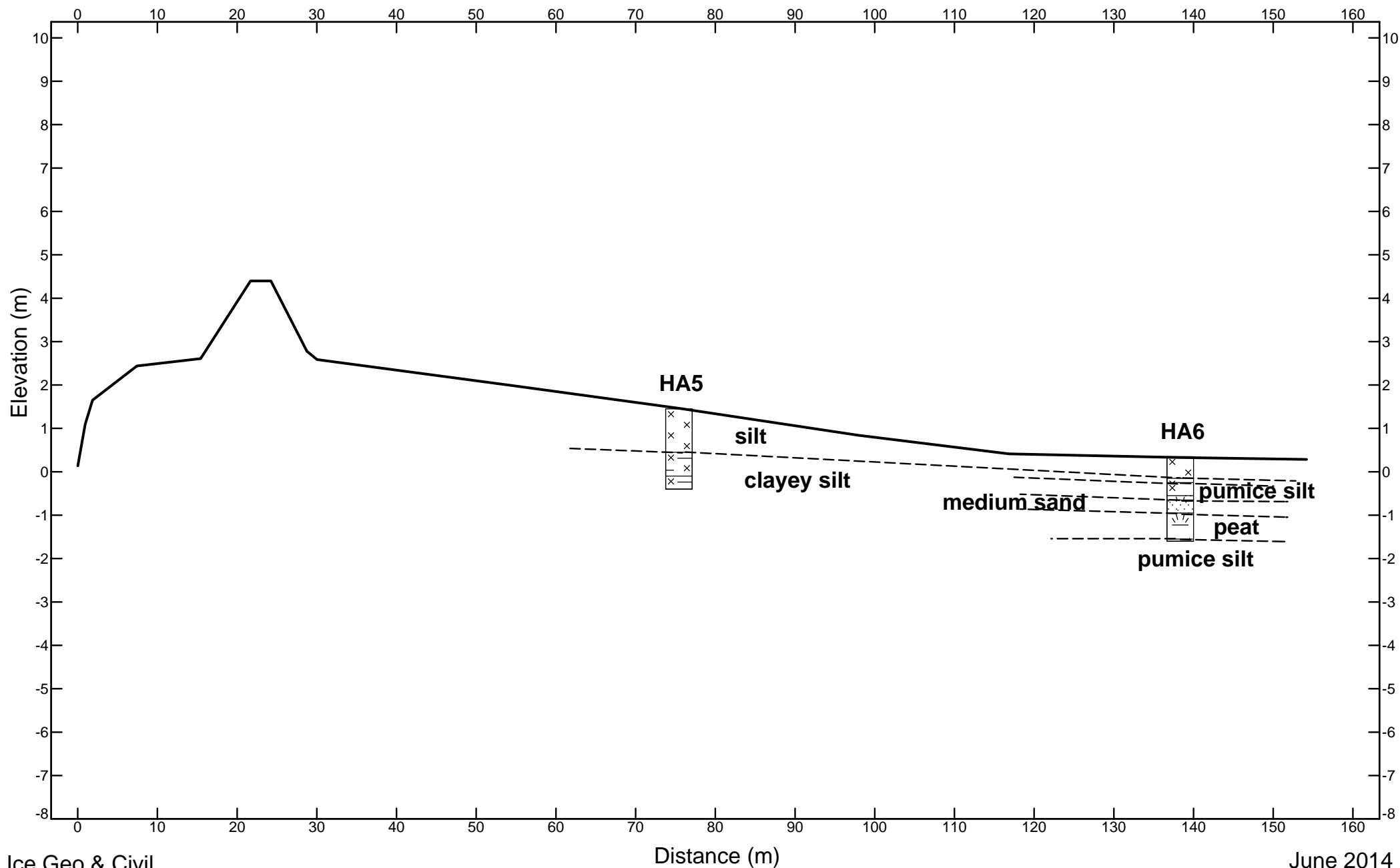
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Regional Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 6



