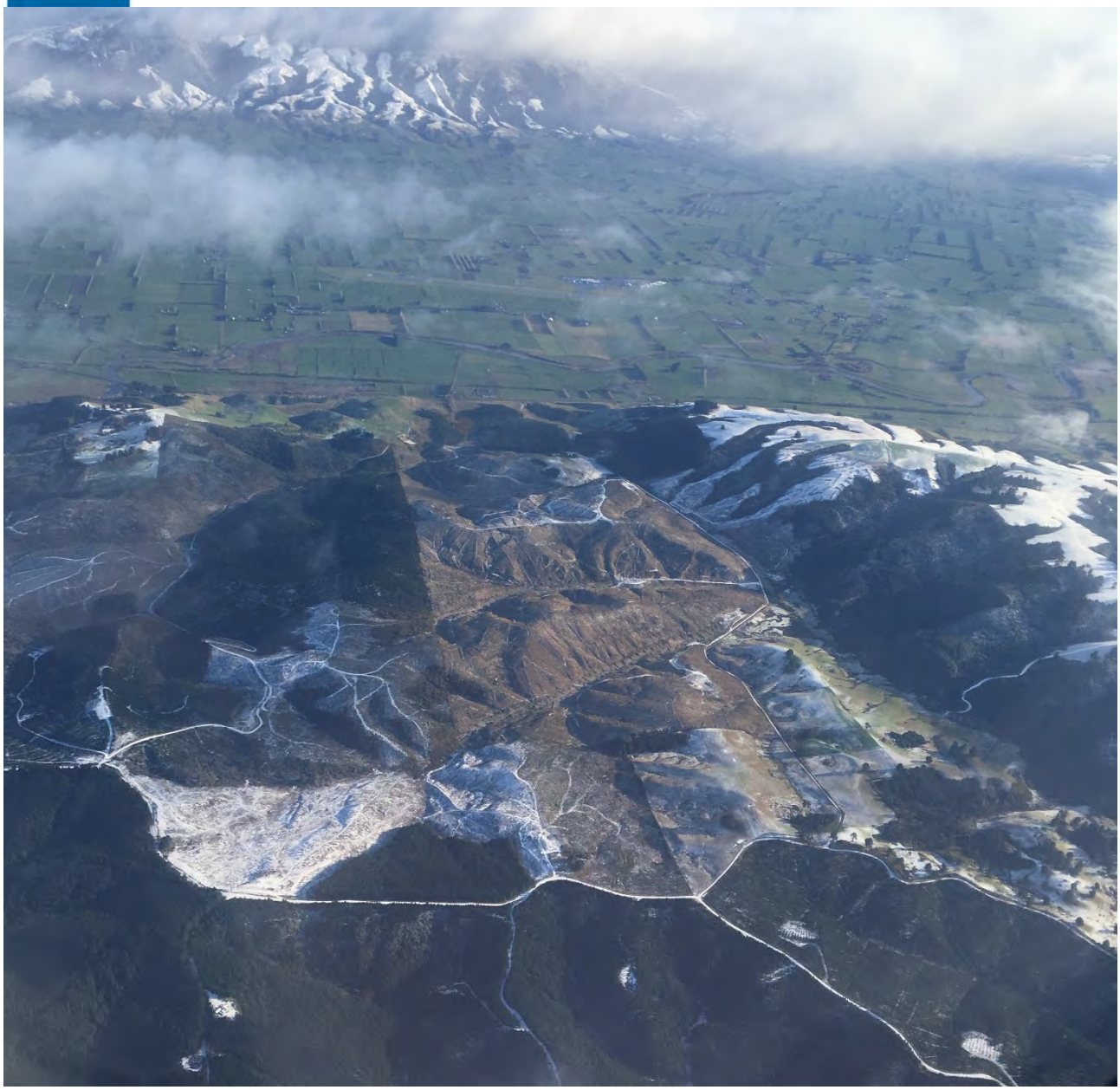
Appendix 8: Groundwater Report



Dunedin City Council

Waste Futures - Smooth Hill Landfill
Assessment of Effects to Groundwater

DUNEDIN CITY COUNCIL | kaunihera a-rohe o Ōtepoti

August 2020

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1. Introduction

1.1 Project Background

The Dunedin City Council (Council) collects residential waste and manages the disposal of both residential and the majority of commercial waste for the Dunedin City area, and environs. The Council has embarked on the Waste Futures Project to develop an improved comprehensive waste management and diverted material system for Dunedin, including future kerbside collection and waste disposal options. As part of the project, the Council has confirmed the need to develop a new landfill to replace the Council's current Green Island Landfill which is likely to come to the end of its functional life sometime between 2023 and 2028.

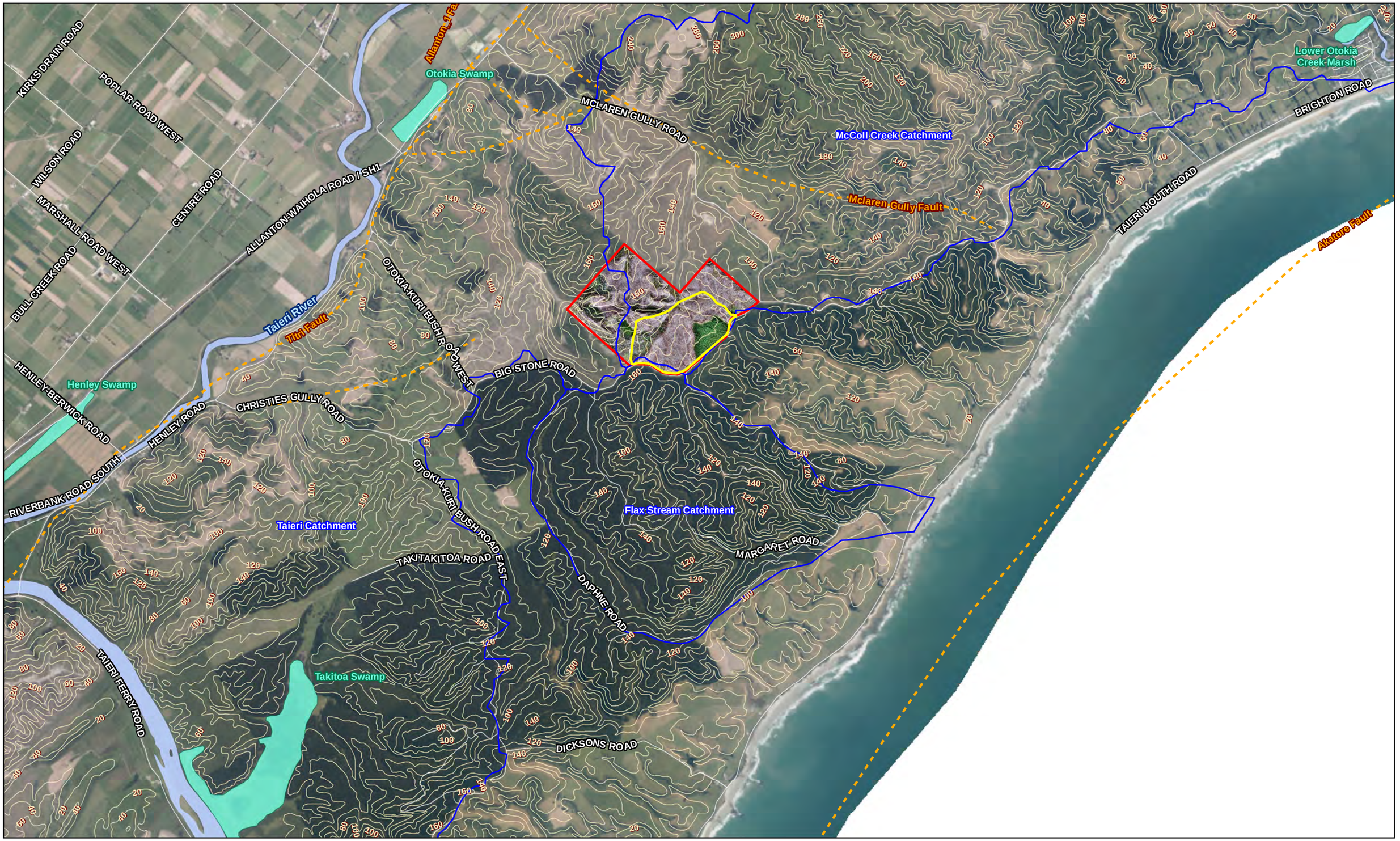
The Council commenced a search for a new landfill location in the late 1980's and early 1990 and selected the Smooth Hill site in south west Dunedin, shown in Figure 1 below, as the preferred option. At that time the site was designated in the Dunedin District Plan, signalling and enabling its future use as a landfill site. The Council also secured an agreement with the current landowner, Fulton Hogan Ltd, to purchase the land.

Over the following period the Council extended the life of Green Island Landfill and further development of the Smooth Hill site has been on hold.

As part of the Waste Future's Project, the Council has reconfirmed the technical suitability of Smooth Hill for the disposal of waste, and has developed a concept design for the landfill and associated road upgrades. The concept design for the landfill has been developed by GHD with technical input from Boffa Miskell, and represents contemporary good practice landfill design that meets adopted New Zealand landfill design standards. The Council is now applying for the remaining RMA authorisations required to enable the construction, operation, and aftercare of the landfill, and construction of the associated roading upgrades.

The proposal includes the following key components:

- The staged construction, operation, and closure of a class 1 landfill within the existing designated site to accept municipal solid waste. The landfill will have a capacity of approximately 6 million cubic metres(equivalent to approximately 5 million tonnes), and expected life at current Dunedin disposal rates of approximately 55 years. The landfill will receive waste only from commercial waste companies or bulk loads.
- Infrastructure to safely contain, collect, manage, and dispose of leachate, landfill gas, groundwater, and stormwater so as to avoid consequential adverse effects on the receiving environment.
- Facilities supporting the operation of the landfill, including staff and maintenance facilities.
- Environmental monitoring systems.
- Landscape and ecological mitigation, including planting.
- Upgrades to McLaren Gully Road (including its intersection with State Highway 1) and Big Stone Road, to facilitate vehicle access to the site.
- The proposed Smooth Hill Landfill site is located approximately 28 km southwest of Dunedin City. The boundary of the proposed site is shown in Figure 1. The waste facility itself will operate within these boundaries.



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

LEGEND

- Site boundary
- Landfill operational extent
- Regional catchment boundary
- Significant wetlands
- Major waterways
- Fault
- Contours (20m)

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Smooth Hill

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Smooth Hill Site Location

Figure 1

N:\NZ\Christchurch\Projects\51\12506381\GIS\Maps\Deliverables\Hydro\12506381_Z001_Hydro_SiteLocation.mxd

Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand **T** 64 3 378 0900 **F** 64 3 378 8001 **E** chcmail@ghd.com **W** www.ghd.com

Data source: Aerial imagery - Stantec, LINZ & esri (Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence); General topo - LINZ 2019; Regional catchments and significant wetlands - ORC 2019; Faults - GNS. Created by:jrprice

1.2 Purpose of this Report

The proposed Smooth Hill Landfill requires resource consents from Otago Regional Council for:

- The taking and diversion of surface water for land drainage of the site, and discharge of stormwater and contaminants to the Otokia Creek (McColl Creek catchment), and Open Stream (Flax Stream catchment).
- Taking of groundwater from the landfill groundwater collection system, and use for non-potable water supply.
- The taking of groundwater and leachate from landfill leachate collection system.
- Discharge of leachate onto land that may result in contaminants entering groundwater.

This report provides technical assessment of the potential effects on groundwater and connected surface water flows, and the effects of leachate leakage on groundwater quality. It is provided to Otago Regional Council as a supporting document to the application for resource consents for the purpose of assisting Council in decision-making.

Note the potential effects of site stormwater on downstream surface water flows and quality are discussed in the Surface Water Report (GHD 2020) and referenced in this report.

1.3 Scope of Assessment

GHD carried out site investigation work at the site between May and November 2019. These works provided information to refine the understanding of geological and hydrogeological conditions in the vicinity of the proposed landfill. The information obtained from the site investigation was also used to carry out an assessment of potential impacts to groundwater and surface water, associated with construction, operation, and aftercare of the proposed landfill at Smooth Hill, Dunedin.

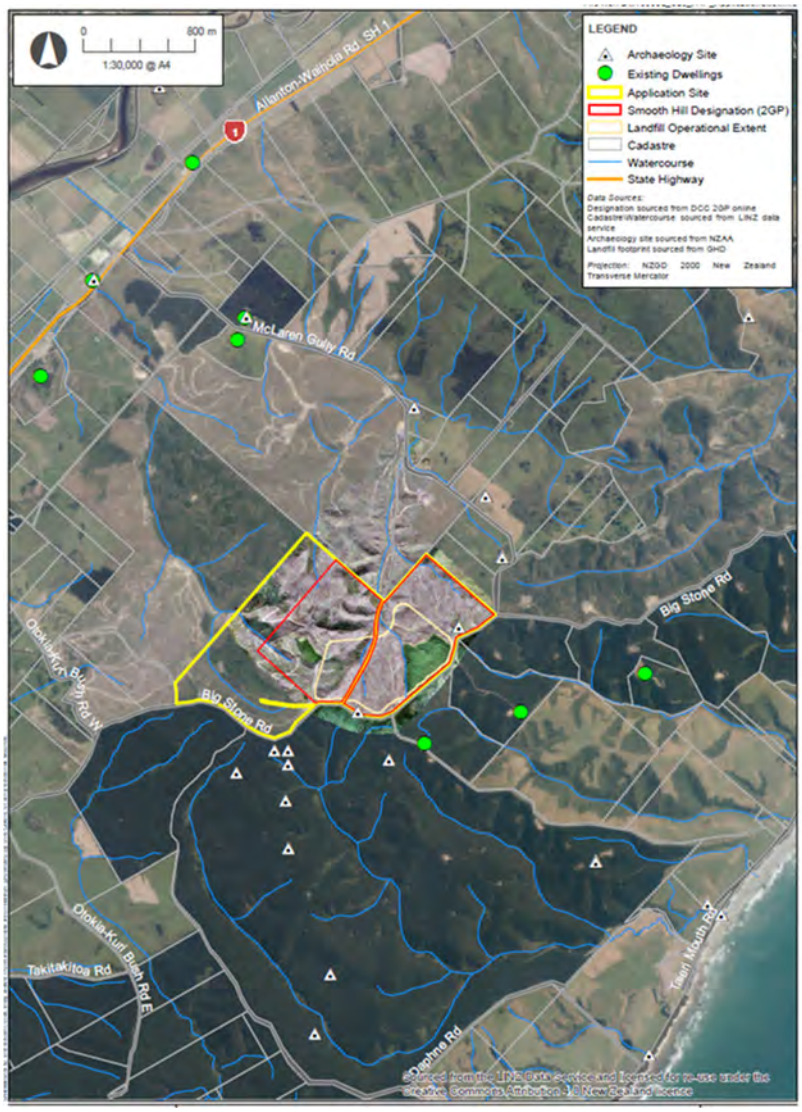
This report outlines the investigation that has been carried out and its findings, and provides an assessment of the potential influences of the proposed landfill on groundwater and surface water levels, flow and quality.

2. Environmental Setting

2.1 Site Description

The proposed Smooth Hill landfill site is bordered by Big Stone Road along its southern boundary. Access from State Highway 1 (SH1) is typically via McLaren Gully Road. The site is bounded to the north and west by forestry land and to the northeast by pastoral farmland (Figure 2).

Figure 2: Site Layout



The proposed site is located within the range of hills that bounds the Taieri Basin on its eastern extent and separate it from the coast. The site extends across two gullies trending approximately south to north, which are connected to smaller gullies from the east and west. The slopes around the southern half of the site form a natural “amphitheatre” shape, which is bisected by a larger central ridge and a smaller ridge in the south western corner – both trending approximately south to north.

The majority of the site was until recently covered by a Radiata Pine plantation, which following harvesting now comprises a mixture of scrub, bare earth and forestry waste, and newly planted

pine seedlings. Approximately 8 ha of Macrocarpa plantation remains in the south eastern section of the site, and areas of remnant native vegetation are present in the bottom of the valleys. A number of existing forestry tracks provide access around the site.

Most of the site and the upper reaches of the gullies are generally dry with ephemeral stream flows during periods of rainfall. Towards the base of the gullies in the northern parts of the site the ground is typically wet and boggy where standing or flowing water has been observed associated with diffuse seepage.

2.2 Geology

A review of the available geological maps (Bishop [1994], and Bishop and Turnbull [1996]) covering the site shows that the main lithology is the Henley Breccia unit (Figure 3). The basement rock in the proposed site area is expected to be Caples Terrane schist (map symbol *IIIA*). The schist basement is overlain unconformably by the Upper Cretaceous Henley Breccia (map symbol *he*), which comprises a terrestrial sequence of piedmont breccias and conglomerates up to 1000 m thick. Taratu Formation (map symbol *ta*) is mapped as outcropping along the tops of several ridgelines to the south and east of the site. Taratu Formation unconformably overlies the Henley Breccia.

The Titri Fault is located approximately 3 km north west of the site, which strikes in a north east south west direction. This fault separates the elevated topography in the vicinity of the site from the Lower Taieri Basin, a tectonic depression resting between two major faults, which has been infilled with approximately 300 m of Tertiary and Quaternary alluvial deposits (Rekker and Houlbrooke, 2010) (Figure 1).

Although not shown on the geological map, the Henley Breccia unit is overlain by several metres of loess deposits, and locally by alluvium and colluvium (slip debris). A description of loess soils in Otago is provided in Bishop & Turnbull (1996): *"In the Dunedin map area, such unmapped surficial materials are dominated by loess which, where remobilised, grades into loess colluvium… Loess forms a widespread blanket across most of eastern Otago, particularly near the coast... Loess typically forms a yellow-brown, massive layer or series of layers, mixed at the base with weathered bedrock and overlain by darker organic-rich soil. Columnar jointing and shrinkage cracks are common. Where loess mantles slopes, down-slope creep and alluvial processes have incorporated clasts of weathered underlying material, upslope material, and organic matter to form 'loess colluvium'."*

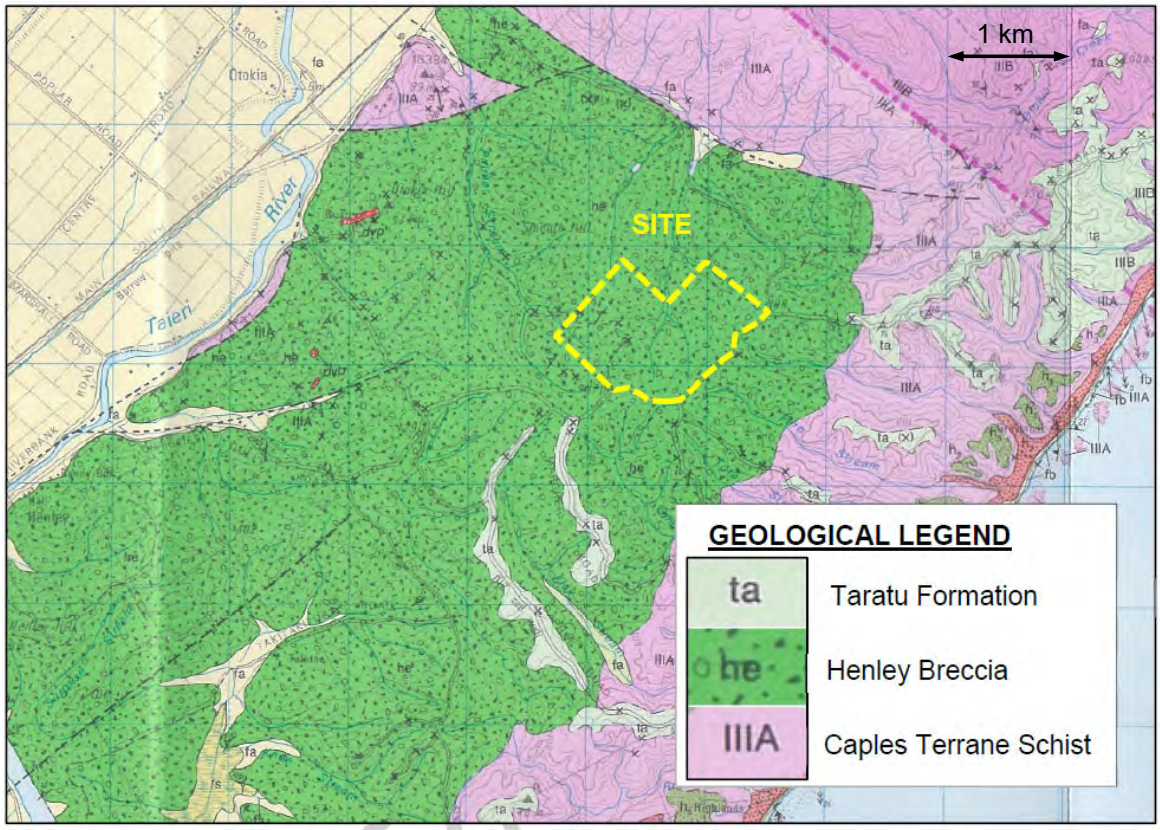


Figure 3: Excerpt from 1:50,000 Geology of the Milton Area (Bishop, 1994)

2.3 Hydrogeology and Hydrology

Otago Regional Council (ORC) designate water allocation regions by surface water catchment and/or aquifer. Due to the limited groundwater resource at the location of the Smooth Hill site, the proposed landfill footprint forms part of the “McColl Creek” surface water allocation catchment (Figure 1 and Figure 4) rather than a defined aquifer system. The catchment has an available allocation of 0.93 L/s and has no recorded active consents (including surface water or groundwater takes) (ORC, 2019). Bounded by Big Stone Road to the south east and by the elevated ridge on the north west, the catchment is approximately 2700 hectares (ha) in area. McColl Creek discharges to the Pacific Ocean at Brighton, with Otokia Creek comprising the main tributary. The proposed Smooth Hill Landfill footprint is located within the upper reaches of the Otokia Creek (Figure 1 and Figure 4). The catchment area for the Otokia Creek at the site is approximately 69 ha, which encompasses the catchments of the two first order streams whose confluence is located approximately 100 m south of where the stream crosses the northern site boundary (Figure 1 and Figure 4).

While almost all of the landfill footprint and related structures/activities will be located within the Otokia Catchment, a small area (approximately 9,000 m^2) of landfill embankment on the southern edge of the landfill is part of the Open Stream surface water catchment located to the south of the site (see Drawing 51-12506381-C303). The Open Stream catchment forms part of the “Flax Stream” surface water allocation catchment (Figure 1 and Figure 4) which is approximately 612 ha in area, and discharges to the Pacific Ocean south east of the Site. The Flax Stream surface water catchment has an available allocation of 0.22 L/s and has no recorded active consents (including surface water or groundwater takes) (ORC, 2019). The embankment proposed to be constructed within the Open Stream catchment will comprise clean engineered fill. Waste is not proposed to be placed in this area.

The catchment of the deep groundwater system is not considered to be constrained to the topographically defined surface water catchments. Instead, the deep groundwater system likely

forms part of a larger, currently undefined, unit within the Henley Breccia in the elevated coastal range between the Taieri Basin and the coast.

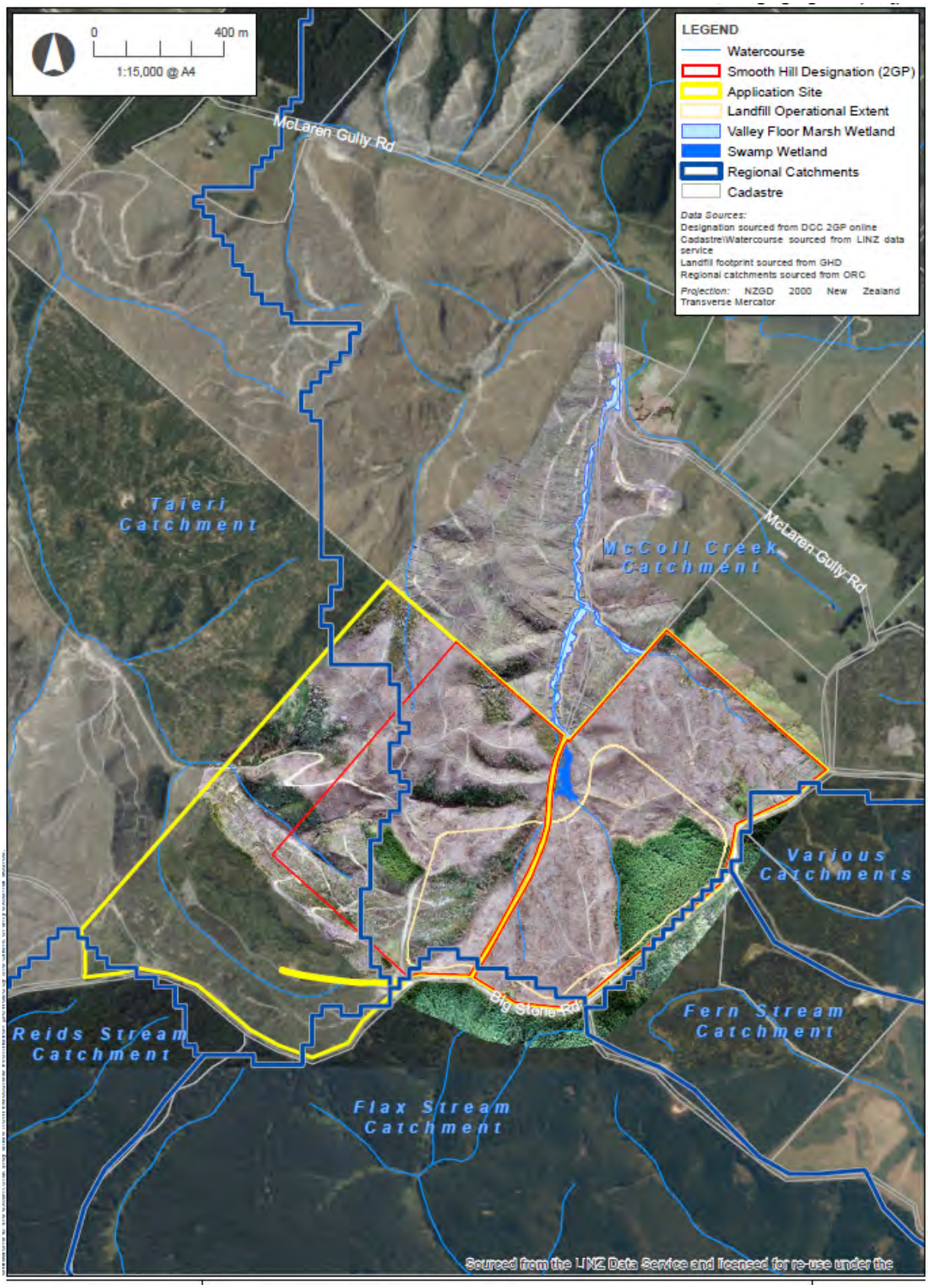
The nearest allocation catchment designated for groundwater is the Taieri Catchment, located in the Taieri Basin west of the Titri Fault. This aquifer comprises Quaternary and Tertiary alluvium deposits (ORC, 2019). The closest active groundwater consent is approximately 5.7 km from the site in the Taieri Catchment, at the Dunedin International Airport (Figure 5). This groundwater take is for operation of a ground source heat pump (Consent number RM11.369.01). The Taieri Basin itself is predominantly recharged from three rivers, the Taieri, Silver Stream and Waipori (Rekker and Houlbrouke, 2010). The Henley Breccia was not included in the Otago Regional Council Lower Taieri Basin groundwater allocation study (Rekker and Houlbrouke, 2010) as the impermeable basement rock was not considered to have the potential for significant hydraulic connection.

Excluding the Otokia Creek, the nearest surface water features to the proposed landfill extent include the Palmer Stream, whose catchment is immediately west of the site and part of the Taieri Catchment, the Taieri River approximately 3.4 km northwest of the site, and the Pacific Ocean approximately 3 km south east of the site.

There are two regionally significant wetlands within the vicinity of the site designated on the ORC mapping tool (2019); Otokia Swamp, located approximately 3.4 km north west of the site adjacent to the Taieri River, and Lower Otokia Creek Marsh, adjacent to McColl Creek approximately 7.6 km north east of the site at Brighton (Figure 1).

Rainfall varies across the region. Annual average rainfall (measured over the period 1981 – 2010) is 652 mm at Dunedin International Airport, approximately 6 km north west of the site, 738 mm at Musselburgh, Dunedin, approximately 23 km north east of the site, and 968 mm at the Botanical Gardens, Dunedin, approximately 25 km north east of the site (NIWA, 2015). It is likely that rainfall at the Smooth Hill site will be greater than the rainfall recorded at the airport due to its elevated coastal location. Mean potential evapotranspiration is 856 mm/year at Musselburgh, Dunedin (1981 – 2010), calculated using the Penman method (NIWA, 2015) with this considered indicative of conditions at the site.

Figure 4 - Surface Water Catchments



Paper Size A3

0 0.5 1 2

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

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LEGEND

- Site boundary
- Regional catchment boundary
- Registered bores
- Groundwater Take Permit - Current

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Bores and Consents

Figure 5

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Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand **T** 64 3 378 0900 **F** 64 3 378 8001 **E** chcmail@ghd.com **W** www.ghd.com

Data source: Aerial imagery - Stantec, LINZ & esri (Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community); General topo - LINZ 2019; Regional catchments, significant wetlands, wells and consents - ORC 2019. Created by:jrprice

3. Investigation Findings and Interpretation

3.1 Investigation Findings

Two phases of site investigation were undertaken in 2019, with ten boreholes and eleven test pits advanced between May and June, and an additional five boreholes and 15 bulk samples collected from a number of shallow test pits between October and November 2019. Thirteen of the boreholes were installed as monitoring wells, with ten of these comprising nested piezometers. A number of shear vane tests were undertaken in the test pits and samples were collected for geotechnical laboratory analysis. A full summary of the site investigation works is provided in the GHD Geotechnical Factual Report (GHD, 2020a).

Following development, hydraulic conductivity testing was undertaken in all monitoring wells. Due to low groundwater recharge rates and associated issues with collecting representative samples, groundwater quality sampling was only undertaken in a few select monitoring wells. Groundwater levels were monitored in all piezometers which had encountered groundwater for a period of 16 days. A summary of the hydrogeological field work undertaken is presented in Appendix A. Bore logs are presented in Appendix B. The boreholes installed as piezometers, and an existing monitoring well at the site, that were used for hydrogeological site investigation are presented in Figure 6.

3.2 Geology

A detailed description of the geological investigations undertaken at the site and the interpreted findings are presented in the GHD geotechnical reports (GHD, 2020a; 2020b).

The site investigation findings confirmed the presence of Henley Breccia overlain by surficial loess across the majority of the site and by Taratu formation along elevated ridgelines (Section 2.2). The Henley Breccia is comprised of Upper Cretaceous terrestrial materials deposited during periods of uplift and erosion of a schist block west of the Titri Fault, caused by movement of the associated fault zone. In more recent times this fault has reversed with uplift of the Henley Breccia, resulting in the present coastal range.

Conceptual geological cross sections from approximately south to north and west to east across the proposed landfill site are presented in Figure 7 and Figure 8, respectively (note that these sections exclude top soil and fill materials). The cross section locations are shown in plan view in Figure 6.

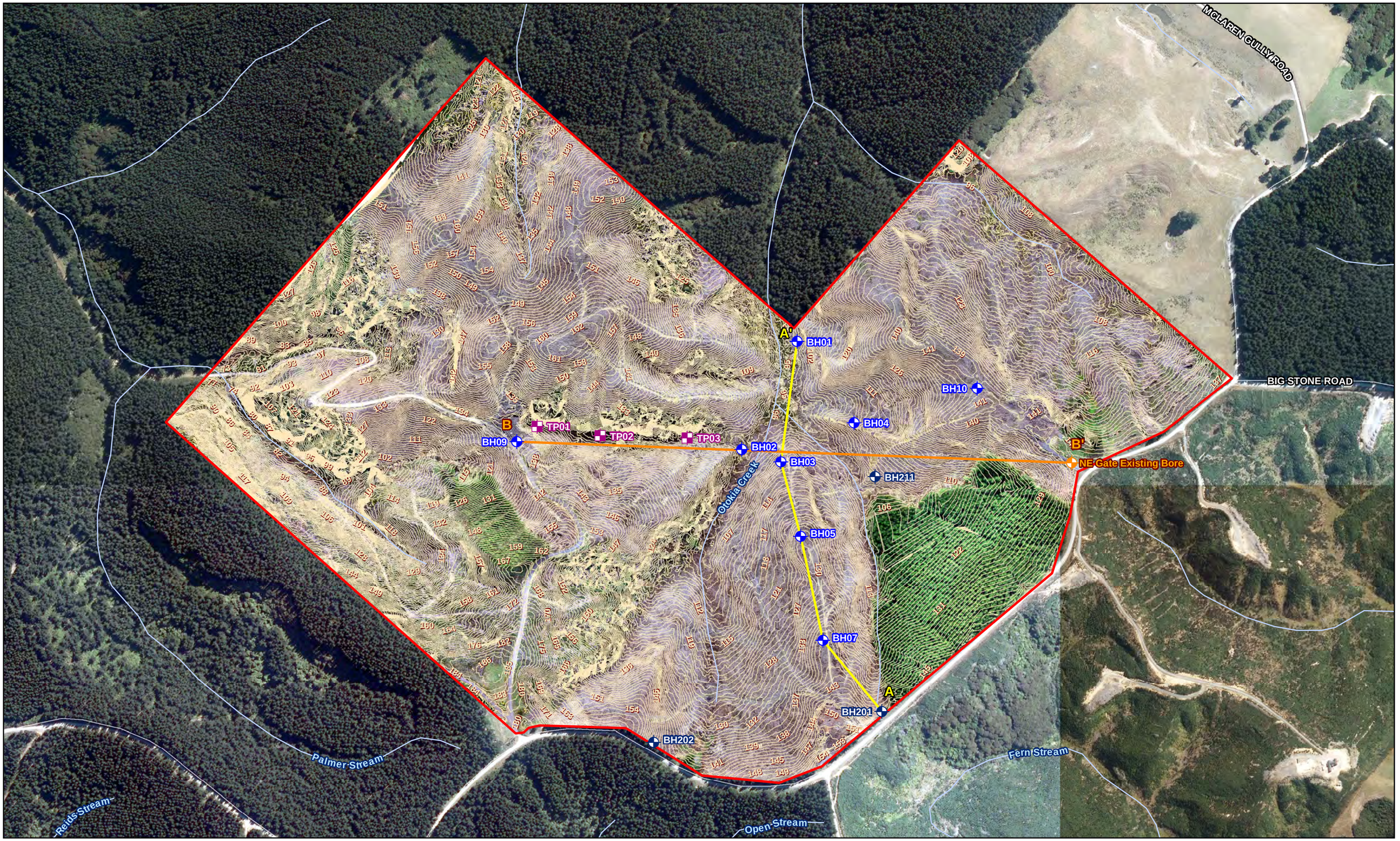
In summary, a thin veneer of top soil was found across the majority of the site, comprising silt with trace to minor clay, and occasional trace to minor fine sand, roots and organic matter. The topsoil is predominantly underlain by loess soils on the ridges and upper sections of the valleys. The loess generally comprised silt, non-plastic to low plasticity, with varying amounts of clay, sand and fine gravel. The loess has largely been eroded away in the valley bottoms, with colluvium and alluvium deposits instead located in these topographical low points (Figure 9). The colluvium is made up of reworked loess with gravel and organics, with the silt, sand and gravel alluvium derived from the easily remobilised loess and weathered Henley Breccia.

The underlying Henley Breccia, was been encountered as sandstone, siltstone, conglomerate and breccia. Completely weathered to highly weathered Henley Breccia is evident at shallow depths, however with increasing depth it was recorded as unweathered to slightly weathered breccia with few defects. Taratu Formation, comprising weakly cemented, slightly to highly

weathered sandstone, siltstone and conglomerate, was encountered overlying the Henley Breccia investigation locations on elevated ridge locations (BH09, BH10, BH203 and BH209).

Fill material was identified at the surface at a number of site locations, where it is typically utilised for ‘skidder pads’ and track formation associated with the recent forestry land use. Shallow slip debris (colluvium) was also located at the surface intermittently around the site. In these locations buried top soil was encountered, to a maximum depth of 4.4 m below ground level (bgl), beneath the slip debris, and overlying alluvium or loess.

A distinctive reddish brown and brown siltstone layer, possibly a historic lake deposit, was also recorded intermittently across the site in a number of bores within the Henley Breccia, at elevations between approximately 95 m RL and 103 m RL (BH03, BH04 BH05 and BH211). A reddish brown layer was also observed during wash drilling of BH201, however no approximate depth for this layer was recorded. The elevation of the siltstone layer indicates that it is likely to have been eroded away at BH01 and BH02, and is therefore not anticipated to be consistent across the whole site.



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Metres

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Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

LEGEND

- Site boundary
- Cross section A-A'
- Cross section B-B'
- Phase 1 investigation groundwater monitoring well
- Phase 1 investigation test pit
- Phase 2 investigation groundwater monitoring well
- Unknown previous investigation groundwater monitoring well
- Waterways
- Contours (1m)

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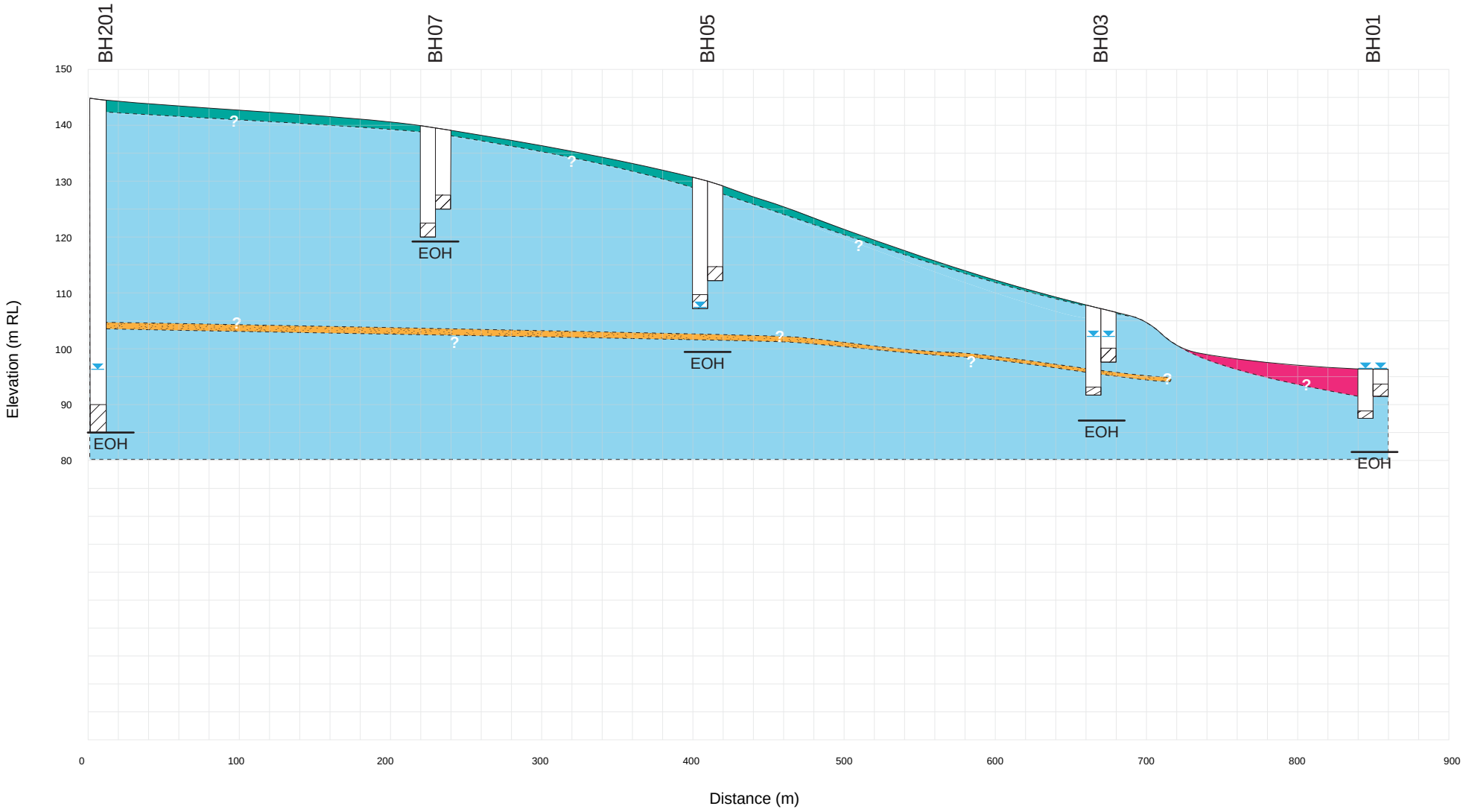
Investigation Location Plan

Figure 6

N:\NZ\Christchurch\Projects\51\12506381\GIS\Maps\Deliverables\Hydro\12506381_Z003_Hydro_InvestigationLocations.mxd

Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand **T** 64 3 378 0900 **F** 64 3 378 8001 **E** chcmail@ghd.com **W** www.ghd.com

Data source: Aerial imagery - Stantec, LINZ & esri (); General topo - LINZ 2019; Contours - Stantec Created by:jrprice



DRAWING NOT TO SCALE

LEGEND

- Loess
- Alluvium / Colluvium
- Siltstone (Henley Breccia)
- Henley Breccia
- Groundwater Level
- Borehole
- Piezometer Screen

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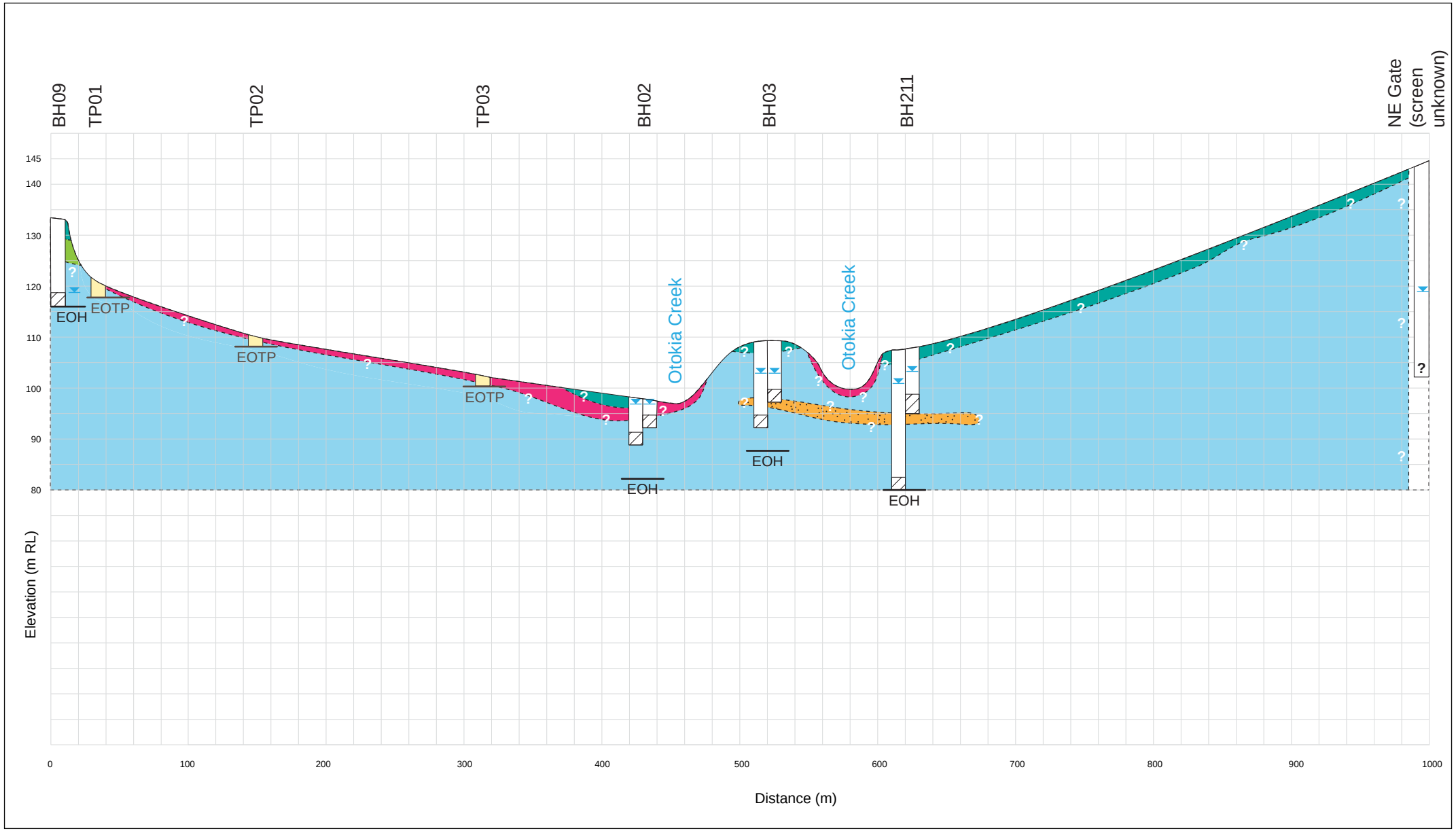
Cross Section A-A'

Figure 7

Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand **T** 64 3 378 0900 **F** 64 3 378 8001 **E** chcmail@ghd.com **W** www.ghd.com

Data source: GHD. Created by:jrprice



DRAWING NOT TO SCALE

LEGEND

- Loess
- Alluvium / Colluvium
- Siltstone (Henley Breccia)
- Taratu Formation
- Henley Breccia
- Borehole
- Piezometer Screen
- Groundwater Level
- Test Pit

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Cross Section B-B'

Figure 8

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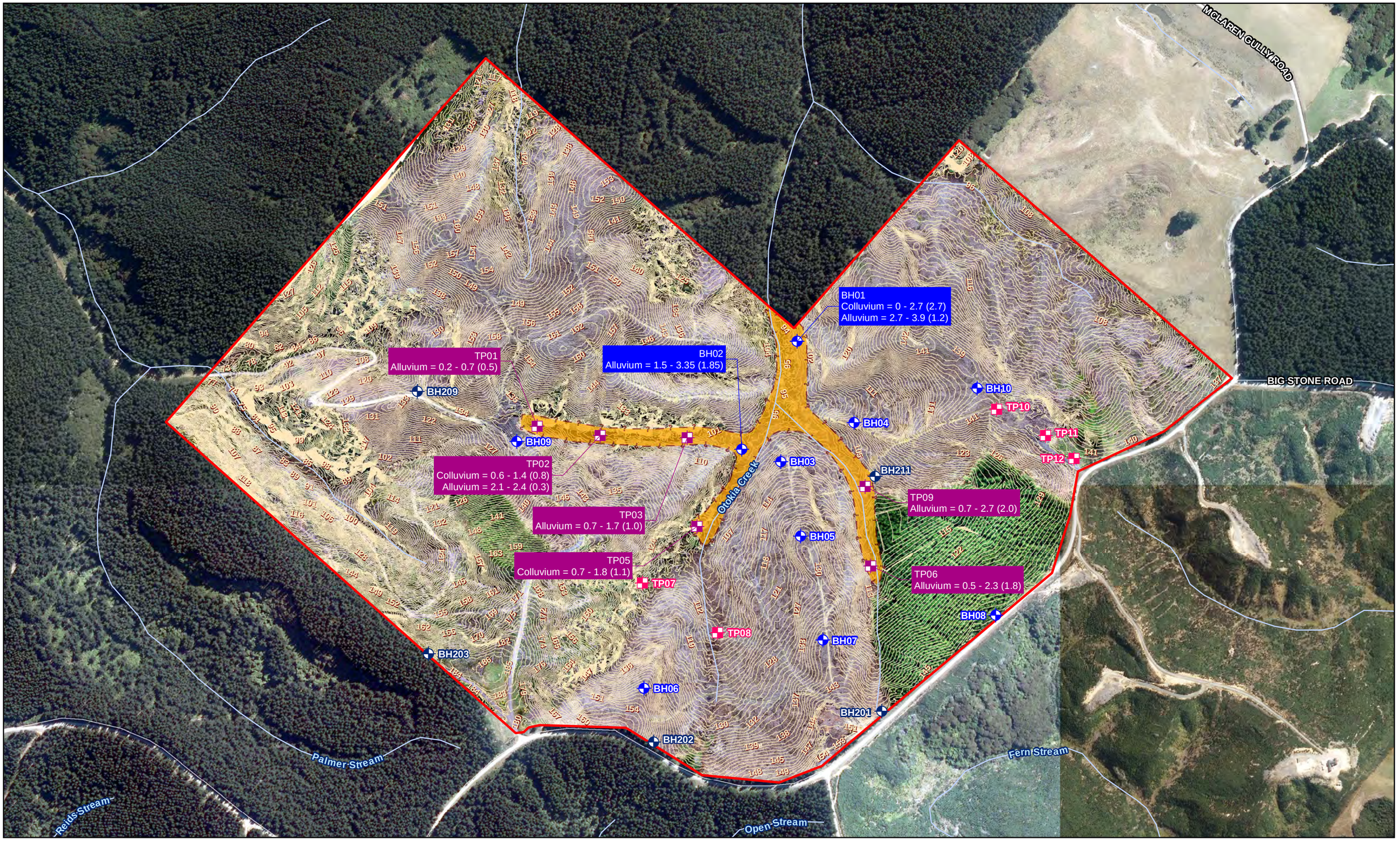
Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand **T** 64 3 378 0900 **F** 64 3 378 8001 **E** chcmail@ghd.com **W** www.ghd.com

Data source: GHD. Created by:jrprice



Paper Size A3

0 50 100 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

LEGEND

- Site boundary
- Phase 1 investigation borehole
- Phase 1 investigation test pit
- Phase 1 trial pit investigation
- Phase 2 investigation borehole
- Inferred colluvium / alluvium extent
- Waterways
- Contours (1m)

Depth recorded (mbgl)

Colluvium/Alluvium = 0.5 - 1.0 (0.5)

Thickness (m)

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Colluvium / Alluvium Extent

Figure 9

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Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand **T** 64 3 378 0900 **F** 64 3 378 8001 **E** chcmail@ghd.com **W** www.ghd.com

Data source: Aerial imagery - Stantec, LINZ & esri (); General topo - LINZ 2019; Contours - Stantec Created by:jrprice

3.3 Hydrogeology

3.3.1 Hydraulic Conductivity

Hydraulic conductivity estimates of the differing geological units at the site, determined from hydraulic testing during the site investigation (Appendix A) are presented in Table 1.

