FINAL REPORT

GEOTECHNICAL INVESTIGATION FOR THE PROPOSED WAIANIWANIWA WATER STORAGE DAM



Prepared for Central Plains Water Enhancement Committee Selwyn District Council and Christchurch City Council c/- Private Bag 1 Leeston

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Comprehensive feasibility level geotechnical investigations were carried out by URS New Zealand Limited for the Central Plains Water Enhancement Scheme during 2001 (URS, 2001). These investigations included a review of available literature including previous investigations (eg Paterson, 1987), geological mapping and new subsurface investigations.

Originally, subsurface investigations were undertaken at a proposed dam site in the Wairiri Valley. These investigations revealed that the site is underlain by up to about 25 m of weak fine-grained sediments (dominantly silt and sand) that would need to be removed prior to embankment construction. Also, the valley geometry (defined by a five metre contour survey) required saddle dams to be constructed at low points in the valley perimeter. Given the cost implications of these variations to the conceptual design for the scheme, additional investigations were proposed to evaluate an alternative water storage dam site in the Waianiwaniwa Valley.

The issues investigated as part of the Waianiwaniwa Valley study include:

- Foundation and reservoir geology;
- Availability of suitable construction materials;
- Presence of active faults beneath the dam footprint; and,
- Effect of historical underground coal mining on reservoir integrity.

The investigations carried out as part of this study included aerial photograph interpretation and geological mapping, excavation of test pits and trenches, and drilling of three cored drillholes. Six Cone Penetrometer Tests (CPTs) were also undertaken (URS, 2002). Eliot Sinclair & Partners Ltd has surveyed locations of all investigation points.

An aerial photograph based Digital Terrain Model (DTM) was produced by New Zealand Aerial Mapping to provide reliable geometric information on the reservoir. The DTM has a 5 m contour interval and is accurate to less than 1.6 metres (vertical height).



2.1 Site Description

The proposed Waianiwaniwa dam site is at the mouth of the Waianiwaniwa valley where the Waianiwaniwa River emerges from the Malvern Hills (Figure 1). The valley has a 1-km wide floor at approximately El 240 m in the vicinity of the proposed dam site. The Waianiwaniwa River follows a 6 km long valley starting near to where the Selwyn River emerges from its gorge upstream from Whitecliffs. Near its headwaters the Waianiwaniwa River flows east for about 3 km, then turns abruptly to flow south for a further 3 km down to the proposed dam site. It then flows across the Canterbury Plains to join the Selwyn River about 16 km to the southeast.

2.2 Regional Geology

Gregg (1964) and Wilson (1988) have undertaken regional geological studies presented as geological maps with scales of 1:250 000 and 1: 100 000 respectively. No detailed studies of the geology of the Malvern Hills have been carried out since Speight (1929). The geological setting for the proposed dam is presented in Figure 2.

The eastern Southern Alps largely consists of Torlesse rocks (greywacke sandstones and argillaceous mudstones) that locally form the basement. In Canterbury, these rocks are overlain by a sequence of terrestrial coal measures (Broken River Coal Measures), marine sandstones and mudstones (Eyre Group), and volcanigenic sediments and basalts (Burnt Hill Group) all of early to mid Tertiary age. In the Malvern Hills, Mount Somers Volcanics (rhyolite and andesite of Cretaceous age) occupy a stratigraphic position between the Torlesse and Tertiary rocks. Mount Somers Volcanics form Mount Misery to the south of the Selwyn River. The basal unit of the Broken River Coal Measures (the Monroe Conglomerate) mainly comprises gravel-sized fragments of the Mount Somers Volcanics.

Fluvioglacial gravels of Pleistocene age (Kowhai Formation) overlie the older rocks. Extensive outcrops of Hororata Formation, Woodlands Formation, Windwhistle Formation, Burnham Formation and Springston Formation underlie the proposed scheme corridor. The gravels generally become younger to the east.

2.3 Seismic Hazard

Recent studies by Stirling et al. (1999) and older studies by Smith and Berryman (1982) describe the regional seismic hazard in Canterbury. Stirling et al. (1999) use a Probabilistic Seismic Hazard Assessment method. Estimates of the level of shaking expected within the projected lifetime of an engineering structure arepresented in Table 1 for Rangiora, which is considered to most closely represent the foothills area. Using this data, we predict peak ground acceleration of about 0.31g for a 150 year return period and 0.47g for a 475 year return period for the scheme area.



Considerable research effort in New Zealand has been directed in the last decade to evaluating the hazard associated with geological structures capable of generating earthquakes (eg. Pettinga et al. 1998, Stirling et al., 1999, 2002). More than 20 active faults have been identified in Canterbury alone. Several of these structures pass within 30 km of the proposed dam site, as shown on Figure 2.

Table 1

Return Period (years)	Stirling et al. (1999)		
	Pga (g)		
50	0.20		
150	0.31		
475	0.47		
1000	0.58		

Estimates of Peak Ground Acceleration for the CPWE area

2.3.1 Porters Pass Fault

The Porters Pass Fault is the expression of the southwestern part of the Porters Pass-Amberley Fault Zone. It crosses the southeastern end of Lake Coleridge and strikes northeast to cross Lake Lyndon and Porters Pass. The fault is the most active structure known in the vicinity of the CPWE scheme. Recent research (Howard et al. in press) indicates that the Porters Pass Fault generates earthquakes of Magnitude $M_w7.2+$ every 2000 years. Associated with this earthquake is up to 8 m of lateral ground displacement. The Porters Pass Fault does not directly cross any part of the CPWE scheme, but passes approximately 27 km north of the proposed Waianiwaniwa dam site.

2.3.2 Springfield Fault

The newly discovered Springfield Fault strikes approximately northeast from the upper Selwyn River through Dalethorpe Station to Springfield (Jocelyn Campbell, University of Canterbury Department of Geological Sciences, personal communication, June 2001). This fault has experienced repeated movement during the last 10,000 years and probably generates earthquakes of M_w 7+ every few thousand years.

The Springfield fault does not cross any structure of the proposed scheme and passes approximately 14 km north of the proposed Waianiwaniwa dam site.



2.3.3 Hororata Fault

The Hororata Fault was discovered following recent seismic reflection surveys carried out for oil exploration. The fault passes within about 1 km of Hororata, and is thought to strike northeast and deforms young gravels at Racecourse Hill. Deformation of young gravels indicates that the fault may have experienced repeated movement during the last 10, 000 years. The Hororata fault probably generates earthquakes of M_w7 + every few thousand years.

The Hororata Fault passes about 3 km south of the proposed Waianiwaniwa dam site. The proposed distribution canal probably crosses the Hororata Fault about 5 km southwest of Hororata.

2.3.4 Other structures

The sequence of Cretaceous to Tertiary aged sediments described in Section 3 dip to the south east in the area of the proposed dam site as a result of tectonic uplift. During investigations for a proposed regional landfill 5 km north of the proposed dam site, a west dipping thrust fault (referred to as the Western Gully Fault) was found at the contact between Cretaceous coal measures and basement Torlesse sandstones (Mark Yetton, personal communication). East dipping reverse faults were also found outcropping south of the Western Gully Fault. These faults were inferred to be active on the basis of displaced Late Pleistocene and Holocene colluvium. Slickensided (sheared) joints were also found in drill core that was interpreted to represent small amounts of displacement along bedding within the Tertiary sediments.

Speight (1928) inferred an east-west striking fault at the contact between a small outcrop of Tertiary sediments in the upper Waianiwaniwa Valley and adjacent Torlesse greywacke outcrop. A similar sliver of Tertiary rocks exists northwest of Mount Misery and this may also be a result of down faulting of the Tertiary block. No comprehensive active faulting study has been completed in this area, but it is likely that these faults have been active during the recent geological past. If these faults are indeed active, their shaking hazard to the proposed dam is expected to be similar to, or lower than, the known active faults shown in Figure 2.

Section 3.5 presents evidence for and against active faulting in the dam footprint.

3.1 Site Investigations

Prior to undertaking the current study, a preliminary investigation (URS, 2002) was undertaken in the vicinity of the proposed site. The main objective of that study was to establish the depth of fine-grained sediments in the Waianiwaniwa Valley. A total of 6 Cone Penetrometer Test (CPT) probes were completed at two possible dam sites and the results of these tests are presented in Appendix A.

Subsequently, a total of 12 test pits and trenches were excavated to investigate the near surface geology. These were excavated using a 20 Tonne tracked excavator operated by W. A. Boyes Contracting Limited. All excavations were logged and representative samples taken by an engineering geologist, and the logs are presented in Appendix B. On completion of logging and sampling the excavations were backfilled.

Three exploratory drillholes were carried out along the proposed dam alignment. These were drilled using a UDR 650 drilling rig operated by McNeill Drilling. The holes were mainly advanced using PQ triple tube techniques, but non-cored "Tubex" techniques were used in some of the near surface gravels. The drill holes were logged and photographed by an engineering geologist, and these are presented in Appendix C.

The locations of all subsurface investigations are presented in Figure 5.

3.2 Geology of the Proposed Dam Footprint and Reservoir

3.2.1 Stratigraphic Sequence and Distribution

The geology of the reservoir is summarised in Figure 4. Cross sections of the reservoir and dam site are presented in Figures 6, 7 and 8.

Speight (1928), Gregg (1964) and Wilson (1988) show basement Torlesse rocks exposed in the upper part of the Waianiwaniwa catchment. An unconformable contact between the basement and the overlying Cretaceous and Tertiary sedimentary sequence strikes approximately northeast from Whitecliffs, passing east of Cairn Hill and Abners Head which are both basement outcrops.

Broken River Coal Measures outcrop to the east of the unconformity and coal has been won, particularly during the late 1800's and early 1900's. The coal measures include conglomerates at the base, sandstones and mudstones, coal seams and oyster beds and probably have a thickness of at least several hundred metres. Where the coal measures were observed in Bush Gully they dip about 45° to the southeast. An outcrop of intrusive dolerites of Paleocene age near to Glentunnel may indicate the easternmost outcrop of coal measures. The dolerite is interpreted to be part of the View Hill Volcanics on the basis of petrography.

Overlying the coal measures is a sequence of marine sandstones and mudstones of Tertiary age including many formational and group names (Conway Formation, Waipara Greensand, and Homebush Sandstone). Confusion regarding the usage of these terms, and the broadly similar sedimentological descriptions and



engineering properties of the different units has led us to lump these units together as "Tertiary sediments". These units are all silty fine to medium grained sandstones and up to 60% glauconitic. In terms of engineering properties, the Tertiary sediments are very weak to weak and joints are generally not present.