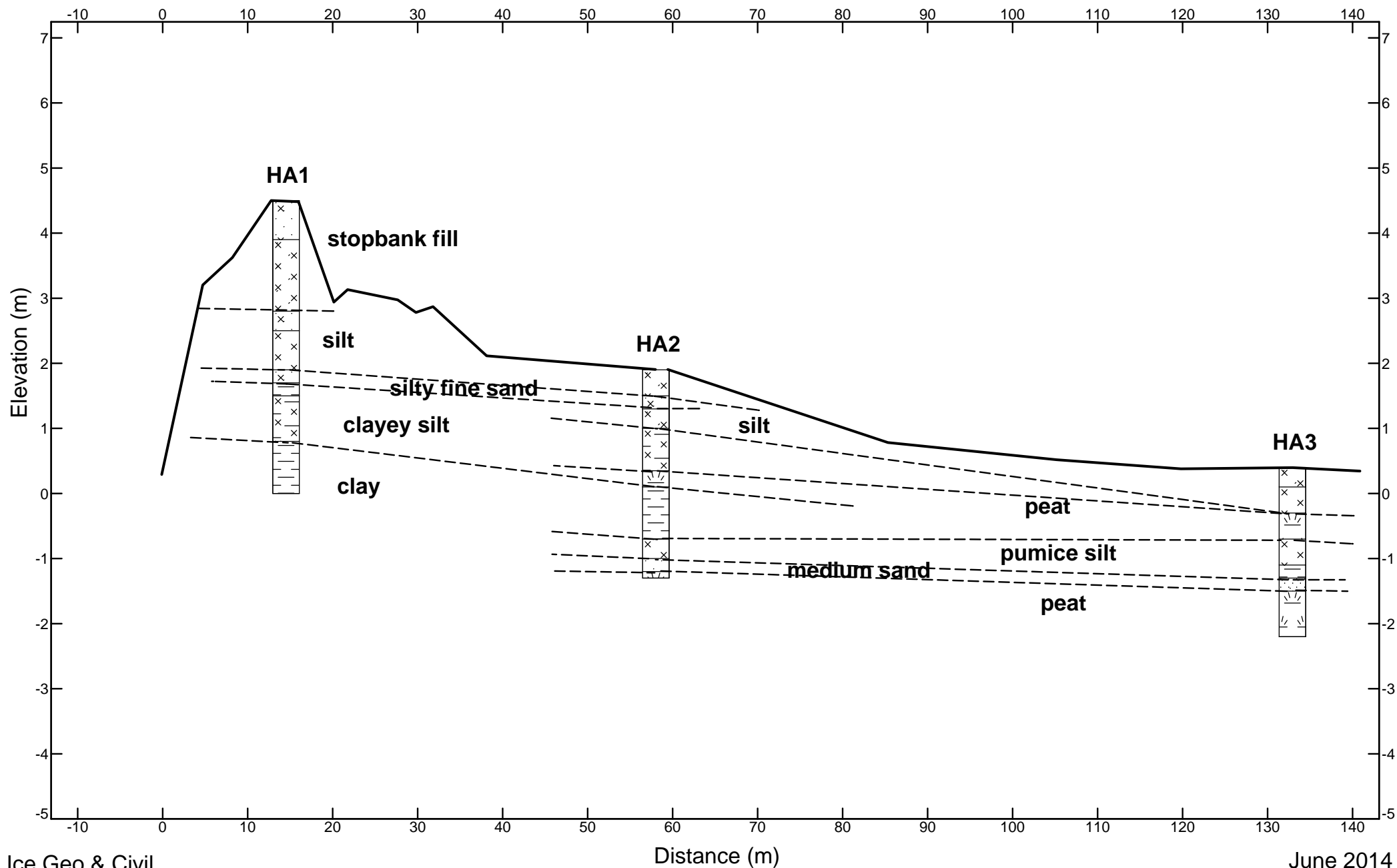
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Regional Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 7