Table 1: Estimated Geological Unit Hydraulic Conductivity Ranges

Geological Unit	Hydraulic Conductivity Range (m/s)	Reference/Justification
Alluvium	1.3×10^{-5}	BH01a Permeability testing
Loess	$5.3 \times 10^{-10} – 3.2 \times 10^{-8}$	Constant head permeability test in a triaxial cell (Laboratory testing (GHD, 2020a))
Henley Breccia	$3 \times 10^{-9} – 3 \times 10^{-6}$	Permeability testing

Testing has suggested a large range of hydraulic conductivity for the Henley Breccia, with a general trend of decreasing hydraulic conductivity with increasing depth evident. Higher permeability results were generally recorded in gravelly or sandstone layers, likely to be the result of weathering and relaxation in the upper materials resulting in greater jointing and fracturing (increased secondary porosity). Lower permeability results were generally recorded in the unweathered breccia (Table A 3 in Appendix A).

3.3.2 Hydraulic Gradients, Groundwater Recharge and Flow

Hydraulic Gradients

As displayed on Figure 7 and Figure 8, the highest static groundwater levels at the site were recorded in the existing piezometer (NE Gate) (118.93 m RL), BH09 (119.46 m RL) and BH10 (120.32 m RL) on the elevated ridges (ground level 133 – 145 m RL) in the eastern and western extents of the site (Figure 6). These bores are screened at elevations between 119 m RL and 103 m RL. BH201, although located at similar ground elevation (144 m RL) to the NE Gate bore (145 m RL), is screened at a lower elevation of 90 m RL. The groundwater level recorded within BH201 was 97.5 m RL in November 2019, with the apparent differences in groundwater elevation between wells indicating that downward vertical hydraulic gradients are present within the Henley Breccia. This is consistent with the topographical setting, where slow percolation to a deep groundwater system is expected in areas elevated above the broader regional setting.

Minor downward vertical gradients are evident within nested monitoring wells installed in the shallow Henley Breccia at the bottom of the valley (BH02 and BH03), however groundwater levels in the alluvium at BH01A and Henley Breccia at BH01B are very similar to one another and are recorded at ground level, potentially under slightly artesian conditions (Table 2). Nested bores BH04A and BH04B, and BH211A and BH211B record greater downward vertical hydraulic gradients (Table 2), with the brown siltstone layer identified in this area separating the nested piezometer screens in BH03, BH04 and BH211.

The brown siltstone layer, and decreasing permeability of Henley Breccia with depth, is interpreted as retarding percolation of groundwater. This has resulted in the formation of a localised shallow groundwater system within the alluvium (BH01A, and evidenced in the moist to saturated conditions in many of the test pits included on Figure 9 (Appendix B) and the surrounding shallow Henley Breccia above the brown siltstone layer (BH02A, BH02B, BH03A, BH04A and BH211A) in the base of the valley.

Table 2: Vertical Hydraulic Groundwater Gradients

Monitoring Well	Date	Shallow Piezometer Groundwater Level (m RL)	Deep Piezometer Groundwater Level (m RL)	Screen separation (m)	Downwards Vertical Hydraulic Gradient
BH01	25/11/19	95.96 (BH01A)	95.99 (BH01B)	6.0	- 0.005
BH02	13/7/20	97.35 (BH02A)	97.22 (BH02B)	4.0	0.03
BH03		103.29 (BH03A)	103.24 (BH03B)	2.5	0.10
BH04		106.03 (BH04A)	104.2 (BH04B)	5.5	0.33
BH211		103.94 (BH211A)	101.59 (BH211B)	10.5	0.22

Downward gradients are expected to dominate the deeper groundwater system but differences in permeability and dipping of layers of the Henley Breccia is expected to promote some horizontal groundwater movement. Comparison of groundwater levels in screens of similar elevation in the deep groundwater system (BH201, BH202, BH211B), suggest a horizontal hydraulic gradient for the deeper groundwater in approximately a south east direction towards the Pacific Ocean.

Horizontal hydraulic gradients in the localised shallow groundwater system are expected to be more influential and are interpreted to also be towards the northwest, following topography towards Otokia Creek. Minor artesian groundwater conditions recorded at BH01A, BH01B and BH02A, and groundwater seeps observed towards the bottom of the valley during site visits, indicate that the shallow groundwater system discharges to the Otokia Creek. The alluvium and colluvium itself is likely to be recharged from rainfall, run off and groundwater recharge from the shallow Henley Breccia towards the base of the valleys.

Groundwater Recharge and Flow

Groundwater is expected to be recharged at different rates across the site due to the different properties of the surficial materials. Low groundwater recharge rates are anticipated to occur through the low permeability loess materials located on the ridges and valley slopes. Instead, the loess soils are interpreted to promote run-off of excess water generating flow to the base of the valleys, where alluvium and colluvium materials have been deposited. The alluvium and colluvium is inferred to have much higher permeability than the loess and is expected to receive greater recharge directly from rainfall. Runoff generated across the loess soils is also expected to provide additional groundwater recharge through these units.

Groundwater flow from the localised shallow groundwater system is calculated using Darcy's Law to be approximately 3,600 m^3/year (Table 3). Total rainfall across the 69 ha catchment area is predicted to be approximately 560,200 m^3/year, when based on an annual average of 809 mm (calculated by the weather generator model (WGEN) in HELP (Appendix C)). This indicates that flow through the shallow groundwater system is less than 1% of the total rainfall over the catchment area. Allowing a component of loss to the deeper groundwater system of less than that flowing to the shallow system (given significantly lower permeability), total recharge of groundwater across the site is expected to be less than 2% of total rainfall.

Table 3: Estimated Groundwater Flow in Shallow Groundwater System

Parameter	Adopted Value	Justification
Area (A)	1650 m^2	Saturated aquifer thickness = 6.6 m (Difference between BH03 groundwater level (103.3 m RL) and top of brown siltstone layer (96.7 m RL))
		Aquifer width = 250 m (Approximate width of valley at location of BH01 where alluvium is anticipated)
Hydraulic Conductivity (K)	3.2 X 10^{-6} m/s	Maximum recorded Henley Breccia permeability during hydraulic testing (BH02A)
Hydraulic Gradient (i)	0.022	Average change in head = 4.4 m (Head difference between BH01 and BH02 = 1.5 m. Head difference between BH01 and BH03 = 7.3 m)
		Distance = 200 m (Approximate distance between BH01 and BH02/BH03)
Discharge (Q)	3663 m^3/year	Darcy's Law Q = A K i

The catchment of the deep groundwater system is not constrained to the topographically defined Otokia Creek surface water and shallow groundwater system catchments. Instead, the deep groundwater system forms part of a larger, currently undefined, unit within the Henley Breccia in the elevated coastal range between the Taieri Basin and the coast.

Recharge into the deeper groundwater is constrained by the low permeability loess. Given recharge to the more permeable shallow groundwater system is predicted to be less than 1% of total rainfall, recharge to the deep system is likely to be no greater than this, with recharge from the shallow groundwater system also potentially limited by the discontinuous siltstone layer.

Flow has not been estimated within the deep groundwater system as discharge to the Pacific Ocean is considered to be negligible.

3.3.3 Groundwater and Surface Water Quality

Groundwater quality sampling was undertaken at the site between 6 and 25 November 2019. The results are compared against the ANZG (2018) 95% freshwater protection guidelines and the Otago Regional Plan Discharge Threshold (2016) for nutrients as presented in Table A 5 in Appendix A. Nitrate-N concentrations at BH01A (26.7 mg/L), BH03A (4.32 mg/L) and BH03B (4.35 mg/L) were recorded to exceed the Otago threshold of 1.0 mg/L. All other bores recorded nitrate-N at concentrations less than 0.1 mg/L. The ammonia as N concentrations at BH201 (2.59 mg/L) and BH04B (0.28 mg/L) were also recorded to exceed the Otago threshold of 0.2 mg/L.

Davis (2014) reported that application of fertiliser at a forestry plantation in Ashley, Canterbury, increased nitrate-N concentrations to a maximum recorded concentration of 39.3 mg/L in the

root-zone soil drainage water. However, it should be noted that this concentration was recorded prior to any dilution in groundwater. The Ashley plantation site had pallic soils, which are typically derived from loess. David (2014) also reported that harvesting, as has occurred recently at the Smooth Hill site, can lead to a short-lived increase in leaching loss of nitrate-N.

It is interpreted that the greatest concentration of nitrate-N, recorded within BH01A, resulted from runoff from the site recharging into the shallow alluvium. The elevated ammonia as N concentration in BH201, where groundwater is 46.45 mbgl, indicates that the influence of inorganic nitrogen has been present at the site for an extended period of time, given the low permeability and low percolation rates within the Henley Breccia.

Reducing groundwater conditions are inferred at BH02 and BH04, as indicated by elevated concentrations of iron, and low concentrations of sulphate. Dissolved oxygen (DO) concentrations and the oxidation reduction potential (ORP) were also low in BH02A during monitoring, with DO recorded between 1.86 and 2.51 mg/L, and ORP between +59.2 and -23.3 mV (Table A 4 Appendix A). This has likely resulted in any nitrate-N present in the groundwater at the location of these piezometers being preferentially used by microbes under the reducing conditions. Reducing conditions are also inferred to be present at BH201 and BH04B given the low concentrations of sulphate, and the presence of ammonia as N.

Trace metals in groundwater were measured at concentrations above the ANZG guidelines in a number of locations for copper (BH01A, BH02B and BH04A), nickel (BH02B, BH04A, BH04B and BH201), and zinc (BH02A, BH03B, BH04A, BH04B and BH201). The elevated concentrations of soluble trace metals is interpreted to be a function of the reducing conditions apparent in groundwater apparent across much of the site.

The relatively consistent water chemistry in the nested piezometers at BH02 and BH03 support inference of downward percolation of water in the Henley Breccia. Likewise, the differences in key parameter concentrations measured at BH04A and BH04B suggests the brown siltstone layer located between these two screens retards downward percolation to some extent, despite the downward vertical hydraulic gradient.

The difference in parameter concentrations at BH01A and BH01B, with higher concentrations of nitrate-N in BH01A, are expected to reflect the lack of downward water movement in the valley floor.

3.4 Surface Water Interactions

An upper branch of the Otokia Creek originates within the site boundary at Smooth Hill. This stream was observed to be flowing during a number of site visits in winter and spring 2019, and winter 2020, however was confirmed as ephemeral in the vicinity of the proposed Smooth Hill landfill footprint during a site visit in January 2020. It is anticipated that the stream becomes perennial between BH01 and McLaren Gully Road. Site observations during the summer months indicate that stream flow adjacent to McLaren Gully Road is less than 10 litres/second.

Minor artesian groundwater levels have been recorded at the base of the valley in the alluvium at BH01A and in the Henley Breccia at BH01B and BH02A, indicating that Otokia Creek baseflow is in part contributed to from groundwater derived from the site. During rainfall events, the low permeability of the loess is likely to result in relatively high runoff, which may flow directly to the Otokia Creek, or recharge the relatively permeable alluvium at the base of the valley. The high runoff, and recent harvesting of forestry at the site, is also likely to result in high sediment loading within the runoff, some of which is expected to be discharged to the Otokia Creek.

As discussed in Section 2.3, a small section of the site (approximately 9,000 m^2) lies within the Open Stream surface water catchment south of the site. Construction of an embankment

comprised of engineered clean fill will be undertaken in this area, with no placement of waste proposed. A catchpit at the edge of the landfill boundary with Big Stone Road will convey runoff from this area through a culvert which will discharge to the Open Stream catchment (see Drawing 51-12506381-C302).

3.5 Conceptual Hydrological and Hydrogeological Model

The current understanding of the groundwater and surface water systems at the proposed Smooth Hill landfill site is that a localised shallow groundwater system is present as a function of the distribution of permeable alluvium and weathered Henley Breccia within the topographical lows of the valleys. This shallow system supports groundwater levels near the surface in the valley bottom and contributes baseflow to the downstream perennial sections of the Otokia Creek. Low rates of infiltration through the loess and seepage from the shallow system to the deeper low permeability unweathered Henley Breccia occurs, with this slow downward percolation constituting the deeper groundwater system.

3.5.1 Deep Groundwater System

Groundwater within the Henley Breccia is subject to vertical downwards hydraulic gradients with minor rainfall recharge occurring through the low permeability loess materials that overlie the breccia across the majority of the site. Horizontal groundwater gradients are relatively flat, with an inferred flow direction towards the Pacific Ocean southeast of the site. Groundwater discharge expected to occur in relatively insignificant quantities.

It is not known where the groundwater divide occurs in the elevated coastal region between the Titri Fault and the coastline, however if this follows topography it is expected the divide will be located along the ridge bounding the west of the site, which separates the McColl Creek Catchment and the Taieri Catchment (Figure 1). Groundwater within the deep system east of this ridge is anticipated to flow approximately south east and discharge towards the coast.

Groundwater quality of the deep groundwater system is represented by samples from BH03B, BH04B and BH201. Elevated concentrations of nitrate-N in BH03B, and ammonia as N in BH201, as well as downward vertical hydraulic gradients measured in nested piezometers across the siltstone layer, infers some recharge from the shallow groundwater system. These elevated concentrations of inorganic nitrogen are likely to have been derived from forestry operations. Nitrate is anticipated to have undergone both denitrification and dissimilatory nitrate reduction to ammonium (DNRA) under reducing conditions. Elevated concentrations of nickel and zinc are also likely to be due to the reducing groundwater conditions and be sourced from minerals in the rock material.

There are no recorded active groundwater takes from the Henley Breccia. The nearest recorded borehole is greater than 1.5 km west of the site (I45/0001), and no recorded bores or consents are recorded south east of the site (Figure 5).

The deep groundwater system within the Henley Breccia is not considered as a viable groundwater resource in the Otago Regional Council Lower Taieri Groundwater Allocation Study (Rekker and Houlbrooke, 2010), given the low permeability and minimal potential yields. While groundwater in this unit is considered to flow towards the Pacific Ocean, meaningful discharge is not anticipated to be occurring. In addition, there are no environmental receptors within 2 km of the site that are likely to be impacted by the deep groundwater system. It is noted that regardless of deep groundwater flow direction, the rates of deep groundwater flow are so low that potential impacts to receptors would be negligible.

3.5.2 Shallow Groundwater and Surface Water System

A localised shallow groundwater system is considered to have formed in the base of the valleys/gullies at the site. The deposition of relatively permeable alluvium and colluvium in the topographical lows has formed a shallow unit which receives recharge directly from rainfall, as well as from runoff over the low permeability loess soils and groundwater from the shallow Henley Breccia.

The shallow Henley Breccia underlying the alluvium and colluvium typically has a greater permeability than the low permeability breccia that hosts the deep groundwater system, due to the presence of gravel and sandstone layers and due to greater weathering and relaxation of the rock mass. Groundwater from the shallow Henley Breccia is inferred to discharge into the alluvium and colluvium unit, with groundwater quality results in BH01A and BH01B demonstrating an upward vertical hydraulic gradient. Horizontal groundwater flow directions in the shallow Henley Breccia also infer groundwater flow follows topography towards Otokia Creek. This shallow groundwater system is anticipated to be the source of baseflow for the Otokia Creek, which is currently understood to be ephemeral up-stream of BH01 and becoming perennial a short distance downstream of BH01. Otokia Creek is also likely to receive runoff during rainfall events, which has the potential to transport a substantial sediment load given the steep topography and recent deforestation at the site. This is discussed further in the landfill design report (GHD, 2020c).

A discontinuous brown siltstone layer within the Henley Breccia, possibly a historic lake deposit, underlies the shallow breccia in a number of locations, and is interpreted as separating the localised shallow groundwater system from the deep groundwater system. Downward vertical hydraulic gradients are observed between the shallow and deep groundwater systems, however recharge from the shallow to deep unit may be impeded at some locations by the siltstone layer. The approximate elevation of the siltstone layer indicates that it may have been eroded away at the locations of BH01 and BH02.

Groundwater quality in the shallow aquifer system is considered to reflect the recent land use at the site, with fertiliser applied to the recently removed forestry likely to have resulted in elevated nitrate-N concentrations in the alluvium and shallow breccia at BH01A and BH03A, respectively.

The assessment of the shallow groundwater and surface water system will focus on the impact of changes in runoff and groundwater discharge to Otokia Creek. There are no recorded active surface water takes from the Otokia or McColl Creeks, therefore risks will be assessed for environmental receptors only.

An assessment of the effects to the Open Stream surface water catchment has been excluded from this report, as placement of clean engineered fill is the only proposed activity in this area. A catchpit and culvert will convey rainfall run off to the Open Stream catchment (see Drawing 51-12506381-C302), therefore the proposed activities in this area are considered to have a very low potential effects and unlikely to significantly impact surface water or groundwater flow and quality within the Open Stream catchment. Furthermore, groundwater recharge is also considered unlikely to be impacted as the landfill waste will not overlie this section of the Open Stream catchment.

4. Assessment of Effects

The proposed landfill at the Smooth Hill site has the potential to influence groundwater and surface water levels, flow and quality in the vicinity of the site. To assess the potential impacts to groundwater and surface water, the landfill activity was considered in the context of the conceptual hydrological and hydrogeological model, with water balance and analytical models developed to represent key processes and predict outcomes.

The following sections outline the assessment and the predicted effects on groundwater and surface water.

4.1 Landfill Activity

4.1.1 Potential Adverse Effects

Placement of the proposed landfill has the potential to impact surface water and groundwater levels due to a reduction in recharge through the loss of infiltration area, runoff interception and removal of groundwater via subsurface drainage. The proposed landfill also has the potential to influence groundwater and surface water quality in the vicinity of the site in the event leakage of leachate were to occur through the landfill liner into the groundwater system.

4.1.2 Landfill Design

The proposed Smooth Hill landfill comprises a capacity of approximately 6 Mm^3 to provide for the safe disposal of municipal solid waste for a period in excess of 35 years, and will occupy a footprint of approximately 44.5 Ha of the 87 Ha designated for the landfill.

Construction of each stage will involve removal of un-consolidated surficial materials, followed by creation of planar surfaces for the placement of the landfill liner. Depth of excavation will typically be between two and 10 metres and include removal of all loess and some of the underlying weathered and unweathered rock. Most excavated materials (excluding those that are unsuitable) will then be used to form the landfill profile, liner and capping. Excavated weathered rock will be used for engineered fill.

Following excavation and filling, a 200 mm layer of selected soils will be placed where necessary to provide a construction base for the compacted clay layer of the landfill liner. A 10 m high toe bund will be constructed at the northern low point of the landfill to facilitate placement of waste and contain leachate.

The landfill has been designed to include five stages, which will be constructed and receive waste in a consecutive manner. Stages 1 and 2 will be in the north eastern portion of the landfill footprint, separated by the natural ridge from Stages 3, 4 and 5 in the south western portion. Each stage will be developed sequentially in a number of sub-stages. Each sub stage will progress through; exposed liner, open waste, daily cover, intermediate cover and final cap.

The Design Report (GHD 2020) specifies that any liner system must comply with either a Type 1 or Type 2 liner system as set out in WasteMINZ. In the Design Report and for the purpose of this assessment it has been assumed that a Type 2 liner will be utilised. This comprises 600 mm compacted clay base layer with a permeability of $1x10^{-8}$ m/s or less, overlain by a 5 mm geosynthetic clay liner (GCL) and 1.5 mm HDPE flexible membrane liner (FML). A 300 mm leachate drainage layer and overlying geotextile will be placed on top of the liner. If a Type 1 liner system was considered the findings from this assessment would be approximately the same with respect to leachate leakage, as the 600 mm compacted clay layer in a Type 1 system

requires a permeability of $1x10^{-9}$ m/s or less which is an order of magnitude lower than for a Type 2 liner system.

The leachate collection system will comprise the 300 mm drainage layer and perforated pipework in the drainage media to transfer leachate to the leachate sumps at the low point of the landfill liner. Two separate systems will be installed to collect leachate from Stages 1 and 2, and Stages 3, 4 and 5. Leachate pumps and risers will convey the leachate to storage tanks, from where it will be transported to the Dunedin City Waste Water Treatment Plant (WWTP). Leachate generation will be minimised by reducing the exposure of waste. Daily cover materials will generally be won from earthworks at the site. The low permeability loess from the site is considered viable for use as intermediate (300 mm) and final cap (600 mm) material.

During the operational phase of the landfill, any stormwater that comes into contact with waste will be treated as leachate. However diversion of stormwater will be undertaken to separate it from waste where possible, and directed to sediment treatment and a flow attenuation basin (see Drawing 51-12506381-C303). Treated stormwater will be discharged to the minor ephemeral tributary of the Otokia Creek downstream of the landfill. After landfill closure, all runoff from the completed landfill surface will report directly to the attenuation basin. The catchment area of the attenuation basin will be 69.2 ha, which is larger than the landfill footprint (44.5 ha) as natural runoff flow paths for the valley immediately north-west of the proposed landfill (where BH09 and BH02 are situated (Figure 6)) will also be intercepted along with other stormwater from the facilities area. The attenuation basin consists of an upstream forebay area and a downstream area separated by a gabion basket (see Drawings 51-12506381-C306 and C307). The forebay will be excavated approximately 1.5 m (to approximately 95.5 m RL) into the existing ground surface and provide capacity for 700 m^3. The unlined forebay provides initial treatment and soakage for stormwater and groundwater collected from a subsoil drainage network. During periods of higher rainfall, water will overflow from the forebay and through a gabion basket, reducing potential velocities, into the unlined downstream area. Water in this area is retained by a small dam and will either soak into the underlying ground or discharge via a low level pipe or spillway to the Otokia Creek tributary downstream. This area may be planted with wetland type flora.

To control groundwater beneath the landfill, a network of subsoil drains will be constructed beneath the lining system to be available to drain groundwater seepage under all stages of the landfill development. The groundwater drainage will report to an access manhole immediately before either discharging to the attenuation basin or being directed to storage for use on site as non-potable water. This facilitates monitoring for effects of leachate that may have seeped through the landfill liner. The perforated HDPE pipes of groundwater drainage system will be installed to a minimum elevation of 99.5 m RL at the northern low point of the landfill.

4.1.3 Landfill Closure and Aftercare

Placement of the final cap after completion of the landfill will include an upper topsoil and / or growth layer, and surface vegetation, likely grass, will be established. Surface contour drains to manage stormwater that falls on the cap will also be connected to the perimeter drainage system that reports to the attenuation basin. Stockpile sites will be graded to conform to the adjacent topography and vegetated.

Post-closure aftercare activities will include operation and maintenance of:

- Landfill gas extraction, treatment and destruction system
- Leachate collection system
- Stormwater systems
- Landfill cap, including fill in locations of differential settlement, repair of surface erosion and vegetation maintenance
- Remaining site infrastructure
- Ongoing environmental monitoring

4.1.4 Leachate Management

Landfill leachate will be produced where rainfall percolates through waste and due to decomposition of the waste. Rates of generation are expected to be at their highest during operation when waste is being placed, however this is mitigated as much as possible through careful management of the active landfill face including the use of daily and intermediate cover. Where it cannot be directed to the surface water system, rainfall that falls on the exposed liner prior to placement of waste will also report to the leachate collection system. Placement of the final cap is designed to minimise leachate generation, however leachate will continue to be generated and report to the collection system after landfill closure.

The landfill liner is designed to minimise leakage of leachate, and will be designed to meet the landfill guideline specifications for either a Type 1 or Type 2 liner (WasteMINZ, 2018). The primary containment layer is the HDPE geomembrane. This is used in both the Type 1 and Type 2 liner systems. Individual sheets are welded together and all welds tested for potential leaks. The HDPE geomembrane is practically impermeable and strict quality control measures are used to promote liner integrity during placement. However, for the purposes of assessing environmental effects a minimum level of leakage through the membrane is assumed based on the assumption that multiple “pinhole” imperfections could occur. For the Type 2 liner system this leakage is mitigated through intimate contact with the underlying GCL or for Type 1 by the compacted clay layer. The rate of leachate leakage is largely controlled by the head of leachate on top of the liner. The minimum leachate collection system requirement in the WasteMINZ (2018) technical guidelines states that the leachate head is not to exceed 300 mm above the liner.

Monitoring of the following will be undertaken to ensure there are no significant effects from leachate leakage:

- Groundwater collected in the subsoil drainage system prior to discharge to attenuation basin.
- The attenuation basin, comprising stormwater runoff and groundwater, prior to discharge to the Otokia Creek.
- Down hydraulic gradient groundwater monitoring wells to provide advance warning of potential impacts to surface water quality.

A landfill management plan is required to be developed to define monitoring requirements for the site, however Appendix D provides some additional details regarding proposed monitoring.

4.2 Landfill Water Balance and Leachate

4.2.1 Assessment Methodology

To inform the assessment of potential effects to surface water and groundwater the Hydrologic Evaluation of Landfill Performance (HELP) software was used to predict average run-off, evapotranspiration, leachate generation and leakage during different phases of construction and after closure. The HELP model provides analytical estimation of water movement and prediction of a water balance for the landfill. Landfill design, material properties and location specific weather data are used in developing the model. Appendix C presents the full methodology and results for the leachate generation, reporting times and leakage assessment.

4.2.2 Landfill Runoff

The rainfall runoff predicted to report to the attenuation basin during operation and after closure of the landfill is presented in Table 4. During landfill operation, the worst case scenario for runoff will occur after the landfill footprint is fully occupied, but sections of exposed liner and open waste are still present in the final stage of development which report all runoff to the leachate collection system. After placement of the intermediate and final caps (which will occur progressively as the landfill is developed), all rainfall runoff will be directed to the attenuation basin before discharge.

During landfill operation, a minimum of approximately 12.7% of rainfall runoff is predicted to report to the attenuation basin, with the remainder either infiltrating into the landfill or undergoing evapotranspiration. After landfill closure, the percentage of rainfall that reports to the attenuation basin increases to approximately 13.8%. This equates to between approximately 45,000 m^3/year to 49,000 m^3/year of runoff from the 44.5 ha landfill area before and after closure, respectively.

Table 4: Rainfall runoff predicted to report to the attenuation basin

Landfill Phase	Worst case area during operation (m^2)	Runoff to attenuation basin (m^3/year)	Percentage of total Rainfall (%)*
Exposed Liner	10,000	0	
Open Waste	2,500	0	
Open Waste with Daily Cover	11,500	0	
Intermediate Cap	43,517	3,745	
Final Cap	364,480	41,420	
Total	**431,997**	**45,165**	**12.7 %**
Landfill Phase	Area after closure (m^2)	Runoff to attenuation basin (m^3/year)	Percentage of rainfall over landfill (%)*
Final Cap	**431,997**	**49,147**	**13.8 %**

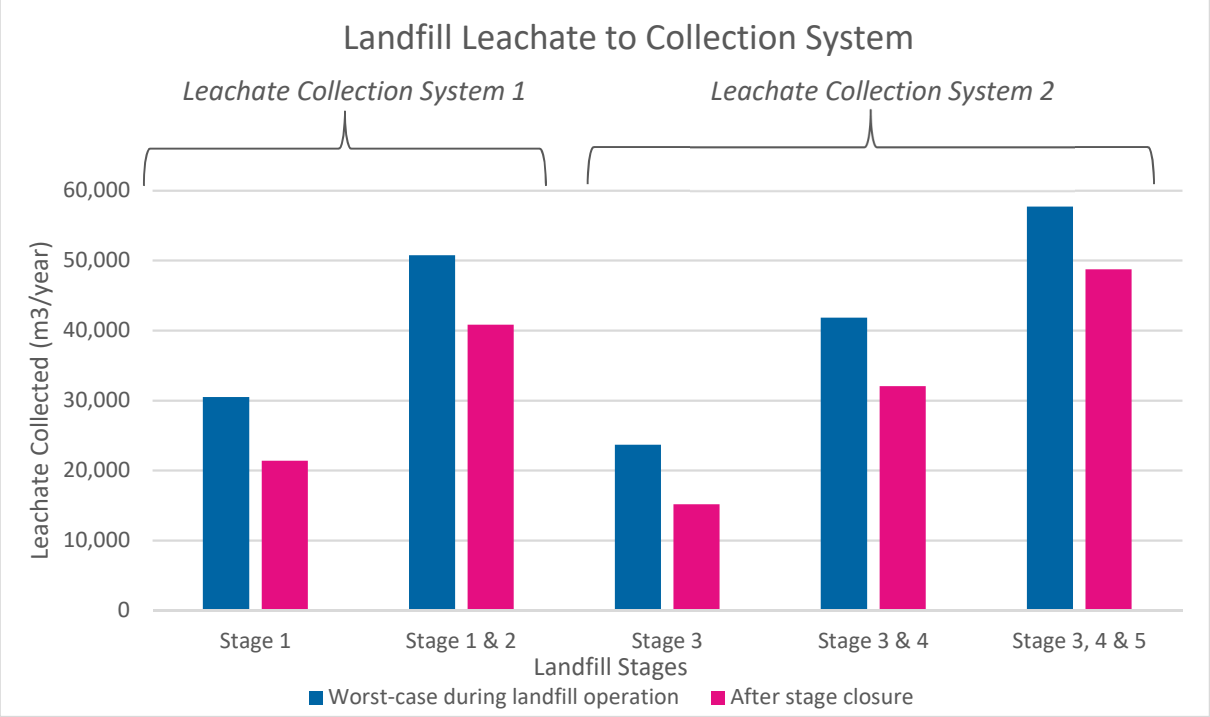
* Assuming annual average of 809.5 mm over 44.5 ha

4.2.3 Leachate Generation and Leakage

Figure 10 presents a summary of the landfill leachate predicted to be collected in the leachate collection systems during operation and after stage closure. There are two drainage collection

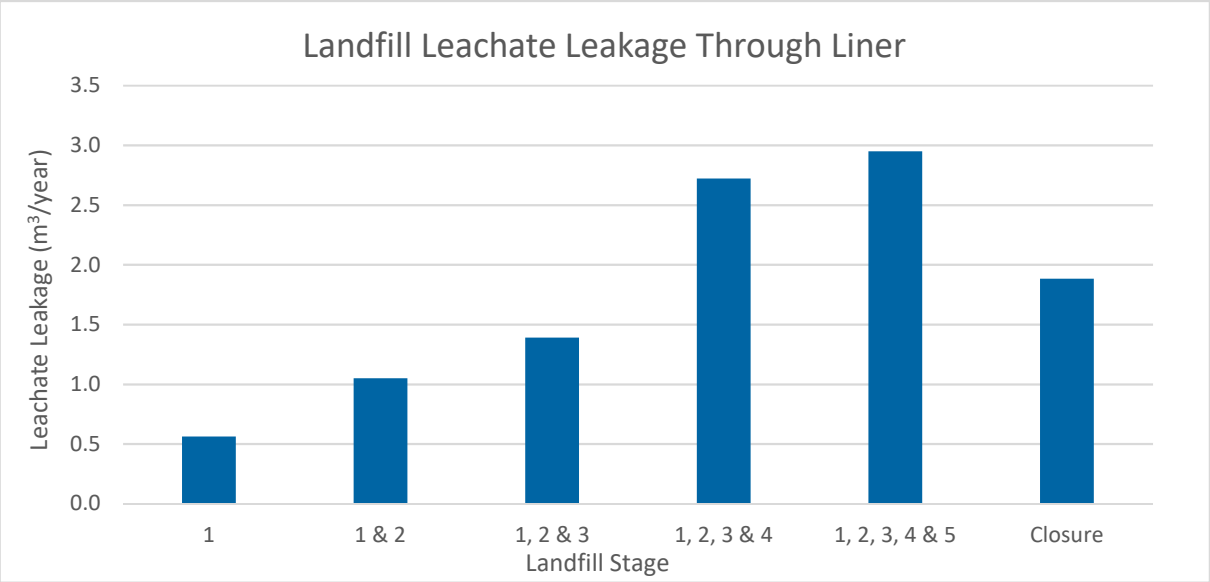
systems for the proposed landfill, which separate the leachate collection in Stages 1 and 2 from leachate collection in Stages 3, 4 and 5. The predicted leachate volumes reported to the collection systems during operation will not occur concurrently as each landfill stage will be closed before the next one is opened. The largest leachate volumes are likely to occur during operation of stage 5, with a total predicted leachate volume of approximately 99,000 m^3/year for the whole landfill (worst case for stages 3, 4 and 5 combined with closed stages 1 and 2). After complete landfill closure, the total leachate predicted from all five stages is approximately 90,000 m^3/year.

Figure 10: HELP Model landfill leachate to collection system



A summary of the predicted leachate leakage through the landfill liner during operation and after stage closure is presented in Figure 11. As with leachate generation, the leachate leakage during landfill operation will not occur concurrently due to sequential stage construction. The maximum leachate leakage is likely to occur during operation of stage 5, with a predicted leakage rate of 3.0 m^3/year (generated from operational stage 5 and closed stages 1, 2, 3 and 4). The predicted total leachate leakage from all stages after landfill closure is approximately 1.9 m^3/year.

Figure 11: HELP Model leachate leakage through the landfill liner



4.2.4 Leachate Quality

Leachate from a Class 1 (municipal) landfill is generated due to the interaction of waste with infiltrating water and the release of liquids directly from the waste. Leachate can have varying quality, dependent upon the relative proportion of different waste types, landfill design, age of the landfill and local environmental setting. Typically, contaminant concentrations in leachate are highest when waste is exposed in an operating cell, and decrease with closure and as the landfill ages. Decomposition of putrescible material and the transition of the landfill waste from an aerobic to anaerobic state, and the generation of organic acids, over time also plays a key role in determining leachate quality, influencing microbial reactions, solubility and physiochemical reactions of leachate constituents.

Decomposition of putrescible waste and the leachate generating environment is often defined to occur in three stages:

1. Aerobic degradation, generating heat and producing organic compounds and carbon dioxide.
2. Anaerobic degradation where large organic molecules are broken down into simple compounds such as hydrogen, ammonia, water, carbon dioxide and organic acids.
3. Methanogenic degradation where organic acids break down to form methane gas and other products.

Table 5 outlines an upper quartile for the highest leachate constituent concentrations of eight New Zealand landfills, provided in the Centre for Advanced Engineering Landfill Guidelines (CAE, 2000).

Table 5: Upper quartile of the highest leachate constituent concentrations

Parameter	Upper Quartile Concentration – Class 1 Landfills (mg/L excluding pH)(1)
Aluminium	7.9
Ammoniacal Nitrogen	705
Arsenic	0.17
Boron	12.3
Cadmium	0.0063
Calcium	378
Chloride	1730
Chromium	0.17
Dissolved Reactive Phosphorus	3.4
Iron	183
Lead	0.13
Magnesium	193
Manganese	5.4
Nickel	0.19
Nitrate Nitrogen	0.86
pH	8.1 pH Units
Potassium	630
Silica	36
Sodium	1165
Sulphate	292
Total Kjeldahl Nitrogen	1220
Zinc	1.2
Total VOC	6.5
Total SVOC	4.4

1) Upper quartile of the highest leachate concentrations recorded in eight consented municipal solid waste (MSW) Class 1 Landfills in New Zealand (CAA, 2000[1]). Note some landfills did not provide concentrations for all parameters.

[1] The more recently published guidance (WasteMINZ, 2018) make use of the same data from eight New Zealand Class 1 landfills. Data from this more recent document has not been used owing to inaccuracies in the presented leachate chemistry.

4.3 Catchment Water Balance

Table 6 presents the water balance comparison of the existing environment with the worst case landfill scenario and after landfill closure.

Total rainfall over the proposed landfill attenuation basin catchment area (69.2 ha) is predicted to be approximately 560,200 m^3/year (based on annual average of 809.5 mm). Actual evapotranspiration and runoff for the existing environment has been predicted using the weather generator model (WGEN) in HELP (Appendix C) to be approximately 218,400 m^3/year and 334,600 m^3/year, respectively. As discussed in Section 3.3.2, groundwater recharge is anticipated to comprise less than 2 % of total rainfall.

With the landfill proposed to occupy 44.5 ha of the catchment, the remaining 24.7 ha will continue to contribute runoff at the same rate as under the existing environment. The ongoing contribution from the landfill footprint area to the attenuation basin is dependent upon the stage of development. Table 4 outlines the worst case for the reduced net runoff to the attenuation basin.

Table 6: Catchment Water Balance (69 ha)

	Existing Environment	Worst Case During Landfill Operation	Landfill Closure
Inputs (m^3/year)			
Rainfall	560,200		
Outputs (m^3/year)			
Evapotranspiration	218,400	285,700	290,600
Runoff	334,600	173,600	177,600
Shallow Groundwater System	3,600	1,200	1,200
Deep Groundwater System	3,600	1,200	1,200
Leachate Collection System	-	98,500	89,600
Leachate Leakage	-	3.0	1.9

The combined runoff to the attenuation basin from both the landfill (Table 4) and the intercepted valley to the north-west is likely to be a minimum of 173,600 m^3/year (Table 6). This is a reduction of nearly 50% compared to the existing environment.

An increase in evapotranspiration is predicted to occur during landfill operation and closure in comparison to the existing environment due to an increase in water infiltration and soil moisture retention within the surface soils, and a ‘good grass’ cover for the final cap, which allows for increased evapotranspiration. The existing scenario is considered to have ‘poor grass’ cover due to onsite forestry operations and the presence of scrub vegetation.

In terms of groundwater impacts from landfill construction two aspects are considered:

- Table 6 indicates a reduction in recharge to both the shallow and deep groundwater systems beneath the landfill footprint.
- In addition, up to 4 m^3/day of groundwater is predicted to be intercepted and collected from sub surface drains beneath the landfill during operation and will be stored and used on site as part of a non-potable water supply (described in 4.4.1 below).

This reduction in recharge to groundwater during the course of landfill operation and post-closure, will likely result in downward adjustment of groundwater levels to a new steady state reflecting the loss of recharge. This is predicted to eventually reduce below the level of the sub-surface drains. In the long-term, groundwater diversion through the sub-surface drains is expected to be negligible.

4.4 Effects to Shallow Groundwater and Surface Water

4.4.1 Assessment Methodology

Estimates of groundwater recharge and discharge for the existing situation, described in Section 3.3.2, provide the basis for assessing the potential impacts to shallow groundwater. A water balance approach has been used in combination with simplistic analytical groundwater flow equations (Darcy's Law) to predict changes to the shallow groundwater system and subsequently surface water.

Assessment considers the potential adverse effects of the following scenarios:

1. Predicted effects excluding the potential mitigation measures of soakage of stormwater to ground down gradient of the landfill, representing an upper bound for potential impacts or a sensitivity scenario.
2. Predicted effects including the mitigating influence of stormwater soakage to ground down gradient of the landfill, representing the expected outcome.

Of these scenarios, Scenario 2, which considers the normal operation of the landfill and current climatic conditions, is considered appropriate for the purpose of assessing effects to the environment associated with the landfill. Scenario 1 is provided for context to the sensitivity of the predicted effects.

4.4.2 Scenario 1 - Potential Upper Bound for Effects to Shallow Groundwater

Groundwater Recharge and Flow

After the placement of the 44.5 ha landfill footprint, there will be no further recharge to the shallow groundwater system from rainfall infiltration over the area of the landfill. Assuming an even distribution of recharge across the entire 69.2 ha catchment this would reduce recharge to the shallow groundwater system by approximately 67 % and reduce groundwater flow through the valley floor from approximately 3,600 m^3/year to approximately 1,200 m^3/year. This reflects the upper bound for potential influence on groundwater recharge and flow, assuming no soakage of stormwater to ground.

Groundwater Levels and Gradients

Groundwater flow in the shallow groundwater system is predicted to reduce from approximately 3,600 m^3/year to approximately 1,200 m^3/year, where loss of recharge across the landfill footprint is considered in isolation. Assuming this scenario, using Darcy's Law to back calculate the discharge (by reducing saturated aquifer thickness and change in groundwater head in

Table 3 by the same factor), groundwater levels in the shallow groundwater system are predicted to reduce by approximately 2 - 3 m in the immediate vicinity of the landfill. The implications of this are three fold:

- A reduction in groundwater discharge to the Otokia Creek system.
- A potential shift downstream where the stream transitions from ephemeral to perennial stream flow.
- A potential impact on water levels in any wetlands located immediately downstream of the landfill.

The 2-3 m change in shallow groundwater levels and the potential effects described above will be confined to the immediate downstream vicinity of the landfill. With increased distance downstream the impact on groundwater levels will diminish as the contribution of groundwater from the wider catchment increases and the proportional contribution from the 44.5 ha associated with the landfill decreases. This is further discussed in Section 4.4.4.

Placement of sub-soil drainage to ensure dewatered conditions beneath the landfill are not expected to intercept groundwater in the southern extent of the footprint, where groundwater has been encountered at relatively deep levels. However in the northern section of the landfill footprint, near the toe of the landfill, there is potential for interception of groundwater within the shallow groundwater system. The sub-soil drainage in this area will be installed to a minimum elevation of 99.5 m RL. Groundwater levels recorded in the shallow groundwater system in nearby monitoring wells have been recorded as 97.5 m RL (BH02A), 103.3 m RL (BH03A) and 106.4 m RL (BH04A). Groundwater levels recorded above the minimum elevation of the sub-soil drainage (99.5 m RL) are generally in monitoring wells located in elevated areas along the valley sides (BH03A and BH04A), whereas the drains are proposed to be located within the existing valley bottoms where groundwater levels are lower (BH02A).

Although sub-soil drainage may provide some initial lowering of groundwater levels within the localised shallow groundwater system, it is anticipated that this will be for a relatively short period of time as groundwater levels are expected to be reduced below the elevation of the drains due to loss of recharge with placement of the landfill liner (Section 4.3). Significant volumes of groundwater are therefore not anticipated to be abstracted through the subsoil drainage system over the life of the landfill, with the maximum estimated discharge in the range of 4 m^3/day. It is noted that this water will be abstracted and used a part of the non-potable water supply for the site.

4.4.3 Scenario 2 – Predicted Effects to Shallow Groundwater

The attenuation basin is designed to provide additional water quality polishing with respect to sediment and moderate flows downstream of the landfill. The two sections of the basin have been designed with no lining in the base to allow infiltration of stormwater to the underlying groundwater system while stormwater is ponded in the basins prior to discharge. This recharge is anticipated to provide sufficient soakage to mitigate the majority of the loss of groundwater recharge and the associated effects described in 4.4.2.

The current groundwater conditions down gradient of the landfill, where groundwater levels are near surface, provide limited opportunity for stormwater to soak to ground as there is no storage capacity within the shallow aquifer. With the proposed landfill development and loss of recharge across the landfill footprint, the lowering of groundwater levels will provide capacity for soakage of stormwater from the attenuation basin. Alluvium and colluvium in the gully floor, and the excavation of the unlined forebay into these materials, is expected to promote soakage, such that at times when stormwater is generated it is expected that soakage to ground downstream of the landfill will occur. The forebay capacity (designed to hold 1% AEP) provides the means to

capture a significantly greater volume of stormwater for soakage than is estimated to presently recharge the shallow groundwater system (approximately 3,600 m^3/year), with this expected to provide a net increase in groundwater flow through the valley floor.

So while the catchment is expected to see changes in where groundwater recharge occurs, the influence of the landfill on groundwater levels and flow in the shallow aquifer is expected to be less than minor and more likely to be beneficial to groundwater flow through the valley floor towards the Otokia Creek.

4.4.4 Effects to Surface Water Level Flow

Assessment of potential effects to surface water flow considers the two scenarios above.

Under the upper bound for effects scenario (Scenario 1), which excludes soakage of stormwater from the landfill attenuation basin, a decrease in groundwater flow by approximately 2,400 m^3/year (equivalent of 0.08 litres/second) and decrease in groundwater levels by up to 3 m at the down gradient edge of the landfill is predicted. This would result in decreased baseflow in Otokia Creek and subsequent potential movement of the perennial flow transition to further downstream. The distance between the proposed landfill and McLaren Gully Road, where Otokia Creek tributary is confirmed as having perennial flow, is approximately 1 km. Ground elevation reduces by approximately 20 m over this distance. Assuming a linear surface gradient, the predicted reduction in groundwater levels due to landfill placement is anticipated to move the transition location for perennial stream flow up to 50 m further downstream from its current location although this will also be mitigated by the contribution of groundwater from the wider catchment.

Under Scenario 2, with clean stormwater diverted from the landfill to the attenuation basin, soakage of stormwater to ground is expected to mitigate the predicted loss of baseflow and subsequent transition of perennial stream flow. With a high capacity to attenuate stormwater discharge from the site and a forebay excavated into the valley floor, the volume of stormwater soaking to ground is likely to be greater than that presently being recharged to the catchment and provide a beneficial increase to stream baseflow.

4.5 Effects to Deep Groundwater

Any change in groundwater levels due to reduced recharge will have a negligible impact on the deep groundwater system, which does not support any registered groundwater takes and is not considered to provide baseflow to any streams. All valleys in the vicinity of the site that host ephemeral streams are anticipated to have their own localised shallow system similar to that encountered and described at Smooth Hill.

With an estimated average horizontal permeability of $1x10^{-8}$ m/s in the deep groundwater system of the Henley Breccia, and a distance of approximately 2.6 km from the south eastern edge of the site, it would take groundwater an average of 8,245 years to reach the Pacific Ocean along a direct flow path. The deep groundwater system is therefore considered to contribute negligible discharge to the Pacific Ocean.

4.6 Effects to Water Quality

4.6.1 Assessment Methodology

Existing contaminant flux from the shallow groundwater system towards the Otokia Creek has been estimated using concentrations recorded in groundwater samples collected at the site (Appendix A Table A 3), as well as estimated rates of shallow groundwater discharge (Section 3.3.2).

The leachate contaminant flux for leakage from the proposed landfill has been predicted using concentrations from Class 1 landfills across New Zealand (CAE, 2000), as presented in Table 5 (Section 4.2.4). The modelled rate of leachate leakage reflects the closed landfill scenario outlined in Section 4.2.3. A comparison of the contaminant flux has been undertaken between the shallow groundwater in the existing environment and the leachate leakage under the closed landfill scenarios, to provide an indication of the potential for long-term adverse influence on groundwater and surface water. The closed landfill scenario is considered an appropriate comparison for the existing situation, owing to the significant time involved with broad scale catchment water mixing compared to the temporary nature of the operational scenarios, and because it reflects the maximum landfill footprint.

4.6.2 Predicted Changes in Contaminant Flux

Table 7 presents the estimated contaminant flux in the shallow groundwater system under existing conditions, and resulting from predicted leachate leakage for the worst case and closed landfill scenarios. The results indicate that contaminant flux is predicted to reduce significantly following construction of the landfill, with the exception of ammoniacal nitrogen. This is the result of the reduction in the existing groundwater flows described in Section 4.5 and the small amount of leachate leakage anticipated.

Nutrient transformation between nitrogen species, nitrate and ammoniacal nitrogen, is dependent upon a variety of environmental conditions, therefore total inorganic nitrogen is considered to represent a better measure for comparing nitrogen nutrient flux for the existing and landfill scenarios. This indicates that following placement of the landfill, total inorganic nitrogen (comprising both ammoniacal nitrogen and nitrate nitrogen) is estimated to significantly reduce from the existing flux, from approximately 73 kg/year to less than 2 kg/year.

Table 7: Predicted Changes in Water Quality

Parameter	Flux (kg/year excluding pH)	
	Existing Shallow Groundwater System (3,600 m^3/year)	Leachate Leakage (Closed Landfill – 1.9 m^3/year)
Aluminium	-	0.015
Arsenic	0.0034	0.00033
Boron	-	0.023
Cadmium	0.00014	0.000012
Calcium	428.8	0.72
Chloride	486.7	3.3
Chromium	0.00081	0.00033
Iron	0.48	0.35
Lead	0.00024	0.00025
Magnesium	137.8	0.37
Manganese	1.2	0.010

Parameter	Flux (kg/year excluding pH)	
	Existing Shallow Groundwater System (3,600 m^3/year)	Leachate Leakage (Closed Landfill – 1.9 m^3/year)
Nickel	0.025	0.00037
pH	7.4 pH Units	8.1 pH Units
Potassium	20.3	1.2
Silica	-	0.068
Sodium	295.7	2.2
Sulphate	505.7	0.55
Zinc	0.028	0.0023
Total VOC	-	0.012
Total SVOC	-	0.0084
Total Kjeldahl Nitrogen	2.7	2.3
Dissolved Reactive Phosphorus	-	0.0065
Ammoniacal Nitrogen	0.17	1.3
Nitrate Nitrogen	72.8	0.0016
Total Inorganic Nitrogen	73.2	1.3

4.6.3 Effects to Groundwater and Surface Water Quality

Under the existing environment, the influence of current and historical site activities is reflected in the quality of the shallow and deep groundwater, particularly in the form of nutrients, which are readily leached from soils.