The Tertiary sedimentary rocks are overlain by a sequence of volcanic and volcanigenic rocks. Carlson and Rodgers (1975) describe the Burnt Hill Formation as sands, ash and breccia. These units outcrop in the Wairiri Valley and are inferred to underlie Homebush Ridge and outcrop on the west side of the ridge. Tuffs and Basalts of the Harper Hills Volcanics (Carlson and Rodgers 1975) outcrop along the crest of Homebush Ridge.

3.2.2 Cover Sequence

Pleistocene glacial outwash gravels form remnant aggradation¹ surfaces overlying the older rocks. Wilson (1988) has studied the glacial stratigraphy of the Canterbury Plains, and Rains (1966) has studied the glacial stratigraphy of the upper Selwyn River catchment.

Many of these outwash gravels have been grouped together as "Hororata Formation" (Wilson 1988) which includes a wide range of ages but is thought to have been deposited at least several hundred thousand years before present. The Hororata Formation includes a covering of up to 15 m thickness of loess that has accumulated since deposition of the gravels. The highest outwash surfaces, which are inferred to be Hororata Formation, are approximately 80 m above current Waianiwaniwa River level.

A prominent terrace at about RL 270 (about 30 m above valley floor level) is interpreted to be an aggradation surface formed by gravels of the Woodlands Formation. This terrace is at a similar elevation to Woodlands surfaces recognised by Wilson (1988), but has previously been mapped as Hororata Formation. Extensive terraces southeast of Homebush Ridge are also inferred to be Woodlands Formation aggradation surfaces.

The Waianiwaniwa valley contains sand and silt dominated alluvium. The valley floor grades toward a Burnham age aggradation surface of the Selwyn River at about RL 235. Colluvium and landslide deposits mantle the valley sides and fill tributary gullies. No peat deposits were encountered during investigations at the proposed damsite.

3.2.3 Drainage Pattern Changes

A complex history of river aggradation and downcutting, has resulted from distributary glaciers of the Rakaia Valley directing meltwater into the Selwyn River catchment (Rains, 1966). Drainage pattern changes have probably resulted from aggradation, downcutting and possibly tectonic adjustment, and we



¹ Aggradation surfaces are extensive, nearly horizontal geomorphic surfaces built up by aggrading rivers as a result of excessive sediment supply, typically during periods of glacial advance.

infer that the Waianiwaniwa Valley may be an abandoned paleochannel of the Selwyn River. After abandoning its old channel and establishing the modern Selwyn River channel, aggradation during the last glacial advance appears to have blocked tributaries including the Waianiwaniwa Valley and the Wairiri Valley and resulted in accumulation of silt dominated lake sediments or sand dominated alluvium.

3.3 Damsite Geology

The proposed embankment alignment runs approximately east-west for most of its length and curves to the northeast at the left abutment end. The total length of the proposed dam is about 2000 m with a crest elevation of about 290 m, giving a maximum height of about 55 m above existing ground level. The dam footprint geology is described here in four distinct areas that are considered to have similar geological conditions:

- Left abutment;
- Valley mouth;
- 270 m terrace; and,
- Right abutment.

The **left abutment** is founded on the end of Homebush Ridge. The geological conditions underlying the left abutment are expected to comprise weak Tertiary sediments, and tuffs in a sequence dipping about 30° to the southeast (i.e. downstream). These rocks are expected to be overlain by a thin layer of colluvium including bouldery volcanic rocks and clay rich tuff derived material. A series of terraces are also evident on the end of Homebush ridge, the most prominent of which is at approximately RL270, the elevation of the terrace that occupies most of the dam footprint. The terraces are expected to be underlain by a small deposit of greywacke gravel with a loess cap up to about 10 m in thickness.

The **valley mouth** is approximately 300 m wide and has a flat floor at about RL 235 m. This elevation corresponds to a Burnham age aggradation terrace formed by the Selwyn River (Wilson, 1988). Test pits 5, 6 & 7, and drillhole WN3 were carried out in this area. The test pits investigated to a maximum depth of 6 m, and between 6 m and 70 m below ground level the geological materials have been described based on the results of WN3. Test pits 5 and 7 encountered interbedded gravels, sands and silts, containing mainly greywacke clasts with rare volcanics. Test pit 6 encountered greywacke gravels to a depth of 4 m.

Drillhole WN3 encountered greywacke dominated gravels to a depth of 18 m. Gravel clasts were typically slightly weathered, brown or black stained on the outside. This sequence included a sandy silt layer at about 5.8 to 8 m depth (drillhole log is presented in Appendix C).

Between 17 and 18 m depth, volcanic clasts were noted within the gravels. Between 18 and 27 m depth grey very stiff silt and very fine sand was encountered. This was laminated in part with typical lamination thickness of less than a few mm. Pocket penetrometer strength measurements were undertaken with most results falling in the range of very stiff to hard (Figure 8). Between 27 m and 38 m depth further gravels



were encountered. These were typically coarse greywacke gravels with a slightly cohesive silty sand matrix, and the clasts were typically relatively weathered. At the base of the gravel sequence an angular gravel layer of a few metres thickness directly overlies rock.

The statigraphic and depositional relationship between the different Quaternary units encountered during this investigation (such as the terrace gravels, valley infill and valley mouth infill) is unknown. We infer that the most likely geological scenario is that the lower part of the channel fill is relatively old (possibly Woodlands age), and that the upper channel fill is of relatively young Burnham age.





Rock was encountered between 38 m and 70 m depth, giving a rockhead elevation of about RL200. The rock comprised very weak silty fine grained slightly glauconitic sandstones, greenish grey in colour. The bedding is typically dipping at about 15° but dip direction of bedding could not be measured as the core was not orientated. Joints were absent in the core, probably as a result of its relatively low strength, and the core was unweathered.

A **terrace** inferred to be a Woodlands Formation aggradational deposit occupies the majority of the dam footprint with a relatively level surface at about RL 270 m elevation. The terrace forms a spur protruding from the west side of the valley. The terrace is between about 200 and 400 m wide in a north-south direction. Malvern Hills Road follows a gully that crosses the terrace, falling to the northeast.

Test pits 1, 2, 3, 4, 8 and 9 and drillholes WN1 and WN2 fall within this area of the dam footprint. The top surface of the terrace is covered by about a 9 m thickness of loess. The loess comprises very stiff, light yellow fine sandy silt. WN1 is located below the proposed dam crest line approximately 400 m from



the right abutment. Surface elevation at WN1 is about RL264 m and gravel was encountered to about 30 m depth underlain by Tertiary sediments (i.e. rockhead is at about 233 m elevation). WN2 is located on the north side of the terrace near the dam centreline, with a ground surface elevation of about RL232 m. In WN2, silt and gravel dominated colluvium and alluvium was encountered to a depth of 12 m, underlain by Tertiary sediments.

A gravel quarry at the eastern end of the terrace exposes brown silty gravel in an exposure about 10 m high. Approximately 1 m thickness of loess is exposed in the quarry, with the majority of the 9 m thickness apparently having been eroded off at that location.

The **right abutment** of the proposed dam will be formed against a terrace with a surface elevation of about RL320 m. Test pit 10 was excavated in the upper terrace surface and encountered 3 m of weathered very stiff to hard yellow brown sandy silty loess overlying highly weathered brown greywacke gravels. Test pit 11 was excavated on a spring line at about elevation RL280 m and it encountered gravelly colluvium and in situ weathered gravel to a depth of 2 m overlying very weak sandstone. Seepage was observed entering the pit at the base of the colluvium. The permeability contrast between outwash gravels and underlying Tertiary sediments is inferred to result in the spring line, which crosses the right abutment at about RL280 m.

3.4 Hydrogeology

Piezometers were installed in the three drillholes, and water level and permeability information is presented in Table 2. Groundwater was encountered in several of the test pits excavated in the valley floor. The Waianiwaniwa River water level at the time of the investigation was about 4 m below valley floor level. Water was encountered in test pits at shallower depths, particularly in the vicinity of TP1 and WN2 where standing water lies on the swampy paddocks.

Borehole and Depth	Depth to Groundwater	Permeability range m/s	Material Description
WN1	>30 m	NA	Outwash Gravels
WN2	1.97 m	1×10^{-4} to 7×10^{-5}	Tertiary Sandstone
WN3	3.69	6×10^{-5} to 4×10^{-6}	Outwash Gravels

Table 2			
Depth to Groundwater and Mass Permeability	Test	Result	s

Note: 1. WN1 contained no standing water so couldn't undertake rising and falling head tests2. Depth to groundwater measured on 17 Sept 2002

The gravel dominated units within the dam footprint are expected to have variable mass permeability. The gravels that form the RL270 m outwash deposit are generally intermediate age greywacke gravels that are expected to have a mass permeability in the range 10^{-4} to 10^{-5} ms⁻¹. The valley fill alluvium encountered in WN3 (between ground surface and about 17 m depth) within the valley mouth includes Burnham age sandy gravels that are expected to be relatively permeable. Permeability tests were not carried out on



these materials during this study but would be expected to be in the range of 10^{-3} to 10^{-4} ms⁻¹. The gravel encountered between 27 and 38 m depth is a relatively silty gravel with a relatively low permeability (see Table 2) as tested by rising and falling head tests.

The general permeability of the Tertiary sediments is expected to be in the range of 10^{-7} to 10^{-9} ms⁻¹ based on previous permeability testing carried out in similar materials at the proposed Wairiri dam site (URS 2001) and elsewhere (Mark Yetton Geotech Consulting Ltd personal communication). Testing carried out in WN2 indicates a permeability of 1×10^{-4} ms⁻¹, which is much higher than expected in these materials. The higher permeability is expected to be due to a locally fractured zone or possibly a malfunctioning piezometer. More extensive permeability testing should be carried out at design stage to establish if any areas of the dam foundation require treatment such as grouting.

3.5 Evidence for Faulting Within the Dam Footprint

As described in Section 2.3.4 a linear topographic step crosses the downstream edge of the dam footprint. Trench TR1 was excavated on a steep south-facing slope west of Malvern Hills Road to look for evidence of fault-related deformation within the near surface materials. The location was chosen to avoid thick fan deposits which have formed at gully mouths along the terrace edge. Subhorizontal brown gravels were encountered in the trench underlying about 1.5 m thickness of loess and gravel colluvium. No evidence for faulting or tectonic deformation was found in TR1.

