

Rangitaiki River Stopbanks Assessment

Section 5

Left Bank 11200 to 11500m

Prepared for

Environment Bay of Plenty

July 2006



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1 Introduction

A study of the information available on the stopbanks along the Rangitaiki River identified some areas where there may be potential problems in major floods (Ice Geo & Civil, September 2005). The section of stopbank on the left bank from 11,200 to 11,500m was identified as a possible problem area due to the relatively high head across the stopbank, damage experienced in the Edgecumbe earthquake and the narrow river berm (Figure 1). This study section is immediately downstream of Section 3 (Ice Geo & Civil, April 2006).

This report presents the following information:

- the results of insitu investigations,
- the results of seepage analyses for the 100 year return period flood and
- possible remedial measures.

This report is the property of our client, Environment Bay of Plenty and Ice Geo and Civil. The comments within relate only to the length of stopbank along the Rangitaiki River left bank from 11,200m to 11,500m.

2 Site Description

Along the length of the study section the stopbank varies in height from 1.75m to 2.8m, with a further fall of about 0.5m from the inland toe of the stopbank to Main Street. The width of the river berm varies from 0 to about 10m and is typically 0.5 to 1.0m lower than the ground on the inland side of the stopbank.

The kerb along Main Street is almost at the stopbank toe opposite Kauri Street. This section of Main Street has recently been rebuilt. The pavement is about 300mm thick and no subsoil drains were installed. There are a gas main and telecom and power cables within the grass berm between the stopbank and Main Street. These services are a constraint on the options for stopbank remediation work.

The only structures between the stopbank and Main Street are an old weatherboard shop and a mechanics workshop and yard. The shop appears to be on timber piles at the front but has a concrete slab floor at the back where there is a garage and toilet. The workshop appears to be on a concrete slab. The yard around the workshop has been considerably built up with gravel. Between the workshop and the road bridge there is an old road under the stopbank and there appears to be some old timber bridge piles at the river's edge.

Two large trees have recently been cut down between the road and rail bridges. The stumps of these trees need to be removed and replaced with

low permeability fill to prevent the formation of preferential seepage paths as the roots rot.

3 Subsurface Investigations

The initial subsurface investigations consisted of nine hand augers arranged in five cross sections along the river. A further two augers were carried out near Cross Section 3 to help refine the analysis. The augers were between 2.3 and 4.2m deep. Some augers were stopped because clayey silts were causing the hole to squeeze in. Figure 1 shows the location of the hand auger holes and the logs are included in Appendix A.

A brown silt layer lies at the surface of most sites along the river. It is usually this layer that prevents high flows under the stopbanks. Below the brown silt most of the augers showed layers of silt and clayey silt between sand layers. The proportion of silt layers compared to sand layers tends to be higher at the upstream end of the site. Some of the deep clayey silt layers had an organic content but no layers of peat were found. Coarse sands and pumice lapilli were only found in HA8 between the road and rail bridges.

The ground water level was found to be at about 1.5m depth on the inland side of the stopbank in April.

4 Analyses

4.1 Discussion

The hand augers carried out provide subsoil profiles in isolated locations only. The hand auger logs show considerable variation in the soil layers and it is possible that in terms of the seepage response to a flood in the river there are worse combinations of soil layers than those identified. In some places along the river buried rotten tree stumps have been found that can cause a short circuit from a deep coarse sand layer through upper lower permeability layers. There is also the possibility of undetected buried pipes below the stopbank.

The trenches for the services to the two structures close to the stopbank could provide pressure relief or may be a point of weakness. The trenches for the stormwater pipes under the road are likely to provide some pressure relief under the seal. The extra width of basecourse behind the kerb along Main Street may also act as a filter helping to relieve high pressures developed under the seal.

The computer programme used to analyse the seepage problems, Geo-Slope Seep/W (Version 5), is a two dimensional programme. Therefore three dimensional effects, such as lateral changes in the soil profile or the presence of an impermeable surface of given width, can not be accurately modelled.

The seepage analyses carried out must therefore be considered indicative only.

The two problems being investigated are heave and piping as these can cause catastrophic failure of the stopbank. The volume of seepage under the stopbank has not been considered. The most common remedial measures for heave are the addition of a surcharge on the ground surface or the construction of a pressure relief trench (or wells). In checking the potential for heave the weight of the upper silt layer has been assumed to be 14kN/m^3 where there has not been significant compaction due to the land use. A higher density has been assumed where the ground has been highly trafficked or there is gravel.

The risk of piping can be reduced by increasing the length of the seepage path by the addition of overlays or by installing a drain in the susceptible area to allow seepage without the removal of soil particles.

Seepage of only small volumes of water from the ground surface can significantly reduce the uplift pressures on a surface layer with a lower permeability than those underlying it. Seepage from the ground surface inside the stopbank has been allowed for where there is no seal or concrete slabs. The increase in uplift pressures below impermeable surfaces compared to the adjacent permeable ground surface is significant. The build up in water pressure below a sealed surface can lead to high concentrations of flow along the edge of the surface.

The soil models analysed for each cross section are included in Appendix B.

4.2 Flood Hydrograph

EBoP has provided a design 100 year return period flood flow hydrograph for the Rangitaiki River at their benchmark number 28 (Figure 2). This is an eight day hydrograph which rises to a peak of RL6.7 on the third day of the flood. The top of the stopbank ranges from RL6.9 to 7.2, therefore it appears that the stopbank should be topped up in places to achieve the required freeboard in an urban area. In the 100 year flood the water level stays close to the peak level for two days before beginning to drop. This is almost long enough for steady state conditions to develop with high permeability soils.