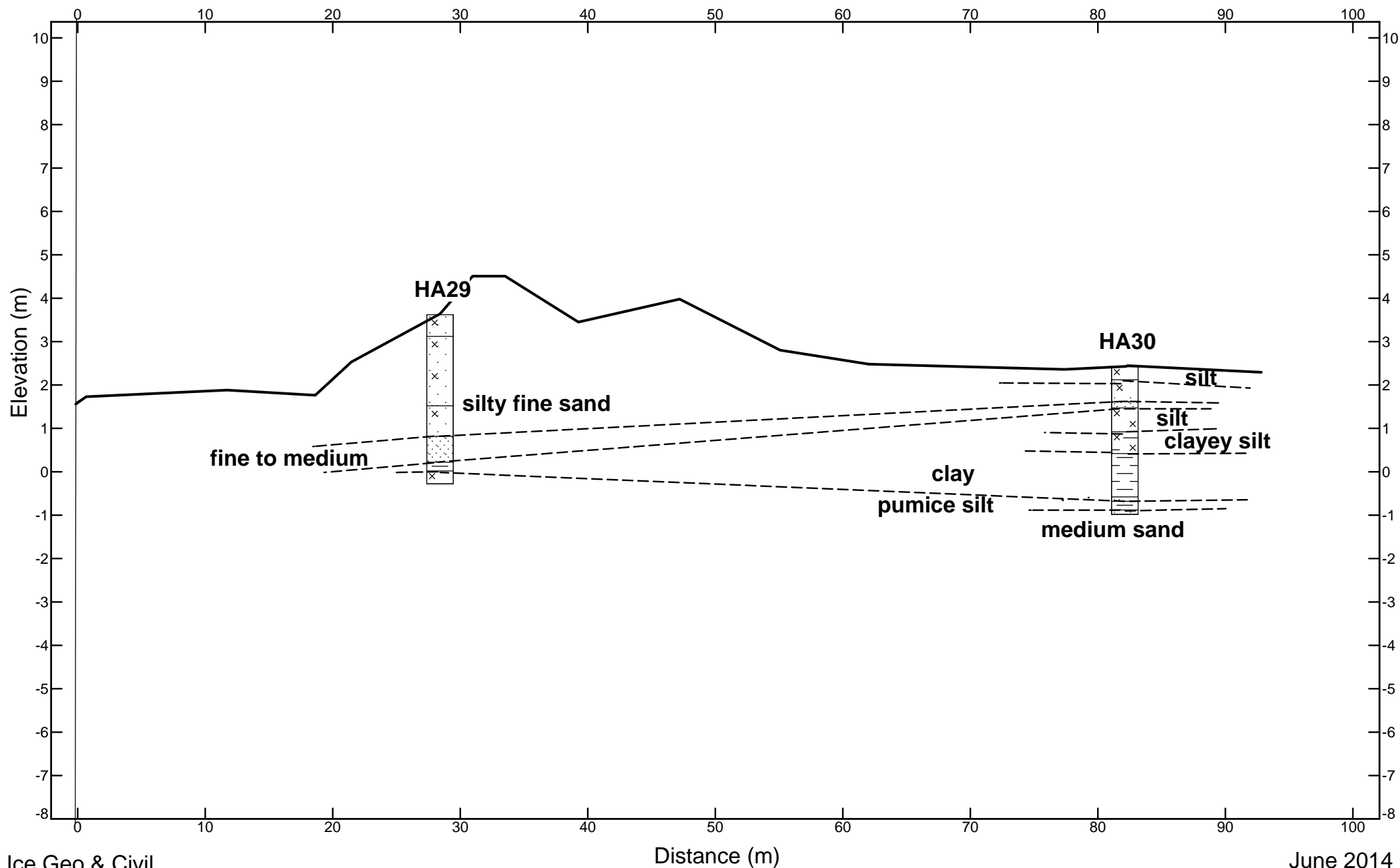
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Regional Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 8



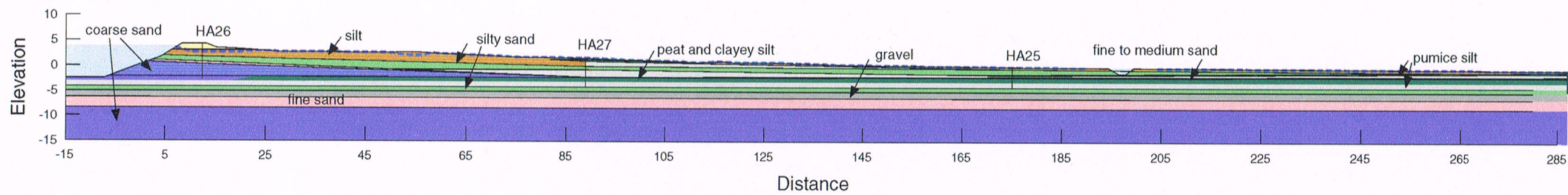
Project: Rangitaiki River Stopbank Assessments
Client: Bay of Plenty Reginal Council
Location: Reynolds Bend
Number:

Subsurface Cross Section 9

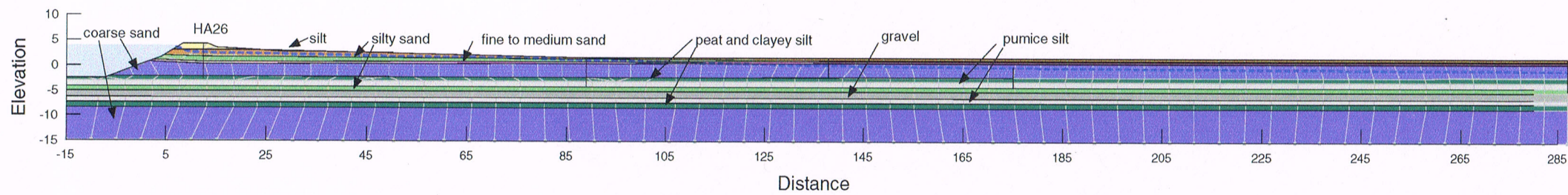


Appendix D

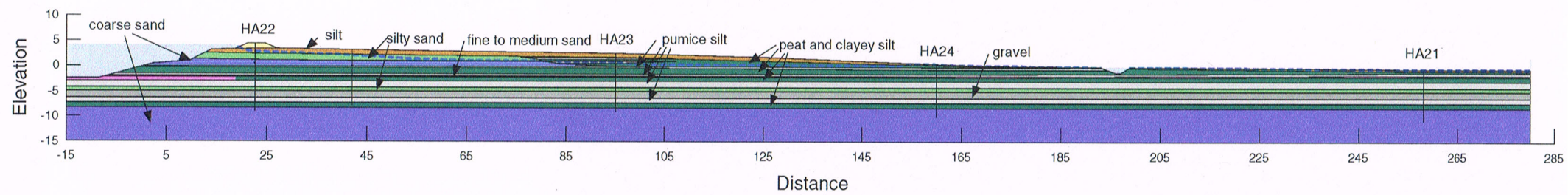
Soil Seepage Models



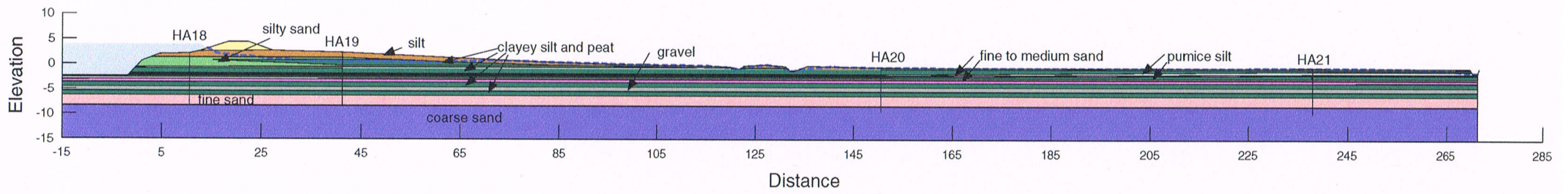