Placement of the proposed Smooth Hill landfill is inferred to preclude recharge from rainfall/runoff to the shallow groundwater system beneath the landfill footprint. Predicted long term leachate leakage through the liner of 1.9 m^3/year (43 L/ha/year) is expected to reflect the only recharge to groundwater across the landfill footprint area, with this decrease in infiltration predicted to locally lower groundwater levels beneath the landfill (refer Sections 4.4.2 and 4.4.3). Widely distributed infiltration, low leakage rates and a significant thickness of unsaturated material below the liner is expected to significantly retard the rate of leachate percolation to groundwater, providing the opportunity for significant attenuation of contaminants.

On reaching and mixing with the underlying groundwater, migration of contaminant constituents will occur with groundwater flow. The rate of groundwater flow through the shallow aquifer is expected to be low, as a function of moderate permeability and a loss of driving head (a function of reduced groundwater recharge). Travel times for migration of groundwater through the shallow aquifer to the toe of the landfill are correspondingly expected to be protracted and potential for further attenuation of contaminant concentrations exists prior to influenced groundwater moving beyond the landfill footprint.

The impacts of leachate leakage on groundwater quality down gradient of the landfill are expected to be limited in the context of the existing groundwater quality, with mixing with groundwater beneath the landfill footprint alone expected to provide greater than 1000 fold dilution. In addition, significant dilution is expected to occur as the catchment stormwater is preferentially enabled to soak to ground from the attenuation basin and expected to mitigate loss of flow to the shallow groundwater system. Soakage from the attenuation basin will further dilute groundwater with any residual landfill leachate influence by approximately three fold. Greater dilution is expected owing to the significant average volumes of stormwater (173,600 m^3/year) predicted to discharge through the attenuation basin and the ability to temporarily retain stormwater in the forebay, promoting soakage to ground (Section 4.3).

Considering the reduction in contaminant flux and the levels of dilution predicted, the effects to groundwater quality in the immediate vicinity of the site are expected to be negligible.

As discussed in section 4.4.4 of this report, the tributary to Otokia Creek downstream of the landfill transitions from ephemeral to permanent flow prior to the Maclaren Gully Road culvert. This permanent flow will be supported by shallow groundwater discharge including a contribution from the groundwater discharge from beneath the landfill. However, given the anticipated impact on groundwater quality is anticipated to be negligible immediately downstream of the landfill, the impact on the surface water quality in the stream is anticipated to be less as the landfill groundwater will be further diluted by groundwater seepage from the wider catchment in the surface water flow.

4.6.4 Surface water Quality Limits – Regional Plan

Schedule 15.2.2 of the regional plan establishes water quality limits for surface water. The relevant limits are:

Nitrate – nitrite	0.075 mg/l
Dissolved Reactive Phosphorus (DRP)	0.01 mg/l
Ammoniacal nitrogen	0.1 mg/l
E Coli	260 cfu/100ml
Turbidity	5 NTU

As described in Section 4.6.2 the total flux contribution for DRP and total nitrogen are expected to decrease in comparison to current shallow groundwater discharges from beneath the landfill footprint. Therefore, on the assumption that shallow groundwater eventually discharges to the surface water system downstream from the landfill, no significant impact is anticipated on these parameters in surface waters.

As discussed in 4.6.2 a small increase in the total annual flux of ammoniacal nitrogen is expected in the shallow groundwater seepage but the associated seepage rate is very small (1,200 m^3/year or less than 0.04 l/second). Furthermore, as discussed in 4.6.2 the flux of total inorganic nitrogen is estimated to reduce from approximately 73 kg/year to less than 2 kg/year, and considering nutrient transformations between nitrogen species, the impact to groundwater and surface water quality is considered to be less than minor.

E.Coli is not anticipated to be a contaminant of concern associated with the groundwater system and turbidity is a storm water issue and discussed in the Sediment and Erosion Assessment Report (GHD 2020).

5. Summary and Conclusions

5.1 Effects to Shallow Groundwater and Surface Water Levels and Flow

Placement of the landfill is likely to reduce groundwater recharge within the 69.2 ha landfill attenuation basin catchment area by approximately 67 %, with groundwater levels in the shallow system beneath the landfill predicted to reduce by approximately 2 – 3 m. Under a scenario which assumes no soakage of stormwater to ground (Scenario 1 Section 4.4.2), this would result in reduced discharge to the Otokia Creek, and the location where the stream transitions from ephemeral to perennial moving up to 50 m further downstream

When soakage of stormwater to ground within the forebay and downstream wetland section of the attenuation basin is considered (Scenario 2 Section 4.4.3), this will mitigate a proportion of the reduced groundwater recharge beneath the landfill footprint. Furthermore, reduction of groundwater levels beneath the landfill will act to provide capacity for soakage of stormwater. Stormwater soakage to ground within the forebay and attenuation basin are likely to provide a more consistent source of recharge to the shallow groundwater system, and baseflow for the Otokia Creek, when compared to current conditions.

Although changes in groundwater recharge are expected at the site due to placement of the landfill, the influence on shallow groundwater and surface water levels and flow are expected to be less than minor and more likely beneficial with respect to Otokia Creek baseflow when considering the above approach.

5.2 Effects to Deep Groundwater System

The deep groundwater system is not considered to currently provide baseflow to any streams, and does not support any registered groundwater takes. The very low estimated hydraulic conductivity of the unit (less than $1x10^{-8}$m/s), indicates that the deep groundwater system contributes negligible discharge to the Pacific Ocean. The reduction in recharge due to placement of the landfill is therefore likely to have a less than minor impact to the deep groundwater system.

5.3 Effects to Groundwater and Surface Water Quality

Given the inferred use of fertilisers during current site conditions, a comparison of the leachate contaminant flux for leakage from the proposed landfill to the groundwater in the existing environment indicates that contaminant flux is predicted to reduce significantly following construction of the landfill. The exception to this is ammoniacal nitrogen, however as the flux of total inorganic nitrogen is estimated to reduce from approximately 73 kg/year to less than 2 kg/year, and considering nutrient transformations between nitrogen species, the impact to groundwater and surface water quality is considered to be less than minor.

5.4 Monitoring Recommendations

Monitoring of groundwater, discharge from sub-surface drainage and surface water is recommended to be undertaken before, during and after operation of the landfill. This will enable the existing environment to be further characterised, and for potential impacts from the landfill to be monitored during operation and after closure. Monitoring is described in Appendix D.

6. Limitations

This report: has been prepared by GHD for Dunedin City Council and may only be used and relied on by Dunedin City Council for the purpose agreed between GHD and the Dunedin City Council as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than the Dunedin City Council and Council officers, consultants, the hearings panel and submitters associated with the resource consent and notice of requirement process for the Smooth Hill Landfill Project arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Dunedin City Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of vegetation and topography. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

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Appendices

Appendix A – Hydrogeology Site Investigation

A.1 Introduction

Two phases of site investigation were undertaken at the site to characterise the geological and hydrogeological conditions, and provide sufficient information to assess effects to groundwater and surface water that may be associated with the proposed activity. Conditions assessed included local geology, groundwater levels and hydraulic properties that may influence drainage and flow of groundwater within the vicinity of the proposed landfill.

This appendix provides details of the following site works:

- **Appendix A.2** Geology and Elevation Survey
- **Appendix A.3** Water Level Monitoring
- **Appendix A.4** Hydraulic Testing (permeability analysis)
- **Appendix A.5** Groundwater Quality (Groundwater Sample Analysis)

The sections below outline the methodologies used; the data outputs are provided in the following pages.

A.2 Geology

Ten boreholes were drilled at the site between 27 May and 17 June 2019 during the phase 1 site investigation (BH01 – BH10) by McNeil Drilling. The boreholes were drilled at PQ size (122 mm outer diameter) using rotary drilling methodology and a truck mounted UDR600 rig. An additional five boreholes were drilled at site between 24 October and 7 November 2019 during the phase 2 site investigation (BH201, BH202, BH203, BH209 and BH211) by Speights Drilling using a tracked, Maruka-mounted rig. BH201 and BH202 were cored to approximately 10 m bgl followed by wash drilling to termination depth. All other phase 2 investigation bores were advanced using rotary drilling methodology. All bores were drilled at PQ size.

Table A 1 below presents all site investigation bores, plus one borehole found to already be installed at the site from an unknown previous site investigation (adjacent to the north eastern site gate). All bore logs from the GHD investigations are presented in Appendix B.

The phase 1 bores (BH01-BH10) were surveyed by Woods Surveying in North Taieri Circuit (2000) projection and New Zealand Vertical Datum (2016). Coordinates and ground elevation for the phase 2 bores and the NE Gate existing bore were not surveyed, and were therefore estimated from Google Earth and a Stantec contour map (Stantec, *undated*).

Table A 1: Boreholes and Piezometers

Bore ID	Coordinates North Taieri Circuit (2000)		Ground Elevation (m RL) NZVD (2016)	Piezometer Screen (mbgl)
	Easting	Northing		
BH01	396465.5	788214.5	96.01	2 – 4 (BH01a) 8 – 9 (BH01b)
BH02	396358.6	788022.9	97.41	3 – 5 (BH02a) 7 – 9 (BH02b)
BH03	396428.4	787998.3	107.48	8.5 – 10.5 (BH03a) 13 – 15 (BH03b)
BH04	396563.6	788063.8	108.15	4.5 – 6.5 (BH04a) 12 – 15 (BH04b)
BH05	396459.8	787862.1	129.5	15 – 17 20 – 23
BH06	396168.3	787594	149.75	Not Installed
BH07	396493.7	787671.9	139.73	12 – 15 (BH07a) 16.8 – 19.8 (BH07b)
BH08	396809.7	787700.7	143.89	Not Installed
BH09	395951.8	788050.4	132.8	14.5 – 16.5
BH10	396788.3	788118.5	139.07	13.5 – 15.5 (BH10a) 18 – 20 (BH10b)
BH201	396593	787538	144	54 – 60
BH202	396181	787498	144	54 – 60
BH203	395779	787672	182	Not Installed
BH209	395775	788148	132	Not Installed
BH211	396592	787977	107	8.5 – 11.5 (BH211a) 22 – 25 (BH211b)
Existing Bore (NE Gate)	396955	787978	145	Unknown (Max bore depth 42.5)

A.3 Groundwater Level Monitoring

Groundwater levels recorded by manual dip on 25 November 2019 and 13 July 2020 are presented in Table A 2.

Table A 2: Manual Groundwater Levels

Piezometer ID	25/11/2019		13/07/2020	
	Groundwater Level (mbtoc)	Groundwater Level (m RL)	Groundwater Level (mbtoc)	Groundwater Level (m RL)
BH01A	0.05	95.96	*Damaged*	
BH01B	0.57	95.99	0.91	95.65
BH02A	0.82	97.47	0.94	97.35
BH02B	1.6	96.665	1.05	97.22
BH03A	4.55	103.29	5.13	102.71
BH03B	4.34	103.24	5.13	102.45
BH04A	2.3	106.36	2.63	106.03
BH04B	5.19	103.54	4.53	104.2
BH05A	Dry		Dry	
BH05B	Dry		22.85	107.25
BH07A	Dry		Dry	
BH07B	Dry		Dry	
BH09	15.27	118.22	14.03	119.46
BH10A	Dry		Dry	
BH10B	Dry		19.29	120.32
BH201	47.06	97.545	47.27	97.34
BH202	*48.15**	*96.45**	41.9	102.7
BH211A	3.23	104.19	3.48	103.94
BH211B	*13.45**	*94.0**	5.86	101.59
NE Gate Existing Piezometer	26.37	118.93	27.93	117.37

** Groundwater levels not fully recovered following well development.*

Groundwater levels were also recorded using Solinst pressure transducers (level loggers). These were installed within all piezometers at the site (excluding the existing bore) to record groundwater levels between 9 November 2019 and 25 November 2019 (Figure A 1 and Figure A 2). Unfortunately data was not able to be retrieved from the pressure transducer installed in BH02B in 2019. Pressure transducers were also installed within BH01B, BH02A, BH02B, BH03A and BH03B between 28 January 2020 and 13 July 2020 (Figure A 3). Groundwater levels were collected using a dip meter during installation and retrieval to enable the data collected by the pressure transducers to be calibrated to relative levels.

The loggers were set to record at 15 minute intervals. A baro-logger was also installed in the air column in BH07 upstand for the duration of the monitoring period to record barometric pressure changes; this allowed compensation for atmospheric pressure changes in the recorded pressure head from each of the level loggers to be undertaken.

Figure A 1: 2019 groundwater levels in all wells (excluding BH02B, BH202, BH211A & BH211B)

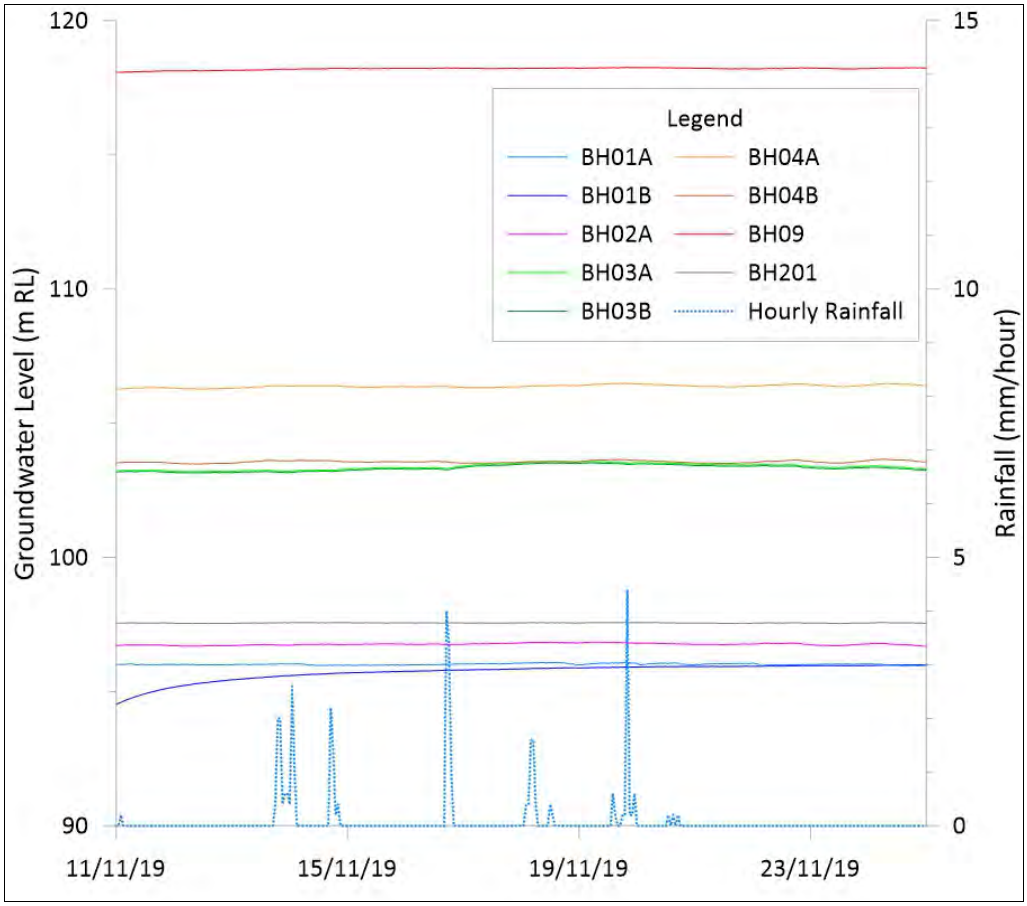


Figure A 2: 2019 groundwater levels in locations where groundwater was still recovering following well development

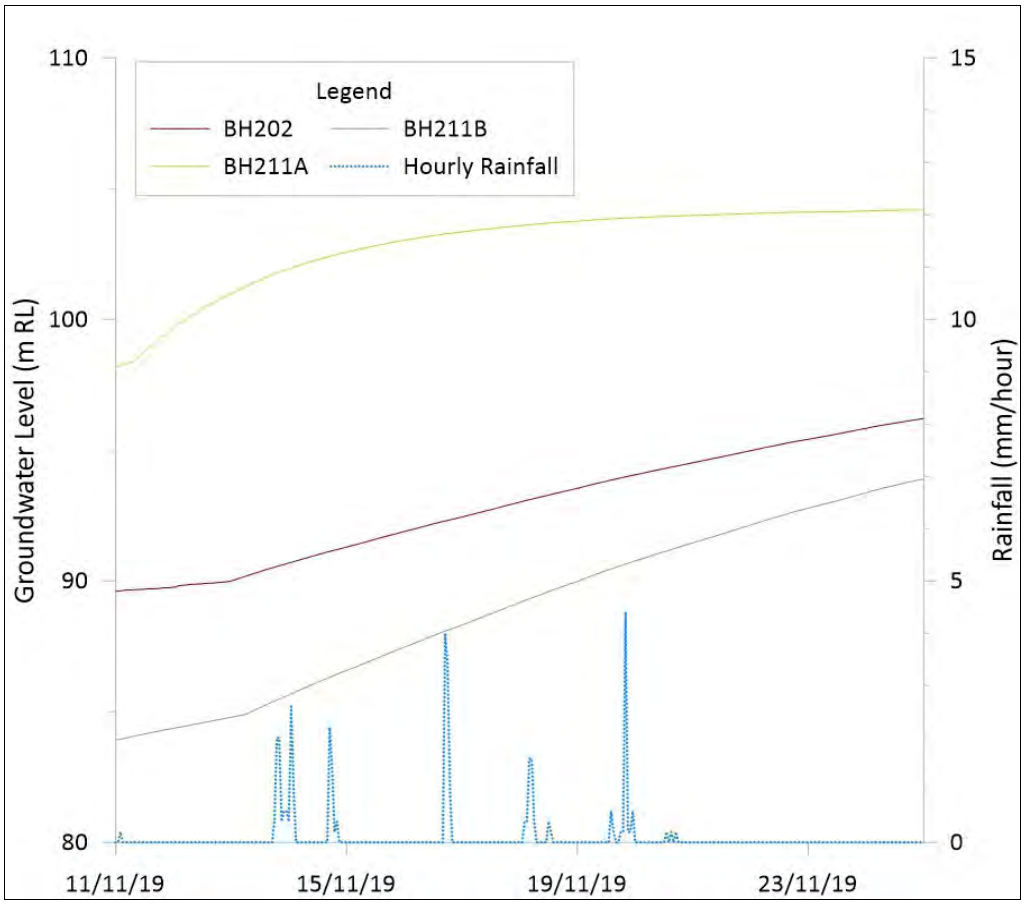
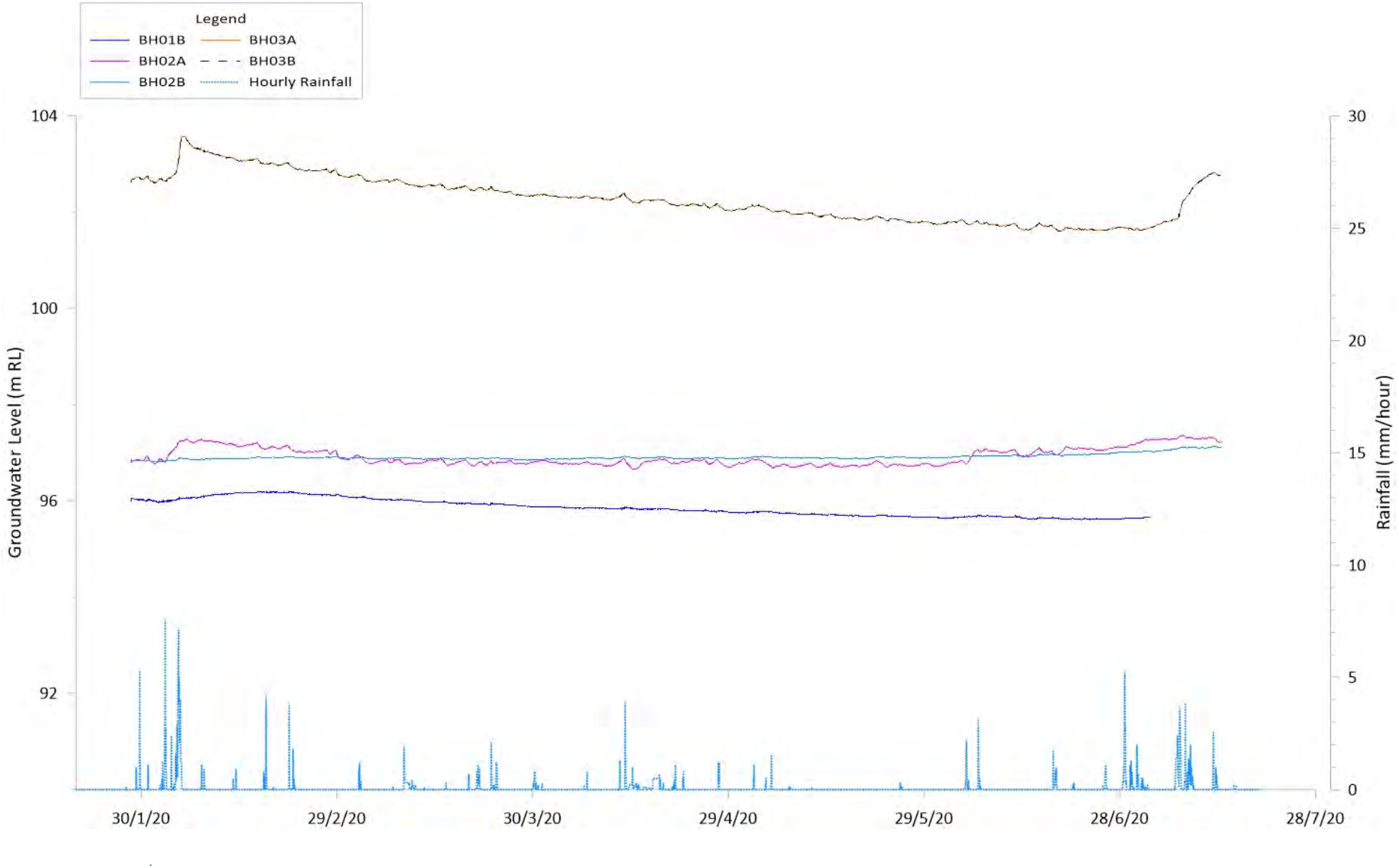


Figure A 3: 2020 groundwater levels



A.4 Hydraulic Testing

Hydraulic permeability testing was undertaken at all boreholes installed at the site. Due to very slow recharge at the majority of monitoring wells, two methods of hydraulic testing were undertaken to obtain as much information as possible from the site.

The first method involved recording the groundwater recovery following removal of water during well development. The second method of hydraulic testing was undertaken using a solid displacement slug was also undertaken at a number of the bores. Results are presented in Table A 3.

The results from the recovery tests following development represent a minimum value of permeability due to non-instantaneous displacement, which is likely to have impacted surrounding groundwater levels. Where hydraulic testing was undertaken with a displacement slug, comparison between the two methods was able to be undertaken. The comparison indicated that the rising head tests following well development underestimated permeability by between approximately half an order of magnitude (BH201) to over two orders of magnitude (BH02A). The discrepancy generally increases with increasing permeability, as development is likely to have had a greater impact to the surrounding groundwater where permeability is higher.

A.5 Groundwater Quality

Groundwater samples were collected from a number of monitoring wells between 6 and 25 November 2019. Groundwater was purged from wells BH01 – BH04 until they either went dry or a minimum of three well volumes was removed. BH201 was not able to be purged as the depth to groundwater was a significant constraint. After groundwater had recharged a grab sample was collected from each monitoring well using dedicated water bailers. A water quality reading was also obtained from BH01 – BH04 at this time (Table A 4). The samples were kept cool in a chilly bin, then couriered to Analytica Laboratories for analysis. The analytical results are presented in Table A 5.

Table A 3: Hydraulic Testing Results

Monitoring Well	Screen Lithology	Hydraulic Test Methodology*	Solution	Hydraulic Conductivity (m/s)	Adopted Hydraulic Conductivity (m/s)	Justification
BH01A	Alluvium / Colluvium	FHT1	B&R	1.1×10^{-5}	1.3×10^{-5}	Geomean of displacement hydraulic testing
			Hvorslev	9.2×10^{-6}		
		FHT2	B&R	8.0×10^{-6}		
			Hvorslev	7.9×10^{-6}		
		FHT3	B&R	2.1×10^{-5}		
			Hvorslev	2.3×10^{-5}		
		RHT1	B&R	2.5×10^{-5}		
			Hvorslev	3.2×10^{-5}		
		RHT2	B&R	8.6×10^{-6}		
			Hvorslev	6.7×10^{-6}		
BH01B	Gravel (Henley Breccia)	Rising head test following well development	B&R	5.3×10^{-9}	5×10^{-8}	1 order of magnitude greater than hydraulic testing following development
			Hvorslev	5.3×10^{-9}		
BH02A	Gravel (Henley Breccia)	Rising head test following well development	B&R	1.8×10^{-8}	3.2×10^{-6}	Geomean of displacement hydraulic testing
			Hvorslev	1.3×10^{-8}		
		FHT1	B&R	3.5×10^{-6}		
			Hvorslev	3.5×10^{-6}		
		RHT1	B&R	2.9×10^{-6}		
			Hvorslev	2.9×10^{-6}		

Monitoring Well	Screen Lithology	Hydraulic Test Methodology*	Solution	Hydraulic Conductivity (m/s)	Adopted Hydraulic Conductivity (m/s)	Justification
BH02B	Unweathered Henley Breccia	Rising head test following well development	B&R	1.7×10^{-9}	2×10^{-8}	1 order of magnitude greater than hydraulic testing following development
			Hvorslev	1.5×10^{-9}		
BH03A	Sandstone / siltstone (Henley Breccia)	Rising head test following well development	B&R	3.8×10^{-7}	1.6×10^{-6}	Geomean of displacement hydraulic testing
			Hvorslev	4.3×10^{-7}		
		FHT1	B&R	1.5×10^{-6}		
			Hvorslev	1.9×10^{-6}		
		RHT1	B&R	1.4×10^{-6}		
			Hvorslev	1.5×10^{-6}		
BH03B	Unweathered Henley Breccia	Rising head test following well development	B&R	6.1×10^{-7}	1.6×10^{-6}	Geomean of displacement hydraulic testing
			Hvorslev	4.3×10^{-7}		
		FHT1	B&R	$1.7E \times 10^{-6}$		
			Hvorslev	1.7×10^{-6}		
		RHT1	B&R	1.6×10^{-6}		
			Hvorslev	1.6×10^{-6}		
BH04A	Conglomerate / sandstone (Henley Breccia)	Rising head test following well development	B&R	5.2×10^{-9}	-	Low permeability potentially due to insufficient well development.
			Hvorslev	7.9×10^{-9}		
		FHT1	Did not reach 70% recovery	$< 5.2 \times 10^{-9}$		

Monitoring Well	Screen Lithology	Hydraulic Test Methodology*	Solution	Hydraulic Conductivity (m/s)	Adopted Hydraulic Conductivity (m/s)	Justification
BH04B	Slightly weathered Henley Breccia	Rising head test following well development	B&R	3.4×10^{-8}	1.9×10^{-7}	Geomean of displacement hydraulic testing
			Hvorslev	2.7×10^{-8}		
		FHT1	B&R	2.2×10^{-7}		
			Hvorslev	2.1×10^{-7}		
		RHT1	B&R	1.9×10^{-7}		
			Hvorslev	1.6×10^{-7}		
BH09	Henley Breccia	Rising head test following well development	B&R	4.1×10^{-9}	6×10^{-8}	1 order of magnitude greater than hydraulic testing following development
			Hvorslev	8.0×10^{-9}		
BH201	Henley Breccia	Rising head test following well development	B&R	1.4×10^{-8}	6.2×10^{-8}	Geomean of displacement hydraulic testing
			Hvorslev	1.6×10^{-8}		
		FHT1	B&R	8.9×10^{-8}		
			Hvorslev	9.4×10^{-8}		
		RHT1	B&R	4.4×10^{-8}		
			Hvorslev	3.9×10^{-8}		

Monitoring Well	Screen Lithology	Hydraulic Test Methodology*	Solution	Hydraulic Conductivity (m/s)	Adopted Hydraulic Conductivity (m/s)	Justification
BH202	Henley Breccia	Rising head test following well development	B&R	2.5×10^{-10}	$< 3 \times 10^{-9}$	1 order of magnitude greater than hydraulic testing following development. Static groundwater level has not yet been determined as bore recovery was still occurring during 25/11/2019 site visit.
			Hvorslev	3.8×10^{-10}		
BH211A	Henley Breccia	Rising head test following well development	B&R	7.5×10^{-10}	8×10^{-9}	1 order of magnitude greater than hydraulic testing following development
			Hvorslev	9.3×10^{-10}		
BH211B	Henley Breccia	Rising head test following well development	B&R	5.6×10^{-10}	$< 6 \times 10^{-9}$	1 order of magnitude greater than hydraulic testing following development. Static groundwater level has not yet been determined as bore recovery was still occurring during 25/11/2019 site visit.
			Hvorslev	7.6×10^{-10}		

* FHT/RHT = Falling/Rising Head Test undertaken using displacement slug

Table A 4: Groundwater Quality Sample Parameters

Monitoring Well	Sample Date	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (us/cm)	ORP (mV)
BH01A	6/11/19	14.3	6.5	2.43	1189	196.4
BH01B	9/11/19	12.3	7.08	4.81	578	176.9
BH02A	9/11/19	12.6	6.55	1.86	337.9	59.2
BH02B	9/11/19	12.3	6.12	2.51	575	-23.3
BH03A	9/11/19	12.4	6.6	4.24	886	206.1
BH03B	9/11/19	12.3	6.81	7.07	923	196.5
BH04A	9/11/19	12.8	6.75	7.14	1145	161.6
BH04B	9/11/19	14.0	6.7	6.31	610	30.2
BH201	25/11/19	Not measured				

Appendix A
Table A 3
Groundwater Analytical Results

Dunedin City Council
Smooth Hill
12506381

												Soluble Trace Elements												
			Total Alkalinity (CaCO3)	Electrical Conductivity	pH	Chloride	Ammonia as N	Nitrite-N (NO2-N)	Nitrate-N (NO3-N)	Total Kjeldahl Nitrogen	Total Nitrogen	Sulphate	Arsenic [1]	Cadmium [2]	Chromium	Copper	Lead	Nickel	Zinc	Magnesium	Calcium	Sodium	Potassium	Iron	Manganese
			mg/L	µS/cm	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Screening values			-	-	-	-	**0.2**	**1.0**	**1.0**	-	-	-	**0.013**	**0.0002**	**0.001**	**0.0014**	**0.0034**	**0.011**	**0.008**	-	-	-	-	-	**1.9**
Sample Name	**Date**	**Laboratory Number**																							
BH01A	6/11/19	19-40125-1	324	1610	7.3	145	0.03	0.05	**26.7**	0.81	28	182	<0.00050	2.6E-05	<0.00020	**0.0025**	<0.000050	0.0061	0.0078	44.6	138	79.9	5.41	0.12	0.159
BH01B	9/11/19	19-40125-2	277	876	7.8	76.9	0.15	0.00563	0.0591	0.7	0.76	59.7	0.00088	2.3E-05	0.00023	0.001	0.00013	0.005	0.0068	18.3	69.9	67.8	6.3	0.021	1.66
DUPE1	9/11/19	19-40125-2	-	-	-	-	-	0.00588	0.058	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH02A	9/11/19	19-40125-3	238	538	7.2	39.3	0.11	0.0013	0.0919	0.57	0.66	0.68	0.0092	<0.000010	0.00024	0.00052	0.000052	0.0032	**0.0091**	12.2	36.3	56.9	2	3.4	1.05
BH02B	9/11/19	19-40125-4	275	772	8	89.3	0.14	<0.0010	<0.0020	1.65	1.7	4.91	0.0012	0.00013	0.00054	**0.0033**	0.00023	**0.0238**	0.0018	8.26	25.7	120	8.72	0.24	0.141
BH03A	9/11/19	19-40125-5	461	1800	7.4	109	<0.005	0.0193	**4.32**	0.53	4.9	57.8	<0.00050	3.9E-05	<0.00020	0.00097	<0.000050	0.0054	0.0063	34.1	135	53.3	14.1	0.018	0.909
DUPE2	9/11/19	19-40125-5	445	1820	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH03B	9/11/19	19-40125-6	497	1310	7.5	106	0.07	0.0194	**4.35**	0.69	5.1	59.8	<0.00050	<0.000010	0.00021	0.0011	<0.000050	0.0056	**0.0097**	38	144	65.2	13.5	<0.0050	1.45
BH04A	9/11/19	19-40125-7	248	1430	7.2	301	0.03	0.0163	0.0672	0.45	0.54	9.28	<0.00050	0.00019	0.00023	**0.0016**	<0.000050	**0.0344**	**0.027**	24.5	63	161	4.6	0.36	1.68
BH04B	9/11/19	19-40125-8	1088	2060	7.2	80.3	**0.28**	0.00609	0.029	0.93	0.96	44.9	0.00086	3.2E-05	<0.00020	0.00047	<0.000050	**0.0268**	**0.0095**	57.3	169	202	9.08	0.879	1.32
BH201	25/11/19	19-41653	267	754	8.1	66.4	**2.59**	0.00676	0.0379	3.75	3.8	17.8	0.0028	6.1E-05	0.0003	0.0011	<0.000050	**0.013**	**0.01**	-	-	-	-	-	-

Notes:
Shaded and **bolded** values exceed the corresponding guidelines.

Guideline References
Regional Plan: Water for Otago. (Updated 2016). Schedule 16A: Discharge Thresholds for Discharge Threshold Area 2
ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Default guideline values for freshwater - protection: 95% of of species.
bold and shaded indicates exceedance over screening values, - no screening value available in Otago Regional Plan or ANZG (2018)
1 - Value for Arsenic (AsV) used
2 - Value for Chromium (CrVI)

			Carbonate/ Bicarbonate/ CO2/ Hydroxide			
			Bicarbonate Alkalinity	Carbonate Alkalinity	Hydroxide Alkalinity	Free Carbon Dioxide
Sample Name	**Date**	**Laboratory Number**	mg/L	mg/L	mg/L	mg/L
BH201	25/11/19	19-41653	264	2.8	<1.0	4.7

Notes:
No screening values available from ANZG (2018)

Appendix B – Borelogs

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Dam Foundation
Job Number: 12506381
Commenced: 6/06/2019 Completed: 6/06/2019

Hole No. : BH01a
Sheet : 1 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396465.49 Northing: 788214.52 System: TAIETM2000
RL: 96.01 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
96	0	Gravelly SILT; trace fine to coarse sand, trace clay; light yellow-brown and orange-brown. Stiff, moist, low plasticity; gravel, fine to medium, sub-angular to sub-rounded or quartz and schist (COLLUVIUM)	COLLUVIUM	M	St				PQTT				77			
95	1															
	1.2	1.20 - 2.70 m: CORELOSS Possible soft material comprising slip base & stream alluvium lost.							PQTT				20			
94	2															
	2.7	Silty CLAY, trace fine sand; grey and orange-brown. Soft to firm, moist, high plasticity (ALLUVIUM)	ALLUVIUM	M	S-F											
93	3															
	3.29	Silty fine to coarse SAND, trace organics; grey. Poorly graded							PQTT				0			
		3.00 - 3.90 m: CORELOSS (inferred depth)														
92	3.9	Slightly weathered, light grey fine to coarse SANDSTONE; moderately strong to strong, no defects (HENLEY BRECCIA)	HENLEY BRECCIA						PQTT				100 35 22			
	4.4	Slightly weathered, grey SILTSTONE; very weak to weak no defects														
91	4.8	Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak, no defects 5.25 - 5.28 m: black organic-rich layer 5.28 - 5.38 m: moderately strong to strong 5.38 - 6.00 m: very weak to weak							PQTT		SW		98 98 80			
90	6	6.00 m: moderately strong to strong, closey spaced black organic-rich laminates														
	6.8	Slightly weathered, light yellow-brown and red-brown SILTSTONE; very weak to weak, no defects 6.90 - 7.05 m: light grey and red-brown 7.05 - 7.30 m: light grey with purple-brown layersvery closely spaced purple interlaminates 7.30 - 7.40 m: gravelly fine to medium SANDSTONE; gravel is fine							PQTT				100 100 100			
89	7															
88	7.8	Slightly weathered, light grey with purple-brown laminates, fine to medium SANDSTONE; very weak to weak, no defects														
	8.3	8.30 - 9.00 m: CORELOSS (possible sandy gravel)							PQTT				53 53 53			
87	9															
	9	Slightly weathered, grey and brown SILTSTONE; very weak to weak, no defects														
	9.5	Slightly weathered, light grey with purple-brown laminates fine to medium SANDSTONE; very weak to weak, no defects							PQTT				100 100 100			
	10															

Notes and Comments:
End of Hole @ 15.00m, Target Depth.

Ground stripped by ~0.6 m, including all topsoil to construct drill pad. Piezo installed 10/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Dam Foundation
Job Number: 12506381
Commenced: 6/06/2019 Completed: 6/06/2019

Hole No. : BH01a
Sheet : 2 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396465.49 Northing: 788214.52 System: TAIETM2000
RL: 96.01 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
85	11		Slightly weathered, light grey with purple-brown laminates fine to medium SANDSTONE; very weak to weak, no defects *(continued from layer starting at 9.5m)* 10.50 - 11.30 m: very thinly bedded							PQTT		SW		100 100 100			
84	12		Unweathered, moderately thickly bedded, grey BRECCIA; moderately strong to strong, no defects. Clasts; fine to medium, angular to sub-rounded; quartz and schist; matrix supported, coarse sand matrix 11.70 - 12.20 slighlty gravelly fine to coarse gravel SANDSTONE 12.20 m: medium to coarse gravel size clasts, clast supported	HENLEY BRECCIA						PQTT			97 97 97			
83	13		12.80 m: fewer clasts, fine to medium gravel size, matrix supported 13.10 m: weak to moderately strong; fine to coarse gravel clasts, clast supported; moderately well indurated							PQTT		UW		100 100 100			
82	14		13.50 - 15.00 m: CORELOSS Driller unable to recover core - slipping out of barrel.						122mm	PQTT				0 0 0			
81	15		End of Hole @ 15.00m,Target Depth.														
80	16																
79	17																
78	18																
77	19																

Notes and Comments:
End of Hole @ 15.00m, Target Depth.
Ground stripped by ~0.6 m, including all topsoil to construct drill pad. Piezo installed 10/06/2019.
Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Dam Foundation
Job Number: 12506381
Commenced: 6/06/2019 Completed: 6/06/2019

Hole No. : BH01b
Sheet : 1 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396465.49 Northing: 788214.52 System: TAIETM2000
RL: 96.01 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
96	0	Gravelly SILT; trace fine to coarse sand, trace clay; light yellow-brown and orange-brown. Stiff, moist, low plasticity; gravel, fine to medium, sub-angular to sub-rounded or quartz and schist (COLLUVIUM)	COLLUVIUM	M	St				PQTT				77			
95	1															
	1.2	1.20 - 2.70 m: CORELOSS Possible soft material comprising slip base & stream alluvium lost.							PQTT				20			
94	2															
	2.7	Silty CLAY, trace fine sand; grey and orange-brown. Soft to firm, moist, high plasticity (ALLUVIUM)	ALLUVIUM	M	S-F											
93	3															
	3.29	Silty fine to coarse SAND, trace organics; grey. Poorly graded							PQTT				0			
		3.00 - 3.90 m: CORELOSS (inferred depth)														
92	3.9	Slightly weathered, light grey fine to coarse SANDSTONE; moderately strong to strong, no defects (HENLEY BRECCIA)	HENLEY BRECCIA						PQTT				100 35 22			
	4.4	Slightly weathered, grey SILTSTONE; very weak to weak no defects														
91	4.8	Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak, no defects 5.25 - 5.28 m: black organic-rich layer 5.28 - 5.38 m: moderately strong to strong 5.38 - 6.00 m: very weak to weak							PQTT		SW		98 98 80			
90	6	6.00 m: moderately strong to strong, closey spaced black organic-rich laminates														
	6.8	Slightly weathered, light yellow-brown and red-brown SILTSTONE; very weak to weak, no defects 6.90 - 7.05 m: light grey and red-brown 7.05 - 7.30 m: light grey with purple-brown layersvery closely spaced purple interlaminates 7.30 - 7.40 m: gravelly fine to medium SANDSTONE; gravel is fine							PQTT				100 100 100			
89	7															
88	7.8	Slightly weathered, light grey with purple-brown laminates, fine to medium SANDSTONE; very weak to weak, no defects														
	8.3	8.30 - 9.00 m: CORELOSS (possible sandy gravel)							PQTT				53 53 53			
87	9															
	9.5	Slightly weathered, grey and brown SILTSTONE; very weak to weak, no defects														
		Slightly weathered, light grey with purple-brown laminates fine to medium SANDSTONE; very weak to weak, no defects							PQTT				100 100 100			
	10															

Notes and Comments:
End of Hole @ 15.00m, Target Depth.

Looks like drill pad on slip debris pile. Scarp above (east) of pad.
Ground stripped ~0.6 m, including all topsoil. Piezo installed 10/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Dam Foundation
Job Number: 12506381
Commenced: 6/06/2019 Completed: 6/06/2019

Hole No. : BH01b
Sheet : 2 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396465.49 Northing: 788214.52 System: TAIETM2000
RL: 96.01 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
85	11		Slightly weathered, light grey with purple-brown laminates fine to medium SANDSTONE; very weak to weak, no defects *(continued from layer starting at 9.5m)* 10.50 - 11.30 m: very thinly bedded							PQTT		SW		100 100 100			
84	12	11.3	Unweathered, moderately thickly bedded, grey BRECCIA; moderately strong to strong, no defects. Clasts; fine to medium, angular to sub-rounded; quartz and schist; matrix supported, coarse sand matrix 11.70 - 12.20 slighlty gravelly fine to coarse gravel SANDSTONE 12.20 m: medium to coarse gravel size clasts, clast supported	HENLEY BRECCIA						PQTT				97 97 97			
83	13		12.80 m: fewer clasts, fine to medium gravel size, matrix supported 13.10 m: weak to moderately strong; fine to coarse gravel clasts, clast supported; moderately well indurated							PQTT		UW		100 100 100			
82	14	13.5	13.50 - 15.00 m: CORELOSS Driller unable to recover core - slipping out of barrel.						122mm	PQTT				0 0 0			
81	15		End of Hole @ 15.00m,Target Depth.														
80	16																
79	17																
78	18																
77	19																

Notes and Comments:
End of Hole @ 15.00m, Target Depth.