The RL270 m terrace shows a slight fall to the south which is consistent with the depositional dip of the fan surface, but could also be a tectonic tilt. Also the older Hororata age terraces show a general southeast tilt which may be tectonic or depositional. No evidence for faulting or folding of these surfaces was found during the investigation.

While no evidence was found for faults within the dam footprint, the possibility exists that faults may be found during design or construction. It is considered very unlikely that a fault could be found within the dam footprint that cannot be accommodated by a local change in embankment configuration, such that the embankment can handle the displacement expected to result from future movement.

3.6 Effect of Historical Underground Coal Mining

Coal mines were operated in the Malvern Hills throughout the late 1800's and early 1900's. The majority of mines were located in Bush Gully and in Surveyors Gully, though other mines were located where coal seams were found to outcrop. Figure 4 shows the locations of coal mines throughout the Waianiwaniwa Valley. The underground mining was extensive in places, particularly in the case of the Klondyke mine, which followed seams up to "1500 feet down dip" (approximately 300 m below ground level), and up to about 600 m along strike (personal communication, Ken Shearer, Canterbury Coal Ltd). Klondyke Mine was unusually extensive, and many mines were discontinued because they were overwhelmed by groundwater or because the coal seams were faulted out. In some circumstances the coal seam was found again, and mining continued. The faults responsible for displacing the coal do not have large throws as the coal seams generally follow a line of strike, that is not radically offset.



The proposed dam is outside the area of coal measures outcrop and it is therefore extremely unlikely that underground mining has been carried out in the dam footprint, however coal mining has been undertaken within the reservoir footprint.

There is not considered to be a significant likelihood of underground coal mines forming a continuous conduit out of the reservoir. The Homebush Mine is located in Surveyors Gully, west of the proposed reservoir. The entrance to this mine is at least 2 km from the nearest point in the reservoir and it is considered very unlikely that the Homebush mine reached to the proposed reservoir footprint. If records are found indicating that mining did reach the reservoir footprint, engineering works may need to be designed to address this. Such measures would probably involve blocking the mines with low permeability fill barriers and this could prove to be expensive.



4.1 Conceptual Embankment Design

The proposed dam design incorporates a zoned earthfill embankment comprising locally borrowed gravel dominated materials. The core material comprises compacted weathered gravels of Hororata Formation with slopes of 0.5 horizontal to 1 vertical. A 3 m wide sand filter drain is required against the downstream face of the dam core to provide filter protection. Shoulder material could comprise younger greywackederived gravels with an outer construction slope of 2.5 horizontal to 1 vertical. A typical cross section of the conceptual embankment design is given in Figure 9.

The conceptual design requires that the loess cap is removed from the 270 m terrace (a depth of about 10 m). Elsewhere the design adopts a foundation level three metres below existing ground level. A cut off system has been included to prevent excessive flow through the gravels under the embankment. This cutoff incorporates a 5 m deep cutoff trench with a ten metre deep slurry trench constructed in the base of the core trench that extends to the Tertiary bedrock. At the valley mouth a deeper cutoff may be required if the lower gravels prove to be too permeable.

The reservoir volume has been calculated from the DTM and indicates that 290 M m³ of storage will require a maximum water level of RL280 m which is significantly less than RL 291 m previously estimated. The storage curve is presented in Figure 10, and Figure 11 indicates the shape of the proposed reservoir when full.



Figure 10 Storage Volume Curve for Proposed Reservoir



4.2 Foundation Suitability

Most of the embankment foundation footprint rests on weathered gravel of the 270 m terrace. The layer of loess that caps the terrace will probably need to be removed prior to embankment construction. Loess can suffer from collapse when saturated, can undergo piping failure under hydraulic gradients and could cause stability problems for the embankment. Additional investigations into the material properties and distribution of the loess will be needed during detailed design.

Springs on the right abutment at about RL280 (Section 3.3) will need to be controlled during construction. The springs indicate that there may be relatively permeable zones within the gravels that cap the abutment. Some form of seepage control will be required in this area to prevent leakage around the dam abutment. This will likely be a cutoff trench or upstream blanket.

The gravels form a suitable foundation for supporting the embankment. The permeability of the gravels is relatively high, and a cutoff beneath the embankment or a leakage reducing low permeability blanket will probably be required to limit leakage to an acceptable level. Where the embankment footprint sits on young valley fill sediments, further investigation will be required to ensure that weak materials are not present that could cause differential settlement. Removal of these materials may be required in some cases. It may also be possible to position the embankment so that a minimum amount of the dam footprint overlies the valley fill materials. Either of these options have implications for embankment volume, and needs to be assessed as part of the costing study for the dam.

Small terrace remnants are evident on the left abutment, which are interpreted to be outwash gravels. No subsurface investigations have yet been carried out on these terrace remnants, and local gravel deposits may need to be removed or treated. Subsurface investigations to map the extent of such deposits should be carried out in this area during the design phase.

4.3 Slope Instability

Existing slope instability has been observed in the reservoir. This includes mainly shallow slides and debris flows on the steep western slope of Homebush Ridge, slumping on dip slopes within the coal measures, and shallow failures of loess colluvium around the edges of the outwash terraces. No very large existing landslides have been observed that could generate significant waves in the reservoir.

Saturation of colluvium and existing landslide debris following lake filling will probably cause increased small scale landslide activity within the reservoir, particularly due to the fluctuation in water level caused by water demand. Increased landslide activity outside the reservoir is not expected due to the long flow paths for groundwater to reach out of the reservoir and the low permeability of the Tertiary sediments.



4.4 **Construction Materials**

4.4.1 Core Material

Weathered greywacke gravels with a relatively high clay content are likely to form a suitable core material. These materials could be borrowed from the terraces approximately 2 km upstream of the dam on the north side of the reservoir. Low permeability materials could also be borrowed from the underlying Tertiary sediments or from colluvial deposits on the northwest side of Homebush Ridge.

Investigations to confirm the available volumes and material properties (in particular grading variability and internal stability) of potential core materials need to be carried out prior to dam design.

4.4.2 Filter Zones

The near surface alluvium of the Waianiwaniwa River comprises gravelly sand, which can be processed to a suitable grading for filter zones. Selective quarrying of this material will require a resource volume investigation to map out the continuity of sand deposits. Testing to confirm the grading and physical properties of the sand will need to be carried out prior to dam design.

4.4.3 Shoulder Material

Strong, free draining greywacke gravels would be suitable shoulder materials for embankment construction. Possible sources could include the Burnham aged fan downstream of the dam site, selective removal of gravel dominated valley fill alluvium, and selective removal of less weathered gravel from the terraces 2 km northwest of the dam site. Internal transition zones could be constructed using gravels that have been weathered to an intermediate degree. Gravel-dominated materials could also be borrowed from some of the fans that have developed from erosion of the outwash gravel terraces.

Resource investigations and testing will be required to confirm the available quantities and mechanical properties of these materials prior to dam design. In particular, the shoulder material needs to be filter compatible with the filter sands.



Based on the results of this investigation we believe it would be possible to construct a dam in the Waianiwaniwa Valley with a storage volume of 290M m³. Maximum reservoir level to accommodate 290M m³ will be RL280 m. The proposed site at the mouth of the valley is considered to have suitable foundation conditions for construction of an earthfill embankment dam.

The dam would have a crest length of about 2000 m and a maximum height of about 55 m. Construction materials are available within a few kilometres of the dam site. Further assessment is required to evaluate the embankment volume, and to estimate the construction cost.

Other issues that need to be assessed as part of the dam design are spillway capacity and design, outlet works design, downstream hazard classification, and a review of possible alternative dam section configurations.



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Layout of the proposed Waianiwaniwa storage dam, pump station and headrace canal



Map showing known active faults within 30 km of the proposed Waianiwaniwa dam site

Figure 2



Plan showing the locations of known underground coal mines in the Waianiwaniwa Valley



GEOLOGICAL LEGEND



Geological map of Malvern Hills Area (after Wilson 1989)

Figure 4











Maximum footprint width ~ 300 m



Engin ring and Environm antal Management JOBS\48685\002\2100\CE002G004.dwg, Layout1, 06/01/2003 11:54:20 a.

Figure No. 11

Appendix A CPT Test Results





Wniwa 2



Wniwa 3














Friction Ratio (%)

CPT ANALYSIS NOTES

Soil Type

Interpretation using chart of Robertson & Campanella (1983). This is a simple but well proven interpretation using cone tip resistance and friction ratio only. No normalisation for overburden stress is applied.

Liquefaction Screening

The purpose of the screening is to highlight susceptible soils, that is sand and siltsand in a relatively loose condition. This is not a full liquefaction risk assessment which requires knowledge of the particular earthquake risk at a site and additional analysis. The screening is based on the chart of Shibata and Teparaksa (1988)

High risk is here defined as requiring a shear stress ratio of 0.4 to cause liquefaction with D_{50} for sands assumed to be 0.25 mm and for silty sands to be 0.05 mm.

Medium risk is here defined as requiring a shear stress ratio of 0.2 to cause liquefaction with D_{50} for sands assumed to be 0.25 mm and for silty sands to be 0.05 mm.