Cross Section 1



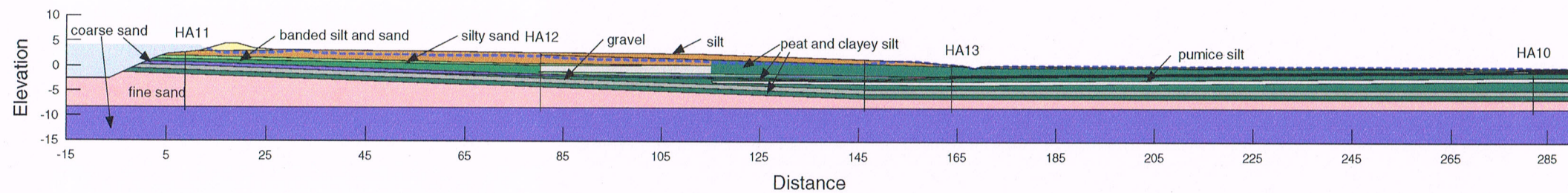
Cross Section 1 Downstream



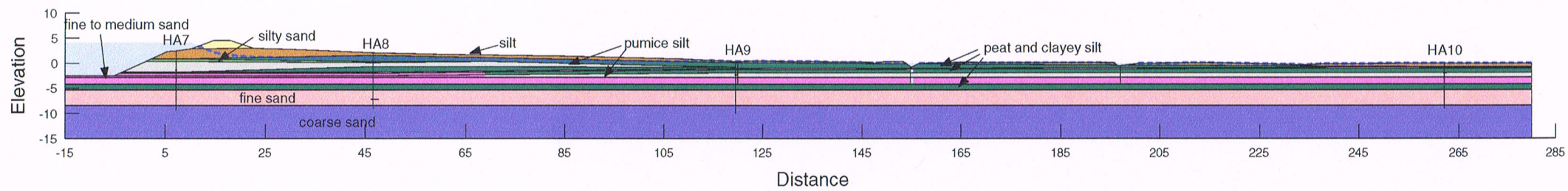
Cross Section 2



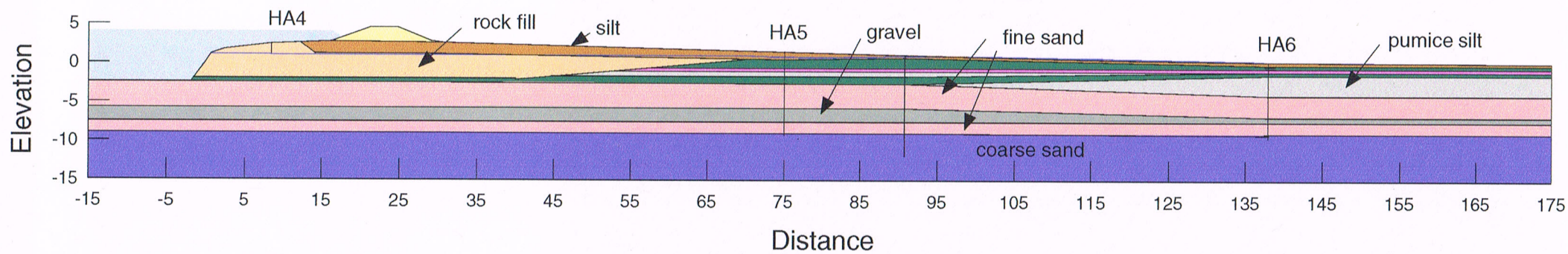