4.3 Soil Model

The soil layers found in the hand augers were simplified in the models used for the seepage analyses (Figures 3, 4 and 5). The surface layers of silt and sandy silt were modelled with the same low permeability. Below this the layers were divided into clayey silt, silty fine sand/ sandy silt, silty fine sand, fine sand, fine to medium sand and coarse sand and lapilli. The permeabilities assumed were conservatively based on the grading test results for near-by

sites previously investigated. Table 1 summarises the saturated soil permeabilities assumed. In the analyses it was conservatively assumed that there is a thick layer of coarse sand and pumice lapilli below the depth of investigations.

Table 1: Assumed Soil Permeabilities

soil	k_h (m/s)
stopbank fill	2×10^{-6}
brown silt	2×10^{-7}
silty fine sand	4×10^{-6}
fine sand	5×10^{-5}
fine to medium sand	8×10^{-5}
clayey silt	1×10^{-7}
coarse sand and lapilli	5×10^{-4}

The Geo-Slope Seep/W (Version 5) 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 tested from near by sites were compared to those in the Seep library and the closest fit chosen as the soil model to be used in the seepage analysis.

Banding was observed within some layers and the horizontal and vertical permeabilities were assumed to be different. The vertical permeability of the stopbank was assumed to be half the horizontal due to the compaction process. The permeabilities were assumed to be the same in both directions in the remaining layers.

4.4 Cross Section 1

Cross Section 1 is at the upstream end of the study section. The stopbank is 2.5m high and there is a 10m wide river berm. On the inland side of the stopbank the upper silt layer is 0.5m thick and is underlain by silty sands, sandy silts and clayey silt at 2.0m depth.

An initial static seepage analysis was carried out assuming a ground water level of RL2.7 on the inland side of the model and a river level of RL2.5. A transient seepage analysis was then carried out modelling the full eight days of the 100 year flood. A two hour time step was used.

An allowance was made in the soil model for seepage from the ground surface between the stopbank toe and the road. The soils below the depth of investigation were assumed to be coarse sands and lapilli.

The transient flood analysis showed that there could be a problem with heave of the upper silt layer and high pressures could develop under the road. The hydraulic exit gradient at the toe of the stopbank was found to be about 0.4. This is considered to be the highest acceptable hydraulic gradient in these silty soils.

An overlay 700mm thick at the stopbank toe, tapering to 500mm thick 5m from the kerb then down to the kerb was modelled. This was combined with a 1m deep strip drain along the back of the kerb. The overlay and drainage improved the factor of safety against heave of the silt to 1.2. The maximum exit gradient was reduced to 0.3.

Care will be required in installing the strip drain to avoid the buried services. It should be backfilled with sand and drained into the existing stormwater system.

The overlay should ideally consist of a silty sand of similar or higher permeability than the surface brown silts. A density of 15kN/m^3 has been assumed. It is considered that the overlay can be shaped down around the existing large trees as the tree roots will prevent heave in these localised areas. The overlay should be extended upstream to the edge of the Council land as shown on Figure 6.

4.5 Cross Section 2

At Cross Section 2 the inland stopbank toe is almost against the kerb of Main Street and there is a gas main under it. The stopbank rises 3.3m above the kerb. The soils found in HA4 on the inland side of the stopbank are silts and silty fine sands. A clayey silt was found at 1.6m depth in HA3 on the narrow river berm.

The transient flood analysis showed high hydraulic exit gradients at the toe of the stopbank. The installation of a wide toe drain should lower the hydraulic gradient to a safe level. The drain should be installed as deep as possible to reduce pressures under the road but the presence of the services is likely to prevent excavation of more than a few hundred millimetres. If possible the strip drain from Cross Section 1 should be extended around this narrow section.

The drainage work will have to be carried out with the supervision of the service providers. The water from the drain could spill onto the road or into the existing stormwater system.

4.6 Cross Section 3

At Cross Section 3 there is no river berm. The stopbank is 2.7m higher than the ground at the edge of the road. Three hand augers were carried out in

this area. The upper silt layer was found to be only 0.4m thick in all of these augers. In HA10 at the stopbank toe the predominant soils are silts. Further away at HA5 there are some silty sands and clean fine to medium sands.

A transient analysis of the 100 year flood indicated that the factor of safety against heave would be close to 1.0 and there would be high hydraulic exit gradients at the stopbank toe. A suitable remedial measure would be an overlay 600mm thick at the stopbank toe, tapering to 400mm 7m from the stopbank and ground level 12m out, combined with a shallow pressure relief trench 17m from the toe. The position of the pressure relief trench should avoid the major services running parallel to the road.

The overlay can not be laid across some of the site due to the old shop with a concrete floor at the back. The back of the shop is only about 3m from the stopbank toe. Analysis of a deep pressure relief trench along the stopbank toe shows that the uplift pressure further out from the stopbank would not be reduced significantly. Another analysis showed that if pressure relief trenches are installed at about 8m centres the uplift pressures under the silt are reduced.

HA11 was carried out between the shop and the adjacent workshop building. The soils here have a lower permeability than at HA10 and the uplift pressures on the upper silt layer are smaller.

It is suggested that the overlay be placed as wide as possible and pressure relief trenches a minimum of 1m deep be installed across the back and down each side of the shop in addition to one running parallel to the road. An additional trench will be needed along the concrete slab outside of the garage (Figure 6).

4.7 Cross Section 4

At 1.8m above the general ground level the stopbank at Cross Section 4 is relatively low. The stopbank is underlain by an old road formation on top of the surface brown silts. The hand augers showed complex layering of sands and silts below the natural ground surface. In the analysis a layer of banded silts and sands has been modelled as having a permeability of 2×10^{-5} m/s in the horizontal direction and 2×10^{-6} m/s in the vertical direction.