Appendix B Test Pit Logs

					T	EST PI	T LOG	TP 1	Sheet 1 of 1
URS New Zealand Umlted. 287 Durham Street, Christchu	rch	Phone (03) 374 8500 Fox (0) 377 0655	Project	1 No.:	1	Project Refere	ince:	A14 A 11/1 4	17714
Drilling Contractor: 80 Excavation Method: EX 200	Logged By: 7 Checked By: Dole Started: Date Finished	28/8/02	48 Relative Coordia Permit	ie Level: mRL inates: mN mE	12100	CPW Client: CEN	TAAL	PLAINS	WATER
DE	SCRIPTION C	DF STRATA		GRAPHIC LOG	GEOLOGICAL	FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - O SILT - yellow grey ma Some san gravel C Volcanic - sandy GRAVEL - A gravel M SOMM. Clasts. S: Between I SILT - blow WILL SON Clasts	lark b brow Hled nd n clasts source layer blue g aximu Volcan trongly .8 and e gra	silt with lo n and digt silt with nd rare as (mainly reed) at 1.6-1. rey sandy an clast si ic and grey Non knew 2.0m. y sandy si ounded grav	re or 200 12 14 14		ishere and theorer Allivium				
GRAVEL- greg clas subronde some some angular below 5.	blue c wh 13 - g 19 last 5m.	hard dast hard dast inded to regaracke? igers and s dominan	f		0 2 4 6 8 0 2				
Terminal	led a	+ 6.0m.	-	20 - 5	4				
		TEST PIT :	SECTIO					TEST PIT TERMIN Target Depth Refusal Flooding Caving/collapse	
								SAMPLE TYPE; Bulk Sample Tube Sample Disturbed Sample	BS TS e DS

						TI	EST PI	T LOG	TPZ	Sheel 1 of
URS New Zeoland Umilied.	6	Phone (03) 374 8500	Project	1 No.:		1	Project Refere	nce:		
287 Durham Street, Christo Drilling Contractor:	nurch	Tax (0) 377 0655	48	685-00	2/210		CPIAL	IT LOG TP . rence: E WAIA JTAAL PL SAM AND TE SAM AND TE I I I I I I I I I I I I I	AIANIWAI	1/1/4
Execution Nethods	Land D. T	MARACINA	FO	a laugh mDl	212100		Clast		11/1/ 0/00/11	VINIA
EX 200	Checked By: Date Started: Date Finished:	28/8/02	Coordin	noles: mN mE No:		_	CEN	TAAL	PLAINS	WATE
D	ESCRIPTION OF	F STRATA		GRAPHIC LOG	DEPTH (m) GEOLOGICAL	DESCRIPTION	FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
Topsoil - SILT - light with - slight and pi with a - mottled brown then brown then brown then brown - slight vertical M soil - generalle Stiff.	dark bro f yello some of variat sand lepk yella between mainly weng sub- f - ligh	inn sitt lon ow brown si clay [LOESS billing the cli content loght mello thering aron olanar jon t grey color to vory	1/1 1 2 1 2 1 A A		0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0	care invited to interest these				
Test pit (Ilmit.	continu f read	red to 6.0 (h)	ъ		5.0 5.2 5.4					
		TEST PIT S	ECTIO	N					TEST PIT TERMINA	ATED AT:
									Target Depth Refusal Flooding Caving/collapse	
									SAMPLE TYPE:	
									Bulk Somple Tube Somple Disturbed Sample	BS TS DS

					Т	EST PI	T LOG	TP 3	
URS New Zealand Limited. 287 Durham Street, Christohu	rch	Phone (03) 374 8500 Fax (0) 377 0655	Project No.:			Project Refere	ince:		
Drilling Contractor: 80	YES O	ONTRACTING	48685	-002/2	2100	CPW	EW	AIANIWAI	NIWA
Excovation Method: EX 200	Logged By: Checked By: Date Started Date Finishe	TM-Morran # 28/8/02 di	Relative Level: Coordinates: Permit No:	mRL mN mE		Client: CEN	TAAL	PLAINS	S WATER
DE	SCRIPTION	OF STRATA	GRAPHIC LOG	S DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPg)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - de SILT - ye brann Si'l (loess av GRAVEL - support stained - clasts highly slightly slightly sobron 200 m. Mest thay - some lagers	dense dense	nown silt loa gown mittle bown mittle (colluvium) boom class ravel, heaving greywacke thered to athered to athered to athered to athered to athere dis max. diments here dis here dis here to the are to here to the are the are to the are the a	the sings	0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8	Late Pleistiene Gravols.				
Test pit	cont	inned to 5.5	20	- 5.2 - 5.4	8				
loess	1	TEST PIT S	ECTION					TEST PIT TERMIN/ Target Depth Refusal Flooding Caving/collapse	
gav	el -	0.0.0.0. 			- 70,	osott		<u>SAMPLE TYPE;</u> Bulk Sample Tube Sample Disturbed Sample	BS TS DS

					Т	EST PI	T LOG	TP 4	
URS New Zealand Limited. 287 Durbam Street, Christoph	arch .	Phone (03) 374 8500	Project No.:			Project Refere	nce:		
Drilling Contractor: BC	YES CO	NTRACTING	48685	-002/	2100	CPW	EW	AIANIWAI	VIWA
Excavation Wethod:	Logged By: 7 Checked By: Date Storted: Date Finished:	McMorran	Relative Level: Coordinates: Permit No:	mRL mN mE		Client: CEN	TAAL	PLAINS	S WATER
DE	SCRIPTION O	F STRATA	GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPg)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - da SILT - mott light gree Clay. Con Weathere gravel and up (loess an GRAVEL - M Weathered Weathered Weathered Weathered	IE bro led ye silf fails d gre clasts to 1 d low greyn fs up	I silt loam llow brown with som are high gwacke (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded (rounded)))))))))))))))))))))))))))))))))))	1 - 1 - 1 - 1 - 0	0.0 0.2 0.4 0.6 0.8 1.0 0.4 1.2 1.4 5 1.4 5 1.6 2.0 2.2 • 2.4	where pleistance and	· · · · · · · · · · · · · · · · · · ·			
Discontinu	red a	f 2.5m		2.6 2.8 3.0 3.2 3.4 3.4 3.6 3.8 4.0 4.2 4.4 4.4 4.6 4.8 5.0					
			-	- 5.2 - 5.4	8				
Loess	Vium	TEST PIT S				Topso."	se of lope.	TEST PIT TERMIN Target Depth Refusol Flooding Caving/collapse SAMPLE TYPE: Bulk Sample	ATED AT:

						Т	EST PI	T LOG	TP 5	
URS New Zeoland Limited.	urch	Phone (03) 374 8500	Project	No.:	_		Project Refere	nce:	1.	
Drilling Contractor: RC	YES CO	NTRACTING	48	685-00	2/	2100	CPWI	EW	41ANIWAN	JIWA
Excavation Method: EX-200	Logged By: 7 Checked By: Date Started: Date Finished	McMorran	Relative Coordin Permit	e Level: mRL nates: mN mE No:			Client: CEN	TAAL	PLAINS	WATER
DI	SCRIPTION O	F STRATA		GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - de SILT - Stif SILT AND A SILT AND A	r/k bro. F yellar RAVEL - Ane g.	n silt lann brown silt mixed grave avell	uly		- 0.0 0.2 0.4 0.6 0.8 - 1.0 1.2	DINA				
RAVEL - A N.AL Main Some Valca SILT AND SI Claycy Sil GRAVEL - I gravel - S Matrix. C rounded	the performances of and	bbly grad end clay d interbedded sand bbly and ret Are graved are greyon of \$ 1000	sts ksh		1.4 1.6 1.8 - 2.0 2.2 2.4 2.6 2.8 - 3.0 3.2 3.4	LATE PLENSTOLENE (?)				∑ <u>−</u>
Disdont Ane to water	inned colla table.	at 3.5m ose below			3.6 3.8 - 4.0 4.2 4.4 - 4.6 4.8 5.0	n.				
					5.2 5.4				3	
SILT -Z SILT AND CURAVEL			SECTIO	N 110000	N. N. 1.	SILT RAVE	AND S	420	TEST PIT TERMINA Target Depth Refusal Flooding Caving/collapse <u>SAMPLE TYPE:</u> Bulk Sample Tube Sample	ITED_AT:

					T	EST PI	T LOG	TP 6	aneer 1 of 1
URS New Zeoland Limited.		Phone (03) 374 8500	Projec	1 No.:		Project Refere	ince:	0	
Drilling Contractor:	nurch	10x (0) 311 0635	48	8685-002	12100	CPIAL	E (0)	ALANIWAN	1/1/14
Excavation Method: EX 200	Logged By: Checked By: Date Started Date Finished	TMcMorran #	Relativ Coordi Permit	re Level: mRL inotes: mN mE t No:	2100	Client: CEN	TAAL	PLAINS	WATER
DE	SCRIPTION (DF STRATA		GRAPHIC LOG	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
Topsoil - B GRAVEL - B Crude B - rare H sandy or per Gravel and m -rarely - then (S clayey and 2. - heavy at 3.5 Discorti	rown brown anizond hin grav clast brown p to ap 1 brown gello lager zm. (manga m.	gravely sift bouldary gav tal stratificat howzons of silty grave vel s are roun greywacke ~ 150 mm to 300 mm. to 300 mm. s at 1.6 m ?) inese stailing	d d d d d	0.2 0.4 0.4 0.6 0.8 0.6 0.8 0.6 0.8 0.6 0.8 0.6 0.8 0.6 0.8 0.6 0.8 0.6 0.8 0.6 0.8 0.6 0.8 0.8 0.6 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8	LATE PLEISTOCENE OUTWASH roader (BUENHAM FW)				
Ane +	- gro	TEST PIT S	ECTIO	- 4.4 - 4.6 - 4.8 - 5.0 - 5.2 - 5.4				TEST PIT TERMINA Target Depth Refusal Flooding Caving/collapse SAMPLE TYPE:	
								Bulk Sample Tube Sample	BS TS

						T	EST P	T LOG	TP 7		
URS New Zealand Limited. 287 Durham Street, Christon	urch	Phone (03) 374 8500 Fox (0) 377 0655	Project	No.:			Project Refer	ence:			
Drilling Contractor: BC	YES CO	NTRACTING	48	8685-	002/	2100	CPW	EW	AIANIWAN	JIWA	-
Excavation Wethod: EX200	Logged By: Checked By: Date Started: Date Finished	McMorran :	Relativ Coordi Permit	ve Level: inoles: No:	mRL mN mE		Client: CEN	ITAAL	PLAINS	WA	FTER
DE	SCRIPTION C	DF STRATA		GRAPHIC LOG	C DEPTH (m)	GEDLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROU WAT DATA COMMI	IND ER AND ENTS
SILT - yello SILT - yello SILT , SANA yellow brow Aire grav SILT AND C clayery SJ - strongly - blae SI/3 ARAVEL - S MAL grey	AND a AND a m sil nd icany- it and tand lightly poracke	M silt RAVEL - inter t, sond and brann land t, sond and sandy sill sandy sill sandy grann clasts to s	bedde 1 tratil t		0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4	LATE PLENSTOLENG (?) AND HOLOCENE SEDIMENTS					4.0
DISCONTIN	JUED	AT 4.5m			- 4.6 - 4.8 - 5.0						
					- 5.2 - 5.4						
		TEST PIT S	ECTIO	N					TEST PIT TERMINA	TED AT:	-
									Target Depth Refusal Flooding Caving/collapse		
									<u>SAMPLE TYPE;</u> Bulk Sample Tube Sample Disturbed Sample		BS TS DS