Looks like drill pad on slip debris pile. Scarp above (east) of pad.
Ground stripped ~0.6 m, including all topsoil. Piezo installed 10/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

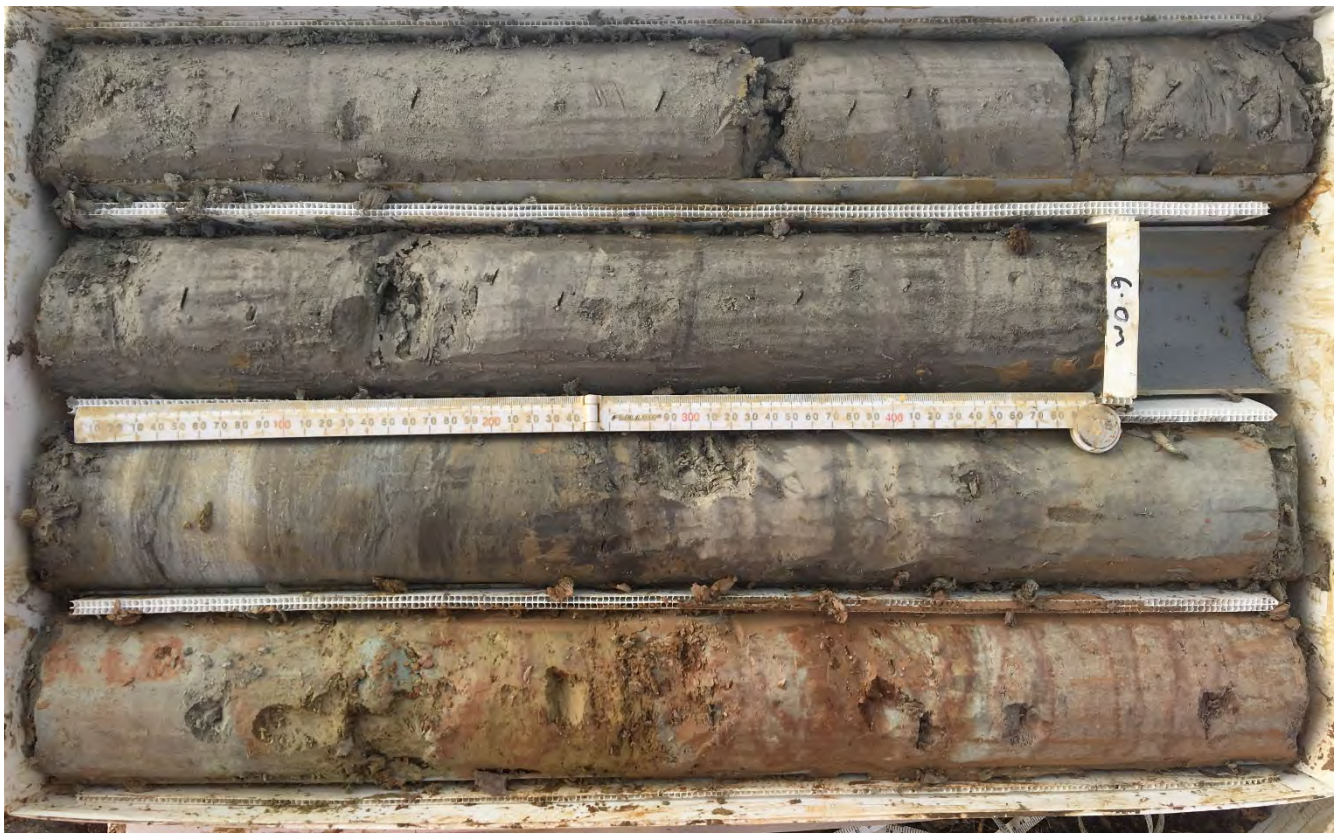
Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

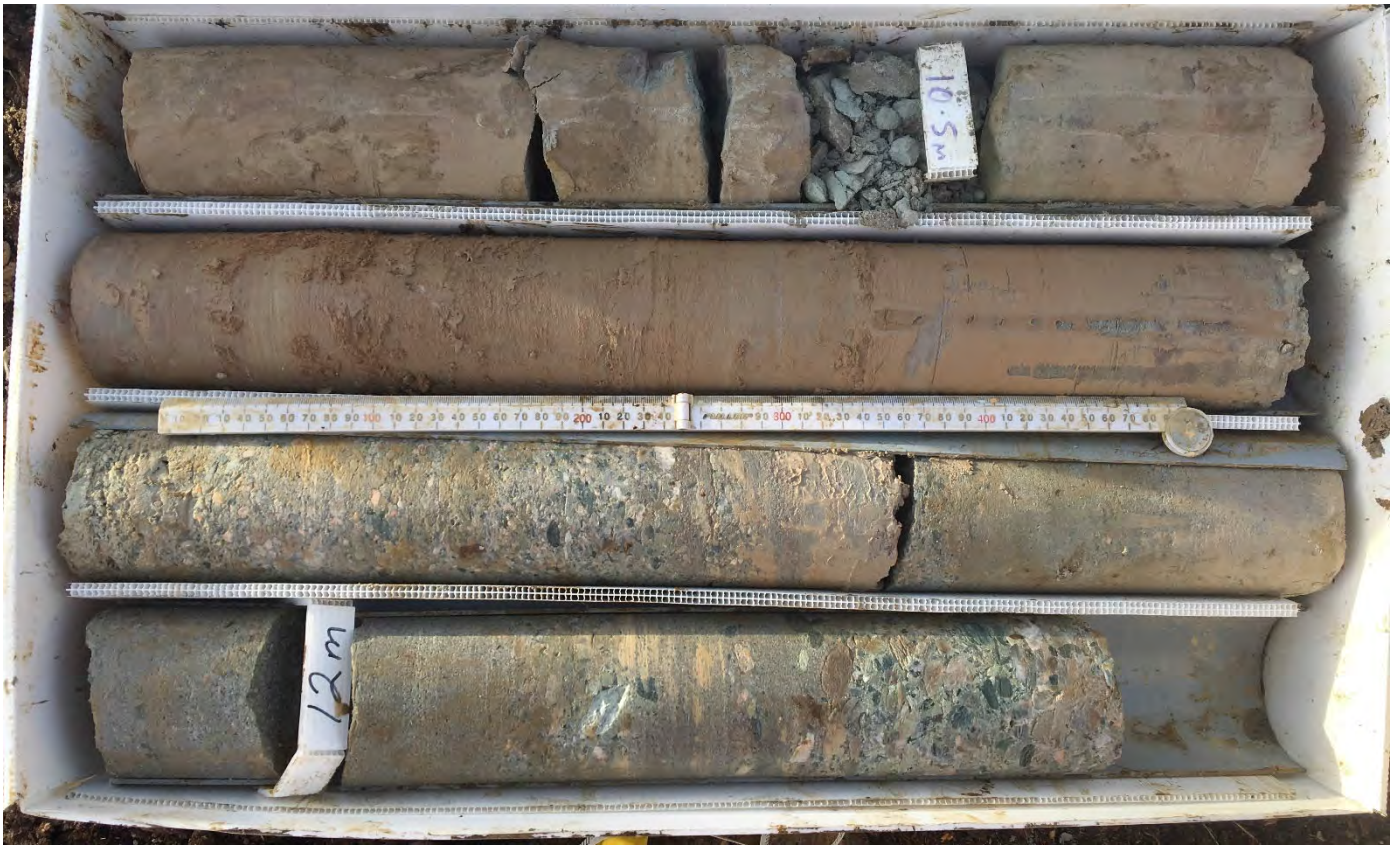
Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 3
Borehole ID	BH01	

Box 1 of 5: 0.00 m to 4.80 m

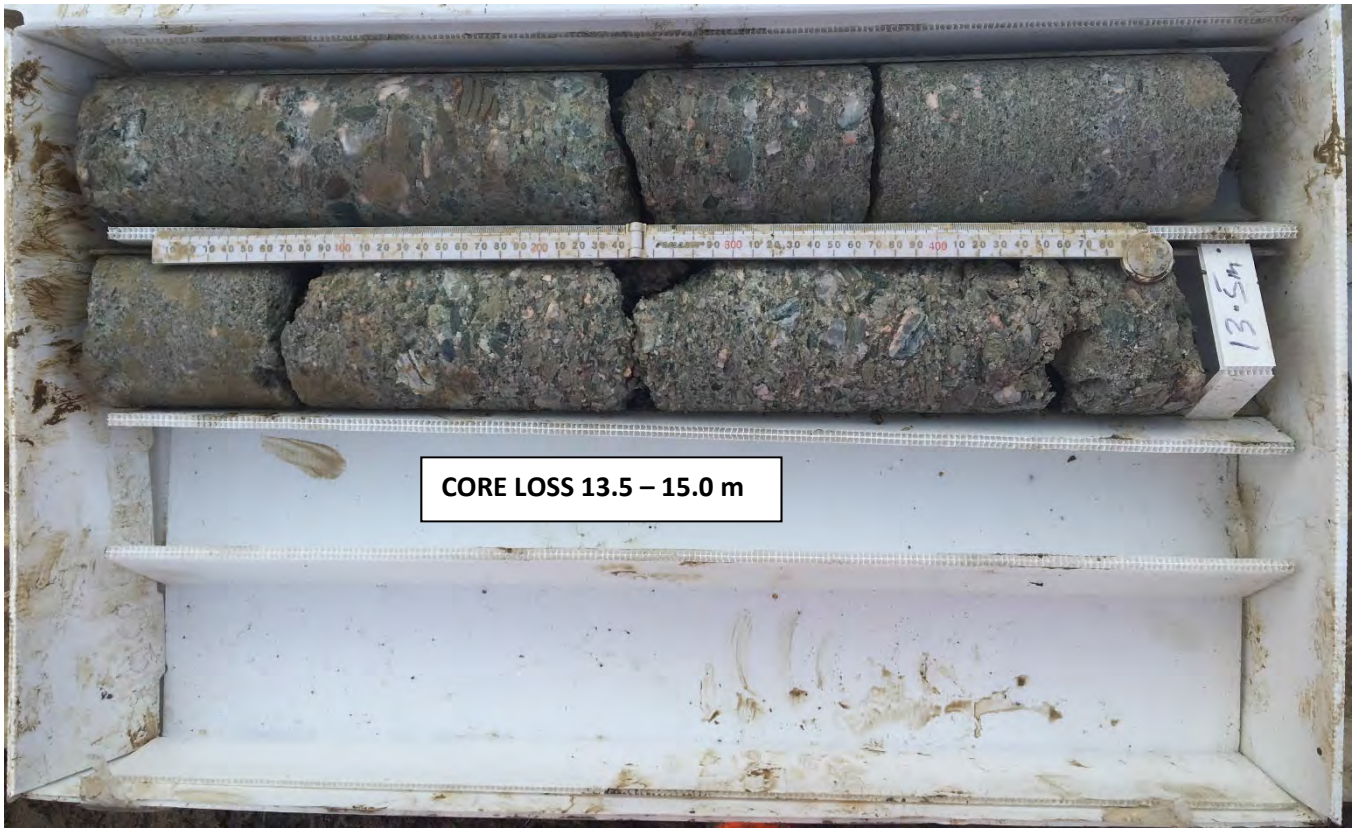


Box 2 of 5: 4.80 m to 7.20 m

Box 3 of 5: 8.20 m to 10 .20 m



Box 4 of 5: 10.20 m to 12.40 m



Box 5 of 5: 12.40 m to 15.00 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund Foundation
Job Number: 12506381
Commenced: 27/05/2019 Completed: 28/05/2019

Hole No. : BH02a
Sheet : 1 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396358.59 Northing: 788022.89 System: TAIETM2000
RL: 97.41 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
97	0	0.00 - 0.50 m: CORELOSS (inferred depth)														
96	0.5	SILT, minor clay, trace to minor fine sand; light grey brown. Stiff to very stiff, moist, non-plastic. Contains iron weathered spots and small (<50mm) lenses of iron staining (LOESS)	LOESS	M	St-VSt				PQTT				67			
95	1.5	1.50 - 2.15 m: CORELOSS (inferred depth)					SV@1.5m 58/7 kPa		PQTT				50			
95	2.15	Fine sandy SILT, trace clay; light grey. Firm, moist, non-plastic	ALLUVIUM	M	F				PQTT				70 70 70			
95	2.45	Silty fine SAND; grey. 'Very loose to loose', saturated, poorly graded (HISTORIC [PRE GLACIAL] ALLUVIUM)		S					PQTT							
94	2.9	Fine sandy SILT; grey. Firm, moist, non-plastic 2.80 m: black fibrous organic material (roots)		M	F				PQTT							
94	3.35	2.90 - 3.35 m: CORELOSS (inferred depth) (possible gravel)							PQTT		MW					
93	3.7	Fine GRAVEL; light grey. Gravel: quartz and schist, angular to sub-angular. Fine matrix washed away (HENLEY BRECCIA - MODERATELY WEATHERED)	HENLEY BRECCIA	S					PQTT				100 100 100			
93	3.95	Fine to coarse SAND, minor to some fine gravel; grey. 'Very dense', dry, non-plastic; gravel: angular to sub-rounded quartz and schist		D			SV@4.3m UTP		PQTT							
92		Unweathered, moderately thinly to moderately thickly interbedded ,grey SILTSTONE and fine grained SANDSTONE; very weak; uniform grainsize within layers *4.60* VN, 30°, QZ							PQTT		UW		100 100 100			
92	5.7	5.30 - 5.70 Unweathered, thinly interbedded grey BRECCIA (60%) and fine to medium grained grey SANDSTONE 40%; strong. Clasts: fine to medium gravel, angular of quartz and schist. Coarse sand matrix.							PQTT							
91	5.9	Silty CLAY; dark grey. Firm to stiff, moist, high plasticity							PQTT				100 100 100			
91	6.55	Unweathered, moderately thickly interbedded, grey fine SANDSTONE and SILTSTONE; very weak, poorly graded 6.11 m: 10 mm lignite							PQTT							
90	6.4	Unweathered, grey silty fine SANDSTONE; weak to moderately strong							PQTT							
89		Unweathered, bedded, grey BRECCIA; weak to moderately strong, no defects; clasts: fine to medium gravel, quartz and schist, angular to subrounded; coarse sand matrix							PQTT				100 100 100			
88		9.10 - 9.20 m: SILT, grey; hard, dry 9.20 - 11.00 m: moderately strong to strong							PQTT				96 96 96			
		9.80 m: clast size increased to fine to coarse gravel														

28-05-2019

Notes and Comments:
End of Hole @ 15.00m, Target Depth.
Groundwater SWL at 0.23 mbgl (31/05/2019).

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund Foundation
Job Number: 12506381
Commenced: 27/05/2019 Completed: 28/05/2019

Hole No. : BH02a
Sheet : 2 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396358.59 Northing: 788022.89 System: TAIETM2000
RL: 97.41 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
87	10		Unweathered, bedded, grey BRECCIA; weak to moderately strong, no defects; clasts: fine to medium gravel, quartz and schist, angular to subrounded; coarse sand matrix *(continued from layer starting at 6.6m)*	HENLEY BRECCIA					122mm	PQTT	25 50 75	UW	EW VW W MS S VS ES		20 60 200 600 2000		
86	11		11.00 - 11.80 m: weak to moderately strong							PQTT				100 100 100			
85	12		11.80 - 12.40 m: clast size fine to medium gravel, more matrix dominated, moderately strong to strong							PQTT				100 100 100			
84	13		12.40 - 13.50 m: matrix silt to coarse coarse sand, minor to some clay; weak to moderately strong clasts fine to corase gravel size														
83	14		13.50 - 15.00 m: matrix silt to coarse sand; moderately strong to strong							PQTT				100 100 100			
82	15		End of Hole @ 15.00m,Target Depth.														
81	16																
80	17																
79	18																
78	19																
	20																

Notes and Comments:
End of Hole @ 15.00m, Target Depth.
Groundwater SWL at 0.23 mbgl (31/05/2019).
Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
28/05/19	00:00	0.7	15

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund Foundation
Job Number: 12506381
Commenced: 27/05/2019 Completed: 28/05/2019

Hole No. : BH02b
Sheet : 1 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396358.59 Northing: 788022.89 System: TAIETM2000
RL: 97.41 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
97	0	0.00 - 0.50 m: CORELOSS (inferred depth)														
	0.5	SILT, minor clay, trace to minor fine sand; light grey brown. Stiff to very stiff, moist, non-plastic. Contains iron weathered spots and small (<50mm) lenses of iron staining (LOESS)	LOESS	M	St-VSt				PQTT				67			
96	1						SV@1.5m 42/5									
	1.5	1.50 - 2.15 m: CORELOSS (inferred depth)														
95	2								PQTT				50			
	2.15	Fine sandy SILT, trace clay; light grey. Firm, moist, non-plastic	ALLUVIUM	M	F											
	2.45	Silty fine SAND; grey. 'Very loose to loose', saturated, poorly graded (HISTORIC [PRE GLACIAL] ALLUVIUM)		S												
	2.9	Fine sandy SILT; grey. Firm, moist, non-plastic 2.80 m: black fibrous organic material (roots)		M	F		SV@2.8m									
94	3	2.90 - 3.35 m: CORELOSS (inferred depth) (possible gravel)														
	3.35	Fine GRAVEL; light grey. Gravel: quartz and schist, angular to sub-angular. Fine matrix washed away (HENLEY BRECCIA - MODERATELY WEATHERED)	HENLEY BRECCIA	S					PQTT		MW		70 70 70			
	3.7	Fine to coarse SAND, minor to some fine gravel; grey. 'Very dense', dry, non-plastic; gravel: angular to sub-rounded quartz and schist		D												
93	4						SV@4.3m UTP									
	3.95	Unweathered, moderately thinly to moderately thickly interbedded ,grey SILTSTONE and fine grained SANDSTONE; very weak; uniform grainsize within layers														
	4.60	*4.60* VN, 30°, QZ														
92	5								PQTT				100 100 100			
	5.3	5.30 - 5.70 Unweathered, thinly interbedded grey BRECCIA (60%) and fine to medium grained grey SANDSTONE 40%; strong. Clasts: fine to medium gravel, angular of quartz and schist. Coarse sand matrix.														
	5.7	Silty CLAY; dark grey. Firm to stiff, moist, high plasticity														
	5.9	Unweathered, moderately thickly interbedded, grey fine SANDSTONE and SILTSTONE; very weak, poorly graded 6.11 m: 10 mm lignite														
91	6								PQTT		UW		100 100 100			
	6.55	Unweathered, grey silty fine SANDSTONE; weak to moderately strong														
	6.4	Unweathered, bedded, grey BRECCIA; weak to moderately strong, no defects; clasts: fine to medium gravel, quartz and schist, angular to subrounded; coarse sand matrix														
90	7															
89	8								PQTT				100 100 100			
	9	9.10 - 9.20 m: SILT, grey; hard, dry 9.20 - 11.00 m: moderately strong to strong														
88	9								PQTT				96 96 96			
	9.8	9.80 m: clast size increased to fine to coarse gravel														
	10															

28-05-2019

Notes and Comments:
End of Hole @ 15.00m, Target Depth.
Groundwater SWL at 0.21 mbgl (31/05/2019).

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO1826

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund Foundation
Job Number: 12506381
Commenced: 27/05/2019 Completed: 28/05/2019

Hole No. : BH02b
Sheet : 2 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396358.59 Northing: 788022.89 System: TAIETM2000
RL: 97.41 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
87	11		Unweathered, bedded, grey BRECCIA; weak to moderately strong, no defects; clasts: fine to medium gravel, quartz and schist, angular to subrounded; coarse sand matrix *(continued from layer starting at 6.6m)*	HENLEY BRECCIA					122mm	PQTT		UW					
86	11		11.00 - 11.80 m: weak to moderately strong							PQTT				100 100 100			
85	12		11.80 - 12.40 m: clast size fine to medium gravel, more matrix dominated, moderately strong to strong														
	13		12.40 - 13.50 m: matrix silt to coarse coarse sand, minor to some clay; weak to moderately strong clasts fine to corase gravel size							PQTT				100 100 100			
84	13																
83	14		13.50 - 15.00 m: matrix silt to coarse sand; moderately strong to strong							PQTT				100 100 100			
82	15		End of Hole @ 15.00m,Target Depth.														
81	16																
80	17																
79	18																
78	19																
	20																

Notes and Comments:
End of Hole @ 15.00m, Target Depth.
Groundwater SWL at 0.21 mbgl (31/05/2019).
Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO1826

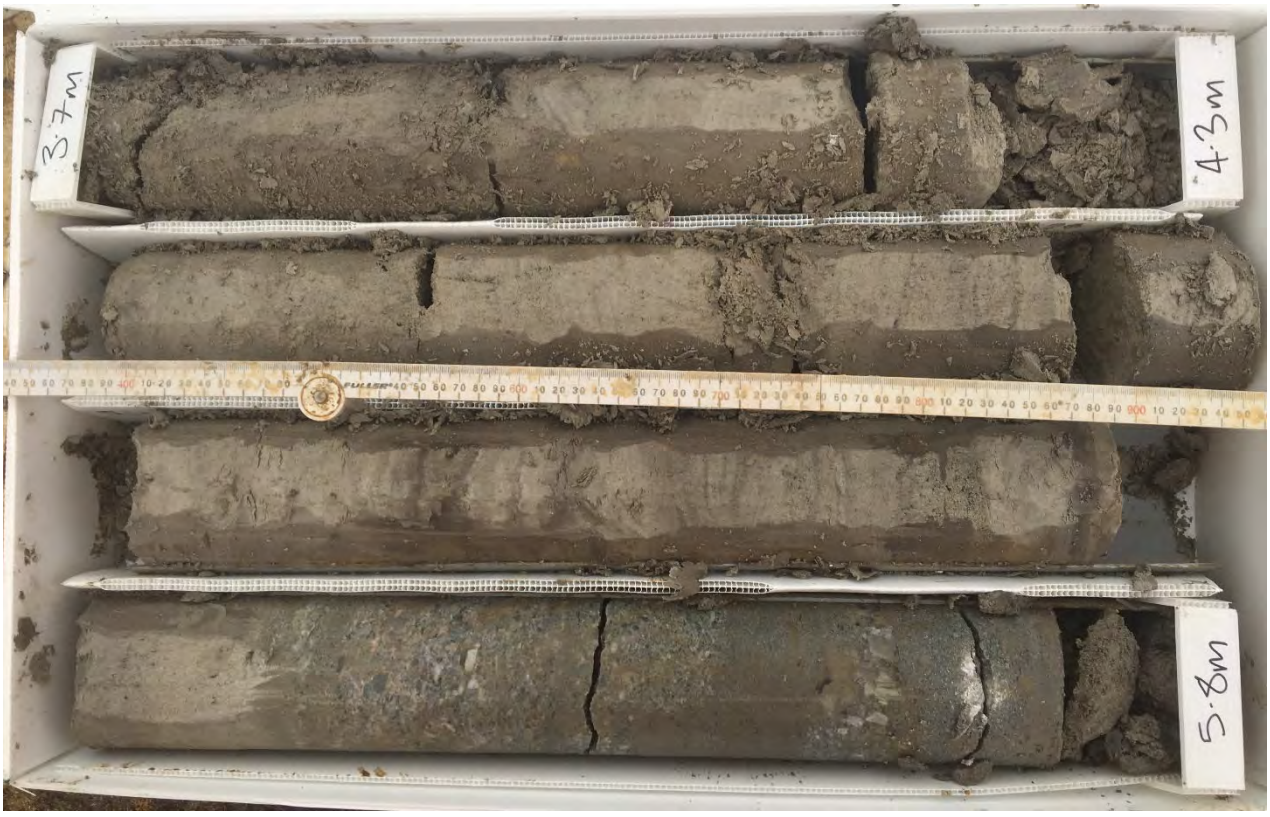
Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
28/05/19	00:00	0.7	15

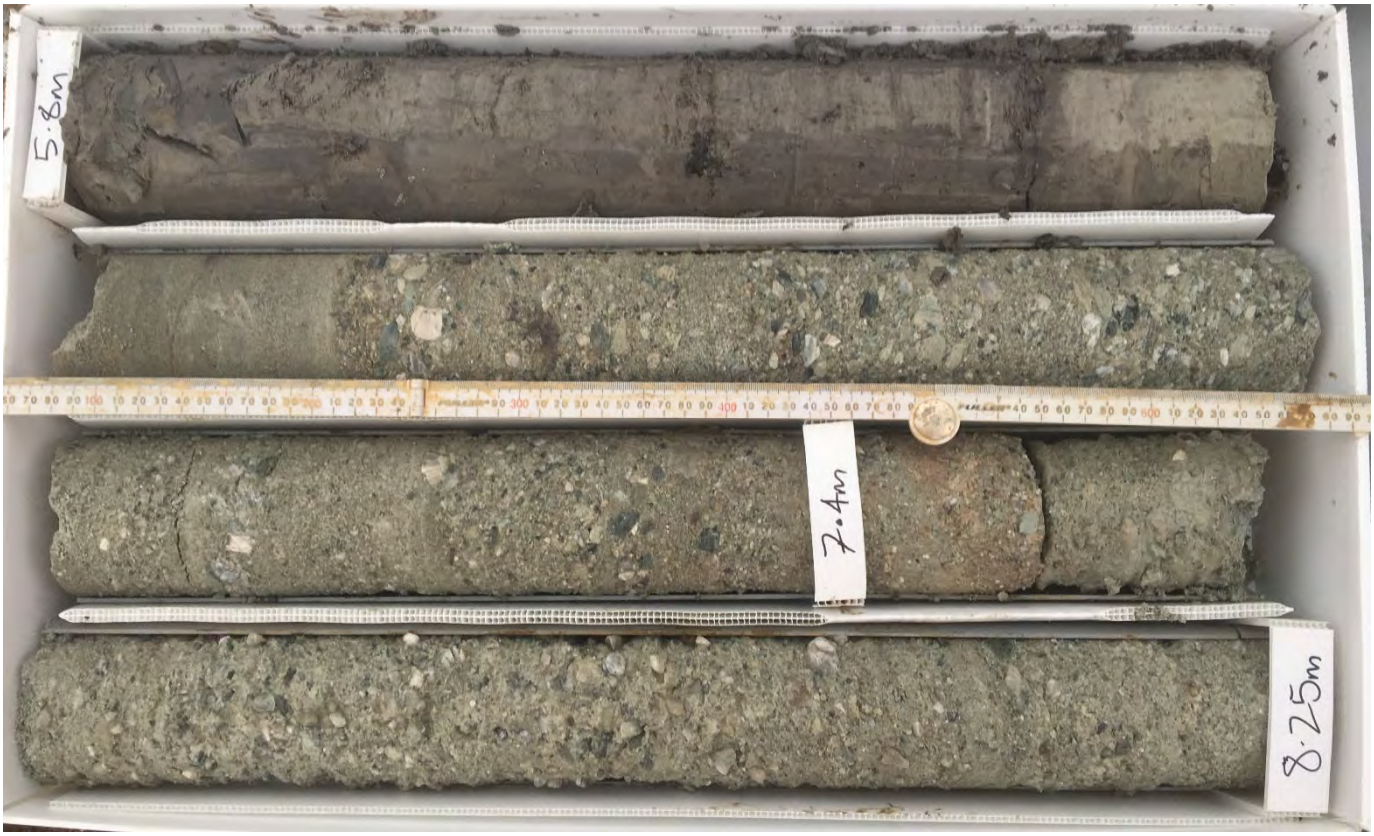
Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 3
Borehole ID	BH02	

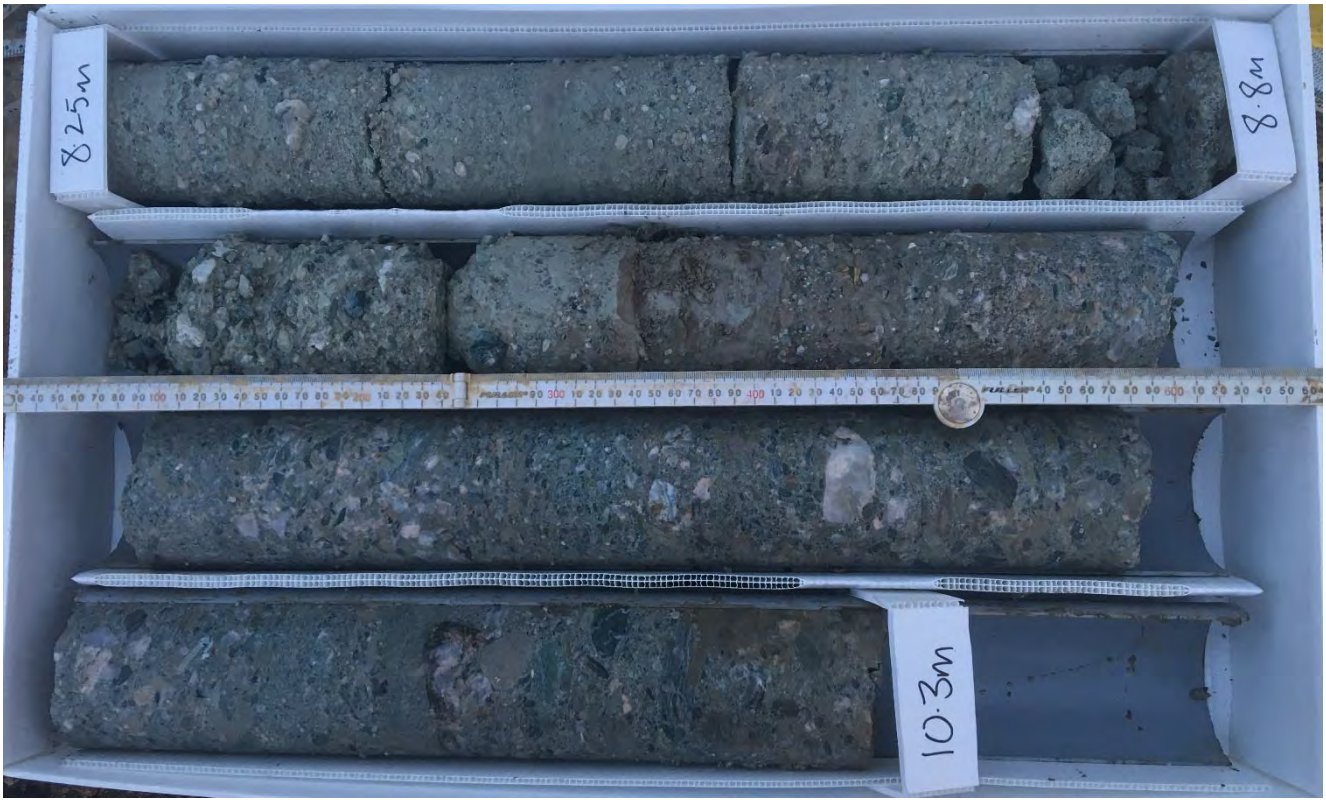
Box 1 of 6: 0.0 m to 3.7 m



Box 2 of 6: 3.7 m to 5.8 m

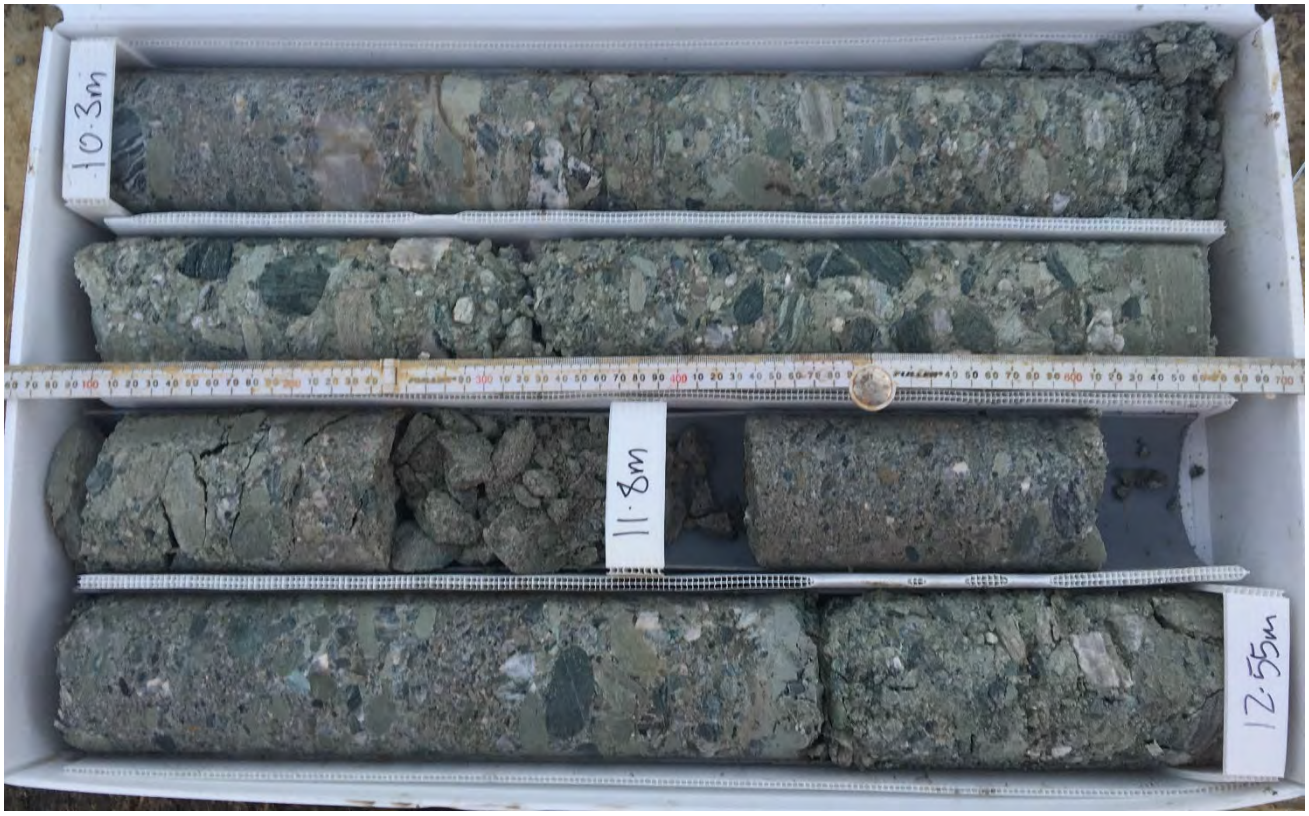


Box 3 of 6: 5.8 m to 8.25 m



Box 4 of 6: 8.25 m to 10.3 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 3 of 3
Borehole ID	BH02	



Box 5 of 6: 10.3 m to 12.55 m

Box 6 of 6: 12.55 m to 15.0 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund/Central Ridge
Job Number: 12506381
Commenced: 28/05/2019 Completed: 29/05/2019

Hole No. : BH03a
Sheet : 1 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396428.38 Northing: 787998.34 System: TAIETM2000
RL: 107.48 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
107	0.2	TOPSOIL: silt, minor clay; light brown and grey. Very stiff, moist, low plasticity; organics mixed in soil	TS	M	VSt				PQTT				73			
		Clayey SILT, trace fine sand, trace fine gravel; yellow-brown and light grey. Very stiff to hard, moist, high plasticity (LOESS)	LOESS		VSt-H		SV@1.5m 194 kPa									
106	1.9	SILT, minor clay, minor fine sand; light grey and orange-brown. Very stiff to hard, dry to moist, low plasticity		D-M	VSt-H				PQTT				100			
105	2.3	SILT, minor fine sand, trace clay; light grey and orange-brown. Hard, dry, non-plastic. Variable iron staining (HENLEY BRECCIA)		D	H				PQTT		CW		60			
	2.6	2.60 - 3.20 m: CORELOSS (inferred depth)														
104	3.2	Silty sandy coarse GRAVEL; brown. Well graded; clasts: angular to sub-angular quartz and schist. Completely weathered breccia														
	3.65	Fine to coarse GRAVEL, some silt, minor fine to coarse sand; purple. Dry, well graded; clasts: subangular to angular, quartz and schist (completely weathered breccia)							PQTT				27			
103	5.7	Highly weathered, red-grey BRECCIA; moderately strong; clasts, fine to coarse gravel, quartz and schist, matrix supported	HENLEY BRECCIA						PQTT		HW		100			
102	6.26.05	Fine to coarse GRAVEL, some silt, minor fine to coarse sand; purple. Dry, well graded; clasts: sub angular to angular, quartz and schist; highly weathered breccia		M												
101	6.6	SILT, minor fine to medium sand, trace to minor fine gravel; grey and yellow-brown. Very stiff, moist, non-plastic														
100	7.5	Fine to medium GRAVEL; white and grey. Well graded; clasts: angular to subangular, quartz and schist (matrix lost during drilling)							PQTT				38			
	7.9	SILT, trace fine gravel; brown-grey-light purple. Hard, dry, non plastic.		D	H											
99	8.45	Unweathered, dark-grey SILTSTONE; weak to moderately strong, no defects							PQTT		UW		100 100 100			
	8.9	Unweathered, grey fine SANDSTONE; weak to moderately strong; no defects														
98	9.2	8.90 - 9.20 m: CORELOSS (inferred depth) Likely 'loose' sand layer washed away							PQTT				73 73 73			
		Unweathered, moderately thickly interbedded, dark grey and grey SILTSTONE and SANDSTONE; weak to moderately strong, no defects														

Groundwater level at the end of drilling 29-05-2019

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
Groundwater SWL at 3.9 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund/Central Ridge
Job Number: 12506381
Commenced: 28/05/2019 Completed: 29/05/2019

Hole No. : BH03a
Sheet : 2 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396428.38 Northing: 787998.34 System: TAIETM2000
RL: 107.48 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
97	10.1		Unweathered, grey fine to medium SANDSTONE; very weak to weak, no defects							PQTT				100 100 100			
	10.7		SILT, minor clay; brown. Very stiff to hard, dry to moist, non-plastic (Possible relic Topsoil)		D-M	VSt-H											
11	10.9 11.05		Unweathered, light grey SILTSTONE; very weak to weak, no defects														
96			Unweathered, light grey and white BRECCIA; moderately strong to strong; clasts: quartz and schist, fine to medium gravel size, angular to subangular. Matrix supported, coarse sand matrix							PQTT				100 100 100			
12																	
95																	
13										PQTT				94 94 94			
94	13.65		Unweathered, light grey fine SANDSTONE; moderately strong to strong; no defects 13.79 m: 30 mm SILT layer; stiff														
14	14.2		Unweathered, moderately thinly to moderately thickly bedded, light grey and white BRECCIA; moderately strong to strong; clasts; quartz & schist, fine to medium gravel size, angular to sub angular. Matrix supported; coarse sand matrix. Distinct beds of fine and coarse clasts	HENLEY BRECCIA													
93																	
15										PQTT		UW		100 100 100			
92																	
16																	
91																	
17										PQTT				93 93 93			
90	17.2		Fine to medium SAND; grey. 'Dense', dry to moist, poorly graded, non lithified (SANDSTONE: Extremely weak to very weak)		D-M	'D'											
	17.6		Unweathered, light grey, fine SANDSTONE, moderately strong to strong, no defects														
18																	
89	18.25		Unweathered, grey BRECCIA; moderately strong to strong; clasts: quartz and schist, fine to medium grained sized; angular to sub-angular; clast supported 18.70 - 19.25 m: clasts fine to coarse gravel sized							PQTT				100 100 100			
19																	
88	19.25		Unweathered, light grey fine SANDSTONE; moderately strong to strong *19.40* JT, 15°, pl, r, VN, VE, Fe-stain End of Hole @ 20.00m,Target Depth.						122mm	PQTT				100 100 100			
20																	

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
Groundwater SWL at 3.9 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
29/05/19	00:00	3.9	20

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe bund/Central Ridge
Job Number: 12506381
Commenced: 28/05/2019 Completed: 29/05/2019

Hole No. : BH03b
Sheet : 1 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396428.38 Northing: 787998.34 System: TAIETM2000
RL: 107.48 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
107	0.2	TOPSOIL: silt, minor clay; light brown and grey. Very stiff, moist, low plasticity; organics mixed in soil	TS	M	VSt											
		Clayey SILT, trace fine sand, trace fine gravel; yellow-brown and light grey. Very stiff to hard, moist, high plasticity (LOESS)	LOESS		VSt-H		SV@1.5m 194 kPa		PQTT				73			
106	1.9	SILT, minor clay, minor fine sand; light grey and orange-brown. Very stiff to hard, dry to moist, low plasticity		D-M	VSt-H				PQTT				100			
105	2.3	SILT, minor fine sand, trace clay; light grey and orange-brown. Hard, dry, non-plastic. Variable iron staining (HENLEY BRECCIA)		D	H											
	2.6	2.60 - 3.20 m: CORELOSS (inferred depth)														
104	3.2	Silty sandy coarse GRAVEL; brown. Well graded; clasts: angular to sub-angular quartz and schist. Completely weathered breccia							PQTT		CW		60			
	3.65	Fine to coarse GRAVEL, some silt, minor fine to coarse sand; purple. Dry, well graded; clasts: subangular to angular, quartz and schist (completely weathered breccia)														
103									PQTT				27			
102	5.7	Highly weathered, red-grey BRECCIA; moderately strong; clasts, fine to coarse gravel, quartz and schist, matrix supported	HENLEY BRECCIA								HW					
	6.26.05	Fine to coarse GRAVEL, some silt, minor fine to coarse sand; purple. Dry, well graded; clasts: sub angular to angular, quartz and schist; highly weathered breccia		M					PQTT				100			
101	6.6	SILT, minor fine to medium sand, trace to minor fine gravel; grey and yellow-brown. Very stiff, moist, non-plastic														
		Fine to medium GRAVEL; white and grey. Well graded; clasts: angular to subangular, quartz and schist (matrix lost during drilling)														
100	7.5	SILT, trace fine gravel; brown-grey-light purple. Hard, dry, non plastic.		D	H				PQTT				38			
	7.9	Unweathered, dark-grey SILTSTONE; weak to moderately strong, no defects											100 100 100			
99	8.45	Unweathered, grey fine SANDSTONE; weak to moderately strong; no defects														
	8.9	8.90 - 9.20 m: CORELOSS (inferred depth) Likely 'loose' sand layer washed away														
98	9.2	Unweathered, moderately thickly interbedded, dark grey and grey SILTSTONE and SANDSTONE; weak to moderately strong, no defects							PQTT		UW		73 73 73			

29-05-2019 Groundwater level at the end of drilling

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
Groundwater SWL at 12.6 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe bund/Central Ridge
Job Number: 12506381
Commenced: 28/05/2019 Completed: 29/05/2019

Hole No. : BH03b
Sheet : 2 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396428.38 Northing: 787998.34 System: TAIETM2000
RL: 107.48 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
97	10.1		Unweathered, grey fine to medium SANDSTONE; very weak to weak, no defects							PQTT				100 100 100			
	10.7		SILT, minor clay; brown. Very stiff to hard, dry to moist, non-plastic (Possible relic Topsoil)		D-M	VSt-H											
11	10.9		Unweathered, light grey SILTSTONE; very weak to weak, no defects														
96	11.05		Unweathered, light grey and white BRECCIA; moderately strong to strong; clasts: quartz and schist, fine to medium gravel size, angular to subangular. Matrix supported, coarse sand matrix							PQTT				100 100 100			
12																	
95																	
13										PQTT				94 94 94			
94	13.65		Unweathered, light grey fine SANDSTONE; moderately strong to strong; no defects 13.79 m: 30 mm SILT layer; stiff														
14	14.2		Unweathered, moderately thinly to moderately thickly bedded, light grey and white BRECCIA; moderately strong to strong; clasts; quartz & schist, fine to medium gravel size, angular to sub angular. Matrix supported; coarse sand matrix. Distinct beds of fi	HENLEY BRECCIA													
93																	
15										PQTT		UW		100 100 100			
92																	
16																	
91																	
17	17.2		Fine to medium SAND; grey. 'Dense', dry to moist, poorly graded, non lithified (SANDSTONE: Extremely weak to very weak)		D-M	'D'				PQTT				93 93 93			
90	17.6		Unweathered, light grey, fine SANDSTONE, moderately strong to strong, no defects														
18																	
89	18.25		Unweathered, grey BRECCIA; moderately strong to strong; clasts: quartz and schist, fine to medium grained sized; angular to sub-angular; clast supported 18.70 - 19.25 m: clasts fine to coarse gravel sized							PQTT				100 100 100			
19																	
88	19.25		Unweathered, light grey fine SANDSTONE; moderately strong to strong *19.40* JT, 15°, pl, r, VN, VE, Fe-stain End of Hole @ 20.00m,Target Depth.						122mm	PQTT				100 100 100			

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
Groundwater SWL at 12.6 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

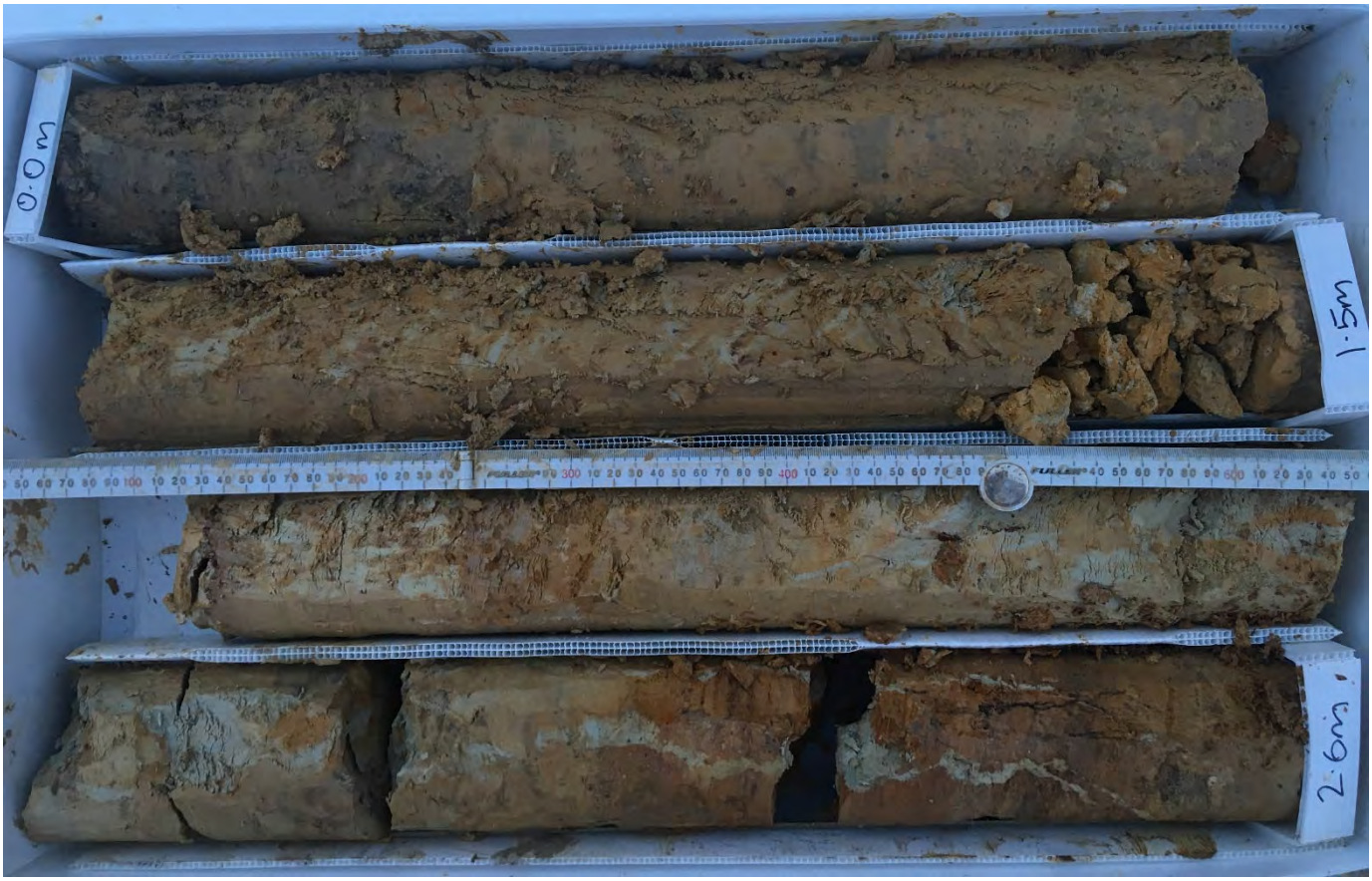
Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
29/05/19	00:00	3.9	20

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 4
Borehole ID	BH03	



Box 1 of 8: 0.0 m to 2.6 m

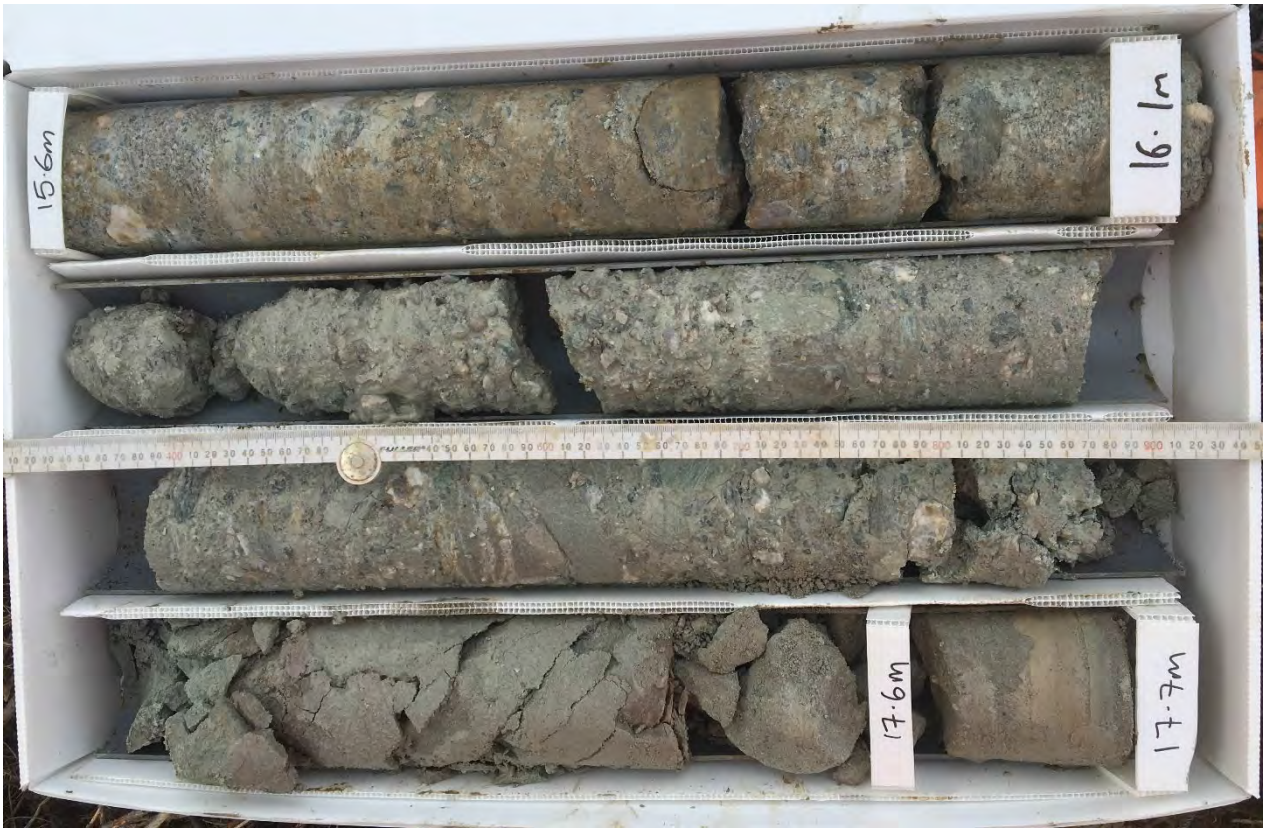
Box 2 of 8: 2.6 m to 6.25 m

Box 3 of 8: 6.25 m to 9.25 m

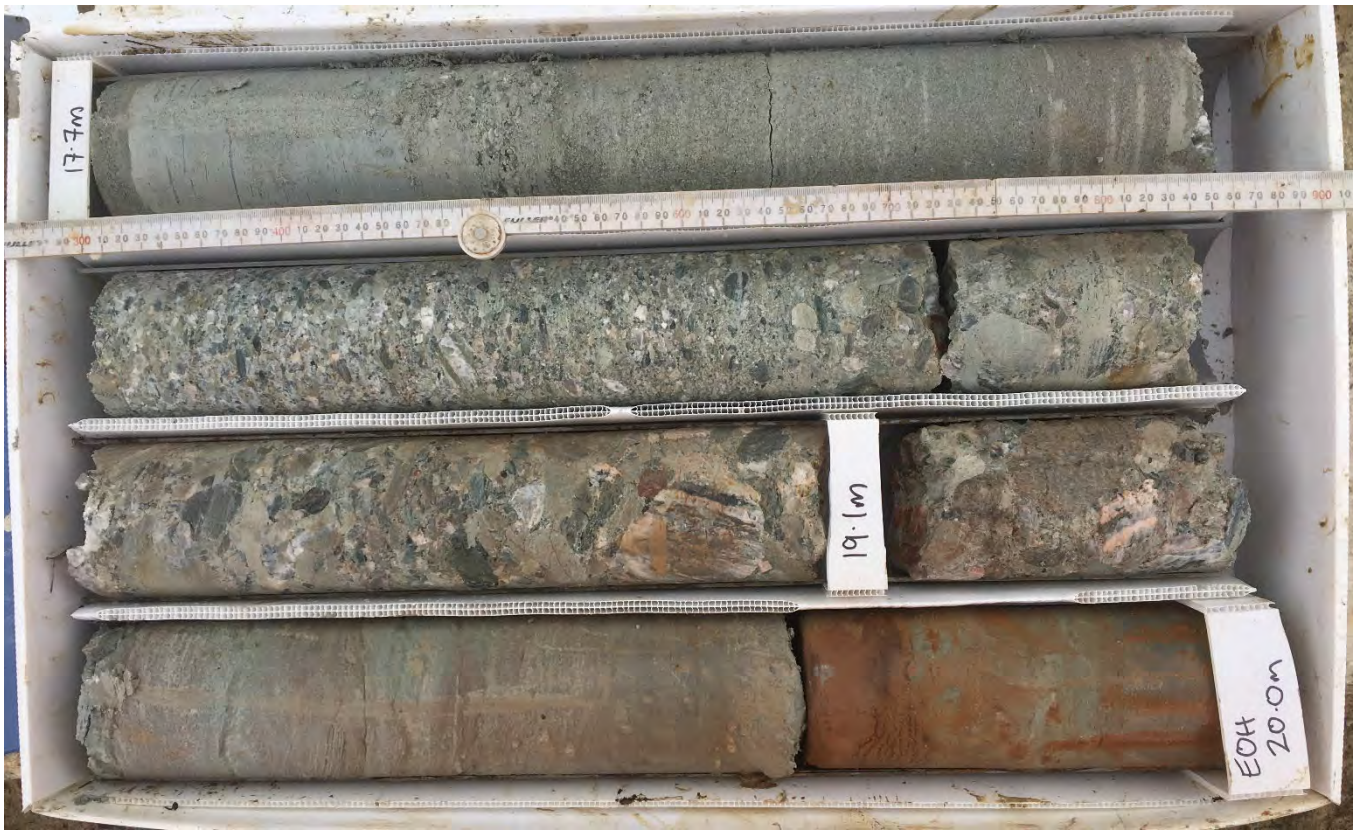
Box 4 of 8: 9.25 m to 11.05 m

Box 5 of 8: 11.05 m to 13.3 m

Box 6 of 8: 13.3 m to 15.6 m



Box 7 of 8: 15.6 m to 17.7 m



Box 8 of 8: 17.7 m to 20.0 m (EOH)

Project : Smooth Hill Landfill Consenting	Hole No. : BH04a
Client : Dunedin City Council	Sheet : 1 of 2
Site : Toe Bund Foundation	Hole Length : 15.00m
Job Number: 12506381	Scale @ A4 : 1:50
Commenced: 6/06/2019 Completed: 7/06/2019	Logged : MF
Easting: 396563.6 Northing: 788063.75 System: TAIETM2000	Processed : HB
RL: 108.15 Datum: NZVD2016	Checked : JHS

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Method	Weathering	TCR SCR RQD (%)
0 - 0.25	TOPSOIL: silt, minor clay; dark grey. Firm, moist, low plasticity 0.20 m: some intermixing with underlying soil	FILL	M	F	PQTT		100
0.25 - 0.9	SILT, minor clay, trace fine sand; orange-brown. Stiff, moist, low plasticity, trace roots (LOESS) 0.60 m: light grey with orange-brown streaks, stiff to very stiff	LOESS	M	St St-VSt	PQTT		100
0.9 - 1.5	Silty fine to medium SAND; grey with orange streaks, moist, poorly graded 1.10 m: trace fine gravel, sub-angular to sub-rounded, quartz and schist	LOESS	M		PQTT		
1.5 - 1.4	SILT with roots; grey. Stiff to very stiff, moist, non-plastic (RELIC TOPSOIL)	B	M	St-VSt	PQTT		73
1.4 - 2.45	Silty, sandy, fine to medium GRAVEL; orange-brown. Well graded; gravel: quartz and schist, sub-angular to sub-rounded; sand: fine to coarse; highly weathered breccia (HENLEY BRECCIA)	HENLEY BRECCIA			PQTT		73
2.45 - 2.8	2.45 - 2.80 m: CORELOSS (inferred depth)	HENLEY BRECCIA			PQTT		
2.8 - 4.4	Moderately weathered, laminated to very thinly bedded, light grey and orange-brown fine to medium SANDSTONE; very weak to weak; no defects. Iron staining throughout. Lamination dip varies from sub-horizontal to sub-vertical	HENLEY BRECCIA			PQTT	HW	100 100 100
4.4 - 4.7	Moderately weathered, CONGLOMERATE; extremely weak to very weak; well graded; clasts: fine to coarse gravel, quartz and schist, sub-angular to rounded; silt matrix, matrix supported	HENLEY BRECCIA			PQTT	HW	20 0 0
4.7 - 5.9	4.70 - 5.90 m: CORELOSS (inferred depth)	HENLEY BRECCIA			PQTT	HW	
5.9 - 6.4	5.90 - 6.40 m: CORELOSS (inferred depth)	HENLEY BRECCIA			PQTT	HW	
6.4 - 8.85	Slightly weathered, grey with purple-brown layers, fine to medium SANDSTONE; very weak to weak; poorly graded 7.00 - 7.40 m: moderately strong to strong 7.40 - 8.40 m: very weak to weak 8.40 - 8.85 m: moderately strong to strong	HENLEY BRECCIA			PQTT	SW	69 69 69 100 100 75
8.85 - 8.7	Slightly weathered, BRECCIA; moderately strong to strong; fine to medium gravel clasts, fine to coarse sand matrix	HENLEY BRECCIA			PQTT	SW	
8.7 - 10	Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak; no defects; poorly graded 9.60 m: moderately strong to strong	HENLEY BRECCIA			PQTT	SW	83 50 50

Water level: 7-06-2019 (approx. 2 m)

Notes and Comments:

End of Hole @ 15.00m, Target Depth.