Cross Section 3



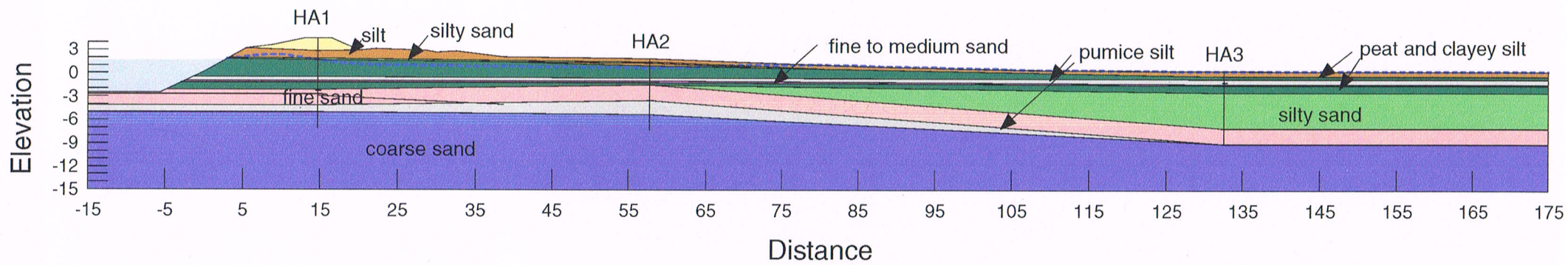
Cross Section 5



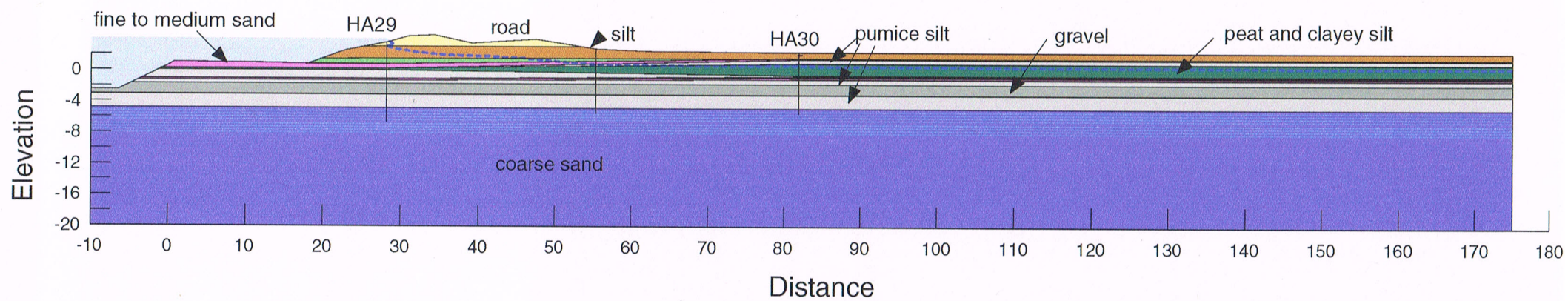
Cross Section 6



Cross Section 7