The transient analysis showed that the factor of safety against uplift of the buried silt is about 1.1 to 1.2. The maximum hydraulic exit gradient at the stopbank toe was found in the analysis to be 0.28. It is therefore considered that no remedial work is required at this cross section.

4.8 Cross Section 5

Cross Section 5 is between the railway and road bridges and is similar to Cross Section 4 in height. The old road formation continues under this section of stopbank. The soils below the surface brown silt are predominantly silty fine sands. Coarse sand and pumice lapilli were found at 3.6m depth below the river berm.

In the 100 year flood analysis the minimum factor of safety against heave of the ground surface was found to be 1.1, between 10 and 20m from the inland toe of the stopbank. The maximum hydraulic exit gradient found was 0.15. It is therefore considered that no remedial work is required at this cross section.

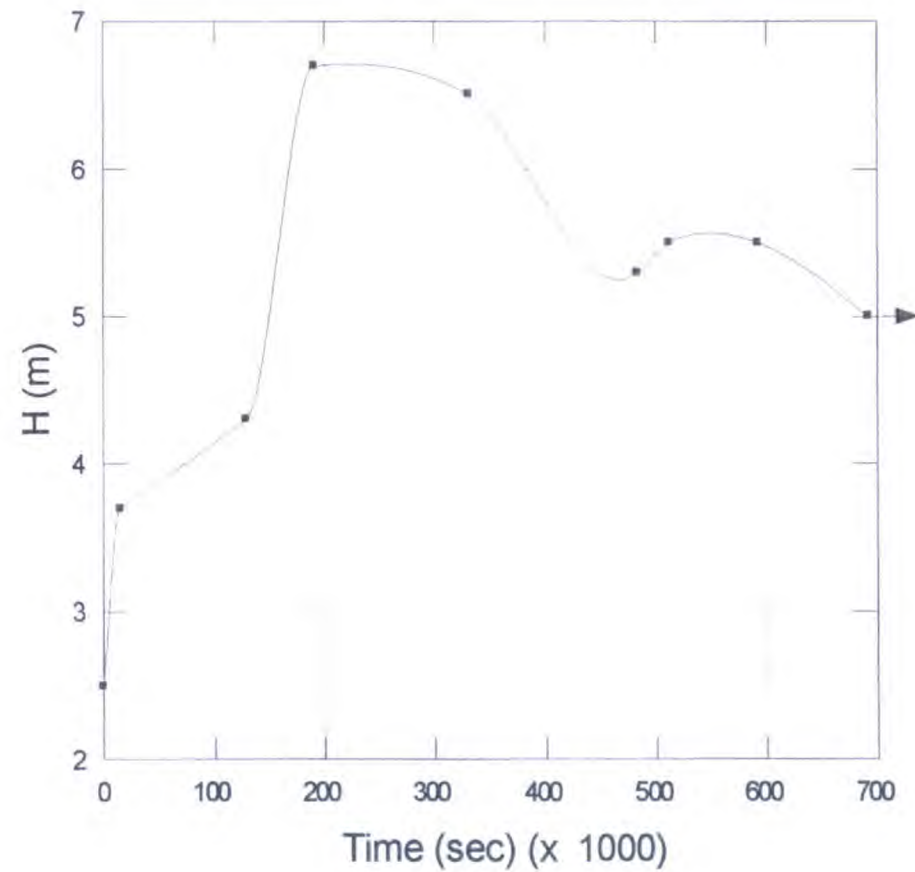
5 Conclusions

1. Transient analysis of the design 100 year flood shows that the existing stopbank could be marginally stable over the upstream portion of the study section.
2. Remedial measures in the form of overlays, pressure relief trenches and strip drains are required as shown in figures 3 to 6.
3. Care will be required with the installation of the remedial measures due to the underground services in the area.
4. The large tree stumps in the inland toe of the stopbank between the road and rail bridges need to be removed to at least 1m below the ground surface and the holes filled with well compacted low permeability fill.
5. It appears that the stopbank does not have the design freeboard in some areas. This should be checked and the stopbank topped up if necessary.