Groundwater at 2.52 mbtoc (TOC 0.53 m agl) - corrected groundwater at 1.99 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: McNeills

Equipment: UDR600 (truck mounted)

Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund Foundation
Job Number: 12506381
Commenced: 6/06/2019 Completed: 7/06/2019

Hole No. : BH04a
Sheet : 2 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396563.6 Northing: 788063.75 System: TAIETM2000
RL: 108.15 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
98	10.1																
			Slightly weathered, grey BRECCIA; moderately strong to strong; very widely spaced defects; well indurated; clasts: fine to medium gravel, quartz and schist, sub-angular to sub-rounded; fine to coarse sand matrix, matrix supported							PQTT				83 50 50			
	10.8 10.6		Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak; no defects														
97	11.1		Slightly weathered, brown SILTSTONE; very weak to weak; no defects (Possible Relic Topsoil) 11.00 m: light grey											97 97 97			
			Slightly weathered, light grey and pink-grey BRECCIA; weak to moderately strong; no defects; moderately well indurated; clasts: fine to coarse gravel, quartz and schist, sub-angular to angular, clast supported, clast size decreases with depth; fine to coarse sand matrix 11.50 - 12.20 m: moderately strong to strong, fine to medium gravel clasts 12.20 - 15.00 m: weak to moderately strong, fine to coarse gravel clasts	HENLEY BRECCIA							SW				
96																	
95														88 64 56			
94			13.90 m: clasts medium to coarse gravel											100 73 73			
93			End of Hole @ 15.00m,Target Depth.														
92																	
91																	
90																	
89																	

Notes and Comments:
End of Hole @ 15.00m, Target Depth.
Groundwater at 2.52 mbtoc (TOC 0.53 m agl) - corrected groundwater at 1.99 mbgl 07/06/2019.
Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/06/19	00:00	1.99	15

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund Foundation
Job Number: 12506381
Commenced: 6/06/2019 Completed: 7/06/2019

Hole No. : BH04b
Sheet : 1 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396563.6 Northing: 788063.75 System: TAIETM2000
RL: 108.15 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
108	0	TOPSOIL: silt, minor clay; dark grey. Firm, moist, low plasticity	FILL	M	F											
	0.25	0.20 m: some intermixing with underlying soil		M	St											
		SILT, minor clay, trace fine sand; orange-brown. Stiff, moist, low plasticity, trace roots (LOESS)	LOESS		St-VSt											
107	0.9	0.60 m: light grey with orange-brown streaks, stiff to very stiff							PQTT				100			
1		Silty fine to medium SAND; grey with orange streaks, moist, poorly graded		M												
	1.4	1.10 m: trace fine gravel, sub-angular to sub-rounded, quartz and schist														
106	1.5	SILT with roots; grey. Stiff to very stiff, moist, non-plastic (RELIC TOPSOIL)	B	M	St-VSt											
2		Silty, sandy, fine to medium GRAVEL; orange-brown. Well graded; gravel: quartz and schist, sub-angular to sub-rounded; sand: fine to coarse; highly weathered breccia (HENLEY BRECCIA)							PQTT				73			
	2.45	2.45 - 2.80 m: CORELOSS (inferred depth)														
105	2.8	Moderately weathered, laminated to very thinly bedded, light grey and orange-brown fine to medium SANDSTONE; very weak to weak; no defects. Iron staining throughout. Lamination dip varies from sub-horizontal to sub-vertical							PQTT		HW		100 100 100			
4																
104	4.4	Moderately weathered, CONGLOMERATE; extremely weak to very weak; well graded; clasts: fine to coarse gravel, quartz and schist, sub-angular to rounded; silt matrix, matrix supported														
	4.7	4.70 - 5.90 m: CORELOSS (inferred depth)														
5									PQTT				20 0 0			
103	5.9	5.90 - 6.40 m: CORELOSS (inferred depth)	HENLEY BRECCIA													
102	6.4	Slightly weathered, grey with purple-brown layers, fine to medium SANDSTONE; very weak to weak; poorly graded							PQTT				69 69 69			
6																
7		7.00 - 7.40 m: moderately strong to strong														
101		7.40 - 8.40 m: very weak to weak														
8									PQTT		SW		100 100 75			
100		8.40 - 8.85 m: moderately strong to strong														
	8.85	Slightly weathered, BRECCIA; moderately strong to strong; fine to medium gravel clasts, fine to coarse sand matrix														
9	8.7	Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak; no defects; poorly graded							PQTT				83 50 50			
99		9.60 m: moderately strong to strong														
																7-06-2019
10																

Notes and Comments:
End of Hole @ 15.00m, Target Depth.

Groundwater at 5.08 mbtoc (TOC 0.53 m agl) - corrected groundwater at 4.55 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Toe Bund Foundation
Job Number: 12506381
Commenced: 6/06/2019 Completed: 7/06/2019

Hole No. : BH04b
Sheet : 2 of 2
Hole Length : 15.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396563.6 Northing: 788063.75 System: TAIETM2000
RL: 108.15 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
98	10.1																
	10.6		Slightly weathered, grey BRECCIA; moderately strong to strong; very widely spaced defects; well indurated; clasts: fine to medium gravel, quartz and schist, sub-angular to sub-rounded; fine to coarse sand matrix, matrix supported							PQTT				83 50 50			
	10.8		Slightly weathered, light grey fine to coarse SANDSTONE; very weak to weak; no defects														
97	11.1		Slightly weathered, brown SILTSTONE; very weak to weak; no defects (Possible Relic Topsoil) 11.00 m: light grey							PQTT				97 97 97			
			Slightly weathered, light grey and pink-grey BRECCIA; weak to moderately strong; no defects; moderately well indurated; clasts: fine to coarse gravel, quartz and schist, sub-angular to angular, clast supported, clast size decreases with depth; fine to coa 11.50 - 12.20 m: moderately strong to strong, fine to medium gravel clasts 12.20 - 15.00 m: weak to moderately strong, fine to coarse gravel clasts	HENLEY BRECCIA						PQTT	SW		88 64 56			
96	12																
95	13																
94	14		13.90 m: clasts medium to coarse gravel							PQTT				100 73 73			
93	15		End of Hole @ 15.00m,Target Depth.														
92	16																
91	17																
90	18																
89	19																

Notes and Comments:
End of Hole @ 15.00m, Target Depth.

Groundwater at 5.08 mbtoc (TOC 0.53 m agl) - corrected groundwater at 4.55 mbgl 07/06/2019.

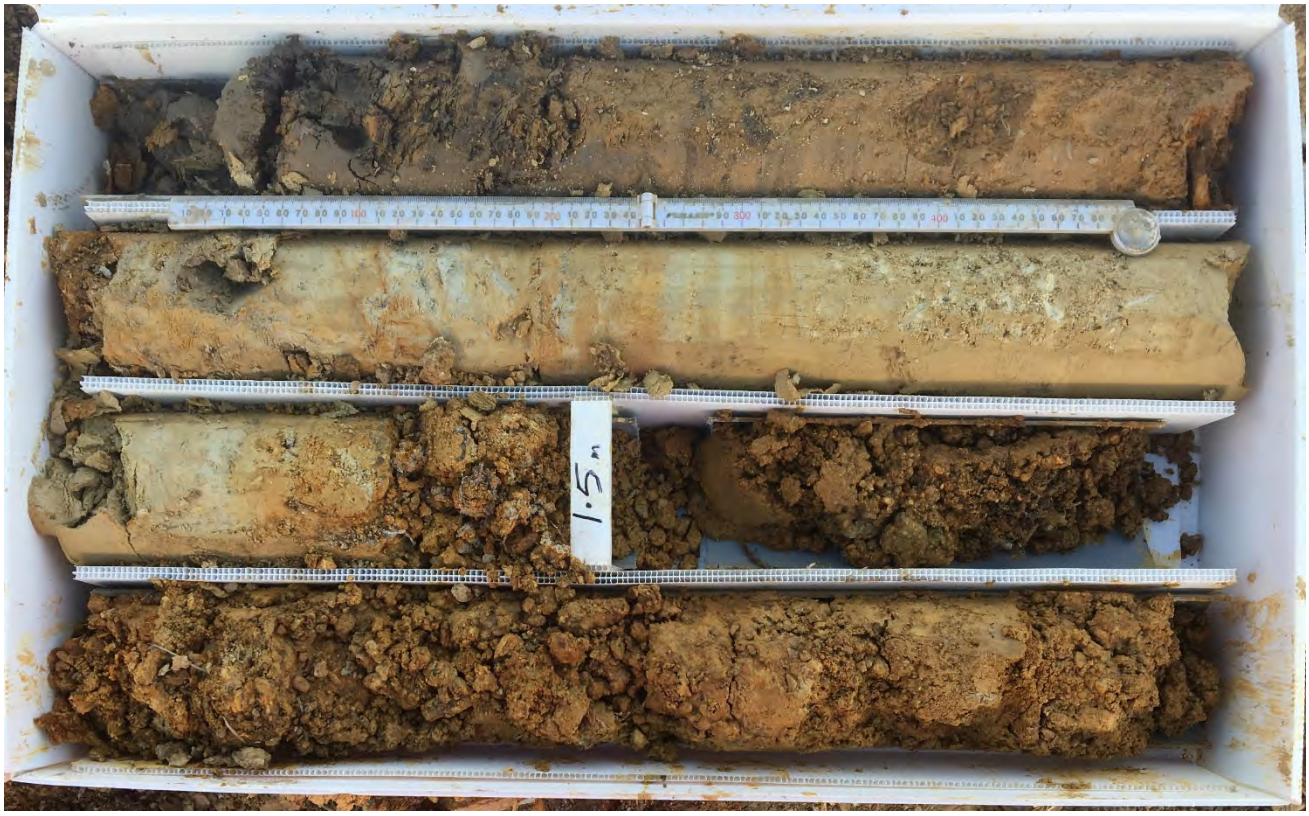
Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

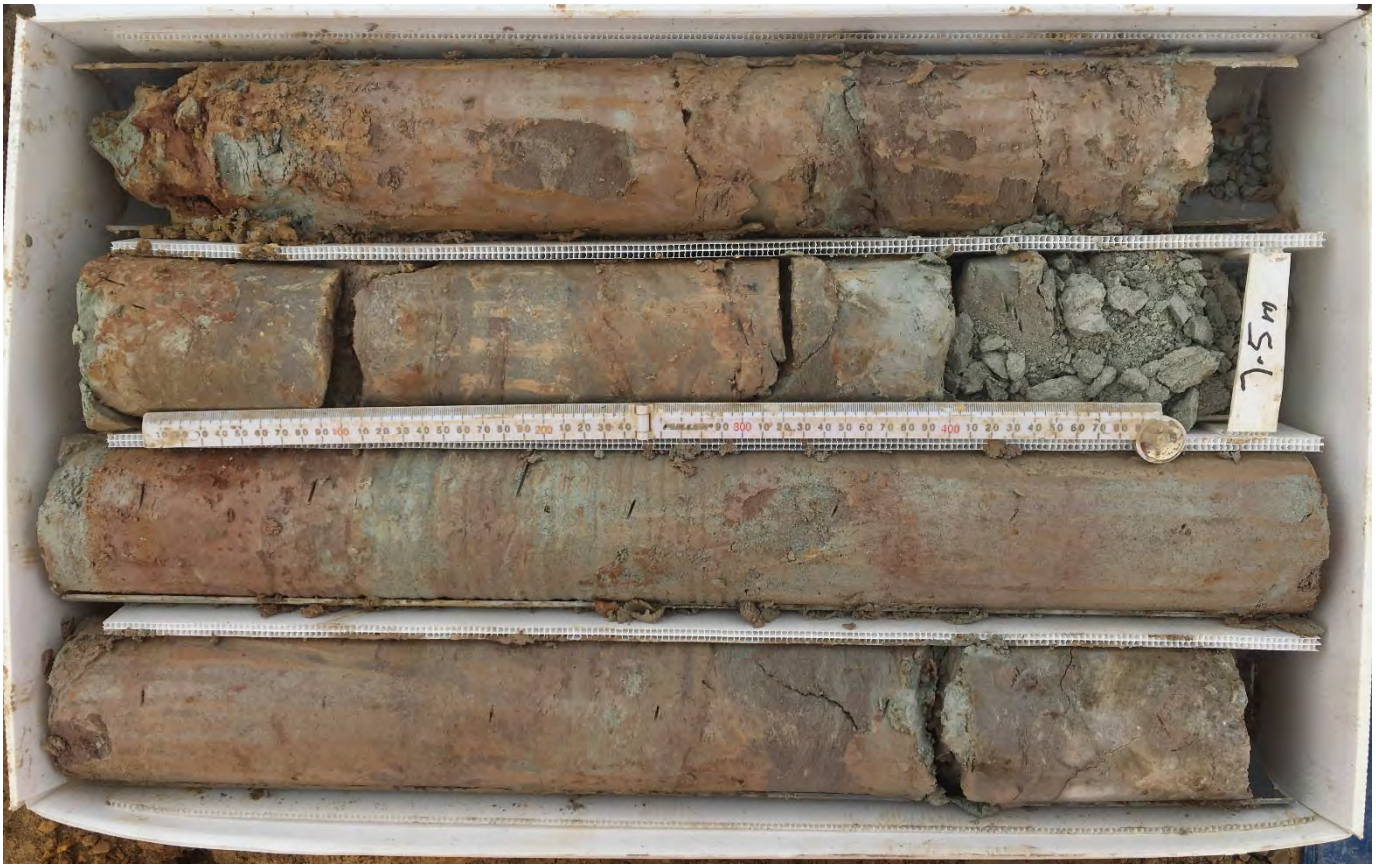
Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/06/19	00:00	4.55	15

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 3
Borehole ID	BH04	



Box 1 of 6: 0.0 m to 2.7 m

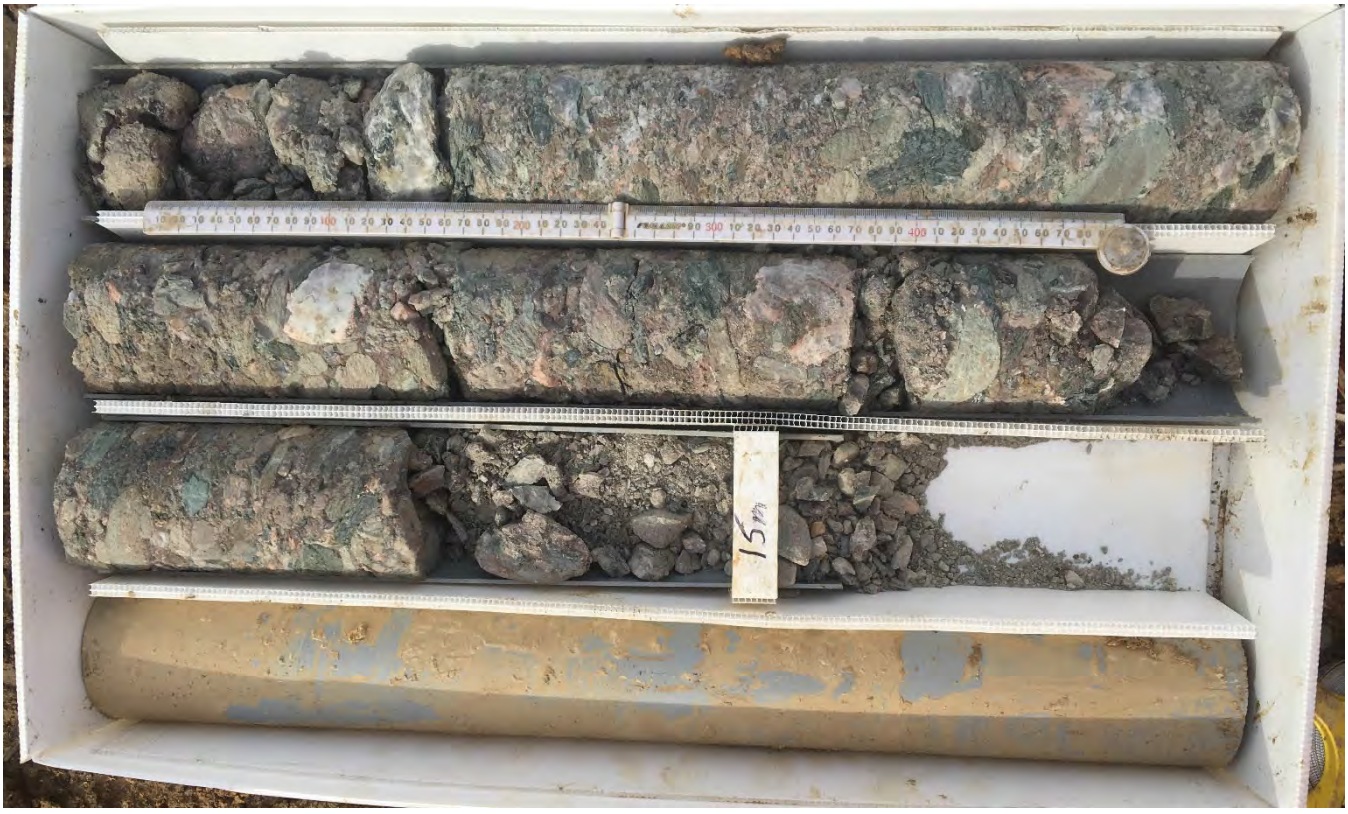
Box 2 of 6: 2.7 m to 5.9 m



Box 3 of 6: 5.9 m to 8.7 m

Box 4 of 6: 8.7 m to 11.1 m

Box 5 of 6: 11.1 m to 13.5 m



Box 6 of 6: 13.5 m to 15.0 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 29/05/2019 Completed: 30/05/2019

Hole No. : BH05a
Sheet : 1 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396459.76 Northing: 787862.12 System: TAIETM2000
RL: 129.5 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
129	0	Clayey SILT; grey and dark orange-brown. Very stiff, moist, high plasticity (LOESS)	LOESS	M	VSt	0.00			PQTT							
	0.8	SILT, minor clay, trace fine sand; orange-brown mottled grey. Very stiff, moist, low plasticity		M	VSt								100			
1	1	Gravelly SILT, trace clay; orange-brown and white. Very stiff, moist, low plasticity; gravel is fine to medium, angular to sub-angular schist		M	VSt	1.20	SV@1.5m UTP									
128	1.5	1.50 - 2.70 m: CORELOSS														
2									PQTT				0			
127	2.7	Gravelly SILT, trace clay; orange-brown and white. Very stiff, moist, low plasticity. Gravel is fine to medium, angular to sub-angular schist. Completely to highly weathered rock (HENLEY BRECCIA)		M	VSt											
3	3.5	2.80 - 3.50 m: CORELOSS														
126	3.8	Fine to medium GRAVEL; cream/white. Well graded, gravel: quartz and schist, angular to sub-angular		M	VSt						HW-CW		53			
		Gravelly SILT, trace clay; orange-brown and white. Very stiff, moist, low plasticity; iron staining on upper contact; gravel is fine to medium, angular to sub-angular, of quartz schist		D-M	H											
4	4			M	VSt											
125	4.45	SILT, trace organics; light grey. Hard, dry to moist, non-plastic. Highly weathered rock		D-M	H											
		Gravelly SILT, trace clay, trace organics; orange-brown and light grey. Very stiff, moist, non-plastic; gravel is fine to medium, angular to sub-angular, of quartz schist														
5									PQTT				100			
124	5.7	SILT, trace clay, trace organics; light grey with orange-brown streaks. Hard, dry to moist, non-plastic 5.10 m: orange-brown mottled light grey 5.35 m: 2-3 mm iron "gravel" beds 5.60 m: thinly laminated	HENLEY BRECCIA	M	St-VSt		SV@5.7m UTP				HW					
6	5.9	Silty CLAY, trace fine sand, trace organics; grey-brown. Stiff to very stiff, moist, high plasticity		M	H											
123	6.5	SILT, trace clay, trace organics; light grey with black flecks. Hard, moist, non-plastic. Iron staining on lower contact		M	H								100			
	6.8	SILT, trace medium gravel; grey-brown. Hard, moist, non-plastic; dark orange-brown iron stained contact at 6.80 m		D	H											
7	7.2	SILT, trace organics; light grey and orange-brown, with black flecks. Hard, dry, non-plastic, thin (<1mm) 'rusty' laminations														
122		Moderately weathered, thinly bedded, dark grey with black streaks SILTSTONE; very weak to weak; moderately wide to widely spaced defects; contains organic-rich layers 7.75 m: 50 mm fine grained sandstone interbed 7.90 - 8.50 m: with closely spaced lignite interlamination/ very thin interbeds														
8									PQTT		MW		100 93 87			
121		8.50 m: slightly weathered 8.70 m: weak to moderately strong														
9	9.1															
120		Slightly weathered, grey, SANDSTONE; weak to moderately strong; wide spaced defects; fine sand to coarse gravel size grains 9.60 m: 170 mm siltstone interbed							PQTT		SW		93 93 93			

Notes and Comments:
End of Hole @ 30.00m, Target Depth.

~ 0.5 m topsoil stripped to make drill pad
Groundwater SWL at 16.4 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 29/05/2019 Completed: 30/05/2019

Hole No. : BH05a
Sheet : 2 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396459.76 Northing: 787862.12 System: TAIETM2000
RL: 129.5 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
119	10		Slightly weathered, grey, SANDSTONE; weak to moderately strong; wide spaced defects; fine sand to coarse gravel size grains *(continued from layer starting at 9.1m)* 10.20 - 10.90 m: fine grained 10.25 m: 20 mm lignite interbed							PQTT				97 97 97			
118	11		10.90 - 11.40 m: fine to coarse sand, trace fine gravel of quartz schist														
117	12		11.40 - 14.10 m: fine grained size, occasional organic laminates, widely spaced defects, black staining on faces							PQTT				100 100 100			
116	13		12.69 m: 50mm thick organic-rich layer, 2 mm lignite at each end 13.20 m: moderately strong to strong														
115	14	14.1	Slightly weathered, massive, grey and white BRECCIA; moderately strong to strong; very widely spaced defects; matrix supported; clasts: fine to coarse gravel size, angular to sub-angular, quartz and schist, some clasts up to cobble size; matrix: coarse sand 14.60 - 15.60 m: weak to moderately strong	HENLEY BRECCIA						PQTT				100 100 100			
114	15											SW					
113	16		15.60 - 16.20 m: moderately strong to strong 16.20 - 16.60 m: weak to moderately strong 16.60 - 17.10 m: moderately strong to strong							PQTT				100 93 93			
112	17	17.7	17.10 - 17.70 m: weak to moderately strong											87 80 67			
111	18	18.1	17.70 - 18.10 m: CORELOSS Slightly weathered, massive, grey and white BRECCIA; very weak to weak; very widely spaced defects; clast supported. Clasts: fine to coarse gravel size, angular to sub-angular, quartz and schist, some clasts up to cobble size 18.30 m: coarse gravel dominated 18.50 - 19.20 m: moderately strong to strong, harder matrix							PQTT				100 93 93			
110	19	19.2	Slightly weathered, grey, fine SANDSTONE; very weak to weak; moderately widely spaced; orange iron stained layer. Breaks preferentially on iron stained layers							PQTT				100 94 94			
	20																

Notes and Comments:
End of Hole @ 30.00m, Target Depth.

~ 0.5 m topsoil stripped to make drill pad
Groundwater SWL at 16.4 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 29/05/2019 Completed: 30/05/2019

Hole No. : BH05a
Sheet : 3 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396459.76 Northing: 787862.12 System: TAIETM2000
RL: 129.5 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
109	20	Slightly weathered, grey, fine SANDSTONE; very weak to weak; moderately widely spaced; orange iron stained layer. Breaks preferentially on iron stained layers *(continued from layer starting at 19.2m)*							PQTT				100 94 94			
108	21	20.00 m: spaced thin siltstone interbeds 20.55 m: moderately strong to strong 20.65 - 21.80 m: very weak to weak							PQTT				100 100 100			
107	22	21.80 - 22.00 m: weak to moderately strong 21.95 m: 20 mm SILTSTONE interbed 22.00 m: moderately strong to strong														
	22.4	Slightly weathered, grey, pink and white BRECCIA; moderately strong to strong; very widely spaced defects; clast supported; clasts: fine to coarse gravel size, angular to sub-angular, quartz and schist	HENLEY BRECCIA						PQTT				87 87 77			
106	23															
105	24	23.80 - 24.20 m: clasts: fine gravel size with occasional coarse gravel 24.10 - 24.30 m: very weak to weak 24.30 - 24.65 m: moderately strong to strong 24.65 - 24.75 m: very weak to weak 24.75 - 26.65 m: moderately strong to strong							PQTT		SW		100 93 93			
104	25	25.30 - 26.65 m: clasts fine to coarse gravel sized														
103	26								PQTT				87 87 73			
	26.65	Reddish brown SILTSTONE; extremely weak to very weak														
102	27	26.80 m: light grey, SILT/SAND mix; hard/very dense							PQTT				100 100 100			
	27.3	Silty fine to medium silty SANDSTONE, very weak; sharp base contact with breccia, dips 20-30°														
	27.8	Slightly weathered, light brown, grey and white BRECCIA; weak to moderately strong; very widely spaced defects; clast supported; clasts: fine to coarse gravel size, quartz and schist, angular to sub-angular 28.40 - 30.00 0														
101	28															
100	29							122mm	PQTT		UW		94 91 91			
	30	End of Hole @ 30.00m,Target Depth.														

Notes and Comments:
End of Hole @ 30.00m, Target Depth.

~ 0.5 m topsoil stripped to make drill pad
Groundwater SWL at 16.4 mbgl during piezo install.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
30/05/19	00:00		30

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 29/05/2019 Completed: 30/05/2019

Hole No. : BH05b
Sheet : 1 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396459.76 Northing: 787862.12 System: TAIETM2000
RL: 129.5 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
129	0	Clayey SILT; grey and dark orange-brown. Very stiff, moist, high plasticity (LOESS)	LOESS	M	VSt				PQTT				100			
	0.8	SILT, minor clay, trace fine sand; orange-brown mottled grey. Very stiff, moist, low plasticity		M	VSt											
1		Gravelly SILT, trace clay; orange-brown and white. Very stiff, moist, low plasticity; gravel is fine to medium, angular to sub-angular schist		M	VSt											
128	1.5	1.50 - 2.70 m: CORELOSS					SV@1.5m UTP									
2									PQTT				0			
127	2.7	Gravelly SILT, trace clay; orange-brown and white. Very stiff, moist, low plasticity. Gravel is fine to medium, angular to sub-angular schist. Completely to highly weathered rock (HENLEY BRECCIA)		M	VSt											
3	3.5	2.80 - 3.50 m: CORELOSS									HW-CW		53			
126	3.8	Fine to medium GRAVEL; cream/white. Well graded, gravel: quartz and schist, angular to sub-angular		M	VSt				PQTT							
	4	Gravelly SILT, trace clay; orange-brown and white. Very stiff, moist, low plasticity; iron staining on upper contact; gravel is fine to medium, angular to sub-angular, of quartz schist		D-M	H											
125	4.45	SILT, trace organics; light grey. Hard, dry to moist, non-plastic. Highly weathered rock		M	VSt											
		Gravelly SILT, trace clay, trace organics; orange-brown and light grey. Very stiff, moist, non-plastic; gravel is fine to medium, angular to sub-angular, of quartz schist		D-M	H											
5		SILT, trace clay, trace organics; light grey with orange-brown streaks. Hard, dry to moist, non-plastic 5.10 m: orange-brown mottled light grey 5.35 m: 2-3 mm iron "gravel" beds 5.60 m: thinly laminated	HENLEY BRECCIA								HW		100			
124	5.7			M	St-VSt		SV@5.7m UTP									
	5.9	Silty CLAY, trace fine sand, trace organics; grey-brown. Stiff to very stiff, moist, high plasticity		M	H											
123	6.5	SILT, trace clay, trace organics; light grey with black flecks. Hard, moist, non-plastic. Iron staining on lower contact		M	H				PQTT				100			
	6.8	SILT, trace medium gravel; grey-brown. Hard, moist, non-plastic; dark orange-brown iron stained contact at 6.80 m		D	H											
7	7.2	SILT, trace organics; light grey and orange-brown, with black flecks. Hard, dry, non-plastic, thin (<1mm) 'rusty' laminations														
122		Moderately weathered, thinly bedded, dark grey with black streaks SILTSTONE; very weak to weak; moderately wide to widely spaced defects; contains organic-rich layers 7.75 m: 50 mm fine grained sandstone interbed 7.90 - 8.50 m: with closely spaced lignite interlamination/ very thin interbeds									MW		100 93 87			
8		8.50 m: slightly weathered 8.70 m: weak to moderately strong														
121	9.1															
9		Slightly weathered, grey, SANDSTONE; weak to moderately strong; wide spaced defects; fine sand to coarse gravel size grains 9.60 m: 170 mm siltstone interbed							PQTT		SW		93 93 93			
120																

Notes and Comments:
End of Hole @ 30.00m, Target Depth.
~ 0.5 m topsoil stripped to make drill pad

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 29/05/2019 Completed: 30/05/2019

Hole No. : BH05b
Sheet : 2 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396459.76 Northing: 787862.12 System: TAIETM2000
RL: 129.5 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
119	10		Slightly weathered, grey, SANDSTONE; weak to moderately strong; wide spaced defects; fine sand to coarse gravel size grains *(continued from layer starting at 9.1m)* 10.20 - 10.90 m: fine grained 10.25 m: 20 mm lignite interbed							PQTT				97 97 97			
118	11		10.90 - 11.40 m: fine to coarse sand, trace fine gravel of quartz schist														
117	12		11.40 - 14.10 m: fine grained size, occasional organic laminates, widely spaced defects, black staining on faces							PQTT				100 100 100			
116	13		12.69 m: 50mm thick organic-rich layer, 2 mm lignite at each end 13.20 m: moderately strong to strong														
115	14	14.1	Slightly weathered, massive, grey and white BRECCIA; moderately strong to strong; very widely spaced defects; matrix supported; clasts: fine to coarse gravel size, angular to sub-angular, quartz and schist, some clasts up to cobble size; matrix: coarse sa 14.60 - 15.60 m: weak to moderately strong	HENLEY BRECCIA						PQTT				100 100 100			
114	15											SW					
113	16		15.60 - 16.20 m: moderately strong to strong 16.20 - 16.60 m: weak to moderately strong							PQTT				100 93 93			
112	17		16.60 - 17.10 m: moderately strong to strong 17.10 - 17.70 m: weak to moderately strong														
		17.7	17.70 - 18.10 m: CORELOSS														
111	18	18.1	Slightly weathered, massive, grey and white BRECCIA; very weak to weak; very widely spaced defects; clast supported. Clasts: fine to coarse gravel size, angular to sub-angular, quartz and schist, some clasts up to cobble size 18.30 m: coarse gravel dominated 18.50 - 19.20 m: moderately strong to strong, harder matrix							PQTT				100 93 93			
110	19	19.2	Slightly weathered, grey, fine SANDSTONE; very weak to weak; moderately widely spaced; orange iron stained layer. Breaks preferentially on iron stained layers							PQTT				100 94 94			
	20																

Notes and Comments:
End of Hole @ 30.00m, Target Depth.
~ 0.5 m topsoil stripped to make drill pad

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 29/05/2019 Completed: 30/05/2019

Hole No. : BH05b
Sheet : 3 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396459.76 Northing: 787862.12 System: TAIETM2000
RL: 129.5 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
109	20		Slightly weathered, grey, fine SANDSTONE; very weak to weak; moderately widely spaced; orange iron stained layer. Breaks preferentially on iron stained layers *(continued from layer starting at 19.2m)*							PQTT				100 94 94			
108	21		20.00 m: spaced thin siltstone interbeds 20.55 m: moderately strong to strong 20.65 - 21.80 m: very weak to weak							PQTT				100 100 100			
107	22		21.80 - 22.00 m: weak to moderately strong 21.95 m: 20 mm SILTSTONE interbed 22.00 m: moderately strong to strong							PQTT				87 87 77			
106	23		Slightly weathered, grey, pink and white BRECCIA; moderately strong to strong; very widely spaced defects; clast supported; clasts: fine to coarse gravel size, angular to sub-angular, quartz and schist							PQTT				100 93 93			
105	24		23.80 - 24.20 m: clasts: fine gravel size with occasional coarse gravel 24.10 - 24.30 m: very weak to weak 24.30 - 24.65 m: moderately strong to strong 24.65 - 24.75 m: very weak to weak 24.75 - 26.65 m: moderately strong to strong	HENLEY BRECCIA						PQTT		SW					
104	25		25.30 - 26.65 m: clasts fine to coarse gravel sized							PQTT				87 87 73			
103	26		Reddish brown SILTSTONE; extremely weak to very weak 26.80 m: light grey, SILT/SAND mix; hard/very dense							PQTT				100 100 100			
102	27		Silty fine to medium silty SANDSTONE, very weak; sharp base contact with breccia, dips 20-30°							PQTT		UW		94 91 91			
101	28		Slightly weathered, light brown, grey and white BRECCIA; weak to moderately strong; very widely spaced defects; clast supported; clasts: fine to coarse gravel size, quartz and schist, angular to sub-angular 28.40 - 30.00 0						122mm								
100	29		End of Hole @ 30.00m,Target Depth.														

Notes and Comments:
End of Hole @ 30.00m, Target Depth.
~ 0.5 m topsoil stripped to make drill pad

Refer to explanation sheets for abbreviation and symbols

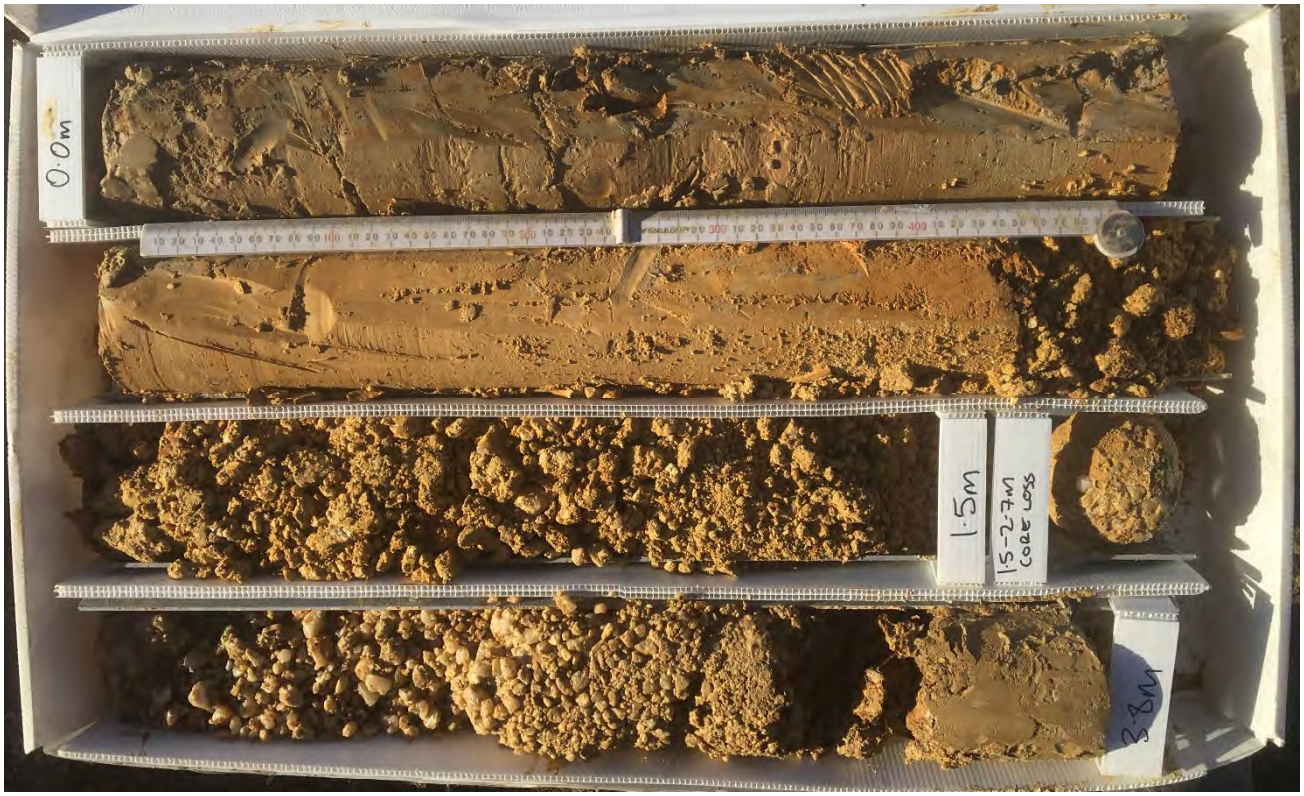
Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

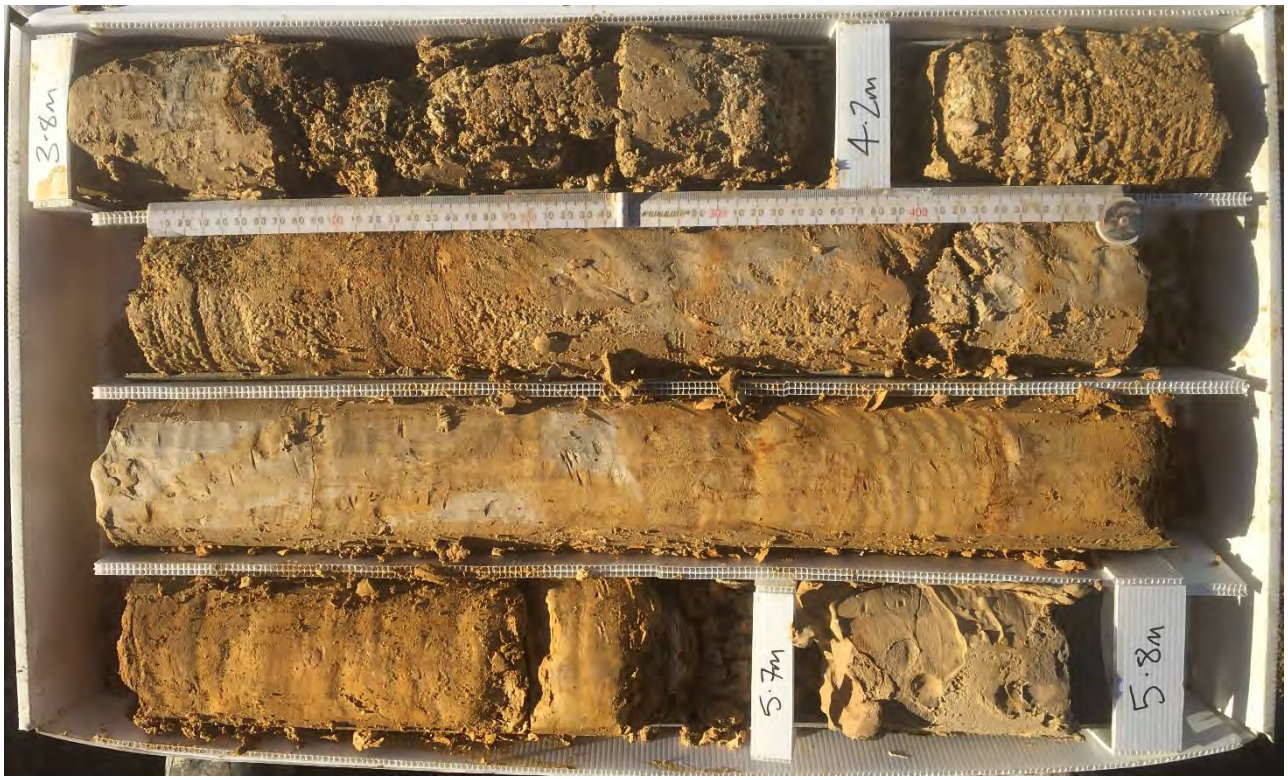
Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

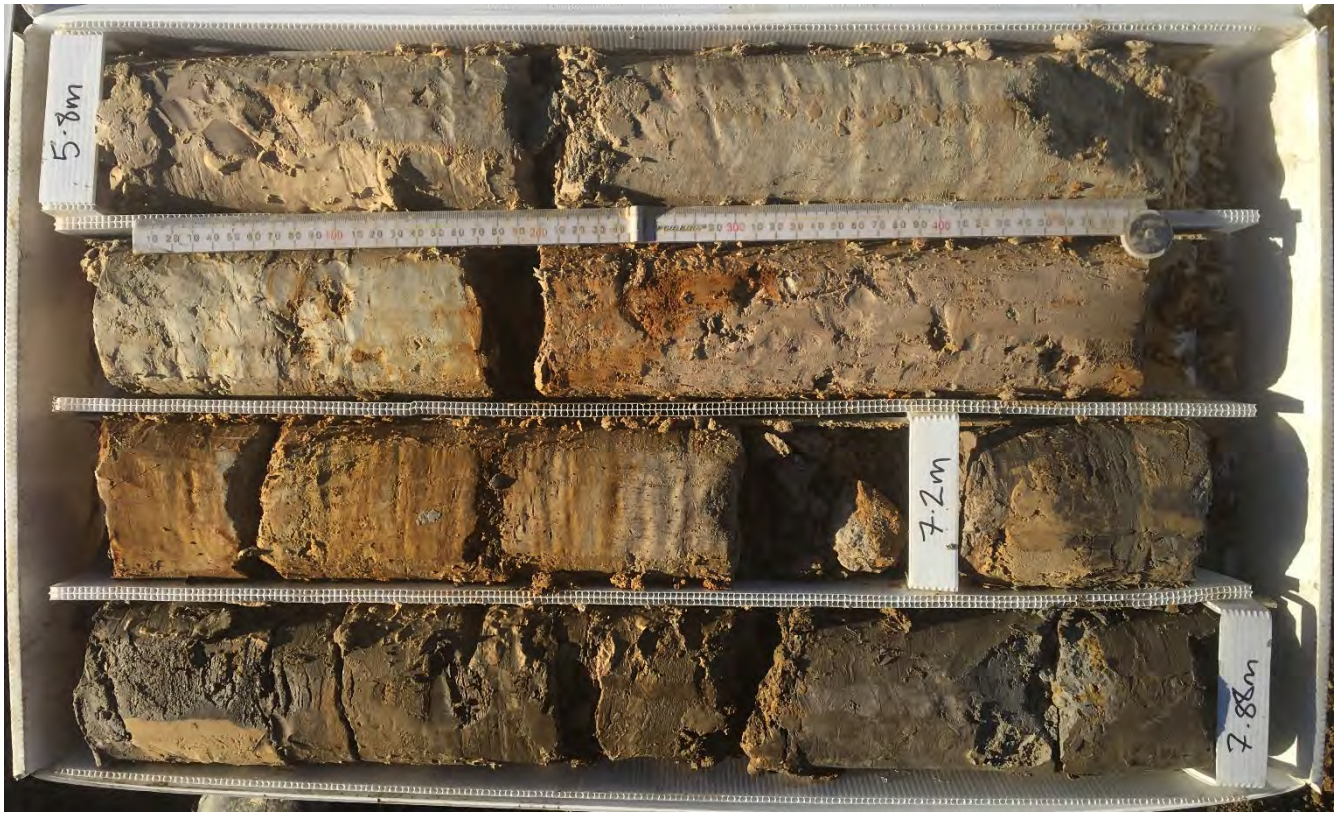
Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 7
Borehole ID	BH05	