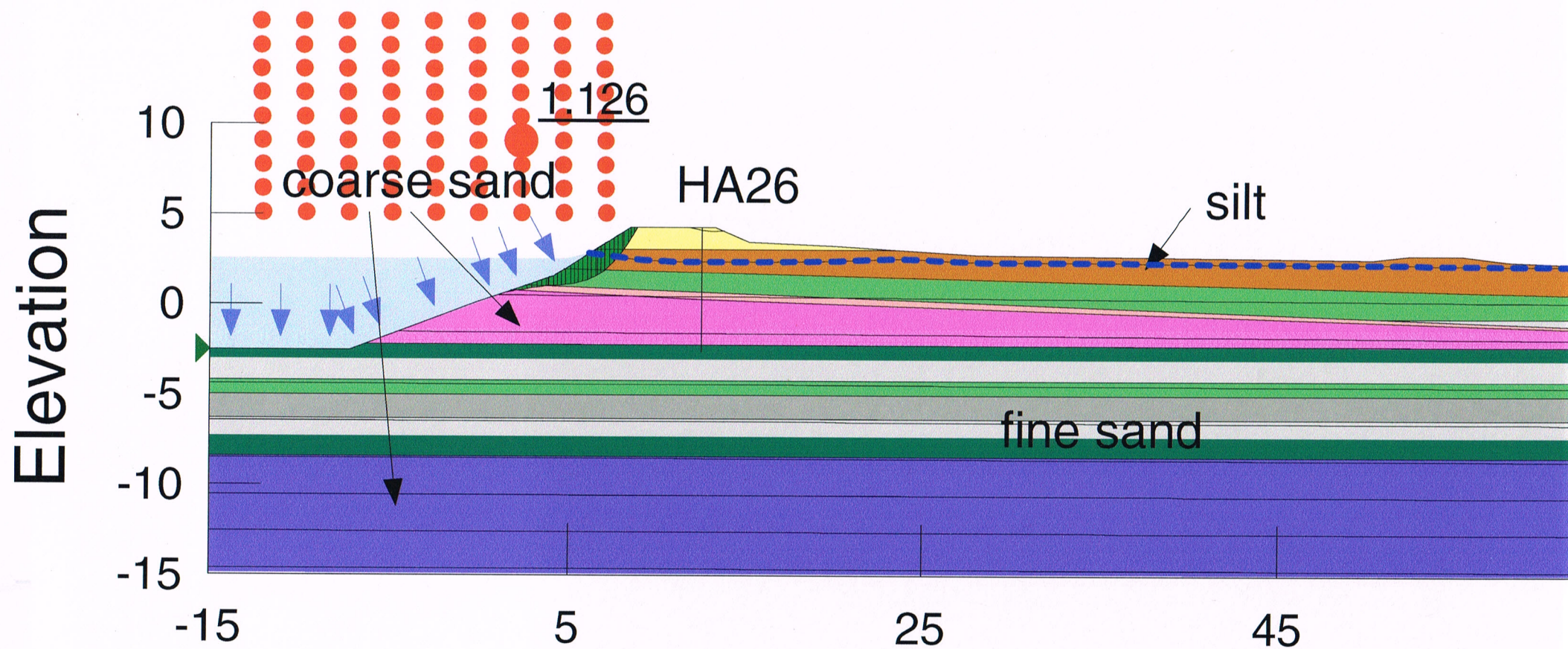
Cross Section 8



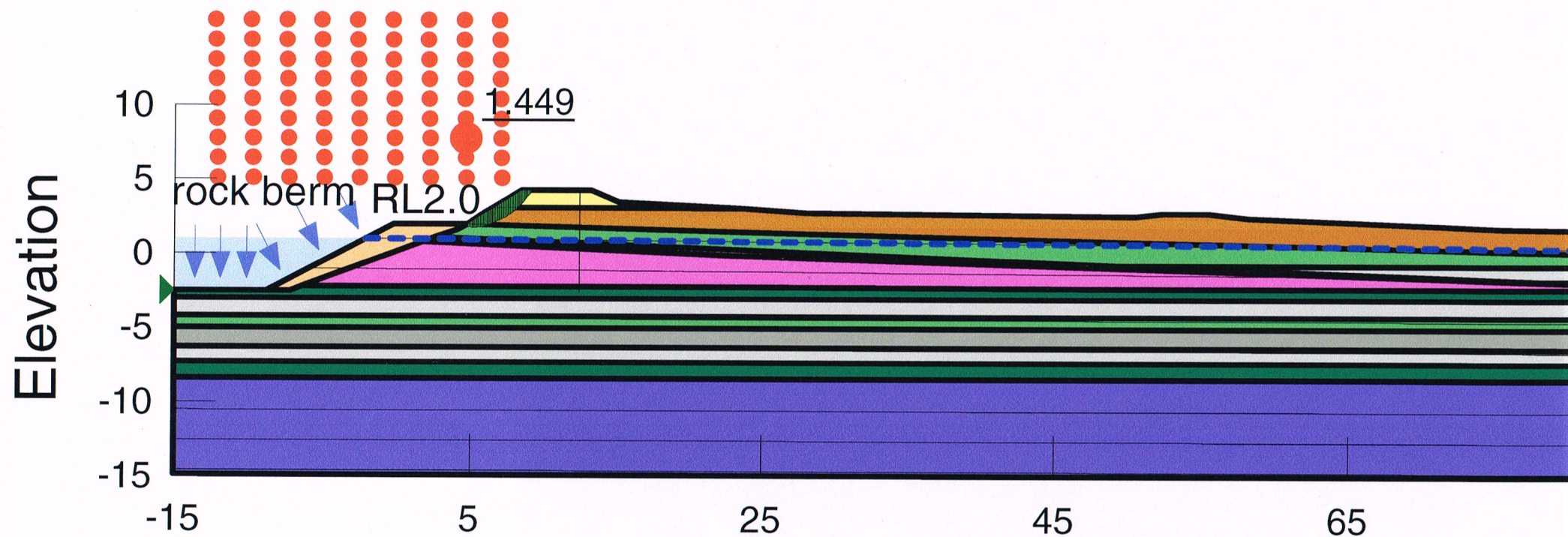
Cross Section 9

Appendix E

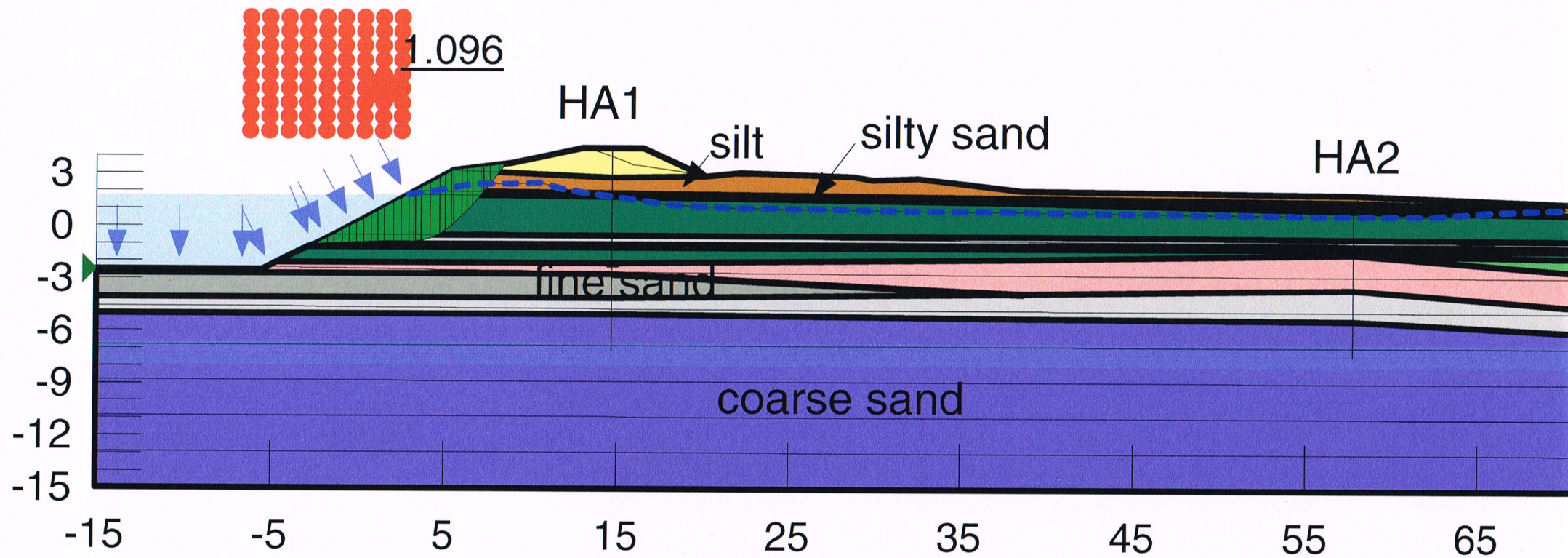
Slope Stability Models