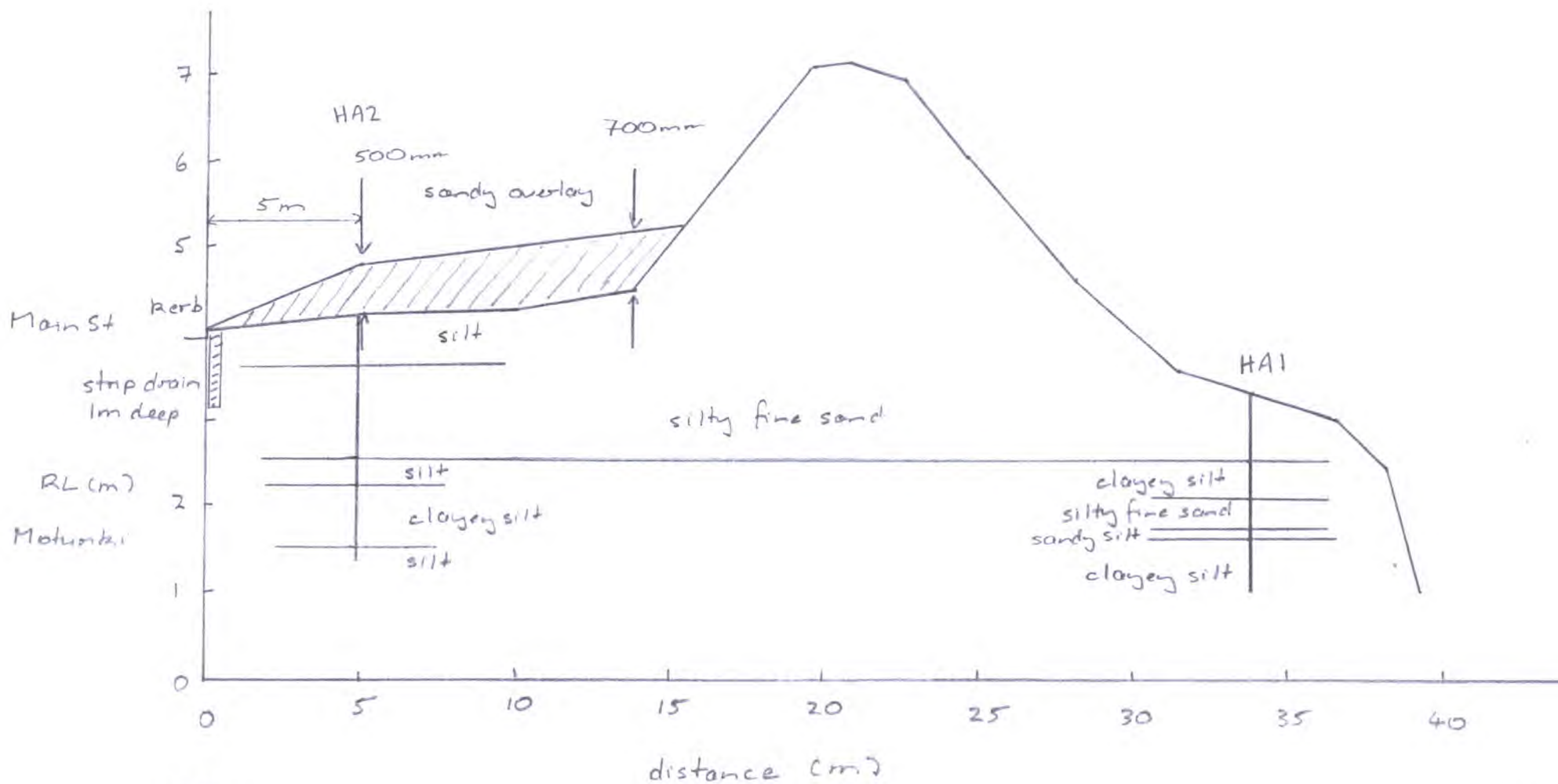
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3 August 2006