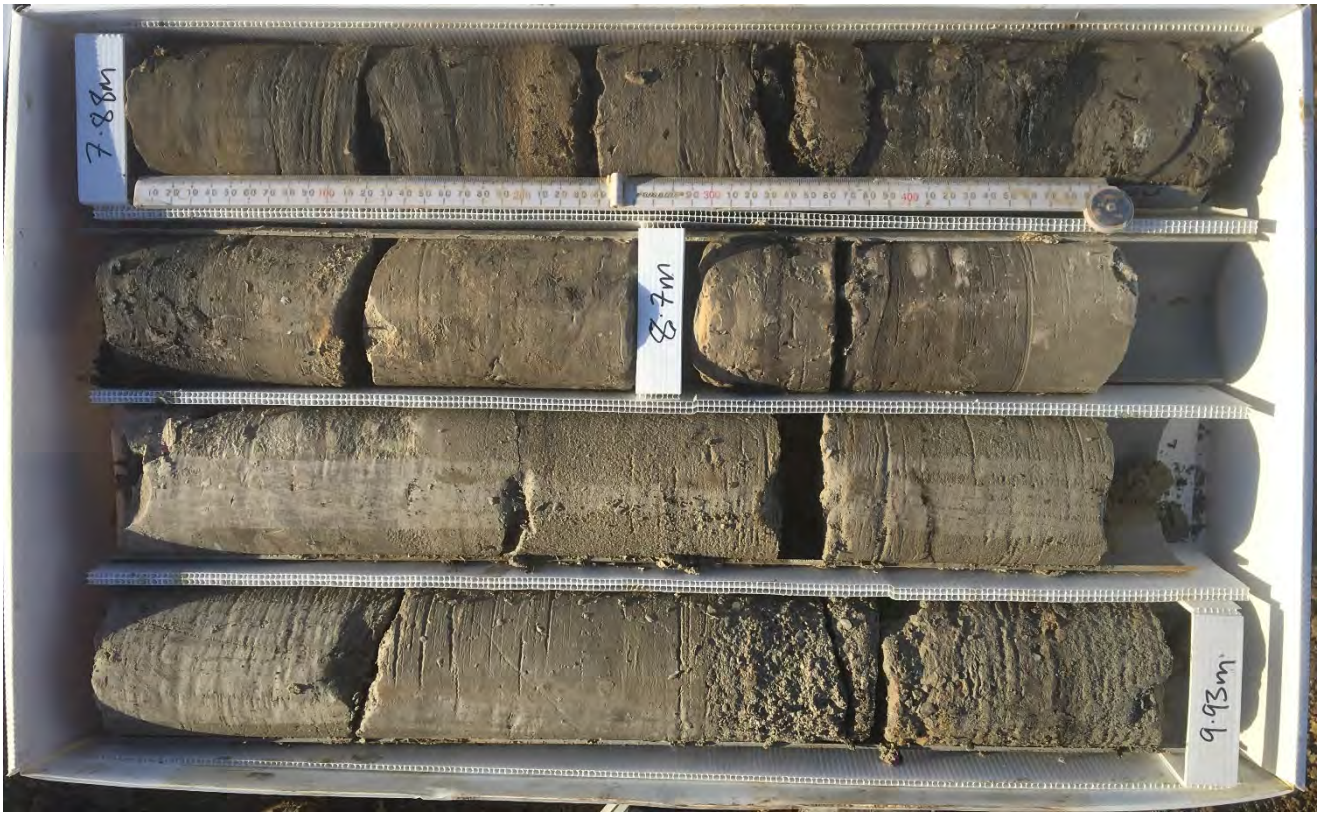
Box 1 of 14: 0.0 m to 3.8 m



Box 2 of 14: 3.8 m to 5.8 m



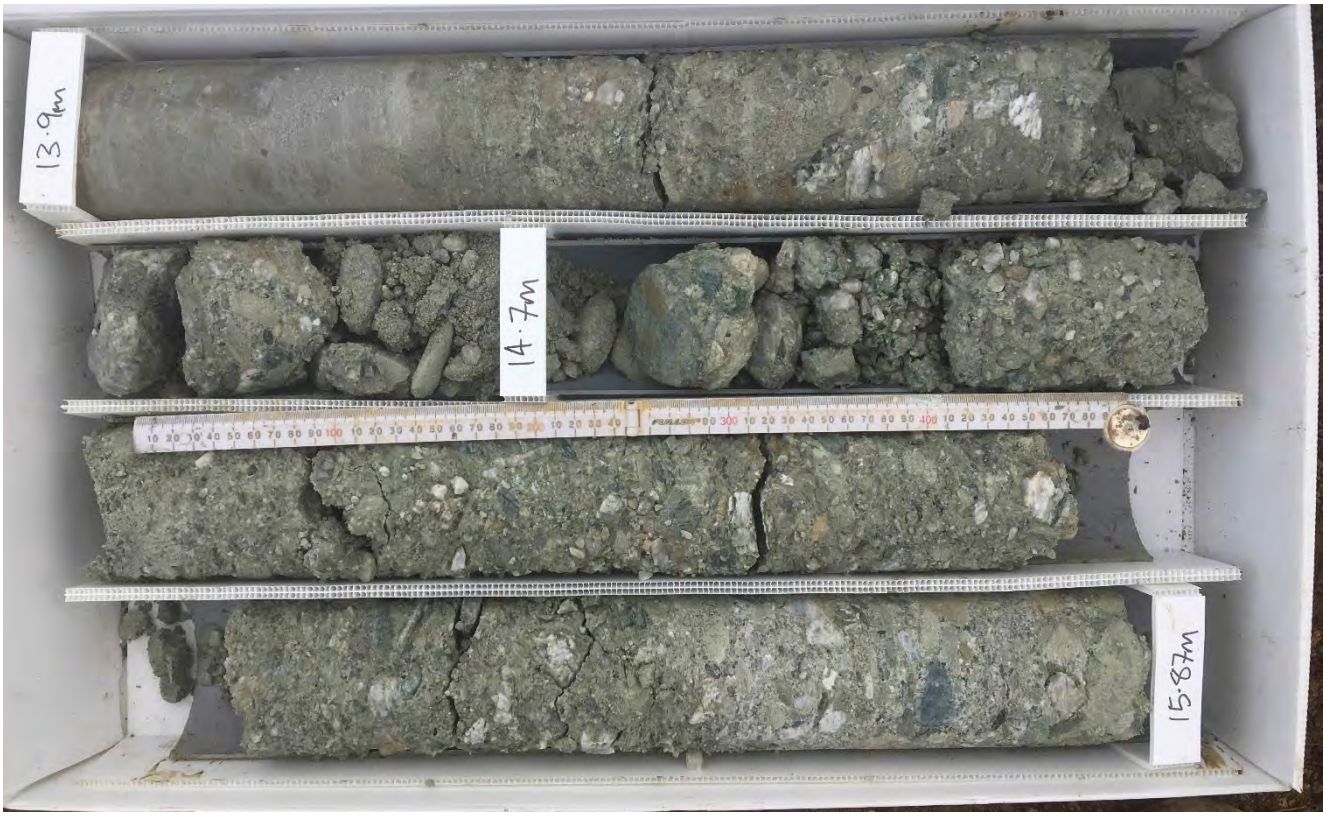
Box 3 of 14: 5.8 m to 7.88 m



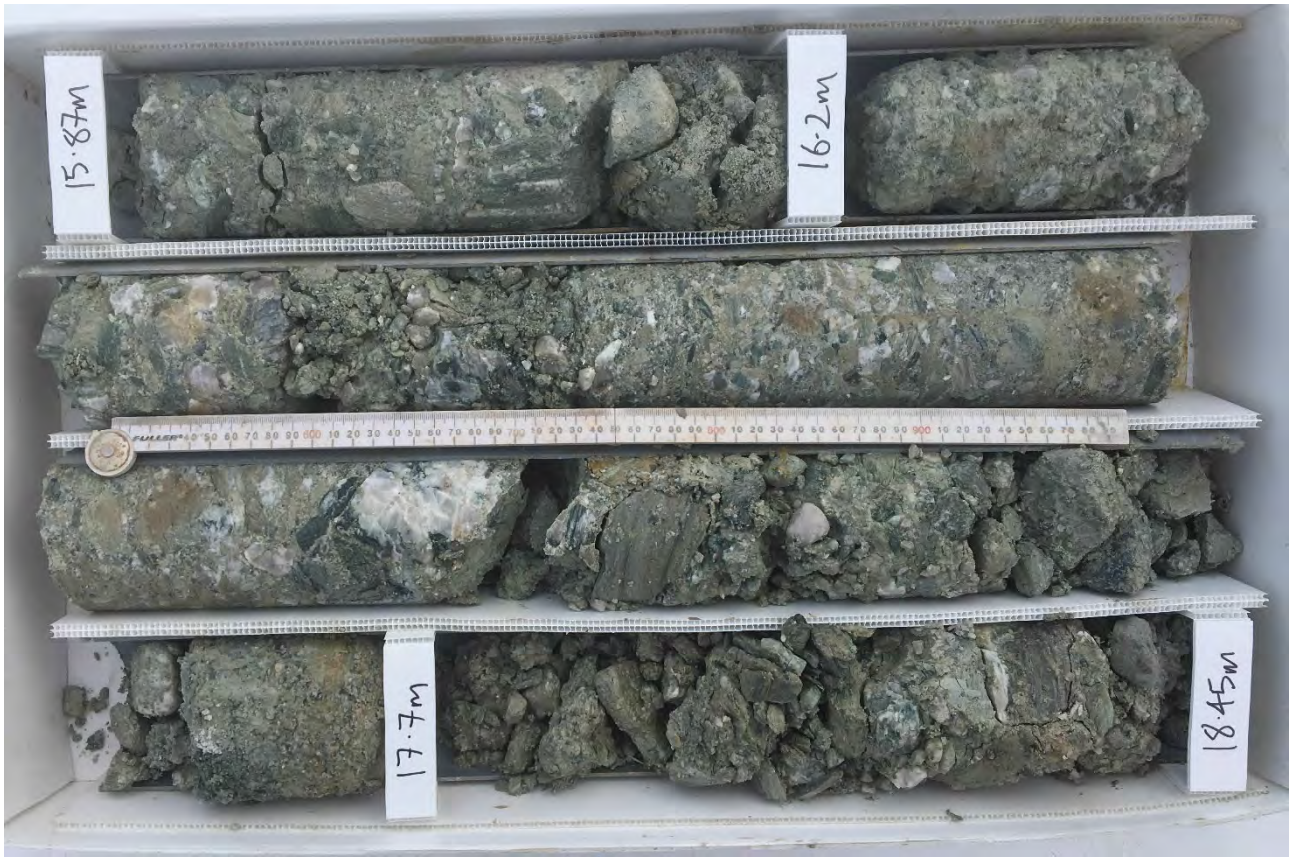
Box 4 of 14: 7.88 m to 9.93 m

Box 5 of 14: 9.93 m to 11.87 m

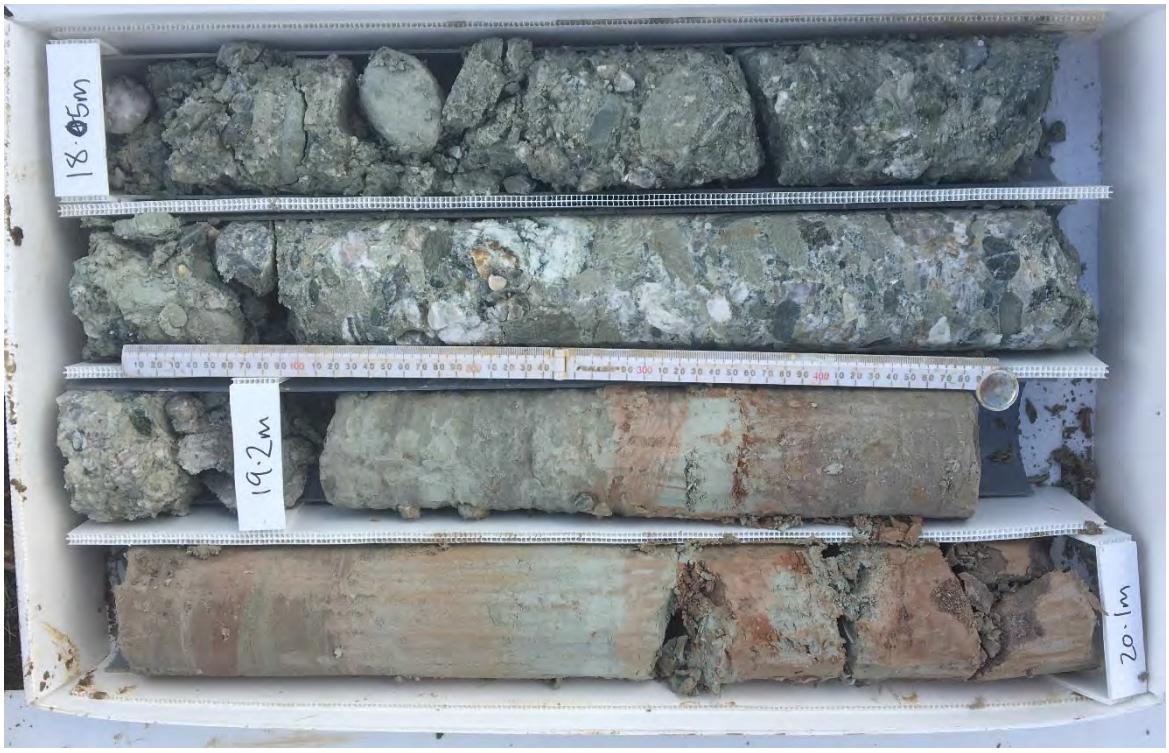
Box 6 of 14: 11.87 m to 13.9 m



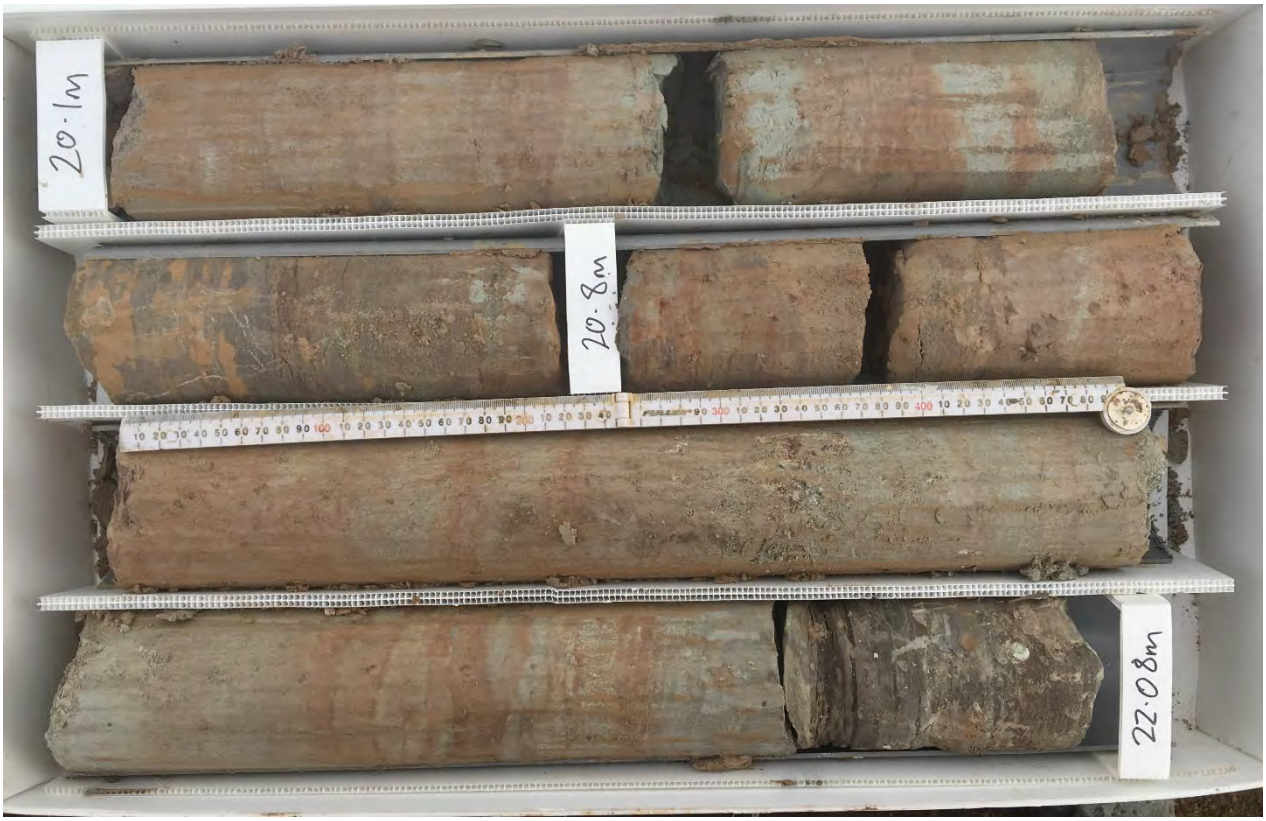
Box 7 of 14: 13.9 m to 15.87 m



Box 8 of 14: 15.87 m to 18.45 m

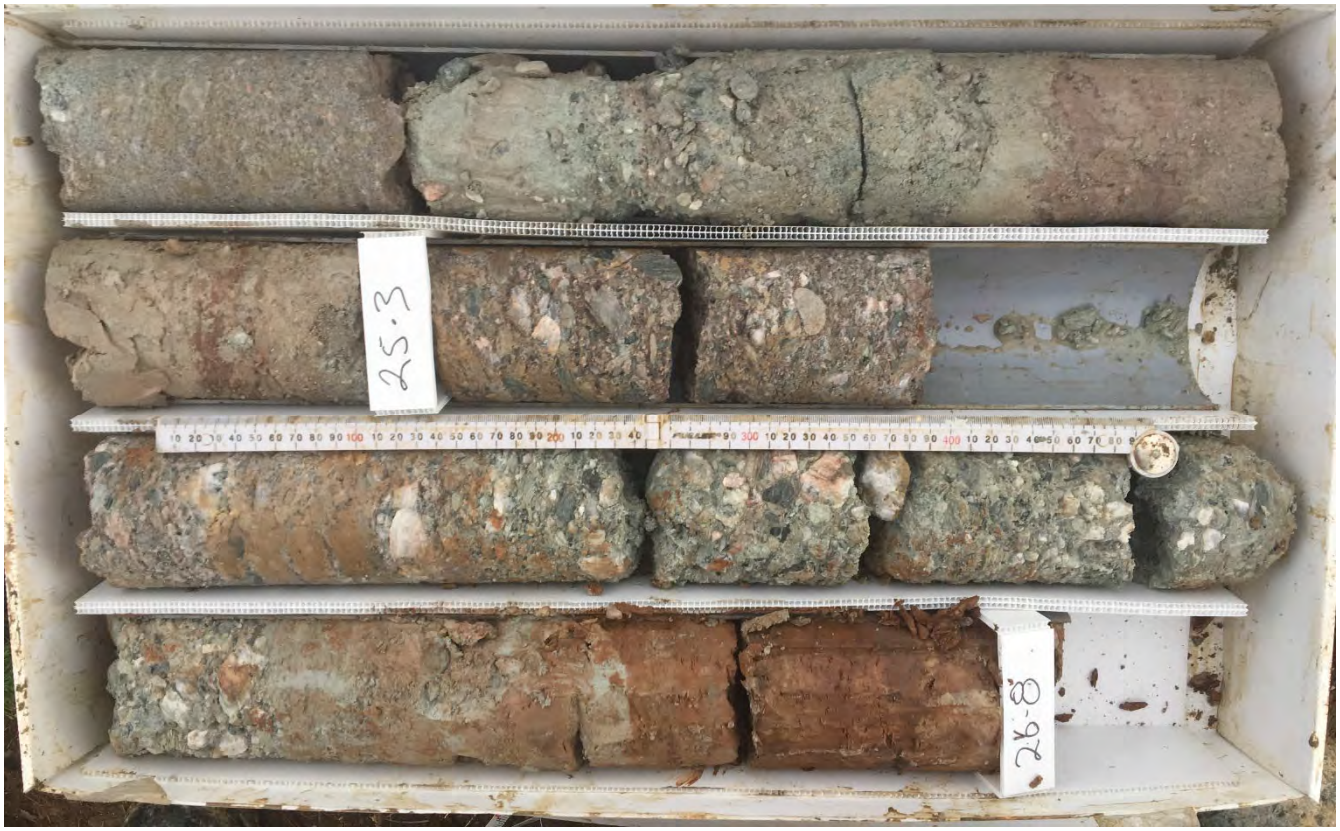


Box 9 of 14: 18.45 m to 20.1 m



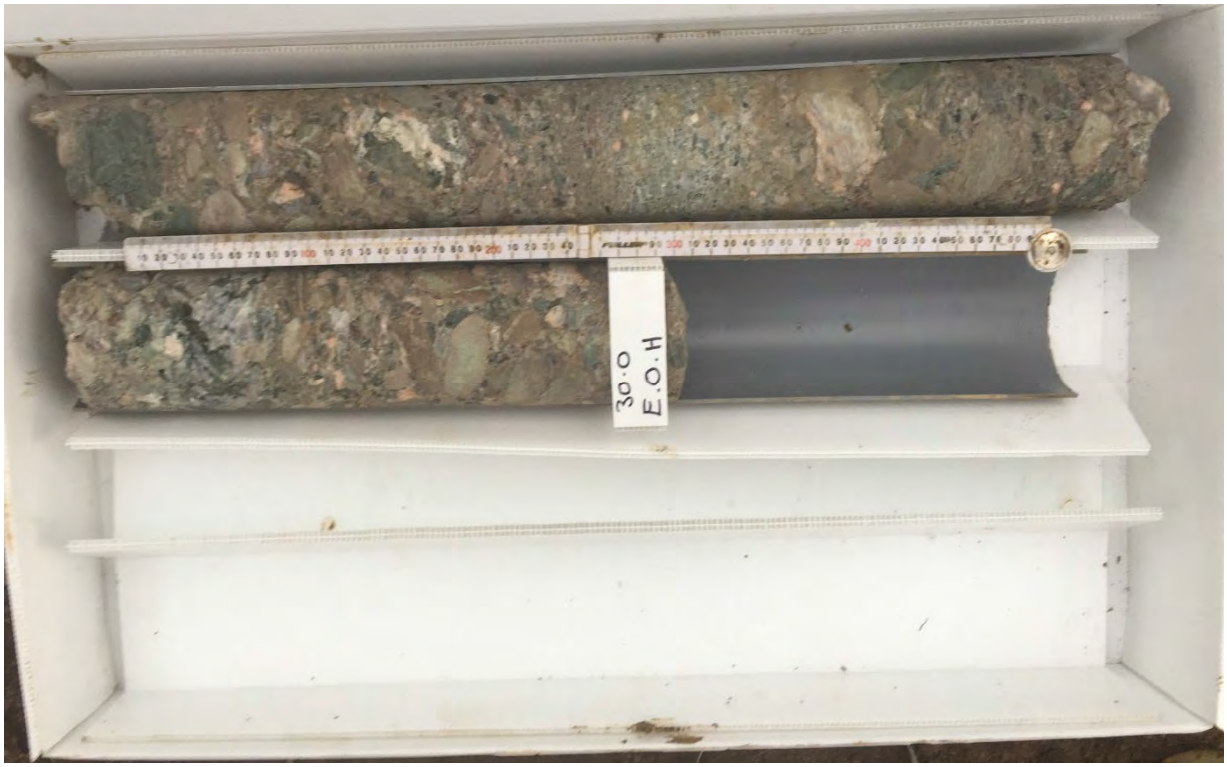
Box 10 of 14: 20.1 m to 22.08 m

Box 11 of 14: 22.08 m to 24.5 m



Box 12 of 14: 24.5 m to 26.8 m

Box 13 of 14: 26.8 m to 29.0 m



Box 14 of 14: 29.0 m to 30.0 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southwest Ridge
Job Number: 12506381
Commenced: 13/06/2019 Completed: 14/06/2019

Hole No. : BH06
Sheet : 1 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396168.25 Northing: 787593.98 System: TAIETM2000
RL: 149.75 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
149	0	Top 250 mm dug out for drill pad (TOPSOIL)	TS													
	0.25	SILT, trace to minor clay, trace fine to medium sand, trace fine gravel; grey and orange-brown. Very stiff, moist, low plasticity (LOESS)	LOESS	M	VSt				PQTT				83 17			
1																
	1.25	Highly weathered, yellow-brown SILTSTONE; extremely weak; no defects (HENLEY BRECCIA)	HENLEY BRECCIA													
148	1.5	Highly weathered, thinly bedded, yellow-brown silty fine SANDSTONE; extremely weak; no defects; iron-staining in layers and spots; trace organics throughout;							PQTT				100 89			
2																
147		2.70 m: 170 mm layer gravelly SANDSTONE							PQTT		HW		93 75 75			
3																
146																
4																
145		4.90 m: 200mm loose sand/pebbly layer; likely coreloss depth							PQTT				78 78 78			
5																
144		5.50 - 5.70 m: Fine gravel (quartz and schist, angular to sub-angular) layer														
6																
143		6.70 - 7.20 m: moderately weathered, very weak to weak							PQTT				100 100 100			
7																
	7.2	Moderately weathered, yellow-brown SILTSTONE; very weak to weak; very widely spaced defects														
142		7.30 - 7.75 m: light grey with black flecks														
		7.75 m: orange-brown with black streaks; break on bedding plane, dark iron-staining on face							PQTT				60 60 60			
8	8.18	Moderately weathered, grey, fine to coarse SANDSTONE; extremely weak to very weak									MW					
141		8.10 - 8.70 m: CORELOSS														
	8.7	Moderately weathered, fine to medium SANDSTONE; very weak to weak; widely spaced defects														
9																
		9.25 m: tight break, iron-stained face, staining decreases for 50 mm above and below break							PQTT				100 87 87			
140		9.72 m: 15-20 mm dark brown layer														
10																

Notes and Comments:
End of Hole @ 30.00m, Target Depth.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southwest Ridge
Job Number: 12506381
Commenced: 13/06/2019 Completed: 14/06/2019

Hole No. : BH06
Sheet : 2 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396168.25 Northing: 787593.98 System: TAIETM2000
RL: 149.75 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
139	10.2		9.75 m: tight break, iron stained face; core stained below break, but not above														
	10.45		10.00 - 10.20 m: with some fine rounded gravel														
			10.20 - 10.45 m: CORELOSS														
11			Moderately weathered, laminated to moderately thickly bedded, light grey and orange-brown SANDSTONE; extremely to very weak; poorly indurated; very widely spaced defects							PQTT		MW		83 83 83			
138			10.75 m: 100 mm SILTSTONE, black basal contact														
			10.85 m: 60 mm light grey with black flecks, minor organic inclusions														
			11.00 m: yellow-brown and orange-brown														
12			11.10 m: 2-3 mm iron stained 'rusty' layer														
			11.55 m: 70 mm light grey interbed														
			12.00 JT, 45°, pl, r, CLAY, Iron stained clay infill.														
137	12.25		12.25 m: 100 mm minor organics, orange-brown and black layer											56 56 56			
			Moderately weathered grey and white CONGLOMERATE; very weak to weak; clasts, fine to medium, rounded to sub-rounded, quartz and schist														
13			12.54 - 13.40 m: CORELOSS														
	13.4		Moderately weathered grey and white CONGLOMERATE; very weak to weak; clasts, fine to medium, rounded to sub-rounded, quartz and schist														
136			Slightly weathered, grey with occasional black, fine to medium SANDSTONE; very weak to weak; poorly indurated, no defects. Closely to very closely spaced laminations of lignite							PQTT				87 87 87			
14																	
135																	
15				HENLEY BRECCIA													
	15.4		Slightly weathered, grey with occasional black SILTSTONE; very weak to weak; no defects; occasional lignite							PQTT				100 100 100			
134			15.60 m: 100 mm SANDSTONE														
16	16		Slightly weathered, grey with occasional black, fine to medium SANDSTONE; very weak to weak; no defects; occasional lignite														
			16.40 - 16.60 m: minor fine gravel (quartz and schist) 'pebbly conglomerate'														
133																	
			17.05 - 17.25 m: SILTSTONE							PQTT		SW		100 100 87			
17																	
132	17.6		Slightly weathered, light grey BRECCIA; extremely weak to weak; no defects; clasts: quartz and schist, fine to medium gravel size, angular to sub-rounded; matrix supported; matrix: fine to coarse sand														
18	18		18.00 - 18.20 m: CORELOSS														
	18.2		Slightly weathered, light grey BRECCIA; extremely weak to weak; no defects; clasts: quartz and schist, fine to medium gravel size, angular to sub-rounded; matrix supported; matrix: fine to coarse sand							PQTT				87 63 63			
131																	
			19.10 - 19.20 m: unweathered, weak to moderately strong														
19			19.20 - 19.40 m: moderately strong to strong, well indurated														
	19.4		Unweathered, light grey and black fine to medium SANDSTONE; very weak to weak; very widely spaced defects; with moderately widely spaced laminated very thin to thin beds							PQTT		UW		93 65 47			
130																	

Notes and Comments:
End of Hole @ 30.00m, Target Depth.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southwest Ridge
Job Number: 12506381
Commenced: 13/06/2019 Completed: 14/06/2019

Hole No. : BH06
Sheet : 3 of 3
Hole Length : 30.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396168.25 Northing: 787593.98 System: TAIETM2000
RL: 149.75 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
129	21		of lignite and widely spaced moderately thin siltstone beds Unweathered, light grey and black fine to medium SANDSTONE; very weak to weak; very widely spaced defects; with moderately widely spaced laminated very thin to thin beds of lignite and widely spaced moderately thin siltstone beds *(continued from layer starting at 19.4m)* 20.20 m: fine to coarse sand 20.70 m: fine to medium sand 21.06 m: 230 mm siltstone interbed	HENLEY BRECCIA						PQTT		UW		93 65 47			
128	22		21.70 m: very thinly bedded (2-10 mm)							PQTT				100 100 100			
127	23		22.20 m: moderately thickly bedded (~ 300 mm) 22.40 m: 150 mm siltstone interbed 22.75 m: laminated (2-10 mm)							PQTT				87 87 87			
126	24									PQTT				100 100 100			
125	25									PQTT				88 88 88			
124	26									PQTT				100 32 32			
123	27		27.50 - 28.50 m: very closey spaced fractures, possibly drilling induced							PQTT				76 76 76			
122	28		28.40 - 28.50 m: dark grey-brown for 100 mm														
121	28.8		28.70 - 28.80 m: dark brown layer - looks like lithified topsoil														
120	29		Unweathered, light grey BRECCIA; weak to moderately strong; no defects; moderately well indurated; clasts: quartz and schist, fine gravel size, sub-angular to sub-rounded; matrix supported; matrix: fine to coarse sand														
	30		End of Hole @ 30.00m,Target Depth.														

Notes and Comments:
End of Hole @ 30.00m, Target Depth.
Groundwater not encountered.
Refer to explanation sheets for abbreviation and symbols

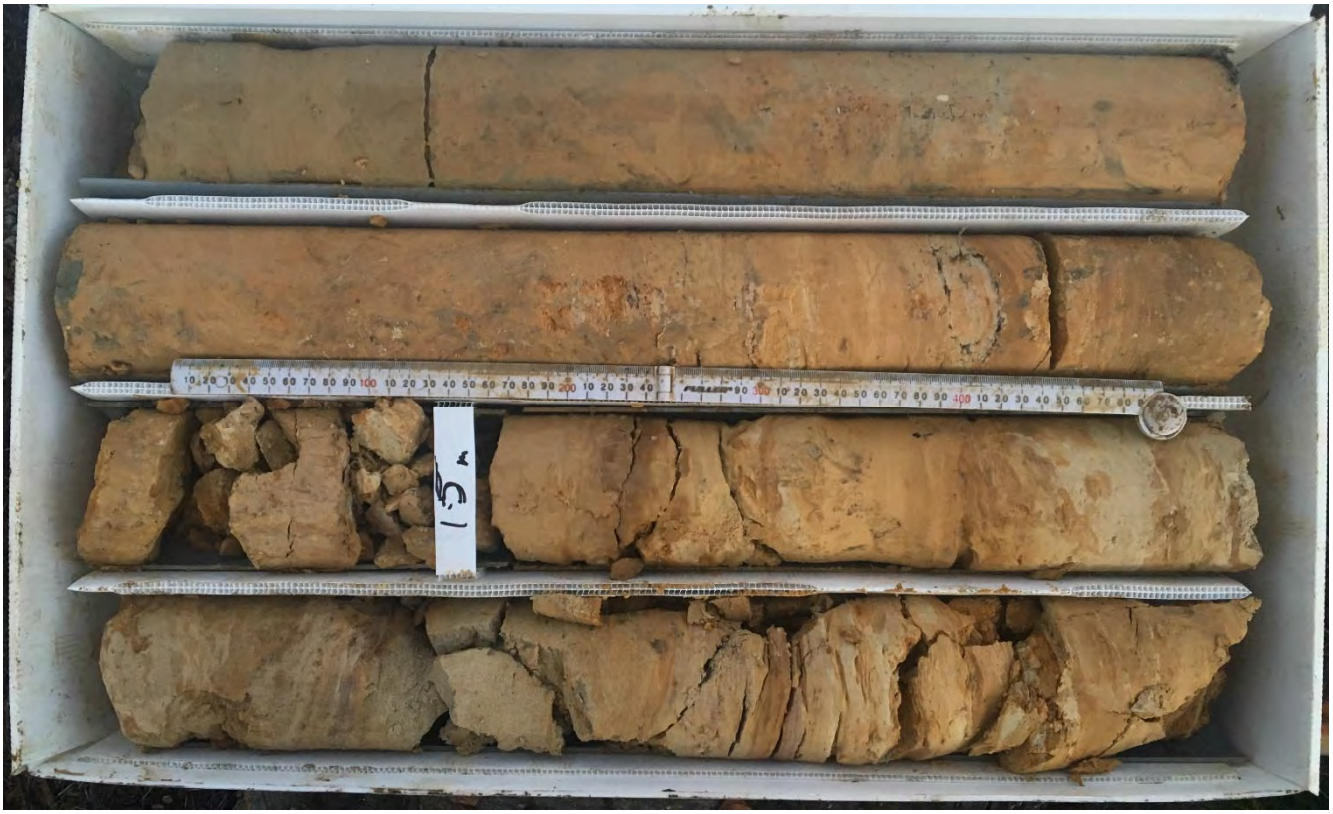
Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
14/06/19	00:00		30

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 7
Borehole ID	BH06	



Box 1 of 13: 0.0 m to 2.4 m

Box 2 of 13: 2.4 m to 4.6 m

Box 3 of 13: 4.6 m to 7.2 m

Box 4 of 13: 7.2 m to 10.0 m

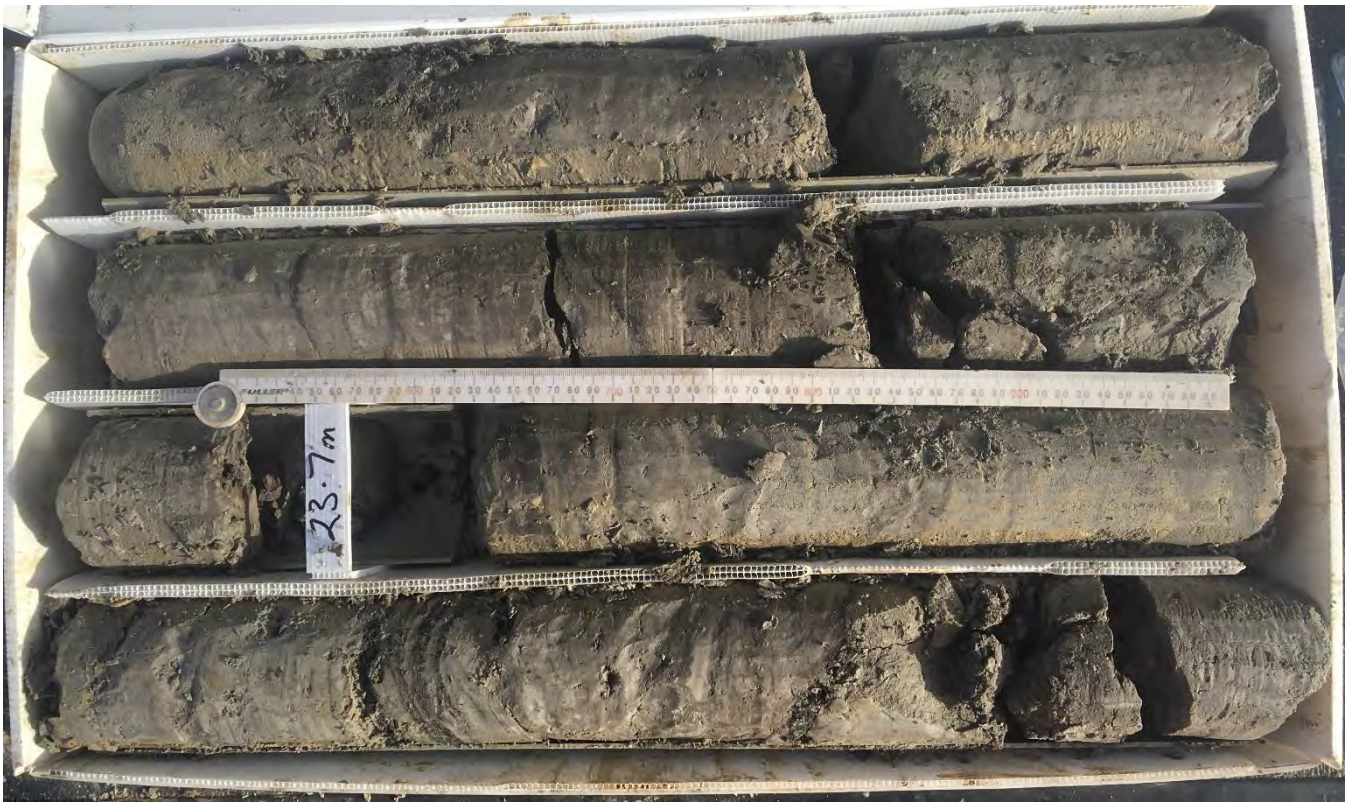
Box 5 of 13: 10.0 m to 13.2 m

Box 6 of 13: 13.2 m to 15.6 m

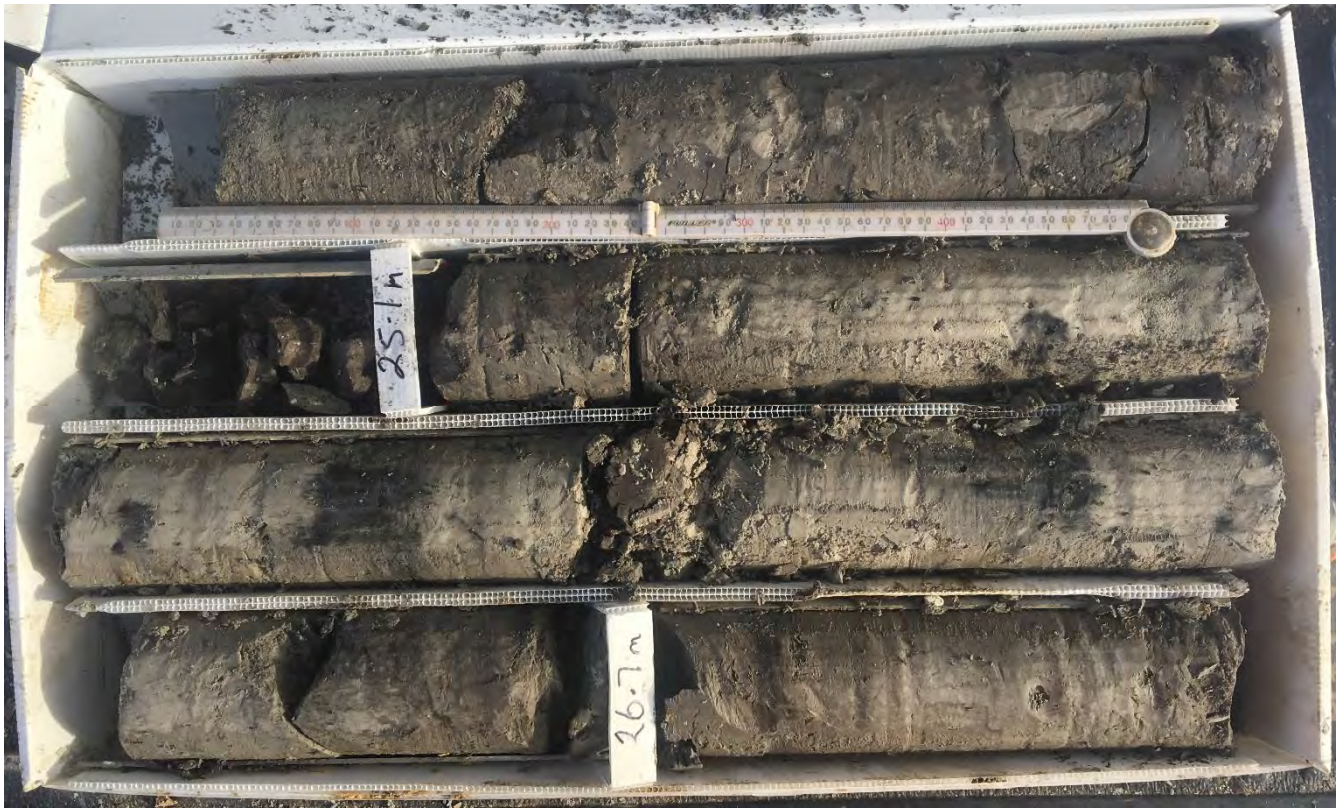
Box 7 of 13: 15.6 m to 17.7 m

Box 8 of 13: 17.7 m to 20.2 m

Box 9 of 13: 20.2 m to 22.2 m

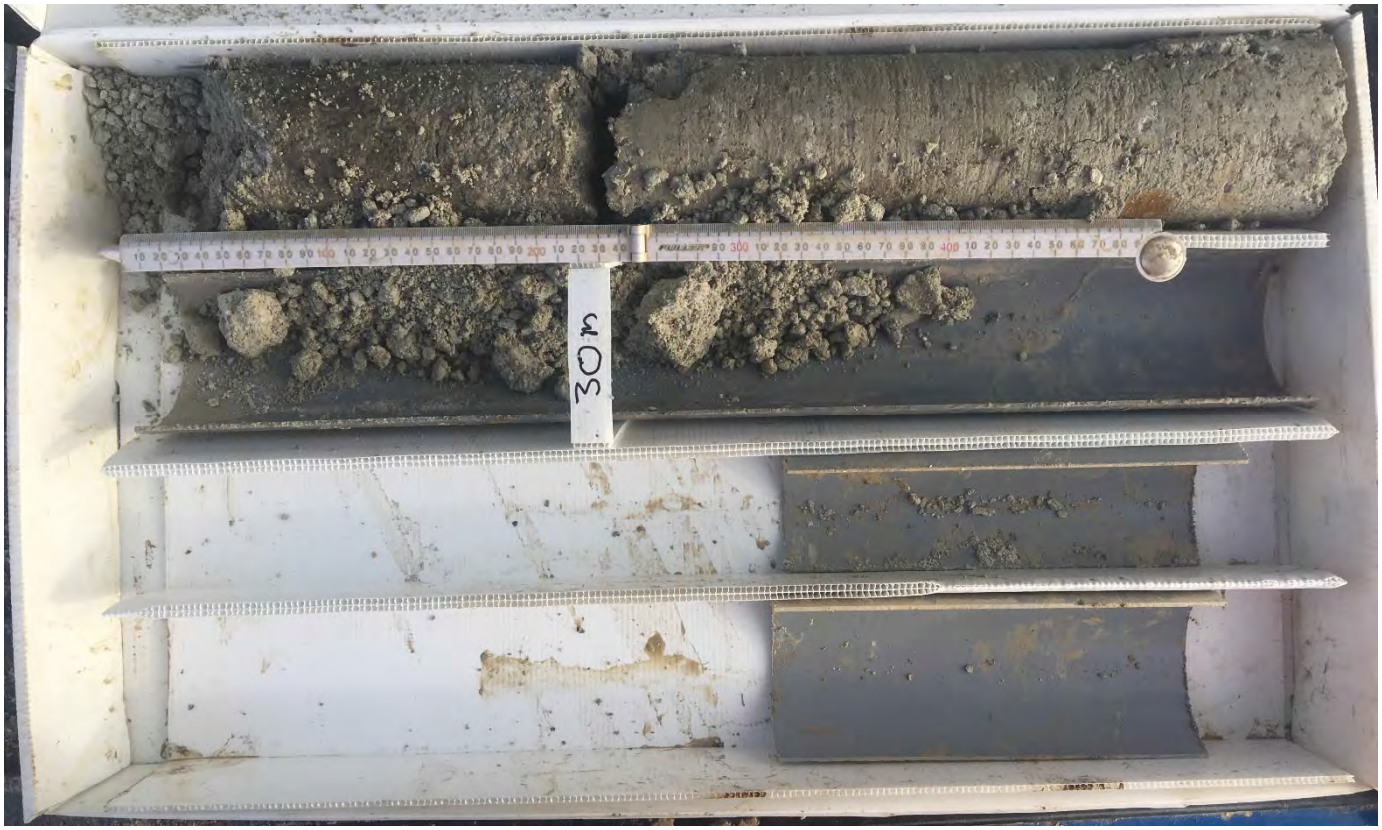


Box 10 of 13: 22.2 m to 24.7 m



Box 11 of 13: 24.7 m to 27.0 m

Box 12 of 13: 27.0 m to 29.3 m



Box 13 of 13: 29.3 m to 30.0 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 30/05/2019 Completed: 4/06/2019

Hole No. : BH07a
Sheet : 1 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396493.65 Northing: 787671.87 System: TAIETM2000
RL: 139.73 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
139	0	SILT, minor clay, trace fine sand, trace organics; light grey and orange-brown. Very stiff, moist, low plasticity (LOESS)	LOESS	M	VSt				PQTT				84			
138	1.4	1.25 m: 50 mm layer with minor to some iron oxide inclusions (red-brown)		D	H				PQTT		HW		85			
137	2	Fine sandy SILT, minor fine gravel; yellow-brown. Hard, dry, non-plastic, highly weathered rock (HENLEY BRECCIA)														
136	3.4	2.05 - 2.30 m: very closey spaced very thin iron stained bed														
135	3.75	2.80 - 3.40 m: no gravel, iron-stained layers more common														
134	4.1	SILT, some clay; light grey and yellow-brown with orange-brown layers. Hard, dry, non-plastic; iron-stained layers throughout		D	H				PQTT				100			
133	4.8	Clayey SILT, trace fine sand; grey-brown. Stiff to very stiff, moist, high plasticity, trace organics; possibly organic origin		M	St-VSt				PQTT		MW		100 100 100			
132	5.95	SILT, some clay; light grey and yellow-brown with orange-brown layers. Hard, dry, non-plastic; iron stained laminates		D	H				PQTT				100 100 100			
131	8.1	Grades into: Moderately weathered, laminates, light grey and yellow-brown SILTSTONE; very weak; widely spaced defects *4.60* BP, 10°, pl, r, VN, VE, Fe-stain	HENLEY BRECCIA													
130	8.8	Moderately weathered, moderately thickly interbedded, SILTSTONE and fine grained SANDSTONE; very weak to weak; very widely spaced defects 5.17 m: 2 x 5-8 mm organic-rich lamination														
		Slightly to moderately weathered, light grey and yellow-brown BRECCIA; weak to moderately strong; matrix supported; matrix: coarse sand; clasts: fine to coarse gravel, quartz and schist, angular to sub-rounded 7.20 m: very weak to moderately strong									SW-MW		100 100 93			
		Slightly to moderately weathered, light grey and yellow-brown silty fine grained SANDSTONE; weak to moderately strong														
		Slightly to moderately weathered, light grey and yellow-brown BRECCIA; very weak to weak; matrix: coarse sand; matrix supported; clasts: fine to medium gravel, quartz and schist, angular to sub-rounded 9.33 - 9.40 m: uncemented silty fine to coarse GRAVEL 9.40 - 10.00 m: weak to moderately strong, clast size increases to fine to coarse gravel 9.70 m: clast size decreases to fine to medium gravel											100 100 97			

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
~ 300 mm topsoil & 100-200 mm loess stripped to make drill pad

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 30/05/2019 Completed: 4/06/2019

Hole No. : BH07a
Sheet : 2 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396493.65 Northing: 787671.87 System: TAIETM2000
RL: 139.73 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
129	10.28	Slightly to moderately weathered, SANDSTONE; very weak to weak							PQTT		SW-MW		100			
128	10.65	Slightly to moderately weathered, BRECCIA; very weak to weak; angular, fine to medium gravel size clasts *10.60* BP, 20°, pl, r, VN, Fe-stain clay infill							PQTT		SW		100			
127	11	Slightly weathered, dark grey sandy SILTSTONE; very weak to weak; occasional organic layers up to 10 mm thick; sand is fine 11.00 - 13.00 m: unweathered							PQTT		UW		100			
126	12								PQTT		UW		83			
125	13								PQTT		UW		92			
124	13	Unweathered, CONGLOMERATE; weak to moderately strong. Clasts rounded to sub-rounded coarse sand to fine gravel sized							PQTT		UW		92			
123	13.3	Unweathered, light grey and white fine to coarse BRECCIA; very weak to weak; no defects; clasts: quartz and schist, angular to sub-rounded; matrix supported; medium to coarse sand matrix.							PQTT		UW		40			
122	14								PQTT		UW		47			
121	14.7	Unweathered, grey SILTSTONE; very weak to weak; no defects	HENLEY BRECCIA						PQTT		UW		78			
120	15								PQTT		UW		78			
	15.1	Unweathered, grey fine to medium SANDSTONE; very weak to weak; no defects														
	15.5	Unweathered, grey SILTSTONE; very weak to weak; no defects														
	15.8	Unweathered, light grey gravelly SANDSTONE; very weak to weak; no defects; no obvious bedding; gravel is fine; sand is fine to coarse														
	17.3	Unweathered, brown SILTSTONE; very weak to weak; no defects 17.65 m: dark grey 17.85 m: grey														
	19.5	Unweathered; light grey, white and purple pebbly BRECCIA; weak to moderately strong; no defects; coarse sand matrix; matrix supported End of Hole @ 20.00m,Target Depth.														

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
~ 300 mm topsoil & 100-200 mm loess stripped to make drill pad

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
04/06/19	00:00		20

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 30/05/2019 Completed: 4/06/2019

Hole No. : BH07b
Sheet : 1 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396493.65 Northing: 787671.87 System: TAIETM2000
RL: 139.73 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
139	0	SILT, minor clay, trace fine sand, trace organics; light grey and orange-brown. Very stiff, moist, low plasticity (LOESS)	LOESS	M	VSt				PQTT				84			
138	1.4	1.25 m: 50 mm layer with minor to some iron oxide inclusions (red-brown)		D	H				PQTT		HW		85			
137	2	Fine sandy SILT, minor fine gravel; yellow-brown. Hard, dry, non-plastic, highly weathered rock (HENLEY BRECCIA) 2.05 - 2.30 m: very closey spaced very thin iron stained bed 2.80 - 3.40 m: no gravel, iron-stained layers more common							PQTT				100			
136	3.4	SILT, some clay; light grey and yellow-brown with orange-brown layers. Hard, dry, non-plastic; iron-stained layers throughout		D	H				PQTT				100 100 100			
135	3.75			M	St-VSt											
134	4.1	Clayey SILT, trace fine sand; grey-brown. Stiff to very stiff, moist, high plasticity, trace organics; possibly organic origin		D	H				PQTT		MW		100 100 100			
133	4.8	SILT, some clay; light grey and yellow-brown with orange-brown layers. Hard, dry, non-plastic; iron stained laminates Grades into: Moderately weathered, laminates, light grey and yellow-brown SILTSTONE; very weak; widely spaced defects *4.60* BP, 10°, pl, r, VN, VE, Fe-stain	HENLEY BRECCIA						PQTT				100 100 93			
132	5.95	Moderately weathered, moderately thickly interbedded, SILTSTONE and fine grained SANDSTONE; very weak to weak; very widely spaced defects 5.17 m: 2 x 5-8 mm organic-rich lamination							PQTT		SW-MW		100 100 97			
131	8.1	Slightly to moderately weathered, light grey and yellow-brown BRECCIA; weak to moderately strong; matrix supported; matrix: coarse sand; clasts: fine to coarse gravel, quartz and schist, angular to sub-rounded 7.20 m: very weak to moderately strong														
130	8.8	Slightly to moderately weathered, light grey and yellow-brown silty fine grained SANDSTONE; weak to moderately strong														
	9.33	Slightly to moderately weathered, light grey and yellow-brown BRECCIA; very weak to weak; matrix: coarse sand; matrix supported; clasts: fine to medium gravel, quartz and schist, angular to sub-rounded 9.33 - 9.40 m: uncemented silty fine to coarse GRAVEL 9.40 - 10.00 m: weak to moderately strong, clast size increases to fine to coarse gravel 9.70 m: clast size decreases to fine to medium gravel														

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
~ 300 mm topsoil & 100-200 mm loess stripped to make drill pad

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Central Ridge
Job Number: 12506381
Commenced: 30/05/2019 Completed: 4/06/2019

Hole No. : BH07b
Sheet : 2 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396493.65 Northing: 787671.87 System: TAIETM2000
RL: 139.73 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
129	10.28		Slightly to moderately weathered, SANDSTONE; very weak to weak							PQTT		SW-MW		100			
	10.65		Slightly to moderately weathered, BRECCIA; very weak to weak; angular, fine to medium gravel size clasts														
11			*10.60* BP, 20°, pl, r, VN, Fe-stain clay infill									SW		100			
			Slightly weathered, dark grey sandy SILTSTONE; very weak to weak; occasional organic layers up to 10 mm thick; sand is fine 11.00 - 13.00 m: unweathered														
12										PQTT				100			
127														100			
	13																
13	13.3		Unweathered, CONGLOMERATE; weak to moderately strong. Clasts rounded to sub-rounded coarse sand to fine gravel sized														
126			Unweathered, light grey and white fine to coarse BRECCIA; very weak to weak; no defects; clasts: quartz and schist, angular to sub-rounded; matrix supported; medium to coarse sand matrix.							PQTT				83 78 78			
14																	
125	14.7		Unweathered, grey SILTSTONE; very weak to weak; no defects	HENLEY BRECCIA													
15	15.1		Unweathered, grey fine to medium SANDSTONE; very weak to weak; no defects							PQTT		UW		92 92 92			
124	15.5		Unweathered, grey SILTSTONE; very weak to weak; no defects														
	15.8		Unweathered, light grey gravelly SANDSTONE; very weak to weak; no defects; no obvious bedding; gravel is fine; sand is fine to coarse														
16																	
123										PQTT				40 33 33			
17																	
	17.3		Unweathered, brown SILTSTONE; very weak to weak; no defects 17.65 m: dark grey 17.85 m: grey														
122										PQTT				47 27 27			
18																	
121																	
19										PQTT				78 78 78			
	19.5		Unweathered; light grey, white and purple pebbly BRECCIA; weak to moderately strong; no defects; coarse sand matrix; matrix supported														
120			End of Hole @ 20.00m,Target Depth.														