					Т	EST PI	T LOG	TP 8	
URS New Zealand Limited. 287 Durham Street, Christon	urch	Phone (03) 374 8500 Fox (0) 377 0655	Projec	:1 No.:		Project Refere	nce:		
Drilling Contractor: BC	YES CON	NTRACTING	48	3685-002	2100	CPW	EW	41ANIWAN	JIWA
Excavation Method: EX 200	Logged By: Checked By: Date Starled: Date Finished:	McMorran	Relativ Coordi Permit	ve Level: mRL inates: mN mE 1 No:		Client: CEN	TAAL	PLAINS	WATER
DE	SCRIPTION OF	STRATA		GRAPHIC LOG DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
Dizine du	at su at su at su fill grey about	the silt loam and silt of the mossil and Clayey ver 4m	h	$25^{2}5^{2} = 0.2$ 1 - 0.4 1 - 0.6 1 - 1.0 1 - 1.2 1 - 1.4 1 - 1.2 2.2 1 - 1.4 1 - 2.0 1 - 2.2 1 - 2.2 1 - 2.4 1 - 2.6 1 - 3.4 - 3.6 1 - 3.8 1 - 3.8 1 - 4.2 1 - 4.4 1 - 4.4 1 - 4.6 1 - 4.8 1 - 4.	LATE PLETSTOLENE AND HALOCENE				
(limit	of read	ch)	a)	5.2				-	
		TEST PIT S	ECTIO	N ¹			S	TEST PIT TERMINA	TED_AT:
								Target Depth Refusol Flooding Caving/collapse	
								SAMPLE TYPE: Bulk Somple Tube Sample Disturbed Sample	BS TS DS

					T	EST PI	T LOG	TP 9	
URS New Zeoland Limited, 287 Durban Street, Christele	urch	Phone (03) 374 850	0 Proje	et No.:		Project Refer	ence:	-	
Drilling Contractor: BC	YES C	ONTRACTING	4	8685-002/	2100	CPW	EW	AIANIWAN	JIWA
Excavation Method: ER 200	Logged By: Checked By Date Starte Date Finish	TMCMorran d: ed:	Relat Coort	live Level: mRL dinates: mN mE nit No:		Client: CEN	ITAAL	PLAINS	WATER
DE	SCRIPTION	OF STRATA		GRAPHIC LOG	GEDLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - do LOESS - do -gene cons	vally sistence	wh silf loan TP 8 Non Very stiff		$\begin{array}{c} 55555 \\ - & 0.2 \\ - & 0.4 \\ 1 \\ - & 0.6 \\ - & 0.8 \\ - & 0.8 \\ - & 0.8 \\ - & 0.4$	LATE PLEISTOLENE AND TOLOOLENE	ŝ			
Assentin	ved .	at 5.5m	4	5.2				5	
		TEST PIT	SECT	ION				TEST PIT TERMIN	ATED_AT:
								Target Depth Refusal Flooding Caving/collapse	
								SAMPLE TYPE:	
								Bulk Somple Tube Sample Disturbed Sample	BS TS e DS

						Т	ES	T PI	r Log	TP /0	
URS New Zeoland Limited, 287 Durham Street, Chulster	wrch	Phone (03) 374 8500	Projec	t No.:			Proje	ect Referen	HC 0:		
Drilling Contractor: R	OYES (ONTRACTING	48	3685-	002/	2100	C	PWE	E W.	AIANIWAN	JIWA
Excovation Nethod: EX 200	Logged By: Checked By: Date Started Date Finishe	TMcMorran t: d:	Relativ Coord Permi	ve Lovel: inates: t No:	mRL mN mE		Clien	nt: CEN	TAAL	PLAINS	WATER
D	ESCRIPTION	OF STRATA		GRAPHIC LOG	o DEPTH (m)	GEOLOGICAL DESCRIPTION		FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOUL -d SILT - lig light gre Clayery s SILF. Slig very sh [weath GRAVEL- yellow b. gravef. Si clast are	hight a hight a hight a	y weathers Lotss] y weathers Lotss]	and	5511-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-	0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 1.3 4 3.6 7.8	PLEASTICENE LATE PLEASTOCENE AND/OR.	when the case coes				
Discon	Anne	l at 3.9m			4.0 4.2 4.4 4.6 4.8 5.0						
			a		5.2					27	
		TEST PIT	SECTIO							<u>TEST PIT TERMINA</u> Target Depth Refusal Flooding Caving/collapse	
										SAMPLE TYPE; Bulk Sample Tube Sample Disturbed Sample	BS TS DS

						-		-		Sheet 1 of
						T	EST PI	T LOG	TP (
URS New Zeolond Limited. 287 Durhom Street, Christen	urch	Phone (03) 374 8500	Project	No.:			Project Refere	ance:	-	
Drilling Contractor: RC	OVES (NTRATTING	48	685-00	21	2100	CPW	EW	AIANIWA	AI/LA
Excavation Mathod:	Logged By: 7	MEMORAN	Relativ	e Level: mRL	-1	0100	Client:	0	11.1	
(Checked By:		Coordi	nales: mN			CEN	TAAL	PLAIN.	S WATER
EX 200	Date Started: Date Finished	e i	Permit	mENo:						
DE	SCRIPTION C	DF STRATA		GRAPHIC LOG	DEPTH (m)	GEOLOGICAL DESCRIPTION	FIELD SHEAR STRENGTH (kPo)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS
TOPSOIL - SILT - 18	dark aht a	brown solf la	an F	55551-	0.2	ŭ	P			
COMICI	INI F			===	0.4	9N				
gravel.	wet ;	grey silty matrix			0.6	4				
supporter	1.	()		0	1.0	6		2		
(slum,	p man	tend?)		01	1.2	35				. 11
GRAVEL -	bo	in caleblus		-0E	1.4	200				inflow at 1.4m
grand.	silty	matrix at		0.0 -	1.6	SLS.				
1.4m ()	support	ving serches	1	O.E	1.8	PC				
W.t.)		5 / 5			2.2	3	5			
-clashs	are	greywacke	,	. PE	2.4	110				
non-ded	and,	hoghly		· 0 -	2.6	72	2			
CANDSTONE	- Ve	m ineet		0 7 -	2.8	-	-			
light are	u br	un sandsto	ne	••••=	3.2	1×1				
)			∵: •E	3.4	1- 3	5			
					3.6	Ro				
Discont	Hnued	at 3-8m		-	3.8					
				E	4.2					
				F	4.4					
				E	4.6					
				F	4.8					
				E	5.2	20				
		-		E	5.4				- 62	
		TEST PIT SI	ECTION	4					TEST PIT TERMIN	ATED AT:
			1	TTT 1	T				Target Depth	
	TE		1		7	SUT	+ 000	VET	Refusal	
	10	- P	1.		-		non		Caving/collapse	
	o. \	00.010		5. 1.0		aRA	WEL		SAMPLE TYPE.	
				TER	1	ARY	SST		Bulk Sample	RS
									Tube Sample	TS
0 11 10	1 10 11				-				N. 1 . 1	0.0

Test Pit 2 showing yellow brown loess to full depth of excavation

Test Pit 4 showing yellow brown loess colluvium containing rare gravel clasts overlying gravel.

Test Pit 3 showing yellow brown loess overlying grey brown gravels. Loess thickens upslope.

Test Pit 6 showing yellow brown silty gravel. Water table is at about 4 m

gravel. Water table is at about 2 m depth.

Test Pit 8 showing yellow brown loess to the full excavation depth of about 6 m.

gravel. Water table is at about 4 m depth.

Test Pit 10 showing yellow brown loess overlying weathered gravel at about 3 m depth.

Test Pit 9 showing yellow brown loess to the full excavation depth of about 5.5 m.

Test Pit 11 showing yellow brown silty gravel colluvium overlying grey sandstone at about 3.0 m.

Appendix C Drill Hole Logs

DOOLECT 4	18685-007-710 FT	-	LC)G	OF	DRIL	LH	OLE	OCATION	IENT	AL PL	AIN	15 4	UATE	ER	-
CRID DECT	0000 -002-2100 FEA	TUR	E WE	TAA	574	TTTT	OA.	N	426260.22	me n	ATUMA	Lin	2 /	A1 51-		
GRID REF	11 L/11G	a	0-00	RD.	2.1.4	1.1.4.5	00 +++	6		D 7/7	MUTA	-100	LI A D		100 7	18.
ANGLE FRO	M HORIZONTAL	ML.	DIR	ECI	NON.			HJ	L DOCK	U	07' 14	11	HAD	1000	LAR A	Per
DESCRIPTIO	N OF CORE	RING	88	EST	COR	E DEPTH	8	FRACTUR	PROMINENT JOH	INTS, BEDDIN	S. SEAMS, VEINS	5 _	LEVEL	WATER	TESTS	- L
WEATHERING, HA	ARDNESS. STRENGTH, COLOUR.	THE	ONE	L ON	LUST	1	2	Searing	SHATTER, SHEA	AR, AND CRUS OSITY (attitude	SH ZONES. FOL width, spacing.	"		LOSS		or
ROCK OR SOIL TH	YPE, DEFECT SPACING.	NEA	HAR	29	174	NS Du	Diff.	natural	smoothness)	DECODIE	ALCONT.	EVD.		ale	PERMEAB	BR.IT'
LITHOLOGICAL FE	EATURES (bedding, foliation, mineralogy,	233	IU	DINT	-	Cost	BRAF	C Cmi	COR SOIL	DESCRIP	ater content.	PAT R.C		0-100	ō ō .	. 9
testure, cement, etc.	Z STRATIGRAPHIC NAME	021	1220) ŭ	11	ř I		n Xn Iuthelei	group symbol	etc.)		1	Date	1111		4
TOPSOIL	Brown Silt Loam						No.									
SILT Yell	how brown boess.		11111		Ш	1-					M					
Firm	n- very stiff		11111		111			11 111	Top 0.20,	m 60853 3	ore, more.					
	0		11111			2-			White co	lowed 'v	veins'	11				
	92 (S		11111			4.			throughout	t, Icm a	wrote.					
		111	11111	1.0		13-	_						2/9			
			11111			4							3/2 3			
	1 million (1997)															
						5-										
						-			2							
						6 -										
							-				0.629					
7.88 - 8.08	m Sandy SILT	++				- 1			7.14 - 7.2	24 07,	hard +					
Red los	own (Iron starth).		IIT	-	-	8 -	1.4.1			V	ONHE					
Grades 1	From SILT above.	+++	HTT	1	-											
8.08-8.45-	CONGEOMERATE		H	1	-1111	9-			Gravels in	congland	vate 22cm					
lector al	sand + silt sized.	H	IUK			- 10	. 0		diameter,	minded	Micausic					
1.45 - 4.20~	SILT Yellas bown Loes.	11	1111		111	- 1	0.		+ /0/123	54 540-1465	Lorde .	11				U
501	ot to stiff	11	11111		111	- // -	· ."					11				<u>è</u> .
1.20 - 31.46		ш	11111		100						115 W 120	11				5
Silty	sandy GRAVELS	111			200	z /2 -	. 0		~ 10% of	gravel ils	nts between					
R	mun to red brown				HH	17	.0.		5- >20	o con clin	meter,				8	44
	7				HH		0.		mostly 7	Torlane 31	indstore.				115	3
						14-			Some vol	leanies -	busalt.					×3
							. 0		N 50% \$	gravel is	diamete				211	1
					+++	15-			1	190	2020-06-06-06-06-06-06-06-06-06-06-06-06-06				and	1
					Ш	16-	0 .								3	
					111		0.								8	
					IIII	17-	1.0					1			-li-it-	
					IIII											
					111	18-	0				1.00					
	2.3					19	0									
							• P									
					Ш	20-	0.0									
							0 .		1.04							
					1111	21									111	
					++++	27										
	1211						. 0								TIL	1
					HH	23	0.									
							. 0									
					IIII	24-	. 0 .									
					HH		0 0									
						25-1	· 0 .									-
						26	0 .								15.862	12
				-			- "							1111		F
						27-	· · ·									1
																E
						28 -	•									
					100000		0 0								100	
					12/10	29-	÷				<u>1</u> 2			111		1
						2.										
	ROCK WEATHERING	1	RO	CK H	ARDNES	ss ⁵⁰	-		FRACTURE LO	NG .	LOGGED /	16H		PROJEC	CT: 4 868	35-
RILLER: 2 HARILY	SW - Slightly weathered		H - H	and oderat	ni Isly hard			10 2	9 tp -0	Spacing of natural	DATE 6/9	102		HOLE	NW OF	V.
TARTED	HW - Moderately weathered		MS - M	oderat	tely soft			+++		fractures	and a manifest	Annual		HOLE I	71.5	C
2/9/02	CW - Completely weathered		VS - V	ery so	R			- 0	5 % <u>55</u>	of core	TRACED			LENGT	Hanna	
NIŞHED:	EXPLANATION										CHECKED:					
5/9/02											ORIGINAL VER	TICAL:		CORE	BOXES:	
RILL											SCALE /	100		(1111111)	a-11-13-131-++++	