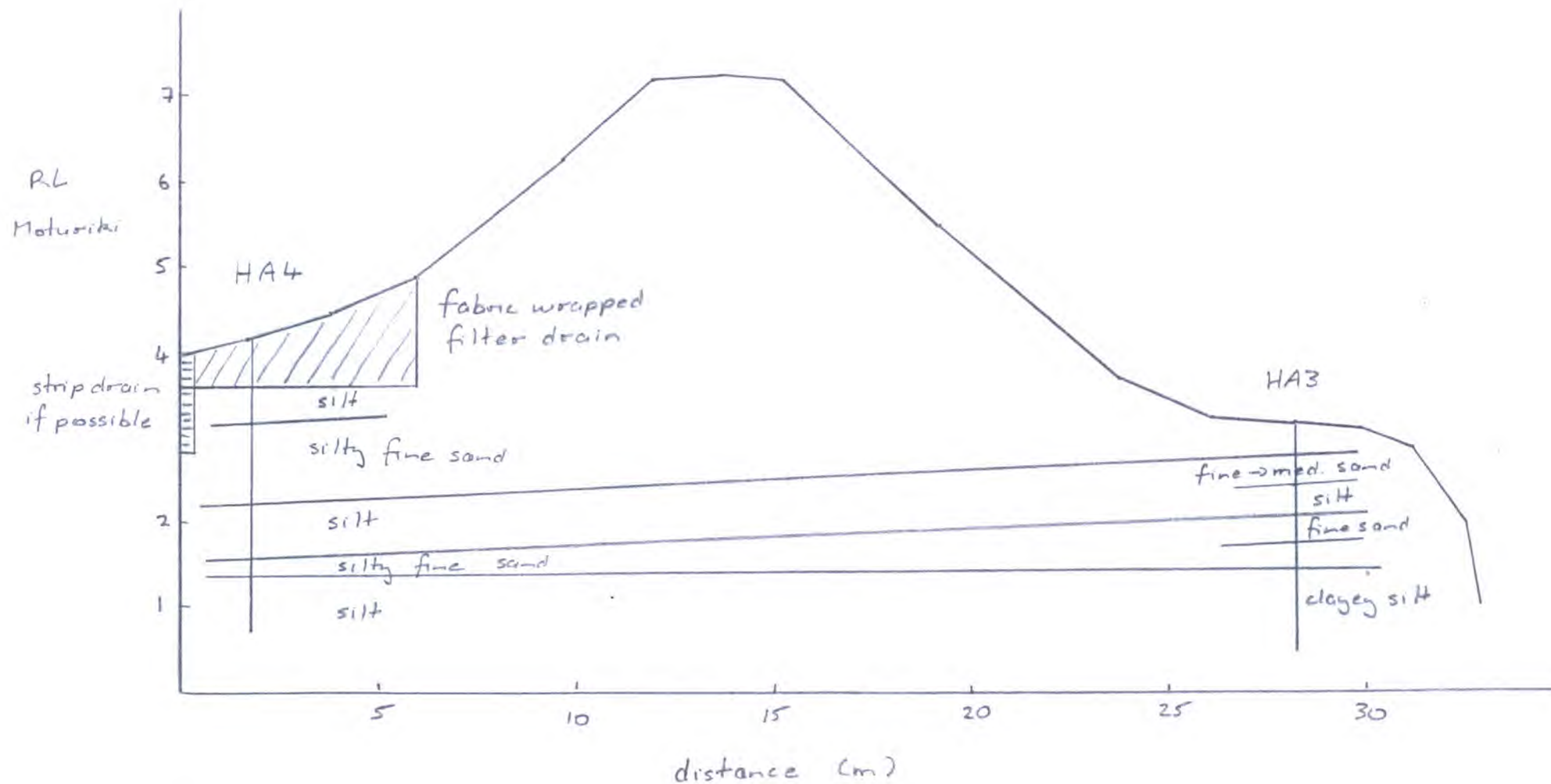




Design 100 year flood flow hydrograph



Cross section 1



Cross section 2

Appendix A

Hand auger logs

Hand auger results

Test Number: HA1

 Job Name: Rangitiki Stopbanks
 Section 5

Date: 13/04/06

Tested by: N.OH

Blows/50mm													soil description	
m	0	2	4	6	8	10	12	C _u (kPa)						
0.2													X X	grey silty fine SAND
0.4													X X	
0.6													X X	
0.8													X X	
1.0													X X	
1.2													X X	
1.4													X X	1.2 grey silty fine SAND
1.6													X X	
1.8													X X	
2.0													X X	
2.2													X X	
2.4													X X	
2.6													X X	1.6 grey clayey SILT with fibrous organics
2.8													X X	
3.0													X X	
3.2													X X	
3.4													X X	
3.6													X X	
3.8													X X	
4.0													X X	

 C_u (kPa)