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
~ 300 mm topsoil & 100-200 mm loess stripped to make drill pad

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
04/06/19	00:00		20

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 4
Borehole ID	BH07	

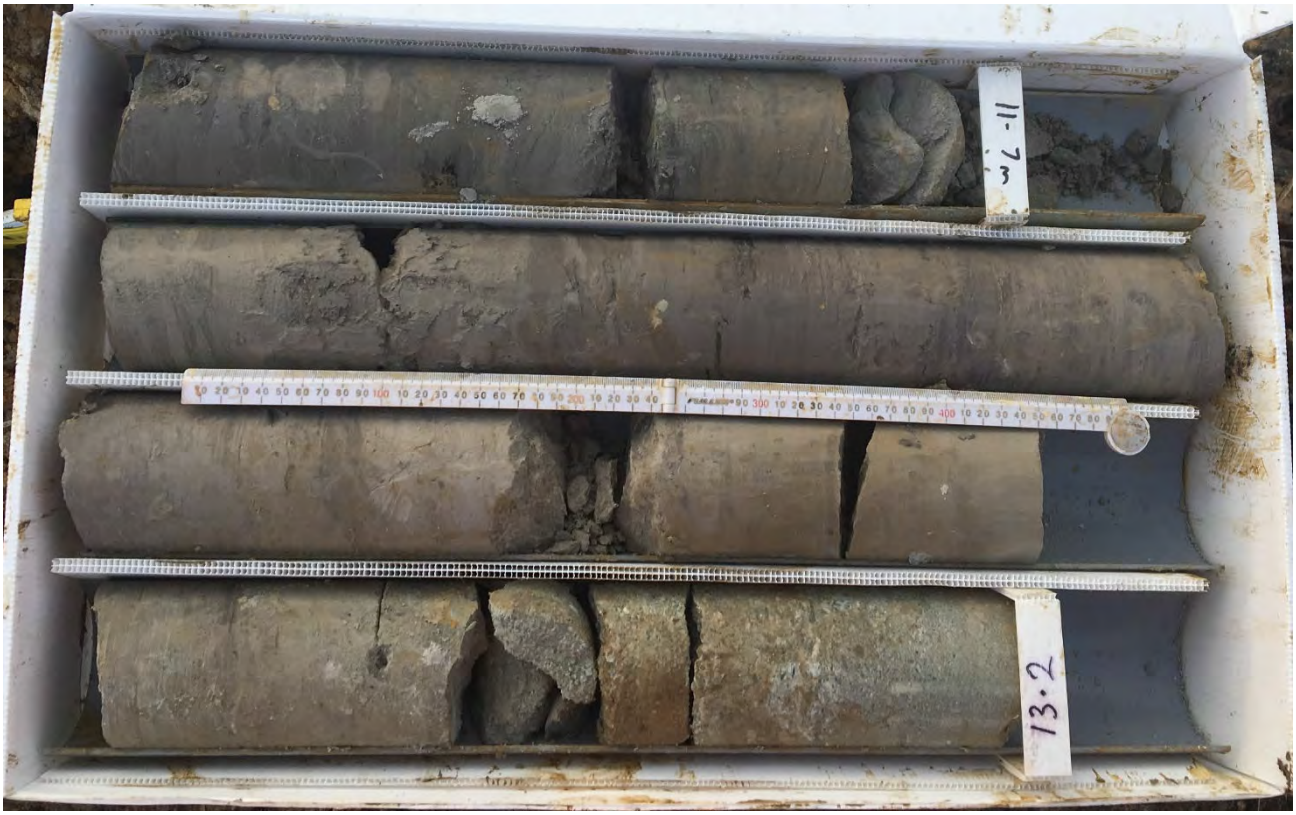
Box 1 of 8: 0.0 m to 2.7 m

Box 2 of 8: 2.7 m to 4.8 m

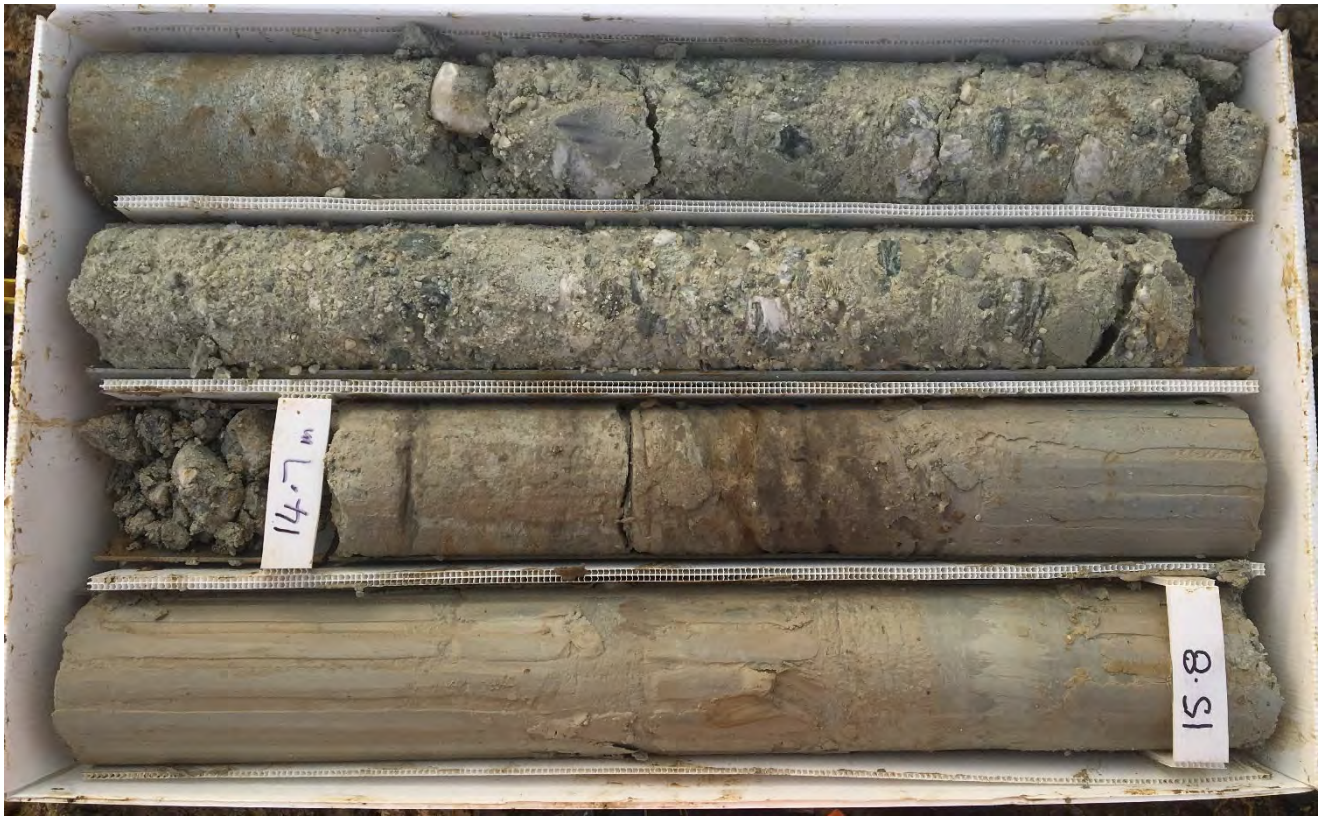
Box 3 of 8: 4.8 m to 7.0 m

Box 4 of 8: 7.0 m to 9.1 m

Box 5 of 8: 9.1 m to 11.2 m



Box 6 of 8: 11.2 m to 13.2 m



Box 7 of 8: 13.2 m to 15.8 m

Box 8 of 8: 15.8 m to 20.0 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Big Stone Road
Job Number: 12506381
Commenced: 11/06/2019 Completed: 11/06/2019

Hole No. : BH08
Sheet : 1 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396809.71 Northing: 787700.67 System: TAIETM2000
RL: 143.89 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
143	0	TOPSOIL; silt, trace to minor clay, trace fine sand; dark grey and yellow-brown. Very stiff, moist, low plasticity; trace roots	TS	M	VSt				PQTT				68			
	0.25	SILT, trace clay, trace fine sand; grey mottled orange-brown. Very stiff, moist, low plasticity (LOESS)		M	VSt											
142	1	0.60 m: more orange-brown mottled grey														
		1.50 m: grey and brown mottled orange iron stained inclusions														
	1.84	1.84 - 2.86 m: CORE LOSS	LOESS						PQTT				23			
141	2															
	2.86	Fine sandy SILT, trace clay; light grey-brown. Very stiff, dry, low plasticity		D	VSt		SV@3m 194 kPa		PQTT				100			
140	3	3.00 m: light grey and orange; iron stained laminations					SV@3.5m UTP									
	3.75	SILT, trace to minor clay, trace coarse sand (rusty); light grey and orange-brown. Very stiff to hard, moist, low plasticity		M	VSt-H				PQTT				90			
	4.1	SILT, minor to some clay; brown with black flecks and streaks. Very stiff to hard, dry to moist, high plasticity; trace to minor organics (BURIED TOPSOIL)	BTS	D-M	VSt-H											
139	4	Highly weathered, grey, orange-brown and yellow-brown BRECCIA; very weak to weak; no defects; clasts: quartz and schist, sub-angular to sub-rounded, fine gravel size; matrix: fine to coarse sand; matrix supported														
	4.4	Highly weathered, grey and orange-brown SILTSTONE; extremely weak to very weak; no defects														
	5	Highly weathered, grey, orange-brown and yellow-brown BRECCIA; very weak to weak; no defects; clasts: quartz and schist, sub-angular to sub-rounded, fine to medium gravel, matrix: fine to coarse sand; matrix supported							PQTT		HW		100 100 100			
138	5.2															
	6	6.20 - 6.90 m: CORELOSS (inferred silty GRAVEL)														
	6.2															
137	6.9	Fine to medium GRAVEL; orange-brown, white, yellow-brown and grey. Poorly graded; inferred silt matrix from minimal matrix recovery; gravel, quartz and schist, angular to sub-rounded.	HENLEY BRECCIA										53 40 33			
	7										MW					
	7.1															
	7.4	Moderately weathered, grey, orange-brown and white BRECCIA; weak; gravel quartz and schist, angular to sub-rounded, fine to medium gravel; matrix: fine to coarse sand; matrix supported														
136	7.65															
	8	Slightly weathered, light grey SILTSTONE; very weak to weak; no defects (grades into next unit)							PQTT		SW		100 100 100			
	8.1															
		Slighty weathered, light grey fine to coarse SANDSTONE; very weak to weak; no defects														
135	9	Slightly weathered, light grey and grey BRECCIA; weak to moderately strong; no defects; no visible bedding; matrix: fine to coarse sand, matrix supported; clasts: quartz and schist, sub-rounded to angular, fine to medium gravel size														
		9.00 - 14.10 m: unweathered, fine to coarse gravel size clasts, clast supported														
134	10								PQTT		UW		93 93 93			

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
Groundwater not encountered. No piezos were installed.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting		Hole No.	: BH08
Client : Dunedin City Council		Sheet	: 2 of 2
Site : Big Stone Road		Hole Length	: 20.00m
Job Number: 12506381		Scale @ A4	: 1:50
Commenced: 11/06/2019	Completed: 11/06/2019	Logged	: MF
Easting: 396809.71	Northing: 787700.67	Processed	: HB
RL: 143.89	Datum: NZVD2016	Checked	: JHS

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
133	10		Slightly weathered, light grey and grey BRECCIA; weak to moderately strong; no defects; no visible bedding; matrix: fine to coarse sand, matrix supported; clasts: quartz and schist, sub-rounded to angular, fine to medium gravel size *(continued from layer starting at 8.1m)*	HENLEY BRECCIA						PQTT		UW		93 93 93			
132	11		11.20 m: fine to medium gravel sized clasts, moderately strong to strong 11.60 m: fine to coarse gravel clasts, weak to moderately strong							PQTT				100 100 100			
131	12									PQTT				97 97 97			
130	13									PQTT				69 67 43			
129	14		14.10 - 14.60 m: CORELOSS														
128	15		Unweathered, grey silty fine to medium SANDSTONE; very weak to weak; no defects; no visible bedding							PQTT				100 100 100			
127	16		16.40 m: 100 mm breccia interbed														
126	17		Fine to coarse grained SANDSTONE, moderately strong to strong, with very closely spaced very thin interbeded of gravelly sandstone; fine gravel. 17.50 m: weak to moderately strong, moderately well indurated							PQTT				100 100 100			
125	18		Unweathered, light grey, grey and white BRECCIA; moderately strong to strong; no defects; no visible bedding; matrix: fine to coarse sand; clasts: schist and quartz, angular to sub-rounded, fine to coarse gravel size; clast supported							PQTT				100 100 100			
124	19		19.20 m: clasts predominantly medium to coarse gravel sized														
	20		Unweathered, light grey fine to coarse SANDSTONE; moderately strong to strong; no defects; well indurated; no visible bedding End of Hole @ 20.00m,Target Depth.							PQTT				100 100 100			

Notes and Comments:
End of Hole @ 20.00m, Target Depth.
Groundwater not encountered. No piezos were installed.

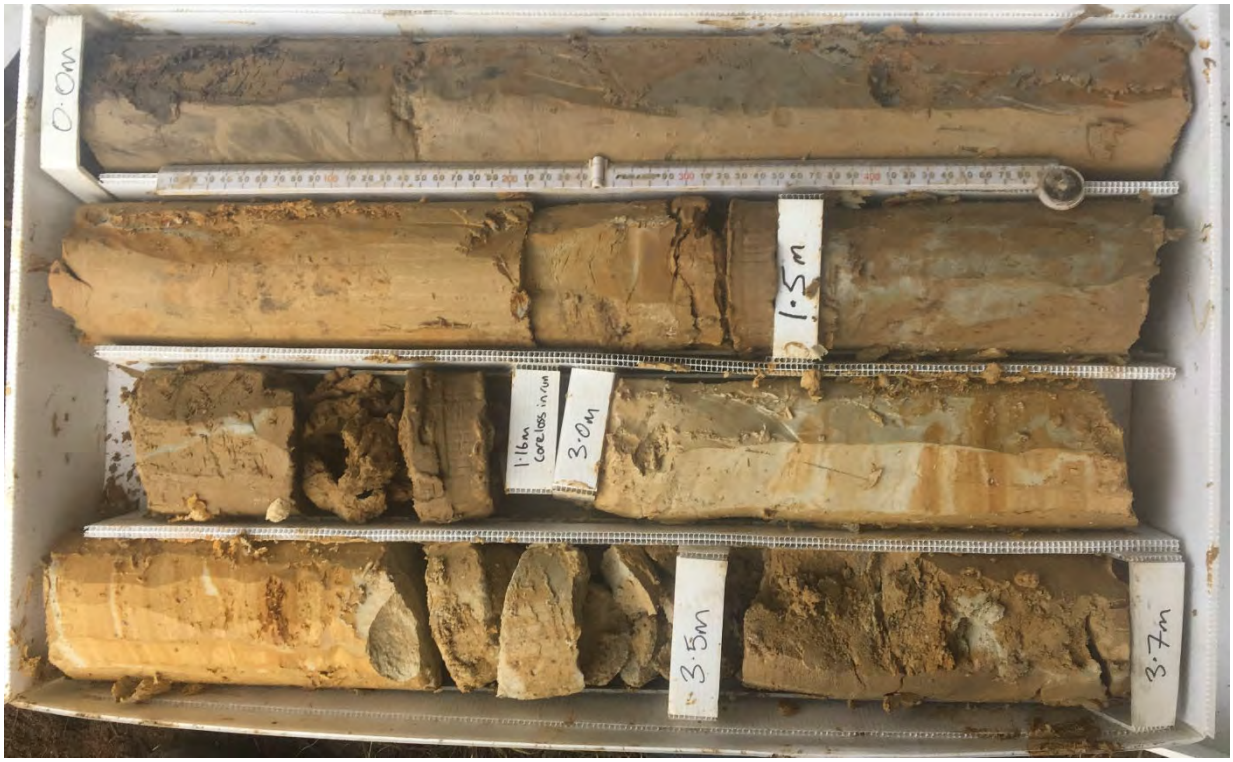
Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id: GEO2288

Ground Water Level

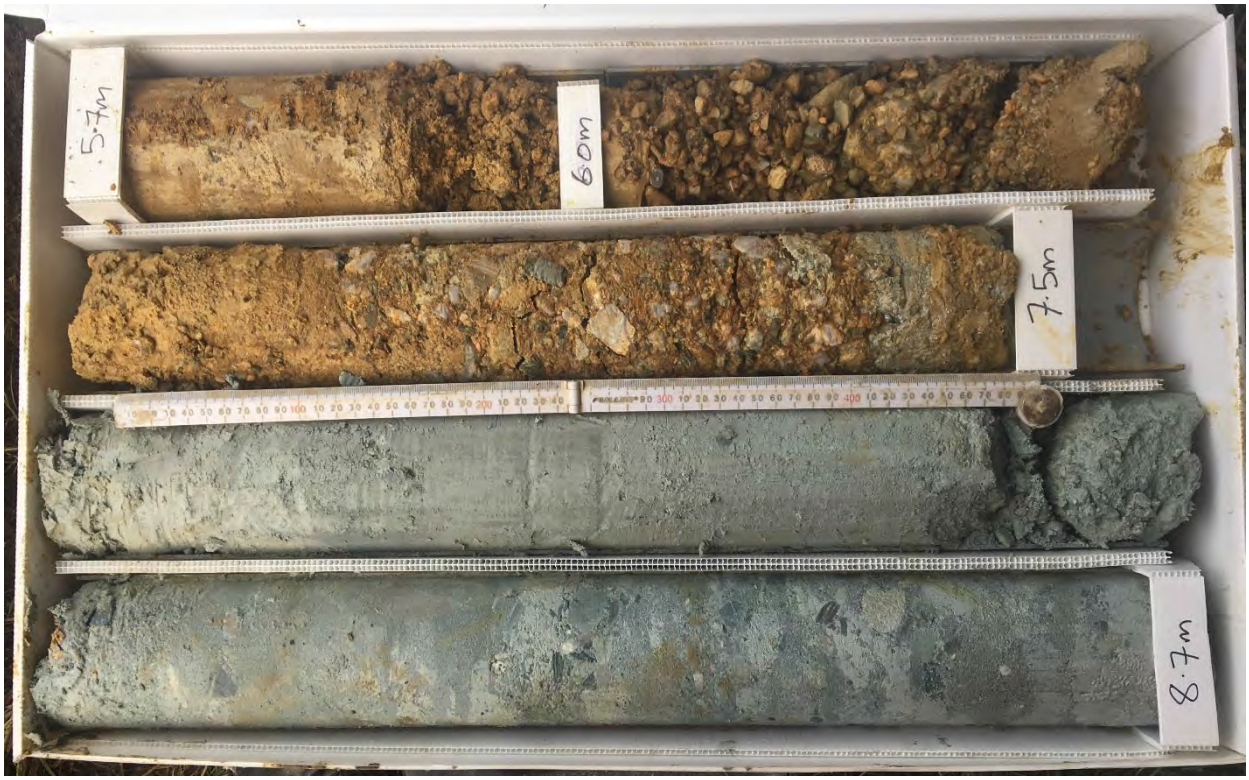
Date	Time	Reading (mbgl)	Hole depth (mbgl)
11/06/19	00:00		20

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 4
Borehole ID	BH08	

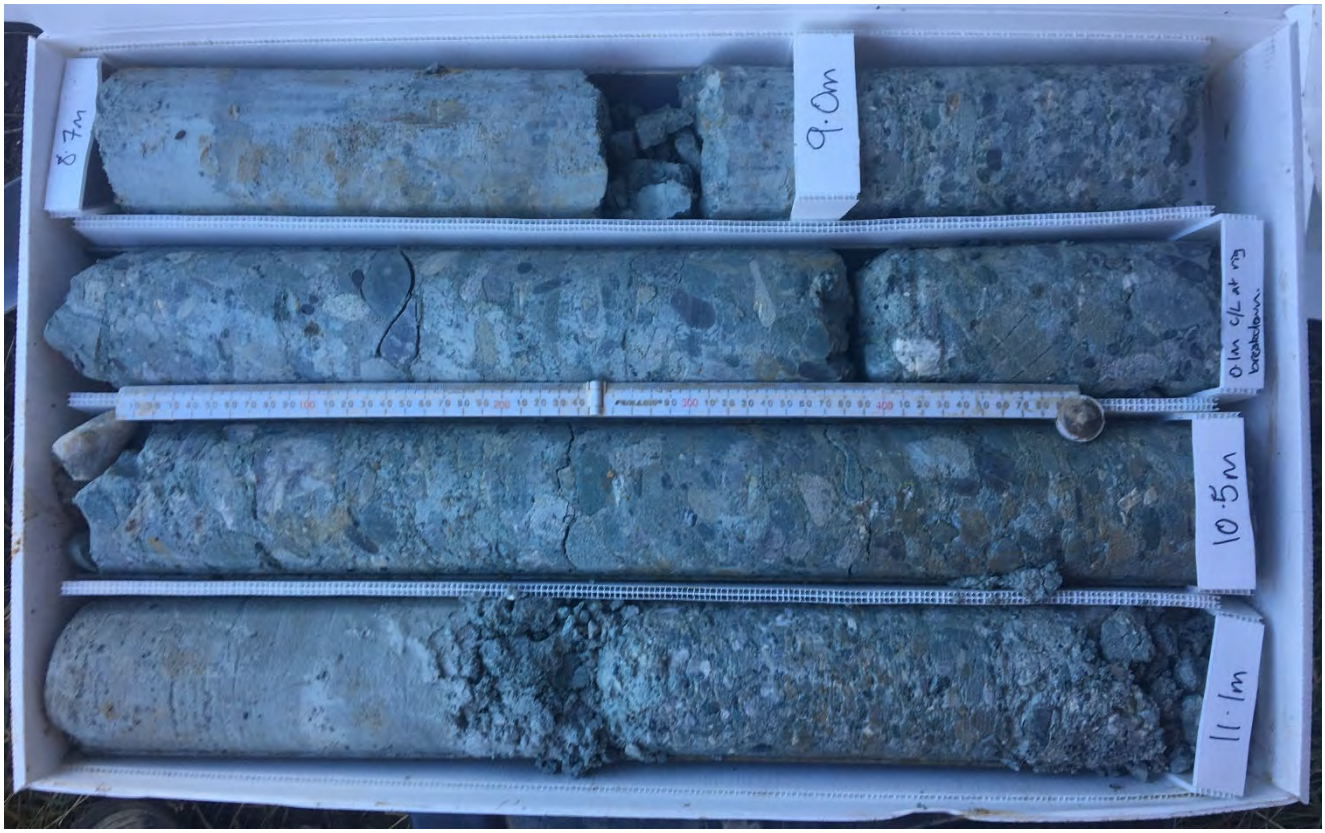


Box 1 of 8: 0.0 m to 3.7 m

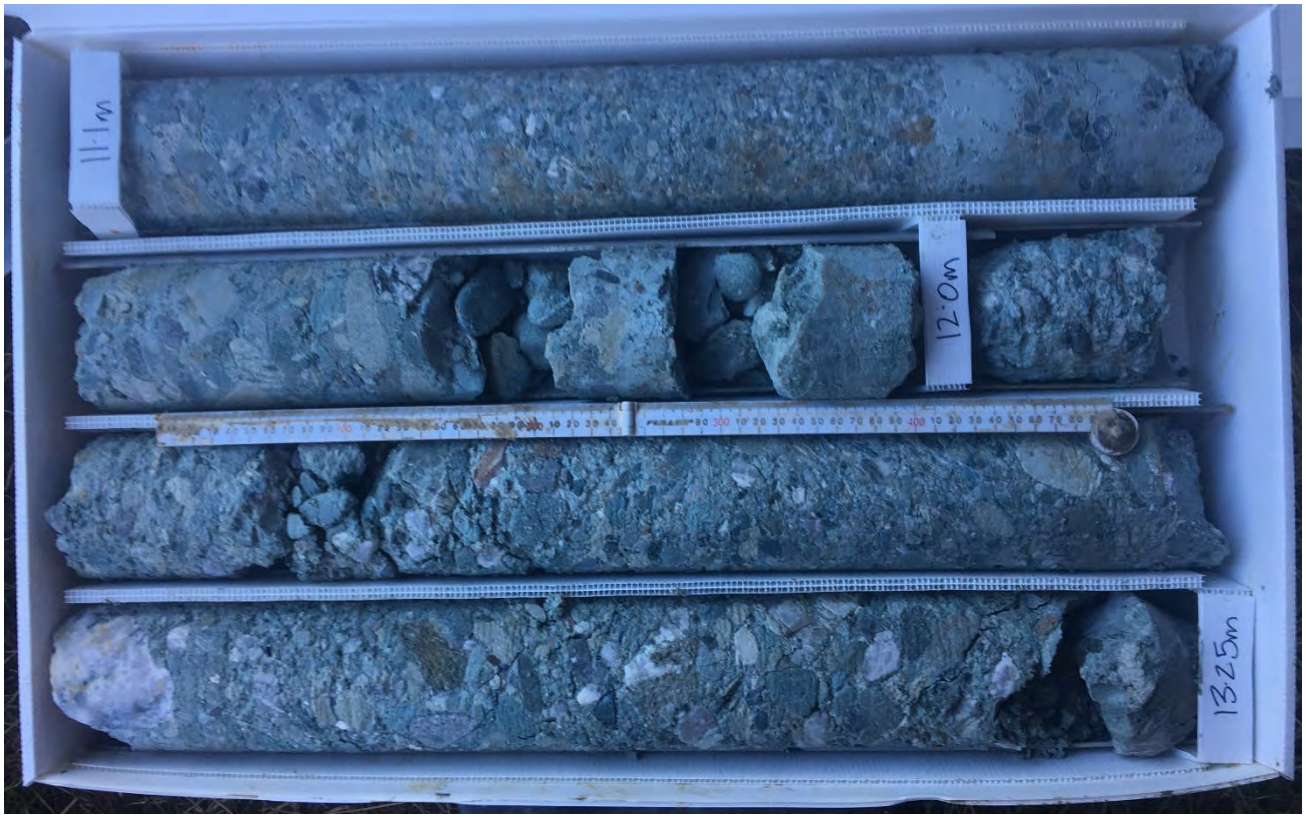
Box 2 of 8: 3.7 m to 5.7 m



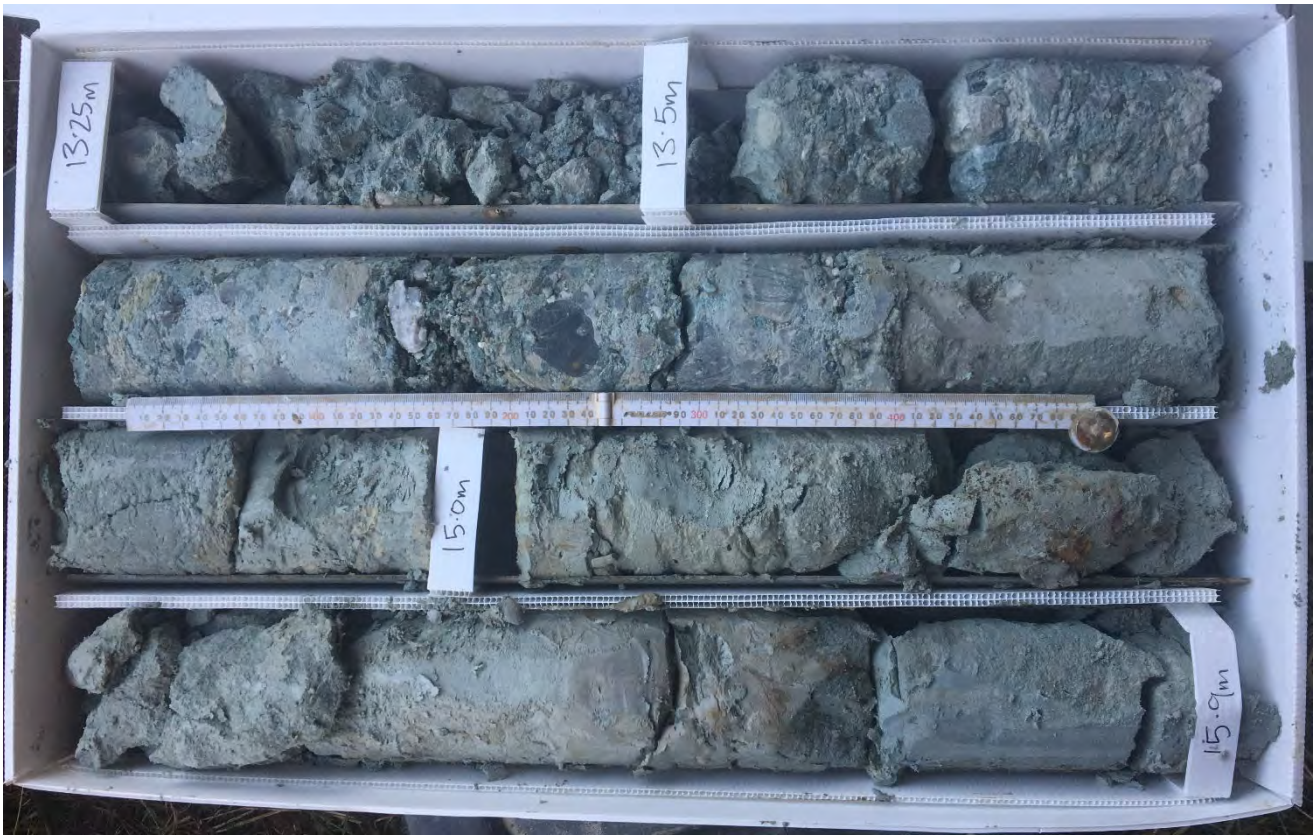
Box 3 of 8: 5.7 m to 8.7 m



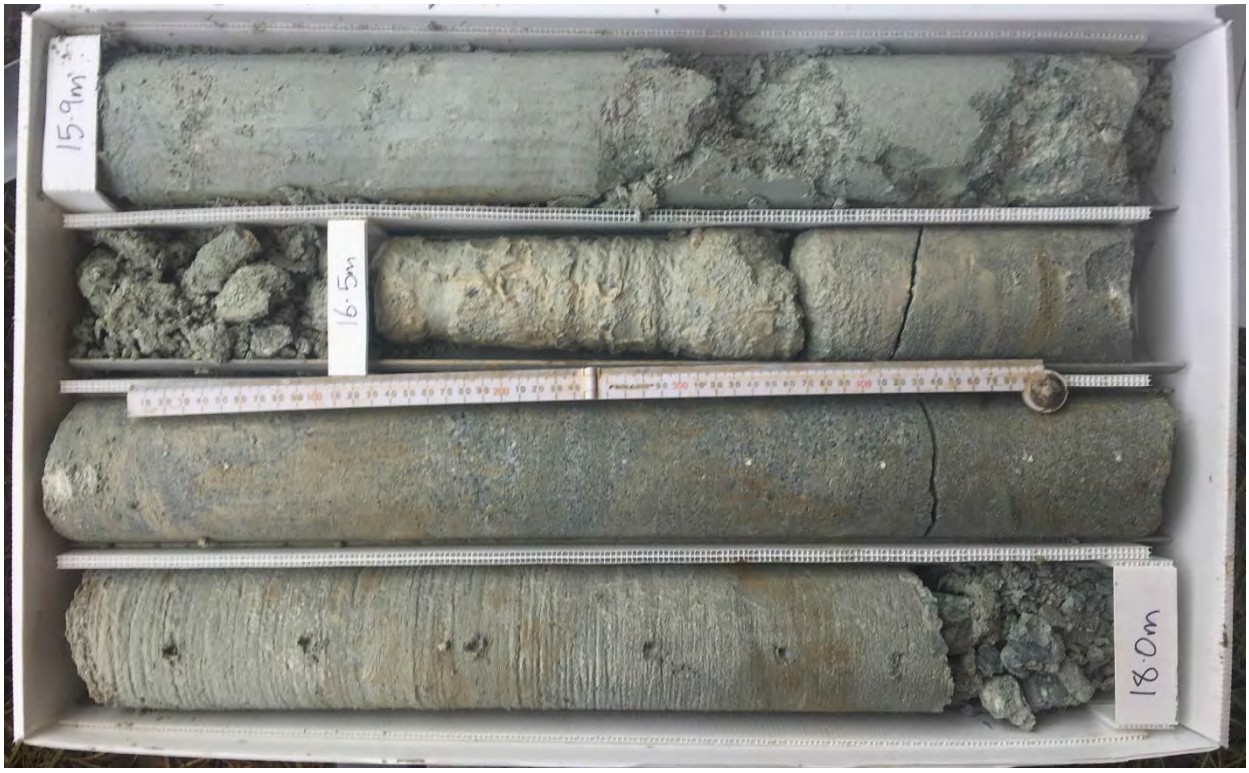
Box 4 of 8: 8.7 m to 11.1 m



Box 5 of 8: 11.1 m to 13.25 m



Box 6 of 8: 13.25 m to 15.9 m



Box 7 of 8: 15.9 m to 18.0 m

Box 8 of 8: 18.0 m to 20.0 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Western Boundary
Job Number: 12506381
Commenced: 12/06/2019 Completed: 12/06/2019

Hole No. : BH09a
Sheet : 1 of 2
Hole Length : 16.50m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 395951.84 Northing: 788050.36 System: TAIETM2000
RL: 132.8 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
132	0	0.00 - 0.50 m: CORELOSS (FILL: reworked Loess)	FILL													
	0.5	SILT, trace to minor clay, trace fine to coarse sand, trace fine gravel; grey and orange-brown. Very stiff, moist, low plasticity; gravel: angular, iron stained (LOESS) 0.90 m: brown	LOESS	M	VSt				PQTT				67			
131	1 1.1	Fine gravelly SILT, trace clay; yellow-brown and orange-brown. Stiff to very stiff, moist, low plasticity		M	St-VSt											
	1.5	1.50 - 2.40 m: CORELOSS *inferred TARATU FORMATION from minimal recovery														
130	2 2.4	Gravelly medium to coarse SAND; yellow-brown. Poorly graded; gravel: fine, quartz and schist, sub-angular to rounded.							PQTT				40			
	2.6 3	Sandy SILT, minor gravel, trace clay; yellow-brown, orange-brown and grey. Firm, moist, low plasticity. Gravel: fine to medium, quartz and schist, angular to rounded. Sand: fine to medium		M	F											
129	3	3.00 - 9.10 m: CORELOSS *inferred gravelly sand (TARATU FORMATION) from minimal recovery	TARATU FORMATION						PQTT				0			
128	4								PQTT				0			
127	5								PQTT				0			
126	6								PQTT				0			
125	7								PQTT				0			
124	8								PQTT				0			
123	9 9.1	Slightly weathered, thinly laminated, grey silty fine SANDSTONE; very weak; very wide spaced defects							PQTT		SW		100 93			

Notes and Comments:
End of Hole @ 16.50m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Western Boundary
Job Number: 12506381
Commenced: 12/06/2019 Completed: 12/06/2019

Hole No. : BH09a
Sheet : 2 of 2
Hole Length : 16.50m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 395951.84 Northing: 788050.36 System: TAIETM2000
RL: 132.8 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
122	10		Slightly weathered, thinly laminated, grey silty fine SANDSTONE; very weak; very wide spaced defects *(continued from layer starting at 9.1m)*							PQTT				100 93			
121	11		10.80 m: very weak to weak							PQTT		SW		100 100 100			
120	12		11.90 m: extremely to very weak; trace to minor fine gravel: quartz and schist, angular to sub-angular							PQTT				27 20 16			
119	13	12.4	12.40 - 16.50 m: CORELOSS *minimal silty fine sand and angular to sub-rounded, quartz and schist gravel recovered (Inferred weathered breccia)	HENLEY BRECCIA						PQTT				15 0 0			
118	14																12-06-2019 Groundwater at 13.93 mbgl
117	15									PQTT				0 0 0			
116	16		End of Hole @ 16.50m,Target Depth.														
115	17																
114	18																
113	19																
	20																

Notes and Comments:
End of Hole @ 16.50m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

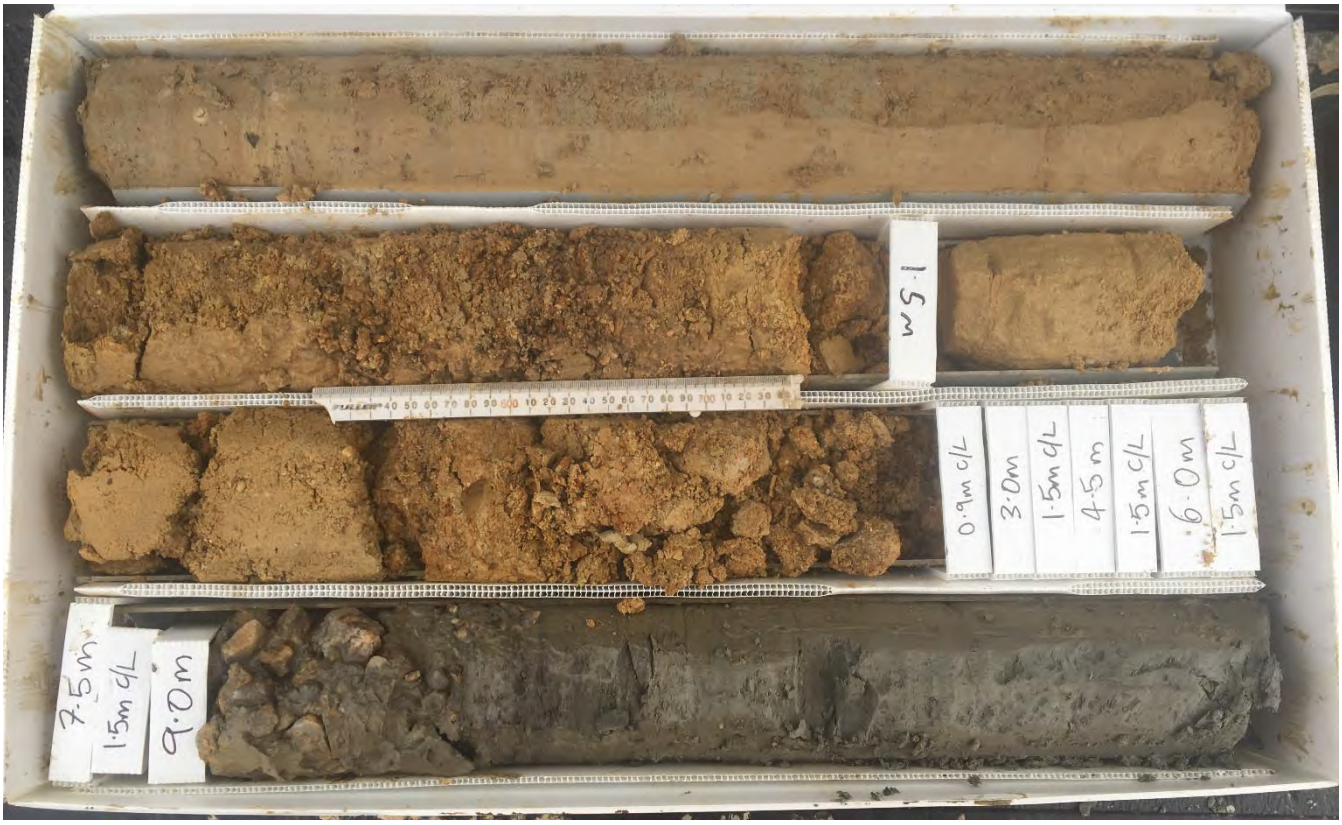
Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
12/06/19	00:00	13.93	16.5

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 7 August 2019

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 2
Borehole ID	BH09	



Box 1 of 3: 0.0 m to 9.6 m

Box 2 of 3: 9.6 m to 11.7 m

Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 2 of 2
Borehole ID	BH09	

Box 3 of 3: 11.7 m to 16.5 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern Ridge
Job Number: 12506381
Commenced: 4/06/2019 Completed: 5/06/2019

Hole No. : BH10a
Sheet : 1 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396788.26 Northing: 788118.5 System: TAIETM2000
RL: 139.07 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
139	0	TOPSOIL; silt, trace fine sand, trace clay; brown. Firm to stiff, moist, low plasticity	TS	M	F-St											
	0.25	0.25 - 1.60 m: CORELOSS							PQTT				12			
138	1		LOESS													
	1.6	Fine sandy SILT; light grey and yellow-brown. Stiff, moist, low plasticity (LOESS)		M	St				PQTT				100			
137	2															
	2.4	Fine to coarse SAND, minor silt. Poorly graded; highly weathered rock (TARATU FORMATION)	TARATU FORMATION													
	2.6	Pebbly coarse SAND. Poorly graded, highly weathered rock									HW					
136	3															
	3.3	Moderately weathered, grey, orange-brown and yellow-brown SILTSTONE; very weak to weak, no defects							PQTT				93 93 93			
135	4	4.30 - 4.60 m: SANDSTONE														
	4.9	Moderately weathered, light grey and orange-brown fine SANDSTONE; very weak to weak; no defects; occasional fine gravel sized lignite fragments 5.50 m: 140 mm SILTSTONE							PQTT				86 86 86			
134	5															
	6.6	Moderately weathered, orange-brown, white and grey CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported. Clasts: fine to medium gravel, quartz and schist, sub-angular to rounded							PQTT		MW		93 93 93			
133	6															
	7.05	Moderately weathered, light grey and orange-brown SILTSTONE; very weak to weak														
132	7															
	7.72	Moderately weathered, orange-brown, white and grey CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported; clasts: fine to medium gravel, quartz and schist, sub-angular to rounded 7.72 - 8.80 m: CORELOSS							PQTT				28 28 28			
131	8															
	8.8	8.80 - 9.10 m: CORELOSS														
130	9															
	9.1	Moderately weathered, orange-brown, white and grey CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported. Clasts: fine to medium gravel, quartz and schist, sub-angular to rounded							PQTT		SW		75 75 75			
	9.55															

Notes and Comments:
End of Hole @ 20.00m, Target Depth.

Hole extended to find groundwater.
Groundwater at 10.17 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern Ridge
Job Number: 12506381
Commenced: 4/06/2019 Completed: 5/06/2019

Hole No. : BH10a
Sheet : 2 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396788.26 Northing: 788118.5 System: TAIETM2000
RL: 139.07 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
128	11		Slightly weathered, laminated to very thinly bedded, grey fine SANDSTONE; very weak to weak; occasional lignite (HENLEY BRECCIA) *(continued from layer starting at 9.6m)*	HENLEY BRECCIA						PQTT		SW		100 81 81			
			10.40 m: yellow-brown, fine to coarse sand grain size														
127	12		11.40 - 11.60 m: weak to moderately strong 11.40 - 17.40 m: very weak to weak							PQTT				100 96 96			
126	13									PQTT				92 92 92			
125	14																
124	15		15.50 m: with closely spaced thin to very thin beds of lignite							PQTT				89 89 89			
123	16																
122	17		17.40 m: moderately strong to strong, well indurated 17.40 - 17.65 m: moderately strong to strong 17.65 - 19.20 m: very weak to weak							PQTT				100 100 100			
121	18									PQTT				100 100 100			
120	19		19.20 - 19.80 m: weak to moderately strong							PQTT				100 100 100			
			19.80 - 20.00 m: moderately strong to strong														
			End of Hole @ 20.00m,Target Depth.														

Notes and Comments:
End of Hole @ 20.00m, Target Depth.

Hole extended to find groundwater.
Groundwater at 10.17 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/06/19	00:00	10.17	20

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 17 January 2020

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern Ridge
Job Number: 12506381
Commenced: 4/06/2019 Completed: 5/06/2019

Hole No. : BH10b
Sheet : 1 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396788.26 Northing: 788118.5 System: TAIETM2000
RL: 139.07 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
139	0	TOPSOIL; silt, trace fine sand, trace clay; brown. Firm to stiff, moist, low plasticity	TS	M	F-St											
	0.25	0.25 - 1.60 m: CORELOSS														
138	1		LOESS						PQTT				12			
	1.6	Fine sandy SILT; light grey and yellow-brown. Stiff, moist, low plasticity (LOESS)		M	St											
137	2								PQTT				100			
	2.4	Fine to coarse SAND, minor silt. Poorly graded; highly weathered rock (TARATU FORMATION)	TARATU FORMATION													
	2.6	Pebbly coarse SAND. Poorly graded, highly weathered rock									HW					
136	3								PQTT				93 93 93			
	3.3	Moderately weathered, grey, orange-brown and yellow-brown SILTSTONE; very weak to weak, no defects														
135	4	4.30 - 4.60 m: SANDSTONE														
	4.9	Moderately weathered, light grey and orange-brown fine SANDSTONE; very weak to weak; no defects; occasional fine gravel sized lignite fragments														
134	5	5.50 m: 140 mm SILTSTONE							PQTT				86 86 86			
133	6								PQTT		MW		93 93 93			
	6.6	Moderately weathered, orange-brown, white and grey CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported. Clasts: fine to medium gravel, quartz and schist, sub-angular to rounded														
132	7								PQTT				28 28 28			
	7.05	Moderately weathered, light grey and orange-brown SILTSTONE; very weak to weak														
	7.72	Moderately weathered, orange-brown, white and grey CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported; clasts: fine to medium gravel, quartz and schist, sub-angular to rounded														
131	8	7.72 - 8.80 m: CORELOSS														
	8.8	8.80 - 9.10 m: CORELOSS														
130	9								PQTT		SW		75 75 75			
	9.1	Moderately weathered, orange-brown, white and grey CONGLOMERATE; very weak to weak; coarse sand matrix, matrix supported. Clasts: fine to medium gravel, quartz and schist, sub-angular to rounded														
	9.55															

Notes and Comments:
End of Hole @ 20.00m, Target Depth.

Hole extended to find groundwater.
Groundwater at 18.36 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern Ridge
Job Number: 12506381
Commenced: 4/06/2019 Completed: 5/06/2019

Hole No. : BH10b
Sheet : 2 of 2
Hole Length : 20.00m
Scale @ A4 : 1:50
Logged : MF
Processed : HB
Checked : JHS

Easting: 396788.26 Northing: 788118.5 System: TAIETM2000
RL: 139.07 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
128	11		Slightly weathered, laminated to very thinly bedded, grey fine SANDSTONE; very weak to weak; occasional lignite (HENLEY BRECCIA) *(continued from layer starting at 9.6m)*	HENLEY BRECCIA						PQTT		SW		100 81 81			
			10.40 m: yellow-brown, fine to coarse sand grain size														
127	12		11.40 - 11.60 m: weak to moderately strong 11.40 - 17.40 m: very weak to weak							PQTT				100 96 96			
126	13									PQTT				92 92 92			
125	14																
124	15		15.50 m: with closely spaced thin to very thin beds of lignite							PQTT				89 89 89			
123	16																
122	17		17.40 m: moderately strong to strong, well indurated 17.40 - 17.65 m: moderately strong to strong 17.65 - 19.20 m: very weak to weak							PQTT				100 100 100			
121	18																7-06-2019
120	19		19.20 - 19.80 m: weak to moderately strong							PQTT				100 100 100			
			19.80 - 20.00 m: moderately strong to strong														
			End of Hole @ 20.00m,Target Depth.														

Notes and Comments:
End of Hole @ 20.00m, Target Depth.