PROJECT 4	8685-007-210 FE	THE	E LI	OG	OF I	DRIL	LH	OLE	OCATION CENT	RAL PL	AIN	5 1	JA TE	F.R.	
GRID REF	NZMG	100	CO-0	RD.	574-	7723.	85 m	N 74	+ 26260.22 m E [DATUM	LIN	z (AN SL)	12.12
ANGLE FROM	HORIZONTAL VEATI	CAL	DIF	RECT	ION	NA		H.A	D. GROUND	3.67m	11	H.A.D	COL	LAR Z	PRESSUR
DESCRIPTION	OF CORE	HERNIG	CK	0 TEST	LOSS	DEPTH HAD	FOG	LOG	ROCK DEFECTS PROMINENT JOINTS, BEDDIN SHATTER, SHEAR, AND CRU	IG, SEAMS, VEINS ISH ZONES, FOL- e, width, spacing,	HLLd	LEVEL	LOSS	TESTS -	- Lugeons or
ROCK OR SOIL TYP	PE, DEFECT SPACING.	NEAT	HARC	LOA	%	e site	DHIC	(Spacing of natural	smoothness)	PTION)	TE/DE		"/a	PERMEAB	LITY-100
I,ITHOLOGICAL FEA	TURES (bedding, Ioliation, mineralogy STRATIGRAPHIC NAME	NWN	HNNA	post i	500	Cor	GRA	S S S S	(CR SOL DECORD	water content,	PA B	Date (0-100	111	999
Silter sandy (GRANDLS cartinved.			-	TH		0				TT				
and may						31-	• D							30.8	20160
31.46 - 71.50	(Ерн)				1111	37	0								
SAVASTONE	weak to very weak ,				H										4
SW (Im st	awning), Fine-course			1		33-	sist?		Glavconitic band	is /quartz					ENT
sand sized.	Reddish grey to green					-34-	مينينين ميني من يتريم من من يتريم		10-15"	9					r.
					1111	35-									aller
					H	-			10						
		111				26-	14								
					IIII	37-									
						38 -									
					III	39									
							1.1		40						
					Π	90	1.5		40.5 Stockenster	ded day					
						41 -			band paralle	L & sealan	7				
						42-	in the second								
					111	- 43									
	17.					43-			(1) I						
					111	44-									
						45-									
					HH	46-	•								
						47	۰÷								
						1	1.						1111		
		111			III	48-	secol			0.00					
	5 B				Htt	49-									
						50-									
					HH		120								
						101									
					IIII	52-									
						13-	in in								
					m	54									
							1								
					m	22	1.1								
					3697.0	56-									
					9///2	57-	1.1				11				
					₩₩	38-									
					1111	59-	1			*			1111		
					1111	60			EDACTUDE LOG	1	Ц		Ш		
DRILLER:	WW - Unweathered		VH - H -	Very hard	HARDNE and	55		0.0	(cms) Specing of	LOGGED	19/1	72	PROJ	ECT: 7.00	N 1
STARTED	MW - Moderately weathered HW - Highly weathered		MH - MS - S -	Modera Modera Solt	alely sof	t		-	tractures	TRACED	here indicated		LENG	TH. 71-	50
2/9/02	CW - Completely weathered		VS -	Very si	oft	-		- N	2 % 22 of core	CHECKED:				*****	
5/9/02										ORIGINAL VE	RTICAL		CORE	E BOXES	
DRILL:										SCALE	:/00				

PROJECT 45	8685-002-210 FE	R	E	OG	OF I	DRILL	H	OLE	OCATION CENT	RAL PL	411	V.5	WAT	ER			
GRID REF	NZMG	(CO-C	DRD.\$	747	123.85	mA	1. 24	26260.22 6	DATUM	LIN	2 (MEL)		17.	47
ANGLE FROM	HORIZONTAL	CAL 10	DI	RECT	ION	NA		H/	D. GROUND	3.6 tm	TT	WATE	D. CC	W	ATER	PRES	SURE
DESCRIPTION WEATHERING, HAR	OF CORE DNESS, STRENGTH, COLOUR,	HERE	OK	D TEST	LOSS	HAD.	200	LOG	PROMINENT JOINTS, BEDD SHATTER, SHEAR, AND CR	ING, SEAMS, VEINS USH ZONES, FOL- de, width, spacing,	HId	LEVEL	LOS	R T	ESTS	- Lug	eons
ROCK OR SOIL TYP	E, DEFECT SPACING.	MEATI	HARD	MPa)	"I.	e size	DHIO	Spacing of natural	smoothness)	NPTION)	TEADE		*/a	PEF	MEAB	ILITY-	-1020
texture, cement, etc);	TURES (bedding, Ioliation, mineralogy STRATIGRAPHIC NAME	WW NNH	HINN	POINT	1000	Cor	GRA	S S S .	fconsistency, compactness, group symbol etc.)	water content,	VO	Date 1	0-10	Ĩ	1 1	1	2 2
SANASTONE	weak to very weak.	ΠĪ	TTT	Î	TTT		14				Π						
SW (Iron sta	wing), Ane -course					6								10000			
sand sized	Reddish grey boren					62-	÷.										
		1111				63	1550							1.1			
					ITT	64						1					
							-							Sumo			
					TTT	65 -	1.1		1.00								
						66								1			
						67 -	•••										
						68-	1111										1.1
						69								- interest			
						70 -			4								
						1											-
504	71 50					11-11-1	3.				₩	-	+				1
EOR	11.300					hun											
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		1111				mil								1	++		
						mu					11			- the second			
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						hum			1.7					1			4
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	毘					mhm								- Alert			
						mili								1			
						Innu								1.0			
						IIIIII				_				1		-	0.00
DRILLER:	ROCK WEATHERING		VH -	Very ha	IARDNE:	SS		80	FRACTURE LOG (cms) Spacing (LOGGED	Ig I.		PRO	ECT:	486	85-N	00
STARTED	MW - Moderately weathered HW - Highly weathered		MH - MS - S -	Modera Modera Solt	tely hard tely soft				tiactures	TRACED	.14	5.3TL	LEM	E NO	71	.50) }
2/9/02	CW - Completely weathered EXPLANATION		VS -	Very so	n	-		0 -	2 % 22 of core	CHECKED:							++++++++
5/9/02										ORIGINAL VE	RTICA	L:	COF	E BC	XES .		
DRILL:										SCALE	100						

PROJECT 48685-002-210 FE	LOG OF DRILL H	OLE LOCATION CENTRAL PL	AINS WATER
GRID REF. NZ MG	CO-ORD \$7477 \$7.03 A	2426944-08 mE DATUM	LINZ (MEL)
ANGLE FROM HORIZONTAL	AL DIRECTION NA	H.A.D. GROUND	H.A.D. COLLAR 231:63
DESCRIPTION OF CORE	AND	FRACTURE ROCK DEFECTS LOG PROMINENT JOINTS, BEDDING, SEAMS, VEINS SMATTER SHEAR AND CRUSH ZONES, FOL-	ILEVEL WATER TESTS - Lugeons
WEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE DEFECT SPACING.	ROC ROC ARON	Spacing of IATION SCHSTOSITY (atilude, width, spacing, smoothness)	PERMEABILITY-100m
LITHOLOGICAL FEATURES (bedding, foliation, mineralogy	V WE WE	tractures) (OR SOIL DESCRIPTION)	041E 0.01 10 10 10 10 10 10 10 10 10
texture, cement, etc); STRATIGRAPHIC NAME	SNT THE C	In Q in _ iconsistency, compactness, while consistency, compactness, while consistency, iconsistency, compactness, while consistency, iconsistency, compactness, while consistency, iconsistency, compactness, while consistency, iconsistency,	
TOPSOIL - Brown Silt Loam		silt Top 0.2m light gray + Iran	
SILT - light brown, hard.		stained. Collovival daposit.	
198-12-30 H & H & H & H & H & H	2	- Crare conquest	2 % /8 % 3 D /8 3
Sandy and to red brain (was stand)		around clasts sandstone, minded	
		Upper In ion stamed.	
	↓↓↓↓ A =		
	······································		11.2.1.0.1.0.1.0.1.0.1.0.1.0.1.0.1.0.1.0
			advantanter eres
Colour changes - blue grey. Fresh.			
	7-70.		
	8-00		80
			170
		Clasts > 10 cm diameter	Q 5
	10 - 000	daily porter.	No E
	11 - 000	a	2000
	17 00		2 S
12.30 -> 71.45m (EOH)		- Internet	26
SANOSTONE Very weak to weak,	N I I I I I I I I I I I I I I I I I I I	Sand - quate + glancaste	
Fresh, unfractional, greenish-	н III и Прина 1997 г.	occasional clay bands generally	
Sand sized.		dipping demente	
		Cancina Eins dipping ~ 20	
	//////////////////////////////////////		
	/7-		1
	18		
			16 10/10 110
	20		
	2	21.70 - 7144 : loose sand	
	State of the second sec		
	22-3**.		
	23 =		WUM
	24		
	25		25.0 (11.1)1.
	26-		<u> </u>
	27		
			R.
28.00 - 30.52	28		8
Iron staining of sANOSTONE (above)	29-		8
ROCK WEATHERING	ROCK HARDNESS VH - Very hard	FRACTURE LOG (cms) Spacing of LOGGED	PROJECT 4 8685 - 00
R. HARREY SW - Slightly weathered MW - Moderately weathered	H - Hard MH - Moderately hard MS - Moderately soft	P S P - 6 natural DATE 3.0/	8/02 HOLE NO. 4/10 2
STARTED: HW - Highly weathered 28/8/02 CW - Completely weathered	S - Soft VS - Very soft	- N 2 R 22 of core	LENGTH
FINISHED: EXPLANATION		CHECKED:	
30/8/07		ORIGINAL VE	100
		CONTRACT CONTRACT	