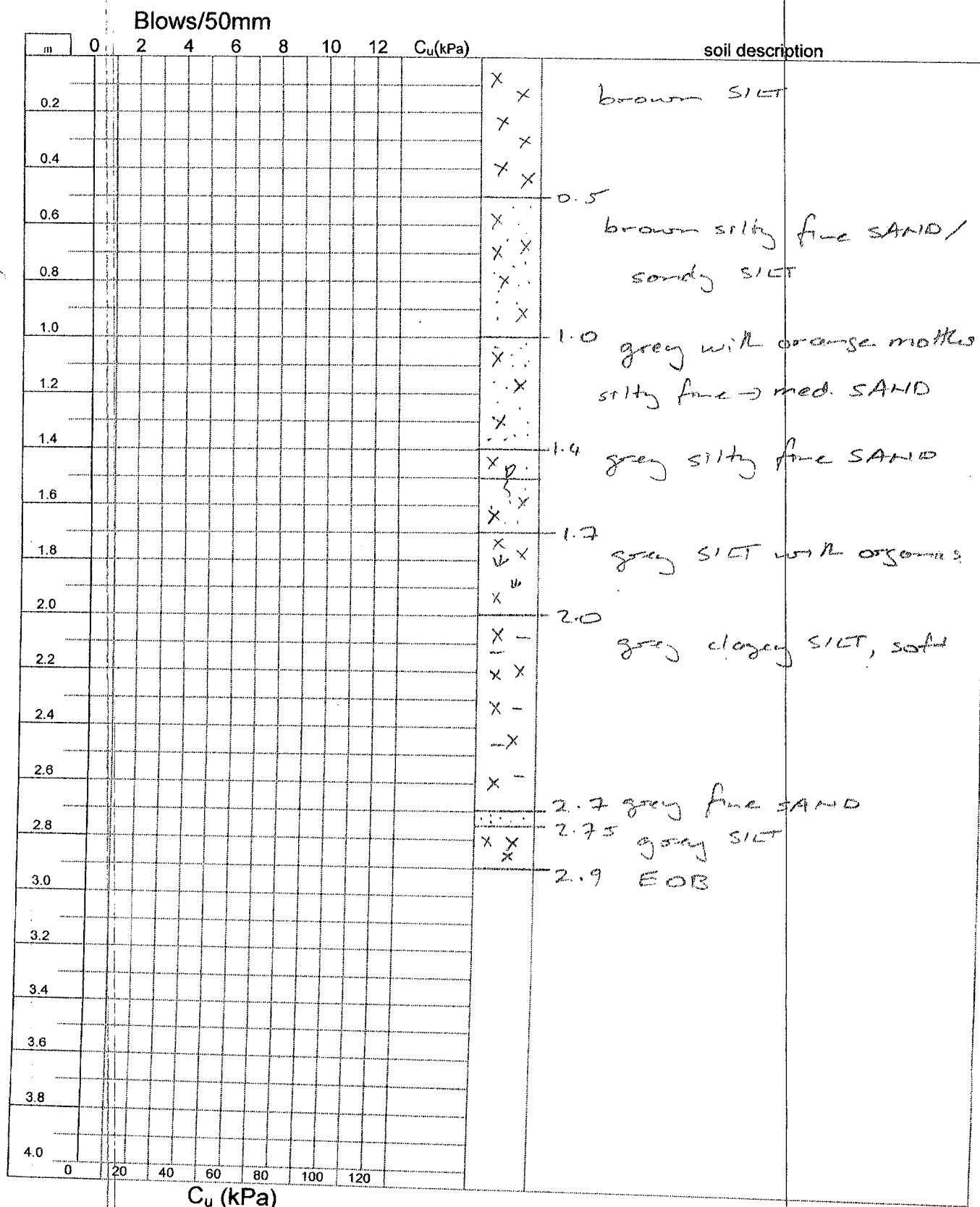
Hand auger results

Job Name: Rangitahi Stopbanks
Section 5

Test Number: HAZ

Date: 13/04/06

Tested by: M.O.H



Hand Auger Log

Test Number: **H A 3**

Job Name: **Rangitikei Stopbanks
Section 5**

Date: **13/04/06**

Tested by: **M.O.H**

		Blows/50mm												soil description	
m		0	2	4	6	8	10	12	C_u (kPa)						
												X X		0.1	grey silty fine SAND
0.2												X X		0.2	brown fine sandy SILT
												X X			brown silty fine SAND
0.4														0.3	
															grey fine → med. SAND
0.6															
												X X		0.6	grey fine sandy SILT
0.8												X X		0.7	
												X			grey SILT, damp
1.0												X X		1.0	grey fine SAND, some
															silt, wet
1.2												X			
														1.3	grey fine sandy SILT
1.4												X X			
												X			
1.6												X X		1.6	
												X -			grey clayey SILT. with
1.8												- X			fibrous organics
												X -			
2.0															
												↓			
2.2												- X			
												↓			
2.4												X			
												X ↓			
2.6												-		2.5	EOB
2.8															
3.0															
3.2															
3.4															
3.6															
3.8															
4.0															

Hand Auger Log

Test Number: **HA4**

Job Name: **Rangitoto Stopbanks
Sections**

Date: **13/04/06**

Tested by: **M.O.H**

Blows/50mm																soil description
m	0	2	4	6	8	10	12	C_u (kPa)								
0.2														X		brown SILT
														X		
0.4														X		
														X		
0.6														X		
														X		
0.8														X		
														X		
1.0														X		0.9 grey with orange staining silty fine SAND, med.
														X		
1.2														X		1.2 grey silty fine to med. SAND
														X		
1.4														X		1.4 grey silty fine SAND/ sandy SILT
														X		
1.6														X		1.8 grey SILT
														X		
1.8														X		2.3 some fibrous material
														X		
2.0														X		2.5 grey silty fine SAND
														X		
2.2														X		2.7 grey SILT, some fibrous material
														X		
2.4														X		3.3 EOB, hole squeezing
														X		
2.6														X		
														X		
2.8														X		
														X		
3.0														X		
														X		
3.2														X		
														X		
3.4														X		
														X		
3.6														X		
														X		
3.8														X		
														X		
4.0														X		

020406080100120

C_u (kPa)

Hand Auger Log

Test Number: *HAS*

Job Name: *Rangitahiri Stopbanks
Section 5*

Date: *13/04/06*

Tested by: *N.O.H*

Blows/50mm										soil description	
m	0	2	4	6	8	10	12	Cu(kPa)			
0.2								X	X	brown sandy SILT	
0.4								X	X	0.4 brown silty fine → med. SAND	
0.6								X	X	0.5 some Terrestrial Ash	
0.8								X	X		
1.0								X	X		
1.2								X	X	1.1 brown sandy SILT	
1.4								X	X	1.2 brown SILT, some clay, moist	
1.6								X	X	1.5 brown sandy SILT	
1.8								X	X	1.7 grey clayey SILT, soft	
2.0								X	X		
2.2								X	X	2.2 grey fine → med. SAND	
2.4								X	X		
2.6								X	X	2.6 grey silty fine SAND	
2.8								X	X	2.8 brown org. smelling SILT	
3.0								X	X	2.9 grey SILT with organic material	
3.2								X	X		
3.4								X	X		
3.6								X	X	3.6 EOB	
3.8											
4.0											
Cu (kPa)											

Hand Auger Log

Test Number: HA 6

Job Name: Ransitarkhi Stopbandes
Section 5

Date: 13/04/06

Tested by: M.O'H

Blows/50mm												soil description	
m	0	2	4	6	8	10	12	C _u (kPa)					
										X X		0.1 brown SILT	
0.2										X		sandy SILT & gravel	
										X		- old road	
0.4										X		0.3	
										X X		brown sandy SILT	
0.6										X			
										X X			
0.8										X X		0.7 brown SILT	
										X			
1.0										X		0.9	
										X		grey brown mottled	
1.2										X		silty fine SAND	
										X			
1.4										X			
										X			
1.6										X			
										X		1.7 grey with orange streaks	
1.8										X X		SILT	
										X			
2.0										X		2.0 orange mottled grey silty	
										X		fine SAND	
2.2										X X			
										X		2.3 moist	
2.4										X X		silty & sandy bands	
										X X		2.5 grey fine med. SAND	
2.6										X			
										X		2.7 grey silty fine SAND	
2.8										X			
										X X		bonds of sandy silt	
3.0										X			
										X			
3.2										X X			
										X			
3.4										X X			
										X			
3.6										X X			
										X			
3.8										X X		3.7 grey fine SAND	
										X			
4.0										X X		3.9 brown organic smelling	
										X		fine sandy SILT	
										X X		4.2 EOB	

Hand Auger Log

Test Number: HA7

Job Name: Rangitikei stopbanks
Section 5

Date: 13/04/06

Tested by: N.O.H

Blows/50mm															soil description
m	0	2	4	6	8	10	12	C _u (kPa)							
0.2													X		grey brown gravelly silty SAND
0.4													X		
0.6													X		
0.8													X		
1.0													X		
1.2													X		1.1 brown SILT
1.4													X		1.4 brown fine sandy SILT
1.6													X		
1.8													X		1.7 grey with orange mottles silty fine SAND/sandy SILT
2.0													X		
2.2													X		2.1 grey with orange mottles silty fine SAND
2.4													X		
2.6													X		2.4 grey with orange mottles clayey SILT
2.8													X		
3.0													X		2.7 grey fine sandy SILT
3.2													X		
3.4													X		3.1 grey fine - med SAND
3.6													X		
3.8													X		3.4 grey sandy SILT, most +
4.0													X		
													X		3.6 grey fine - med SAND
													X		3.7 grey sandy SILT
													X		3.8 grey silty fine SAND, med
													X		4.0 EOB