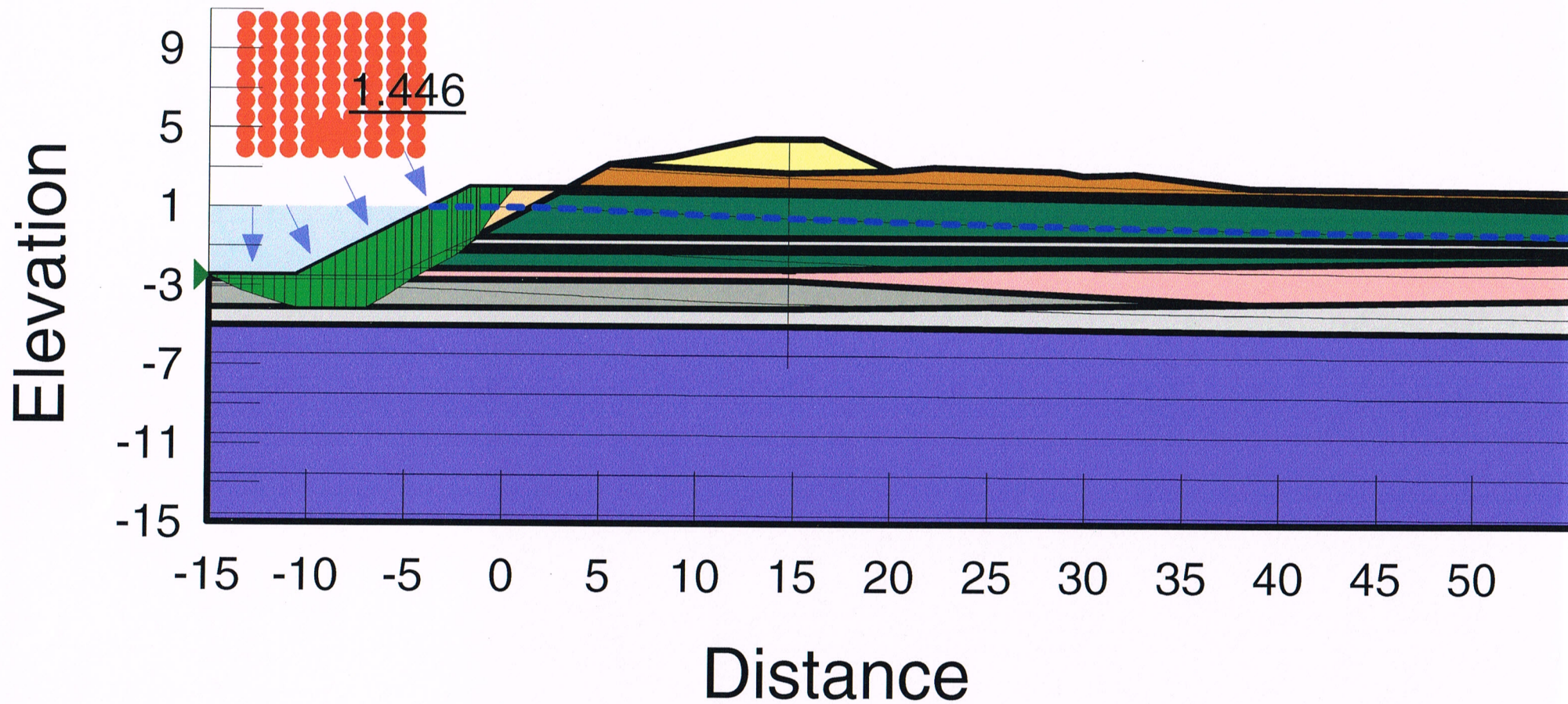
Cross Section 1 rapid draw down



Cross Section 1 Berm - low river



Cross Section 8 rapid draw down



Cross Secion 8 berm - low river