NOILOI	ATURE	WA	IAN	IWAN	IWA	OAN	ULE L	CATION	ENTR	AL PLI	41N	5 6	JA TE	F.R.		
RID REF. NZMG	C	O-OF	RD. 3	7.4.7	757	m N.	24	+26944-03	m.E. DA	TUM	LIN	z (AT 54	1.40	781	
ANGLE FROM HORIZONTAL	CAL	DIR	ECTI	ON	NA		H.A	D. GROUND	231	.63	TT.	H.A.D	. COL	WATE	R PRE	55
ESCRIPTION OF CORE NEATHERING, HARDNESS, STRENGTH, COLOUR, ROCK OR SOIL TYPE, DEFECT SPACING.	ROCK	ROCK ARDNESS	CAD TEST	CORE LOSS/ LIFT	HAD.	DO1 OH	FRACTURE LOG (Spacing of natural	PROMINENT JOIN SHATTER, SHEAS IATION SCHISTO smoothness)	R. AND CRUSI SITY (attitude, v	SEAMS, VEINS H ZONES, FOL- width, spacing,	C/DEPTH	LEVEL	NATER LOSS	TEST	or SILIT	Y-1
ITHOLOGICAL FEATURES (bedding, foliation, mineralogy	232	IU	(N)		Core	RAP	(ractures)	(OR SOIL I	DESCRIP mpaciness, wa	HON) ter content,	DAT		0-100	10 0		1
esture, cement, etc); STRATIGRAPHIC NAME	621	1220	1ª	m28 1111	E	0	in Sun-	group symbol e	tc.)		++	Date I				
SAMISTORE Very weak to weak, Gresh, unfractured, greenish-					31											
whiteich grey. Fine-med-coarse sand sized. continued.					33											
17an staining of sandstante (almore)					34 minun											
5.55 SANOSTONE (as above) blue-green				s alaca	a 22	in T		increase in	glanco	ite content						
8.9					14 minut											
				1.11	39 Junuuru	بري: ندريد . د										0.000
					40											
				•	42											
					43											
					45-1											
					46		1									
					47-											
			*		49 -											
					20 1			22								
					22 Juni											
					12 International			-								E. C.F
5.00 = 71.45m (EOH) KANGSTONE (as above) with some silt					5			Strengt 13	noveased	by solt.						
					12 I	N.			i ma he	deling						4
					58 -			le lancari te	CANNY YEA	0						
					57					1						1
ROCK WEATHERING		RC VH - V	DCK H	ARDNE	\$\$		0	FRACTURE LO	OG Specing of	LOGGED	nen la l		PROJ	ест: А	8685	110
K FlgR,265 SW - Stightly weathered MW - Moderately weathered HW - Highly weathered WW - Completely weathered CW - Completely weathered		H - H MH - H MS - 1 S - 5 VS - 1	Hard Modern Modern Soft Very si	ately han ately sof	đ		2 -50	10 10 20 5 100 1 1000 1	natural fractures Fractures/m of core	DATE	6/0	fean an a	LENG	тн. 7/	·45,	1 A
NISHED: EXPLANATION										ORIGINAL VE	RTICA	U	COR	E BOXES	l:	

LOG OF DRILL HOLF												NO	. 3	1010 2				
PROJECT 48685-002 - 2100 FE	ATUR	FWA)GI	UFI	URIL WA d	LHI	ULE	LO	CATION CE	NTRAL	MAIN	15	LAT	TER				
GRID REF. NZMG	1	CO-0	RD. S	747	757,	m N		24	26944 ·03 m 6	E DA	TUM 4	NZ	(m.	54)				
ANGLE FROM HORIZONTAL	CAL	DIF	ECTI	ION	NA	ł	H	IAI	D. GROUND .	731.6	3		H.A.D	, COI	LAR 23/ 63			
DESCRIPTION OF CORE	Đu	100	151	CORE	DEPTH	0	FRACT	URE	ROCK DEFE	CTS BEDDING.	SEAMS, VEINS		WATER	DRILL	TESTS - Lugeons			
WEATHERING, HARDNESS, STRENGTH, COLOUR,	THER	DNEX	AD TE	LISS	HAD.	3	ISracio	n ol	SHATTER, SHEAR, A	AND CRUSH ry (attitude, w	ZONES, FOL- idth, spacing,	EPTH	Lever	LOSS	or			
ROCK OR SOIL TYPE, DEFECT SPACING.	WEA	HAR	NPa)	"/"	e siz	PHIC	natural	9 0.	amcothness)	ESCRIPT	ION)	O.D.		-70	PERMEABILITY-10 on			
LITHOLOGICAL FEATURES (bedding, faletion, mineralog	NA	TON	LINIO		Cos	GRA	S 0	cm8	(consistency, comp	actness, walk	er content.	DA	Date 1	0-100				
Isabe, center, era, ornerigine dis tent	1111	1111	1		E		Luthe		group sympter ency			TT		TITT				
SANDSTONE weak, mesh, infration	:					4.4												
blue-green grey. Fine-med-course	1111			1111	61													
send sized. CONTINUED.	1111			1111	62-	1.50								1111				
	1111			1111	12	1.								1111				
	1111		12	1111	0	• .•						11		1111				
	1111				64-	1.00												
	1111				15-							11						
	1111				0,	· · ·			6									
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FOH 71.45m			1	111			III	Ħ										
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411					- P													
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ROCK WEATHERING		R	DCK H	ARDNE	SS				FRACTURE LOG		LOGGED	nen		PROJ	ECT: 48685-00			
R HARREY SW - Slightly weathered		H - MH -	Hard Modera	tely har	d		100	2	2 sh -0 m	atural actures	DATE SO	8/0	2	HOLE	NO WAYZ			
STARTED: HW - Highly weathered		MS - S -	Modera Soft	nely sof	R				000	ractures/m	TRACED			LENG	TH. 71.45m			
28/8/02 EXPLANATION		42 -	VERY SC	n.			1=0			- vorte	CHECKED:							
30/8/02											ORIGINAL VE	RTICAL	4	COR	BOXES:			
											SCALE: /	100						

												NC).	wr	0	
PROJECT 48	8685-007-2100 EE	ATHD	ELC	GG	UFI	DRIL	LH	ULE	C	CATION CENTRA	AL PL	AIN	15 h	IA-TE	R	
CRID DEF	17 MG	ATUR	E .M/	PD S	747	763.	73 m	NZ	4	274-63.08 ME DA	TUM	LIN	2 (1	152)		
ANGLE EDOM	HODIZONTAL VERTI	CAL	DIE	FCT	ON	NA	1	Н.	A	D. GROUND 231	20-		H.A.D.	COL	LAR Z	31.20,
ANGLE FROM	OF CODE	T g	1 40	15	CORE	DEPTH		FRACTUR	RE	ROCK DEFECTS		T	WATER	DRILL	WATER	PRESSU
DESCRIPTION	OF CORE	ET S	ES:	TES	LOSS	HAD.	100	LOG		PROMINENT JOINTS, BEDDING, SHATTER, SHEAR, AND CRUSH	SEAMS, VEINS 4 ZONES, FOL	E	LEVEL	VATER	TESTS	- Lugeor
ROCK OR SOIL TYPE	F DEFECT SPACING.	ROH	NOR NO	DAD (a	LIFT	size.	₽.	Spacing	01	INTION SCHISTOSITY (attitude, v amooffiness)	width, spacing,	/DEP		0/4	PERMEAE	31LITY-10
LITHOLOGICAL FEAT	TURES (bedding, foliation, mineralogy	ME	Ĩ	NT L	-	ore .	HIN	fractures	0	(OR SOIL DESCRIPT	FION)	BUILD		-	5 ÷ .	2 §
testure, cement, etc); 5	STRATIGRAPHIC NAME	WW-	HWN	p 0	198	00	GB	in Sin	ns Ti	(consistency, compactness, wat group symbol etc.)	er content,	М	Date 1	0-100	II	111
0 - 18 (TC		TITT	TITT	1	TTT	1	~·		Π		1					
1. RAVEL		1111			1111	1	0.		11							
Sinday GRA	WEL		1111		1111				11				2-10			
SAND			1111		1111	2	0.		11	4			200			
SAMO	a + lieu				1111	7				40 D			31/5 1	111		
$0\omega - s\omega$	Brown to ung	1111		1.1	1111	1	•							111	100	
Torcesse s	and stone.	1111			1111	4-	. 0		1	-					1 1	
) one volca	with chances.	1111			1111		0						1 11			
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		111		4	1111	- 18-			+	18-DOM LARE RELOVED	18 LAMMEN	60.	+++	+++		
18-00 - 18.43m	of silt light bran	++++	++++-	+	1111		1	+++	t	sand med- Ane	quarte +					
massive.		1111			200	19-				voleanies.						
18.43- 25-81m		1111			12.22	2 70-		11 11		SILTITONE TOP 0.30m	greensh					
SILTSTONE Ve	y weak to weak, W.	1			1111	1	1			· grey of iron stain	ed,					
unfrastured, a	lark grey, silc-siled.				Ш	21-		1		SILT : SAND = 4:1						
Interbedded in	inter with -		IIII		MA	8			I	SANDSTANZ beds lar	Enhands 40					
SANDSTONE NO	and sized	1111			1111	122				to 0.4m.	Shures up					
,		1111			++++	23 -				to 0.9m					1.1	
		1111			1111											
		1111	1111		1111	24-	-								1	
					HH	25	-									
									1							1
25-81 - 27-20	J.m.				39.HA	26 -	:								Zan	14
SANNOSTONTE Vi	ay weak, UW,				2224032	1										13
infractional ,	grey, fine-course sites					64-				27.40 carbon sample	e taken					17
sand with	some gravel.				14/1	78-	0									
27.91-31.08	1 111-1				100		0			Lever dianeter	e8en,					
GRAVEL. Loos	se, clean, ow.				19	29-				mostly & Icm.	iorlesse san	6			1.1.1	-
					101	20	0			store - 5% volcan	wies				1 12	1
	ROCK WEATHERING		R	OCK H	ARDNE	ISS .		1		FRACTURE LOG	LOGGED	nen	1	PROJ	ст. 4.8	685-0
RILLER:	UW - Unweathered SW - Slightly weathered		H -	Hard Modern	no Ilely han	d		20-100		2 w -6 natural	DATE 3/	1/02		HOLE	NO. A	N3
STAPTED	MW - Moderately weathered HW - Highly weathered		MS -	Modera	stely sol	fi		1+	++	Fractures/m	TRACED			IENC	TH 70	.08~
30/8/02	CW - Completely weathered		VS -	Very so	pR			+ 11	_	2 8 22 ol core	IRAGED	********		LEING	17 1. 44 (F 111)	
FINISHED:	EXPLANATION										CHECKED:					
1/9/02											ORIGINAL VI	LAN	4	COR	BOXES:	
DRILL	1										SCALE	100				