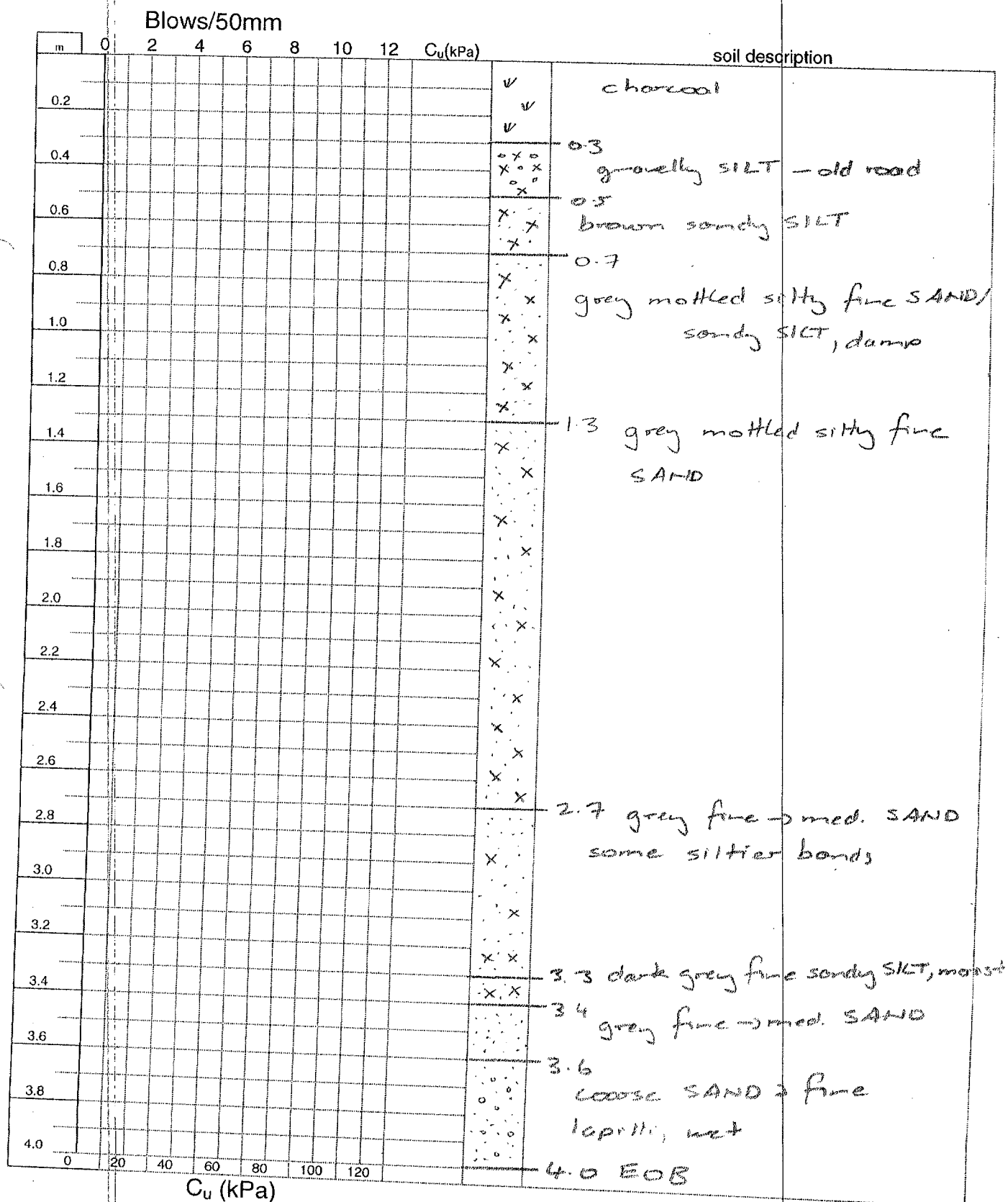
Hand Auger Log

Job Name: Rangitahi Stopbanks
Section 5

Test Number: HA8

Date: 13/4/06

Tested by: M O H



Hand Auger Log

Test Number: HA9

Job Name: Rangitaiti Stopbanks
Section 5

Date: 13/4/06

Tested by: M.O.H

Blows/50mm													soil description	
m	0	2	4	6	8	10	12	C _u (kPa)						
0.2									x x					dark brown SILT
0.4									x x					0.2 brown fine sandy SILT clay
0.6									x x					0.4 brown mottled silty fine SAND / sandy SILT
0.8									x x					0.5 some hard gravel - old road
1.0									x x					0.7 cream pumice → 3mm old road?
1.2									x					0.8 dark brown SILT - old ground surface
1.4									x x					1.4 brown fine sandy SILT / silty SAND
1.6									x x					1.7 brown silty fine SAND becoming mottled grey with depth
1.8									x					
2.0									x					
2.2									x					
2.4									x					
2.6									x					
2.8									x					
3.0									x					3.0 moist
3.2									x					3.2 grey SILT, moist
3.4									x x					3.3 brown silty fine SAND
3.6									x					3.6 grey fine → med SAND
3.8									x					
4.0									x					4.0 EOB

Hand Auger Log

Test Number: HA10

Job Name: Rangitikei Stopbanks
Section 3

Date: 16/6/06

Tested by: MWH

Blows/50mm		C _u (kPa)		soil description	
m					
0.2			X X	0.2 brown SILT	
			X X		
0.4			X X	0.4 brown fine SAND, some SILT	
			X X		
0.6			X X	0.5 brown silty fine med SAND	
			X X		
0.8			X X	0.8 orange stained grey	
			X X	SILT, wet	
1.0			X X		
			X X		
1.2			X X		
			X X		
1.4			X X		
			X X		
1.6			X X		
			X X		
1.8			X X		
			X X		
2.0			X X	2.0 orange stained dark grey	
			X X	clayey SILT	
2.2			X X	2.2 light grey, pum. SILT /	
			X X	fine SAND	
2.4			X X		
			X X		
2.6			X X	2.65 EOB - losing sample.	
			X X		
2.8					
3.0					
3.2					
3.4					
3.6					
3.8					
4.0					

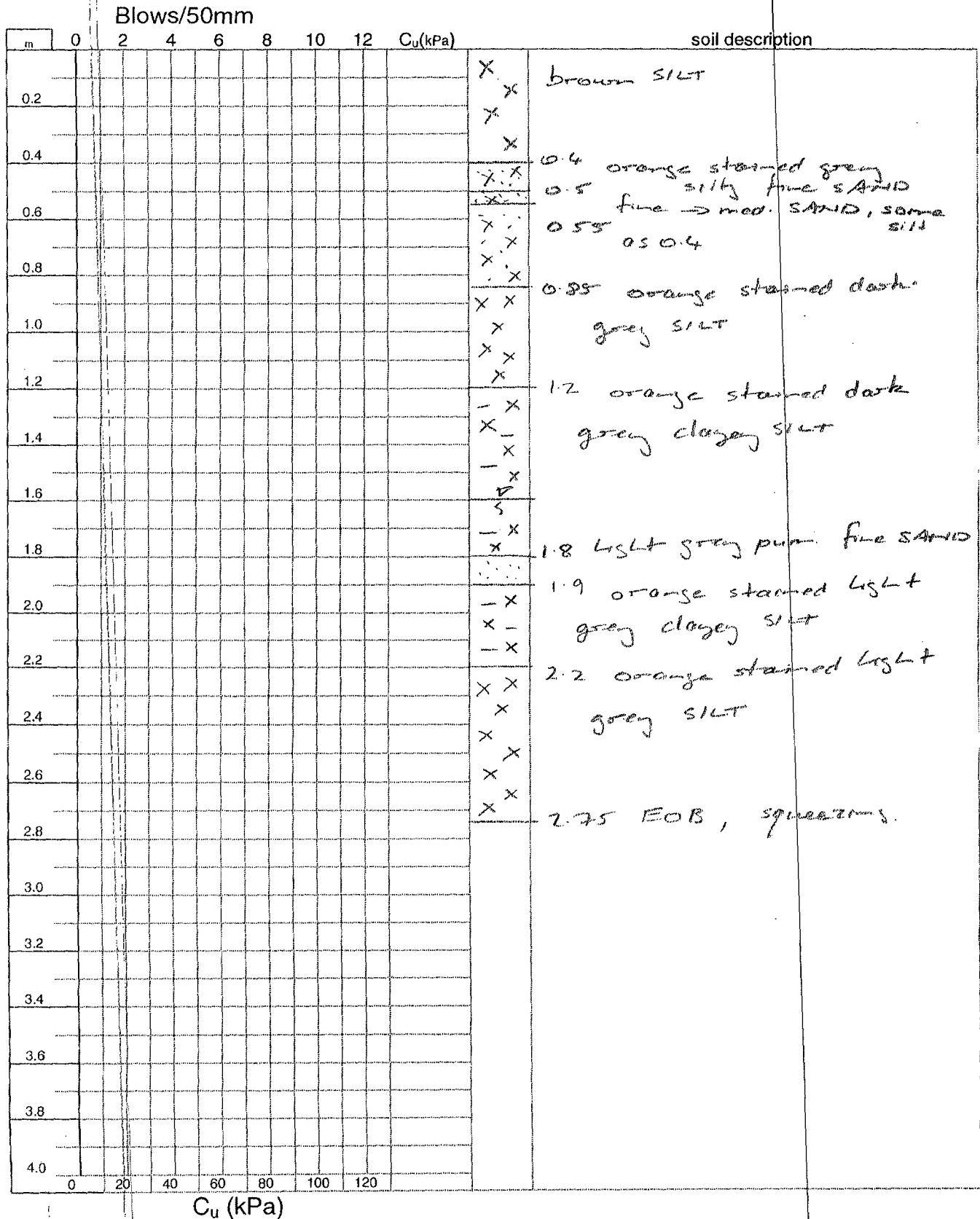
Hand Auger Log

Test Number: HA11

Job Name: Rangitikei Stopbanks
Section 5

Date: 16/6/06

Tested by: N.O.H



Appendix B

Seepage Models

Name: cross section 1 overlay 100yr.gsz
 Title: Rangitaiki Stopbanks Section 5
 Comments: Cross Section 1 overlay 100 year
 Date: 03/08/2006 Time: 10:53:35 a.m.

0.5m overlay and strip drain at kerb

Time step 40 80 hours

Material #: 1	Description:	Hyd K Fn: 1	Vol WC Fn: 1	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 2	Description:	Hyd K Fn: 2	Vol WC Fn: 2	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 3	Description:	Hyd K Fn: 3	Vol WC Fn: 3	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 4	Description:	Hyd K Fn: 4	Vol WC Fn: 4	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 5	Description:	Hyd K Fn: 5	Vol WC Fn: 5	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 6	Description:	Hyd K Fn: 6	Vol WC Fn: 6	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 7	Description:	Hyd K Fn: 7	Vol WC Fn: 7	Ky/Kx Ratio: 1	Direction of Kx: 0