		LOC	GOF	DRILL	HOLE	E		L	NO.		
PROJECT 4	8685-002-2100 FEAT	URE WAW	NIWA	NIWA 0	AM	LO	CATION CENTA	LAL PL	91115	LIA TO	ER
GRID REF	NZMG	CO-ORE	5747	7763.73,	N	2427	1463.08 mé D	ATUM	LINZ (MEL)
ANGLE FROM	HORIZONTAL VEATICA	14DIRE(CTION .	NA		HAD). GROUND	20 ~	H.A.I	D. CO	LLAR 231 . Zem
DESCRIPTION	OF CORE	SS 35	COR	E DEPTH	FRAC	TURE	ROCK DEFECTS	SEAMS VEINS	WATE	RORILL	TESTS - Lunance
WEATHERING, HAR	RDNESS, STRENGTH, COLOUR,	DOCK DAR	LOS	S/ H.A.D.	LO	G	HATTER, SHEAR, AND CRUS	Width, specing.	HE .	LOSS	ar
ROCK OR SOIL TYP	PE, DEFECT SPACING.	HART PART	(8d) %	aize D	T natura	al a	mothrees)		000	°/n	PERMEABILITY-10
LITHOLOGICAL FEA	ATURES (badding, foliation, mineralogy,	AN IN		Con	fractu	cme	(OR SOIL DESCRIP	ater content.	R.O	0-100	0-1 0-1 0-1 000 1000
lexiure, cement, etc);	STRATIGRAPHIC NAME	55 II220 8	11	1 E	- A -	udad.	group symbol etc.)		Date I		
GRAVEL. Loos	e, clean, UW continued.		67								
31-08-> 31.5	1.	+++++++	- ITT	31 - 10							E
GRAVEL as a	shore + coarse send +		= HT								E.
trace sill	T. Pim	11/11/1	100	P ²].	-						37.52
31.51 -5 51.0	very werk SW infractived	ИШШ	190050	33							
acertic bo	wa- encersh grey,		T	Π. 🗄	0				1 24		
med sand	sized A		III	183.			34				
31.80-37.9	Zm		10052	35-1							3
Mix /inter be	dded				8		1				177
GRAVEL	+ SANDSTOLE CHE any		III	186 1.0	·						
				37-1-	0					1111	1
			111-							1111	28
37.91-70.0	8m (EOH)		7170	32-			Green : glancerit	3			
SANOSTENE	weak, UN, unFractored,				31		SILTSTONE bands	e 3 cm wide			
greensh gr	very sand sized.					111.	every NO.IM-	0.50		1111	
1	<i>v</i>		2017300	₩ 4 0		111	Oip ~ 20° approx.				
1				A	8	111					
			Ш	111:							
			111	42		111				1111	
1			111			111				1111	
1			HT	143	3	111				1111	
1			HAN YO	44		111				1111	
										1111	
			1111	45 - F	2	111				1111	
0.00				46 -		111	white sand lens	es 60.5cm		1111	
			1111	1.		111	dianeter. Bistur	bation :			
				47-3-		111					
				48-1.3	2	111				1111	
	12 12		-			111		- 50		1111	
			·	19-9 - 1		1111	samosrante only, a	= \$14T.			
			1111	50		111	e.				
Í			HH		4	111	5			1111	
			1111	2		111				1111	
			Ш	52-1:		111				1111	
				- min	2	111				11111	
			1111	22 - 24	•						
			HT	54 - 67	2	111					
						111					
			HH	5-		111					
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			111		-	111		- SA		11111	
				57-							
			htt	· ·							
			1111	5-1-				÷			
				- E -							
0000	ROCK WEATHERING	ROCK	HARDNE	SS		F	RACTURE LOG	LOGGED /24	64	PROF	CT: 48685-002
R HARZEY	SW - Slightly weathered	H - Hard MH - Mode	rately hard	8	100	8 1	Spacing of natural	DATE 3/9	102	HOLE	NO LIN 3
STARTED:	HW - Highly weathered	MS - Mode S - Soft	erately soft			+++	Fractures/m	TRACED		LENGT	H 70.08m
30/8/02	CW - Completely weathered	VS - Very	soft		- 0	N	= & xx of core	CHECKED			
FINISHED:	EAFLANATION .							ORIGINAL VED	TICAL-	COPE	BOXES
1/1/02	8							PONE /:/	'00	1 Source	

-					~~	05	0.01							NO		WN	5				
	PROJECT 4	8685 - 002 - 2100 FE	ATUR	E	OG	UF	URIL	LH	OLE	LC	DCATION	CENTRA	AL ALAIN	VS	1A.	ATER					
	GRID REF	NZMG	(20-0	RD.	574	1763-7	3 -	v :	24	27463.08	n€ D	ATUM	1.12	CM	54]					
	ANGLE FROM	HORIZONTAL	car	DIF	RECT	ION .	NA	1		H.A.	D. GROUN	ND	81.20 m		H.A.E). CO	11/	R?	31-3	2000	
	DESCRIPTION	N OF CORE	SING	50	EST	COR	E DEPTH	Ø	FRACT	URE	ROCK D	EFECTS	G. SEAMS, VEINS		WATE	DRILL	W	ATER	PRES	SURE	
	WEATHERING, HA	RDNESS, STRENGTH, COLOUR.	THEF	Noo King	NO TI	LIFT	S/ HAD.	3	Spacin	a of	SHATTER, SHE IATION SCHIST	EAR, AND CRU TOSITY (anitude	SH ZONES, FOL- width, spacing,	EPTH	LEVEL	LOSS	1	cara	or	peoro	
1	ROCK OR SOL TY	PE, DEFECT SPACING. ATURES therefore initiation mineralism	WEA	HAR	TLO	*/.	re siz	UH4	fractor	esi	(OR SOIL	DESCRI	PTION)	TE/DI		1 %	PEF	MEAE	BILITY-	-10°cm	
	testure, cement, etc)	STRATIGRAPHIC NAME	NW HW	TAN	POBN	in Di	66 G	GRA	92 93	cms n	(consistency, proup symbol	compaciness, v	reter content,	DA B	Date t	0-100	0		2	1 100	
	SANASTONIE L	reak UW infractured.	iiii	TTT	1	TT	1 3	·. ·						TT		TIT	T	1	1	11	
	greenish gr	ey sand sized					61 -									1111	1.00				
			1111			П		• •								1111	1				
	62.00 - 68	00m) Anck area					62-				hickor	Concert	ration of			1111	-10	1		11	
	SANOSTONE	(as aloose) our of all				IT	63-	4			danco	nite	v			1111	100	·			
			1111		1		40	1			0					1111					
						H						1		11		1111					
			1111				65-	1.51									42.00				
						H	66	1								1111				1000	
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Ê.							TITLE														
							min														
1		ROCK WEATHERING	Щ	RO	CK HA	RDNES	E S	_		11	RACTURE LO	DG .	LODGER AN	BM		ш	1	48.65	5-1	:	
D	RILLER:	UW - Unweathered SW - Slightly weathered		H - H	ery hard	1			000	1	(cms) 2 m _51	Spacing of natural	LOGGED 3/9	102		PROJE	UT:	61	V3		
10	TAPTED	MW - Moderately weathered		MS - M	oderate loderate	ely soft			H	++		Iractures	DATE	Laurent		HULE	INC:	70.	08		
110	10 /8/02	CW - Completely weathered		VS - V	ery soft				- 11	_	2 8 20	of core	TRACED			LENGT	Ht	Carringan			
F	NISHED:	EXPLANATION .											ORIGINAL VERT	10.01	**********	COPE	BOY	ES.			
	1.1.9.102												CHURCH VERI	ALC: N		OUNE	200			enneen	

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WN 1 0 to 8.20 m



WN 1 8.20 to 16.82



WN 1 16.82 to 25.37



WN 1 25.87 to 34.45



WN 1 34.45 to 43.10



WN 1 43.10 to 53.34



WN 1 53.34 to 62.35



WN 1 62.35 to 71.35



WN2 0 to 8.65 m



WN2 8.65 to 20.80



WN2 20.80 to 29.55



WN2 29.55 to 39.18



WN2 39.18 to 47.70



WN2 56.10 to 64.35



WN2 64.35 to 71.45



WN3 18.00 to 28.16



WN3 28.16 to 40.22



WN3 40.22 to 49.45



WN3 49.45 to 58.03



WN3 58.03 to 67.00



WN3 67.00 to 70.08