Hole extended to find groundwater.
Groundwater at 18.36 mbgl 07/06/2019.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: McNeills
Equipment: UDR600 (truck mounted)
Shear Vane Id:

Ground Water Level

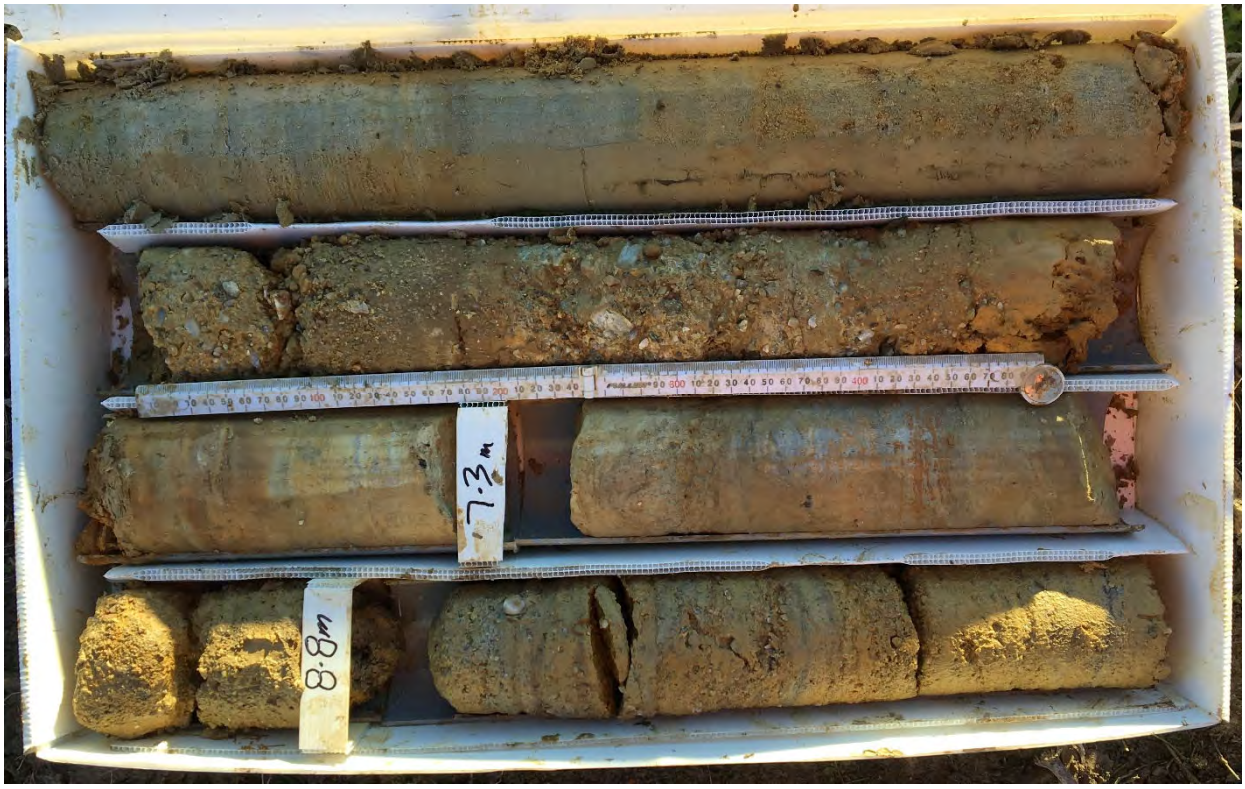
Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/06/19	00:00	18.36	20

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 17 January 2020

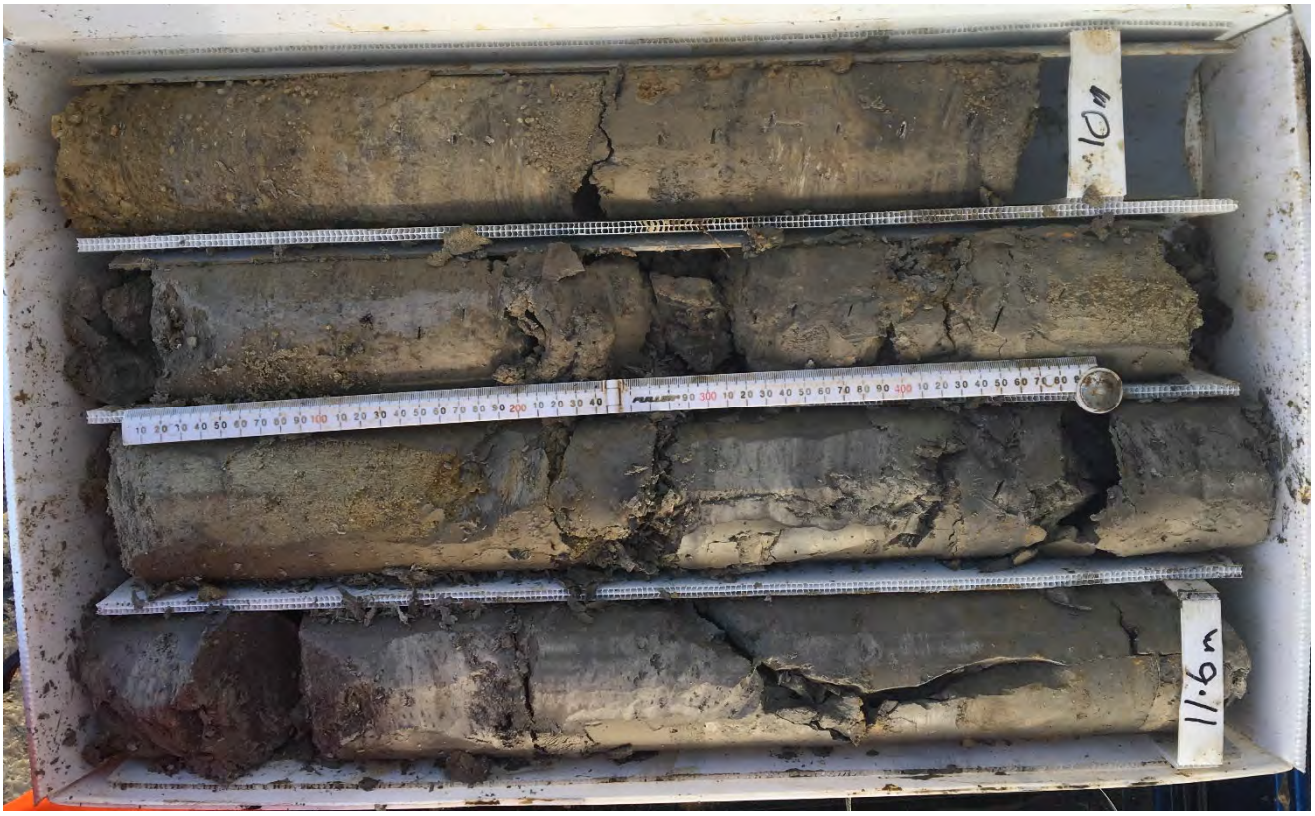
Project	Smooth Hill Landfill Consenting	
Client	Dunedin City Council	
Job number	12506381	Page 1 of 4
Borehole ID	BH10	

Box 1 of 8: 0.0 m to 3.2 m

Box 2 of 8: 3.2 m to 5.8 m



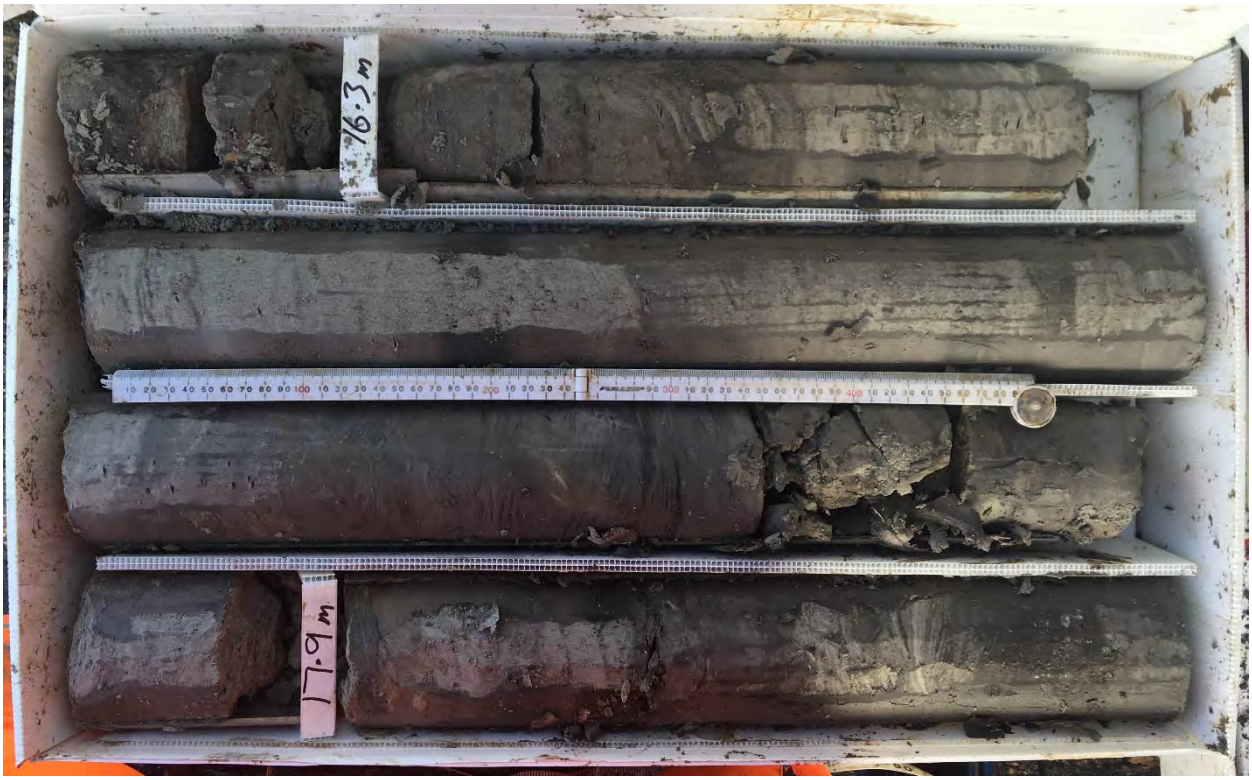
Box 3 of 8: 5.8 m to 9.2 m



Box 4 of 8: 9.2 m to 11.6 m

Box 5 of 8: 11.6 m to 13.8 m

Box 6 of 8: 13.8 m to 16.0 m



Box 7 of 8: 16.0 m to 18.4 m

Box 8 of 8: 18.4 m to 20.0 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Manuka Gully (Stockpile Area)
Job Number: 12506381
Commenced: 12/06/2019 Completed: 12/06/2019

Easting: 395988.85 Northing: 788077.23 System: TAIETM2000
RL: 121.2 Datum: NZVD2016

Hole No. : TP01
Sheet : 1 of 1
Hole Length : 2.50m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
121	0		SILT, trace to minor clay; dark grey-brown. Firm, wet, low plasticity; minor to some organics/roots (TOPSOIL)	TS	W	F											
	0.2		SILT, trace clay, trace fine to medium sand; light grey with orange streaks. Stiff to very stiff, moist, low plasticity; iron-stained organics throughout (ALLUVIUM)	ALLUVIUM	M	St-VSt											
	0.7		Gravelly SILT, minor clay, minor fine to coarse sand; orange-brown. Very stiff, moist to wet, low plasticity; gravel: fine to medium, quartz and schist, sub-angular to rounded; highly weathered rock (HENLEY BRECCIA) 1.10 m: grey with some orange-brown	HENLEY BRECCIA	M-W	VSt						HW					
120	1																
	1.9		Slightly weathered, grey with black streaks SILTSTONE; very weak; ripped easily with toothed excavator bucket									SW					
119	2																
			End of Hole @ 2.50m,Target Depth.														
118	3																
117	4																
	5																

Notes and Comments:
End of Hole @ 2.50m, Target Depth.

Soils too gravelly for shear vane.
Groundwater seepage into test pit at 1.0 mbgl

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - toothed bucket
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Manuka Gully (Stockpile Area)
Job Number: 12506381
Commenced: 12/06/2019 Completed: 12/06/2019

Easting: 396103.5 Northing: 788056.91 System: TAIETM2000
RL: 110.4 Datum: NZVD2016

Hole No. : TP02

Sheet : 1 of 1
Hole Length : 2.60m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
110	0		SILT, trace to minor fine sand, trace to minor clay; brown. Firm, moist, low plasticity; minor organics/roots (TOPSOIL)	TOPSOIL	M	F		SV@0.3m 65/17 kPa									
	0.6		Silty SAND, trace clay; light grey with orange-brown streaks. 'Loose to medium dense', poorly graded; sand: fine (COLLUVIUM)	COLLUVIUM		'L-MD'											
109	1.4		SILT, minor clay, trace to minor fine sand; brown. Firm, moist, low plasticity; wood fragments throughout layer, most at top (BURIED TOPSOIL)	BURIED TOPSOIL	M	F		SV@1.8m 90/33 kPa									
108	2.1		Gravelly SILT; grey. Wet, well graded; gravel: fine to coarse (ALLUVIUM)	ALLUVIUM	W												
	2.4		Slightly weathered, grey SILTSTONE; ripped easily with toothed bucket (HENLEY BRECCIA)	HB								SW					
107			End of Hole @ 2.60m,Target Depth.														
106																	

Groundwater seepage into test pit at 0.4 mbgl
12-06-2019

Notes and Comments:
End of Hole @ 2.60m, Target Depth.
Groundwater seepage into test pit at 0.4 mbgl.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - toothed bucket
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
12/06/19	00:00	0.4	2.6

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Manuka Gully (Stockpile Area)
Job Number: 12506381
Commenced: 12/06/2019 Completed: 12/06/2019

Hole No. : TP03
Sheet : 1 of 1
Hole Length : 2.00m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

Easting: 396262.16 Northing: 788048.16 System: TAIETM2000
RL: 102.61 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
102	0		SILT, trace to minor fine sand, trace to minor clay; brown. Soft, moist to wet, low plasticity; minor organics/roots (TOPSOIL)	TOPSOIL	M-W	S											
	0.7		Silty SAND, trace clay; light grey with brown streaks. Moist, poorly graded; sand is fine (ALLUVIUM)	ALLUVIUM	M												
101	1.2		Gravelly SILT; grey. Wet to saturated, well graded; gravel: fine to coarse		W - S												12-06-2019 Groundwater encountered at 1.2 mbgl
	1.7		Slightly weathered, grey SILTSTONE; extremely to very weak; no defects - ripped easily (HENLEY BRECCIA)	HB								SW					
100	2		End of Hole @ 2.00m,Target Depth.														
99	3																
98	4																
	5																

Notes and Comments:
End of Hole @ 2.00m, Target Depth.

Test pit sides too soft to get shear vane readings.
Groundwater encountered at 1.2 mbgl.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - toothed bucket
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
12/06/19	00:00	1.2	2

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southwest Gully Base
Job Number: 12506381
Commenced: 13/06/2019 Completed: 13/06/2019

Hole No. : TP05
Sheet : 1 of 1
Hole Length : 3.30m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

Easting: 396281 Northing: 787868 System: TAIETM2000
RL: 125 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
125	0		SILT, minor clay; brown. Soft, wet to saturated, low plasticity; minor organics throughout (TOPSOIL)	TOPSOIL	W-S	S											
	0.7		Silty fine to medium SAND; grey and yellow-brown. 'Loose', wet, poorly graded (COLLUVIUM)	COLLUVIUM	W	'L'											
124	1		Fine to coarse SAND, minor to some silt; grey with black streaks. 'Loose', saturated, poorly graded; organics throughout		S	'L'											
	1.4		Tree trunks and branches with some gravel. Groundwater outflow from base of layer														
	1.8		SILT, minor clay, trace fine sand; grey with yellow-brown streaks. Stiff, moist, low plasticity; highly weathered rock (HENLEY BRECCIA)	HENLEY BRECCIA	M	St						HW					
123	2																
	2.8		Slightly weathered, SILTSTONE; ripped easily									SW					
122	3																
			End of Hole @ 3.30m,Target Depth.														
121	4																
120																	
	5																

13-06-2019 Groundwater flowing into pit

Notes and Comments:
End of Hole @ 3.30m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - toothed bucket
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
13/06/19	00:00	1.9	3.3

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Gully East of Central Ridge
Job Number: 12506381
Commenced: 13/06/2019 Completed: 13/06/2019

Hole No. : TP06
Sheet : 1 of 1
Hole Length : 2.50m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

Easting: 396585.7 Northing: 787800.45 System: TAIETM2000
RL: 108.24 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
108	0		Organic SILT, minor clay; dark brown-grey. Firm, moist, low plasticity; minor to some roots (TOPSOIL)	TOPSOIL	M	F											
	0.5		SILT, minor clay, light grey with orange-brown streaks. Stiff, moist, low plasticity; minor organic inclusions (ALLUVIUM)	ALLUVIUM	M	St											
107	1																
106	2																
	2.3		SILTSTONE; difficult to rip (HENLEY BRECCIA)	HB													
105	3		End of Hole @ 2.50m,Target Depth.														
104	4																
	5																

Notes and Comments:
End of Hole @ 2.50m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - toothed bucket
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
13/06/19	00:00		2.5

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southwest Gully Base
Job Number: 12506381
Commenced: 28/05/2019 Completed: 28/05/2019

Hole No. : TP07
Sheet : 1 of 1
Hole Length : 2.50m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

Easting: 396182 Northing: 787790 System: TAIETM2000
RL: 120 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
120	0		SILT/organic matter, brown. Soft, moist to saturated, fibrous, non plastic (TOPSOIL)	TOPSOIL	M-W	S				TP		SW					28-05-2019 Water perched on SILTSTONE
	0.5		SILT, minor clay, trace fine sand; light grey and yellow-brown. Stiff to very stiff, moist, low plasticity (LOESS)	LOESS	M	St-VSt											
119	1																
	1.4		Slightly weathered, grey SILTSTONE; weak to moderately strong; no defects (HENLEY BRECCIA)	HENLEY BRECCIA													
118	2																
	2.4		BRECCIA														
			End of Hole @ 2.50m,Target Depth.														
117	3																
116	4																
115																	

Notes and Comments:
End of Hole @ 2.50m, Target Depth.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - smooth bucket
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
28/05/19	00:00	1.4	2.5

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Gully Between Southern Ridges
Job Number: 12506381
Commenced: 28/05/2019 Completed: 28/05/2019

Hole No. : TP08
Sheet : 1 of 1
Hole Length : 4.50m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

Easting: 396303 Northing: 787682 System: TAIETM2000
RL: 115 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
114	0		SILT, minor clay, trace fine sand; dark grey. Firm to stiff, moist, low plasticity;, minor organic matter (FILL)	FILL	M	F-St											
	0.6		0.50 m: grass and trees - buried surface, saturated		S												
	1		SILT, minor clay, trace fine sand; dark grey. Firm to stiff, wet, low plasticity; trace to minor organics (BURIED TOPSOIL)	BURIED TOPSOIL	W	F-St											
113	1.2		SILT, minor to some clay, trace fine sand; light grey and yellow-brown. Stiff to very stiff, moist, low plasticity; trace organics (LOESS)	LOESS	M	St-VSt											
	2																
112	3																
	3.5		SILT, some coarse sand, minor fine gravel; light grey. Stiff to very stiff, moist, non-plastic; gravel comprises quartz and schist; highly weathered rock (HENLEY BRECCIA)	HENLEY BRECCIA	M	St-VSt						HW					
111	4																
	4.5		End of Hole @ 4.50m,End of Reach.														
110	5																

Notes and Comments:
End of Hole @ 4.50m, End of Reach.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator - smooth bucket
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
28/05/19	00:00		4.5

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : South East Gully Outflow
Job Number: 12506381
Commenced: 13/06/2019 Completed: 13/06/2019

Hole No. : TP09
Sheet : 1 of 1
Hole Length : 3.00m
Scale @ A4 : 1:25
Logged : MF
Processed : MF
Checked : MF

Easting: 396577.97 Northing: 787947.86 System: TAIETM2000
RL: 101.04 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
101	0		SILT, minor fine to coarse gravel; yellow-brown and grey. Stiff, moist, low plasticity; minor organic content (SLIP DEBRIS)	SLIP DEBRIS	M	St											
	0.4		Branches and grass (BURIED VEGETATION)														
	0.5		SILT, minor clay; brown. Firm to stiff, moist, low plasticity (BURIED TOPSOIL)	BTS	M	F-St											
	0.7		Gravelly silty SAND; orange-brown. Moist, poorly graded; gravel is fine; sand is fine to coarse (ALLUVIUM)	ALLUVIUM	M												
100	1		1.00 m: light grey and orange-brown														
			1.30 m: light grey with orange-brown streaks														
99	2																
	2.7		Fine SANDSTONE; easily ripped (HENLEY BRECCIA)	HB													
98	3		End of Hole @ 3.00m,Target Depth.														
97	4																
	5																

Notes and Comments:
End of Hole @ 3.00m, Target Depth.
Test pit dug to side of gully base - too boggy in gully base to excavate

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor:
Equipment: 22t Excavator
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Future Laydown Area
Job Number: 12506381
Commenced: 10/06/2019 Completed: 10/06/2019

Hole No. : TP10
Sheet : 1 of 1
Hole Length : 3.60m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

Easting: 396820.11 Northing: 788079.25 System: TAIETM2000
RL: 140.74 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
140	0		SILT, trace to minor clay, trace fine sand; dark grey. Very stiff, moist, low plasticity; tree roots throughout (TOPSOIL)	TOPSOIL	M	VSt											
	0.4		SILT, minor clay; light grey and yellow-brown. Very stiff, moist, low plasticity; root webs throughout (LOESS)		M	VSt		SV@0.5m 136/62 kPa									
139	1							SV@1m 194 kPa									
	1.2		SILT, minor fine sand, trace clay; orange-brown and light grey. Very stiff, dry, low plasticity	LOESS	D	VSt		SV@1.5m 194 kPa									
138	2							SV@2m 194 kPa									
	2.2		SILT, minor fine sand, trace clay; orange-brown. Very stiff, dry, low plasticity; iron-stained horizon		D	VSt											
			SILT; orange-brown and grey alternating. Very stiff, dry, non-plastic		D	VSt	2.20	SV@2.5m UTP									
137	3							SV@3m UTP				HW					
			Highly weathered SILTSTONE (HENLEY BRECCIA) 3.00 - 3.60 m: hard, root webs visible in places	HENLEY BRECCIA		H		SV@3.5m UTP									
136	4		End of Hole @ 3.60m,Target Depth.				3.60										
	5																

Notes and Comments:
End of Hole @ 3.60m, Target Depth.

EOH at 3.6 mbgl, too hard to dig/end of reach.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Future Laydown Area
Job Number: 12506381
Commenced: 10/06/2019 Completed: 10/06/2019

Hole No. : TP11
Sheet : 1 of 1
Hole Length : 3.80m
Scale @ A4 : 1:25
Logged : MF
Processed : HB
Checked : MF

Easting: 396907.03 Northing: 788032.98 System: TAIETM2000
RL: 141.24 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
141	0		SILT, trace to minor clay, trace fine sand; dark grey and orange-brown. Very stiff, moist, low plasticity; tree roots extend to approximately 1.2 m bgl (TOPSOIL)	TOPSOIL	M	VSt											
	0.5		SILT, trace to minor clay; grey with orange-brown streaks. Very stiff, moist, low plasticity (LOESS)	LOESS	M	VSt		SV@0.5m 140/36 kPa									
140	1							SV@1m 194 kPa									
	1.3		SILT, trace clay; light grey/white and orange-brown. Very stiff, dry, low plasticity; powdery when crumbled, iron-staining throughout; strength increases with depth 1.80 m: 50-100 mm iron-stained layer. 2.00 m: 50-100 mm iron-stained layer.		D	VSt	1.50	SV@1.5m 194 kPa									
139	2							SV@2m UTP									
	2.6		Highly weathered, orange-brown SILTSTONE (HENLEY BRECCIA) 2.70 m: light grey and orange-brown 3.00 m: grey and orange-brown.	HENLEY BRECCIA			3.50	SV@2.8m UTP				HW					
138	3							SV@3.7m UTP									
137	4		End of Hole @ 3.80m,Target Depth.														

Notes and Comments:
End of Hole @ 3.80m, Target Depth.
EOH at 3.08 mbgl, too hard to excavate.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Fulton Hogan
Equipment: 22t excavator
Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
10/06/19	00:00		3.8

Project	: Smooth Hill Landfill Consenting	Hole No.	: TP12
Client	: Dunedin City Council	Sheet	: 1 of 1
Site	: Future Laydown Area	Hole Length	: 4.40m
Job Number: 12506381		Scale @ A4	: 1:25
Commenced: 10/06/2019	Completed: 10/06/2019	Logged	: MF
Easting: 396596.93	Northing: 787986.46	Processed	: HB
System: TAIETM2000		Checked	: MF
RL: 142.28	Datum: NZVD2016		

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
142	0		SILT, minor clay, trace fine sand, dark grey and brown. Stiff to very stiff, moist, low plasticity. Trace to minor roots (FILL)	FILL	M	St-VSt		SV@0.4m 139/44 kPa									
	0.7		Sandy SILT, grey. Very stiff, dry, non-plastic; some large roots extend to approximately 1.2 m bgl; trace organics; sand is fine (BURIED TOPSOIL).	BTS	D	VSt											
141	1		Sandy SILT; light grey, light yellow-brown and orange-brown. Very stiff, dry, non-plastic; sand is fine; occasional roots to 1.2 m bgl; strength increases with depth (LOESS)		D	VSt	1.00	SV@1m UTP									
140	2							SV@2m UTP									
			2.50 m: 50-100 mm iron-stained layer	LOESS													
139	3							SV@2.9m UTP									
			3.60 m: 50-100 mm iron-stained layer														
138	4		Highly weathered, SILTSTONE (HENLEY BRECCIA)	HB			4.00					HW					
			End of Hole @ 4.40m,Target Depth.					SV@4.4m UTP									

Notes and Comments:

End of Hole @ 4.40m, Target Depth.

EOH at 4.4 mbgl, deepest excavator could excavate soil.
Groundwater not encountered.

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:

Contractor: Fulton Hogan

Equipment: 22t excavator

Shear Vane Id: GEO2288

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
10/06/19	00:00		4.4

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 29 July 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 29/10/2019 Completed: 1/11/2019

Hole No. : BH201
Sheet : 1 of 7
Hole Length : 61.00m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396596 Northing: 787540 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
144	0	Clayey SILT, trace fine sand; dark grey. Soft, moist to wet, high plasticity; minor to some organic matter, reducing with depth (TOPSOIL)	TS	M-W	S											
	0.35	SILT, minor clay, trace fine sand; grey and orange-brown. Very stiff, moist, low plasticity (LOESS)	LOESS	M	VSt				PQTT				100			
143	1	1.00 - 1.90 m: grey and brown														
142	1.9	SILT, trace clay; light grey with orange-brown streaks. Very stiff, moist, non-plastic; completely weathered (HENLEY BRECCIA)		M	VSt				PQTT		CW		96			
	2															
141	2.65	SILT, some clay to clayey; red-brown, orange-brown and grey. Firm to stiff, moist, high plasticity; minor rock fragments; completely weathered		M	F-St											
	3	SILT, trace to minor clay; red-brown. Very stiff to hard, moist, low plasticity; completely weathered		M	VSt-H											
	3.4	Moderately weathered, grey and yellow-brown, moderately thickly bedded, fine to medium grained SANDSTONE; very weak; very widely spaced defects							PQTT				100 62			
140	4	4.20 - 5.00 m: fine to coarse sand														
139	5	*4.60* BP, 10°, pl, r, Fe-stained, black 4.90 - 5.00 m: grades into breccia														
		Moderately weathered, brown, grey, orange-brown and red-brown BRECCIA; extremely to very weak; very widely spaced defects; matrix supported; fine sandy silt matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel. Soil description: fine to coarse gravelly, fine sandy silt	HENLEY BRECCIA						PQTT		MW		88 34			
138	6															
	6.45	*6.12* JT, 15°, pl, r, clean *6.15* JT, 85°, pl, r, clean *6.17* JT, 20°, pl, r, clean 6.30 - 6.45 m: transition from moderately to slightly weathered							PQTT				100 70			
137	7	Slightly weathered, grey and light grey BRECCIA; very weak to weak; no defects; matrix supported; fine sand matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel														
	7.9	7.00 - 7.90 m: weak to moderately strong 7.20 - 7.90 m: clast supported 7.50 - 7.90 m: medium to coarse gravel							PQTT		SW		100 48			
136	8															
	8.6	Slightly weathered, grey and light grey BRECCIA; extremely to very weak; no defects; matrix supported; fine to medium sand matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel. Soil description: fine to coarse gravelly, fine sandy silt														
135	9															
		Slightly weathered, grey and light grey BRECCIA; weak to moderately strong; no defects; matrix supported; fine to medium sand matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel 9.10 - 9.35 m: 250 mm light grey, fine grained SANDSTONE							PQTT				100 29			
134																

Notes and Comments:
End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 December 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 29/10/2019 Completed: 1/11/2019

Hole No. : BH201
Sheet : 2 of 7
Hole Length : 61.00m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396596 Northing: 787540 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
133	10.8		Slightly weathered, grey and light grey BRECCIA; weak to moderately strong; no defects; matrix supported; fine to medium sand matrix; clasts are angular to subrounded, quartz and schist, fine to coarse gravel *(continued from layer starting at 8.6m)*							PQTT		SW		100 29			
			10.8 m to 61.0 m: Wash drilling							Wash drilled							

Notes and Comments:
End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 December 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 29/10/2019 Completed: 1/11/2019

Hole No. : BH201
Sheet : 3 of 7
Hole Length : 61.00m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396596 Northing: 787540 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
123	21		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							
122	22																
121	23																
120	24																
119	25																
118	26																
117	27																
116	28																
115	29																
114																	

Notes and Comments:
End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 December 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 29/10/2019 Completed: 1/11/2019

Hole No. : BH201
Sheet : 4 of 7
Hole Length : 61.00m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396596 Northing: 787540 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
113	31		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							
112	32																
111	33																
110	34																
109	35																
108	36																
107	37																
106	38																
105	39																
104																	

Notes and Comments:
End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 December 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 29/10/2019 Completed: 1/11/2019

Hole No. : BH201
Sheet : 5 of 7
Hole Length : 61.00m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396596 Northing: 787540 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
103	41		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							
102	42																
101	43																
100	44																
99	45																
98	46																
97	47																
96	48																
95	49																
94																	

Notes and Comments:
End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 29/10/2019 Completed: 1/11/2019

Hole No. : BH201
Sheet : 6 of 7
Hole Length : 61.00m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396596 Northing: 787540 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistency / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
93	51		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							
92	52																
91	53																
90	54																
89	55																
88	56																
87	57																
86	58																
85	59																
84																	

Notes and Comments:
End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 29/10/2019 Completed: 1/11/2019

Hole No. : BH201
Sheet : 7 of 7
Hole Length : 61.00m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396596 Northing: 787540 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
83	61		10.8 m to 61.0 m: Wash drilling *(continued from layer starting at 10.8m)*							Wash drilled							
			End of Hole @ 61.00m,Target Depth.														
82	62																
81	63																
80	64																
79	65																
78	66																
77	67																
76	68																
75	69																
74																	

60 61 62 63 64 65 66 67 68 69 70

Notes and Comments:
End of Hole @ 61.00m, Target Depth.

0.0 - 10.8 m PQTT coring
10.8 - 61.0 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track Mounted Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 December 2019

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH201

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	28/10/2019	**Completed**	01/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.8 m		

Box 1 of 5: 0.00 m to 2.30 m

Box 2 of 5: 2.30 m to 4.50 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH201

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	28/10/2019	**Completed**	01/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.8 m		

Box 3 of 5: 4.50 m to 6.80 m

Box 4 of 5: 6.80 m to 9.00 m

Report of Photographs

Site Identification: BH201

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	28/10/2019	**Completed**	01/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.8 m		

Box 5 of 5: 9.00 m to 10.80 m

10.80 m to 61.00 m (EOH) – Wash drilled, no core recovered

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 2/11/2019 Completed: 4/11/2019

Hole No. : BH202
Sheet : 1 of 7
Hole Length : 60.60m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396181 Northing: 787498 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
144	0	SILT, trace to minor clay; grey and orange-brown. Firm to stiff, moist, low plasticity (FILL/COLLUVIUM?)	FILL/COLLUVIUM?	M	F-St				PQTT							
		0.30 - 0.80 m: brown and grey, very stiff			VSt											
143	1	0.80 - 0.90 m: trace clay, grey, stiff, minor to some organic matter (roots)			St								100			
		0.90 - 1.20 m: grey and brown, very stiff, trace iron-oxide nodules, "chaotic" texture			VSt											
	1.5	1.20 - 1.60 minor iron-oxide nodules														
142	2	SILT, trace to minor clay; dark brown. Very stiff, moist, low plasticity; small branches (BURIED TOPSOIL)	T	M	VSt-H				PQTT				100			
		SILT, trace clay; orange-brown and grey; Very stiff to hard, moist, non-plastic; trace iron-oxide nodules; completely weathered (HENLEY BRECCIA)														
141	3	2.60 - 2.80 m: minor to some iron-oxide nodules - increases with depth														
	3.5	Gravelly, sandy SILT; orange-brown, brown and grey; Very stiff to hard, moist, non-plastic; sand is medium to coarse; gravel is fine to medium, angular to subrounded, quartz and schist; completely weathered		M	VSt-H				PQTT				94			
140	4	4.10 - 4.50 m: CORE LOSS							PQTT		CW		0			
	4.5	4.50 - 5.70 m: CORE LOSS							PQTT				0			
139	5															
	5.7	Gravelly, sandy SILT; orange-brown, brown and grey; Very stiff to hard, moist, non-plastic; sand is medium to coarse; gravel is fine to medium, angular to subrounded, quartz and schist; completely weathered	HENLEY BRECCIA	M	VSt-H				PQTT				100			
138	5.9	SILT, trace to minor clay; grey and brown. Very stiff to hard, moist, non-plastic; completely weathered		M	VSt-H											
	6.3	Gravelly, silty SAND; orange-brown. Moist; well sorted; sand is fine to coarse; gravel is fine to medium, angular to subrounded, quartz and schist; completely weathered		M					PQTT				95			
137	6.75	Gravelly, sandy SILT; orange-brown and grey. Firm, moist, non-plastic; sand is fine to coarse; gravel is fine to medium, angular to subrounded, quartz and schist; completely weathered		M	F											
	7.4	Highly weathered, light brown, thinly to moderately thickly bedded SILTSTONE; extremely weak; no defects. Soil description: SILT, minor clay; hard							PQTT		HW		100			
136	7.8	Moderately weathered, dark grey, thinly bedded SILTSTONE; extremely to very weak; no defects; trace to minor lignite									MW		83			
	8	Moderately weathered, light grey, fine to coarse grained SANDSTONE; very weak; no defects														
	8.2	Moderately weathered, black, LIGNITE; very weak, no defects														
135	8.5	Slightly weathered, light grey and grey, thinly to moderately thickly bedded, fine to medium grained SANDSTONE; very weak; no defects; occasional lignite layers							PQTT		SW		100			
	9	8.60 - 8.85 m: fine to coarse sand											90			
134		8.99 - 9.02 m: 30 mm lignite														

Notes and Comments:
End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 6 November 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 2/11/2019 Completed: 4/11/2019

Hole No. : BH202
Sheet : 2 of 7
Hole Length : 60.60m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396181 Northing: 787498 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
133	11		9.84 - 9.89 m: 50 mm lignite Slightly weathered, light grey and grey, thinly to moderately thickly bedded, fine to medium grained SANDSTONE; very weak; no defects; occasional lignite layers *(continued from layer starting at 8.5m)* 10.30 - 10.45 m: 150 mm lignite 10.60 m to 60.60 m: Wash drilled	HENLEY BRECCIA						PQTT		SW		100 90			
132	12																
131	13																
130	14																
129	15									Wash drilling							
128	16																
127	17																
126	18																
125	19																
124	20																

10.6

Notes and Comments:
End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 2/11/2019 Completed: 4/11/2019

Hole No. : BH202
Sheet : 3 of 7
Hole Length : 60.60m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396181 Northing: 787498 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
123	21		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*	HENLEY BRECCIA						Wash drilling							
122	22																
121	23																
120	24																
119	25																
118	26																
117	27																
116	28																
115	29																
114																	

Notes and Comments:
End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 6 November 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 2/11/2019 Completed: 4/11/2019

Hole No. : BH202
Sheet : 4 of 7
Hole Length : 60.60m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396181 Northing: 787498 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
113	31		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*	HENLEY BRECCIA						Wash drilling							
112	32																
111	33																
110	34																
109	35																
108	36																
107	37																
106	38																
105	39																
104																	

Notes and Comments:
End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 6 November 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 2/11/2019 Completed: 4/11/2019

Hole No. : BH202
Sheet : 5 of 7
Hole Length : 60.60m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396181 Northing: 787498 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
103	41		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*	HENLEY BRECCIA						Wash drilling							
102	42																
101	43																
100	44																
99	45																
98	46																
97	47																
96	48																
95	49																
94																	

Notes and Comments:
End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 6 November 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 2/11/2019 Completed: 4/11/2019

Hole No. : BH202
Sheet : 6 of 7
Hole Length : 60.60m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396181 Northing: 787498 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
93	51		10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*	HENLEY BRECCIA						Wash drilling							
92	52																
91	53																
90	54																
89	55																
88	56																
87	57																
86	58																
85	59																
84																	

Notes and Comments:
End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 6 November 2019

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southern Boundary
Job Number: 12506381
Commenced: 2/11/2019 Completed: 4/11/2019

Hole No. : BH202
Sheet : 7 of 7
Hole Length : 60.60m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396181 Northing: 787498 System: TAIETM2000
RL: 144 Datum: NZVD2016

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample: Number / Type	Sample: Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
			10.60 m to 60.60 m: Wash drilled *(continued from layer starting at 10.6m)*														
	61		End of Hole @ 60.60m,Target Depth.														

Notes and Comments:
End of Hole @ 60.60m, Target Depth.

0.0 - 10.6 m PQTT coring
10.6 - 60.6 m wash drilling

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

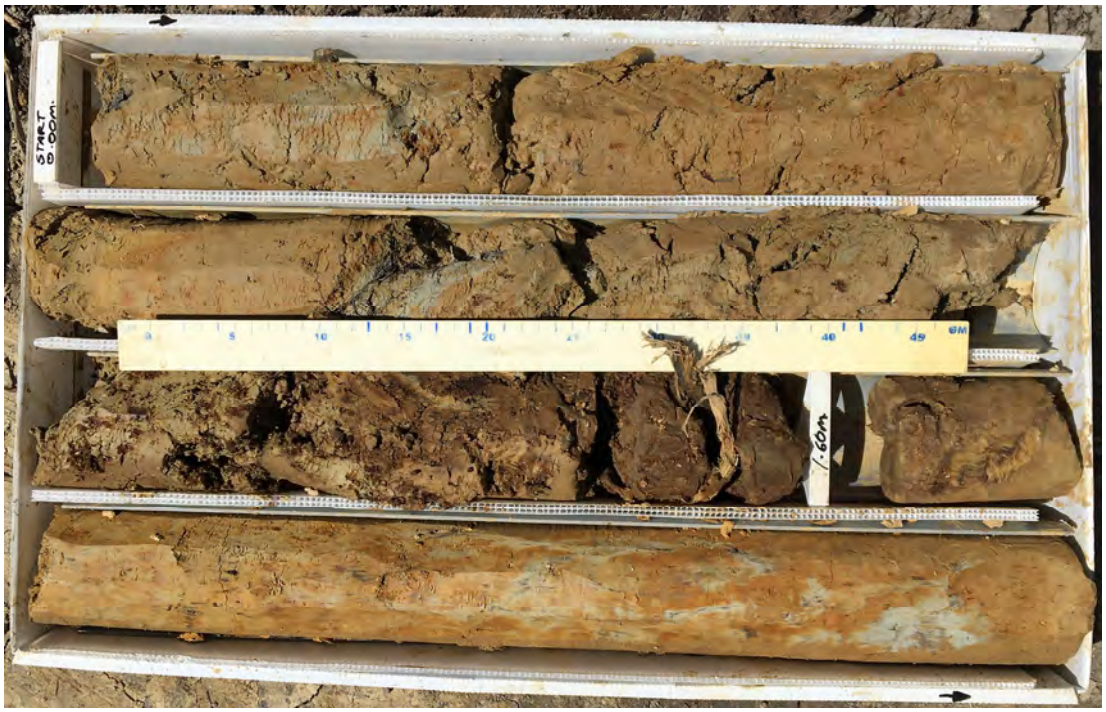
Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 6 November 2019

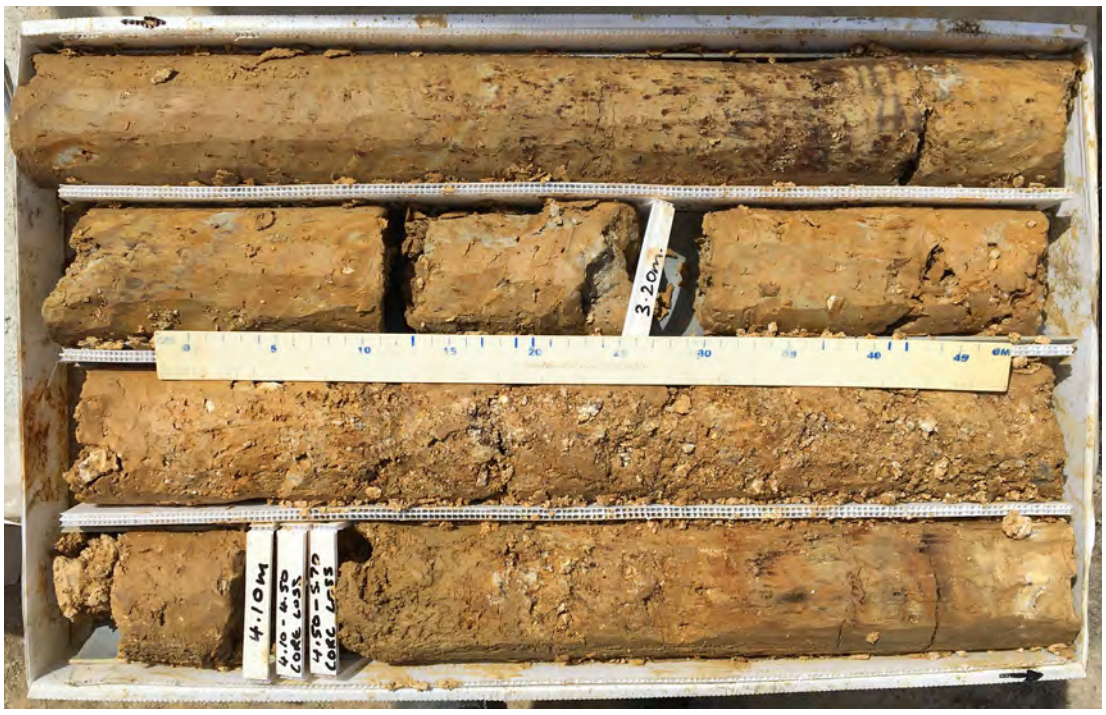
Report of Photographs

Site Identification: BH202

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	02/11/2019	**Completed**	04/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.6 m		



Box 1 of 4: 0.00 m to 2.30 m



Box 2 of 4: 2.30 m to 6.10 m

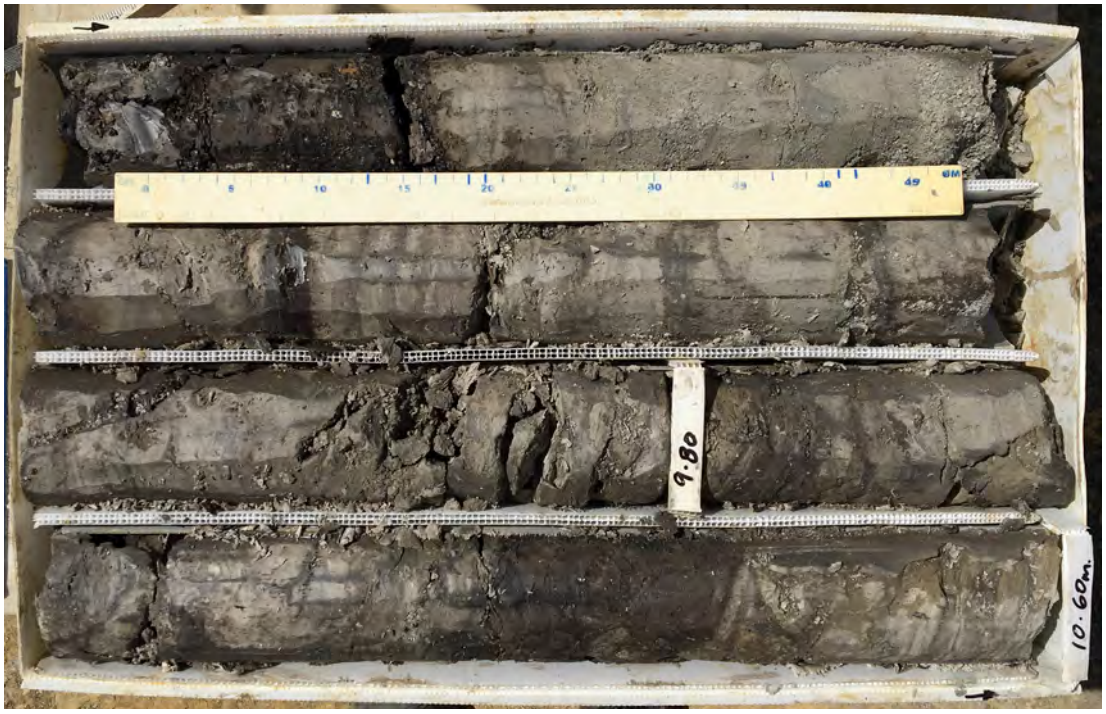
CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH202

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	02/11/2019	**Completed**	04/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.6 m		

Box 3 of 4: 6.10 m to 8.30 m



Box 4 of 4: 8.30 m to 10.60 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH202

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	02/11/2019	**Completed**	04/11/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.6 m		

10.60 m to 60.60 m (EOH) – Wash drilled, no core recovered

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southwest Boundary
Job Number: 12506381
Commenced: 7/11/2019 Completed: 7/11/2019

Hole No. : BH203
Sheet : 1 of 2
Hole Length : 19.70m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 395779 Northing: 787672 System: TAIETM2000
RL: 182 Datum: NZVD2009

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
181	0		Highly weathered, cream, orange-brown and yellow-brown, CONGLOMERATE; extremely weak; no defects; matrix supported; matrix is fine to coarse sandy silt; clasts are fine, rounded to subrounded, quartz and schist gravel. Soil description: gravelly sandy silt (TARATU FORMATION)							PQTT		HW		96 85			
180	1.1		Highly weathered, orange-brown and grey, laminated to moderately thickly bedded SILTSTONE; extremely weak; no defects. Soil description: Silt, minor fine to medium sand, hard	TARATU FORMATION						PQTT				97 76			
179	2.1		1.90 - 2.10 m: moderately weathered, grey with occasional orange-brown Grades into: moderately weathered, grey with occasional orange-brown, laminated to moderately thickly bedded, silty fine grained SANDSTONE; extremely weak; no defects. Soil description: silty fine sand														
178	2.9		Moderately weathered, brown and grey, moderately thickly bedded CONGLOMERATE; very weak to weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine, rounded to subangular, quartz and schist gravel							PQTT				100 66			
177	4.8		Moderately weathered, brown and grey, BRECCIA; very weak; no defects; matrix supported; matrix is silty fine sand; clasts are fine to medium, angular to subrounded, quartz and schist gravel (HENLEY BRECCIA)	HENLEY BRECCIA						PQTT		MW		98 58			
176	5.8		5.80 - 6.00 m: CORE LOSS														
175	6		BRECCIA (continued from 4.8 m) 6.10 - 6.40 m: iron staining, orange-brown							PQTT				82 28			
174	7.5		Moderately weathered, orange-brown, very thinly to moderately thickly bedded SILTSTONE; very weak; no defects; moderately widely spaced lignite layers 5-20 mm thick 7.90 - 11.15 m: slightly weathered, grey							PQTT		SW		100 89			
173	9									PQTT				100 87			
172	10																

Notes and Comments:
End of Hole @ 19.70m, Target Depth.
Groundwater not encountered

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Southwest Boundary
Job Number: 12506381
Commenced: 7/11/2019 Completed: 7/11/2019

Hole No. : BH203
Sheet : 2 of 2
Hole Length : 19.70m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 395779 Northing: 787672 System: TAIETM2000
RL: 182 Datum: NZVD2009

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
171	11		Moderately weathered, orange-brown, very thinly to moderately thickly bedded SILTSTONE; very weak; no defects; moderately widely spaced lignite layers 5-20 mm thick *(continued from layer starting at 7.5m)* 10.00 - 10.10 m: fine SANDSTONE							PQTT		SW		100 87			
170	12		Unweathered, light grey, laminated to moderately thickly bedded, fine grained SANDSTONE; very weak; no defects; moderately widely spaced lignite layers 5-30 mm thick							PQTT				100 53			
169	13									PQTT				100 100			
168	14		14.45 - 14.55 m: grades into BRECCIA	HENLEY BRECCIA						PQTT		UW		100 81			
167	15		Unweathered, light grey, BRECCIA; weak to moderately strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine, quartz and schist, angular to subangular gravel														
166	16		Unweathered, light grey, laminated to moderately thickly bedded, fine grained SANDSTONE; very weak to weak; no defects 16.00 - 16.15 m: moderately strong							PQTT				100 92			
165	17		17.30 - 17.60 m: grades into BRECCIA							PQTT				97 75			
164	18		Slightly weathered, light grey and white, BRECCIA; moderately strong to strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel									SW					
163	19									PQTT				83 19			
162			End of Hole @ 19.70m,Target Depth.														

Notes and Comments:
End of Hole @ 19.70m, Target Depth.
Groundwater not encountered

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 19.7 m		

0.00 m to 2.30 m

2.30 m to 4.60 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 19.7 m		

4.60 m to 6.90 m

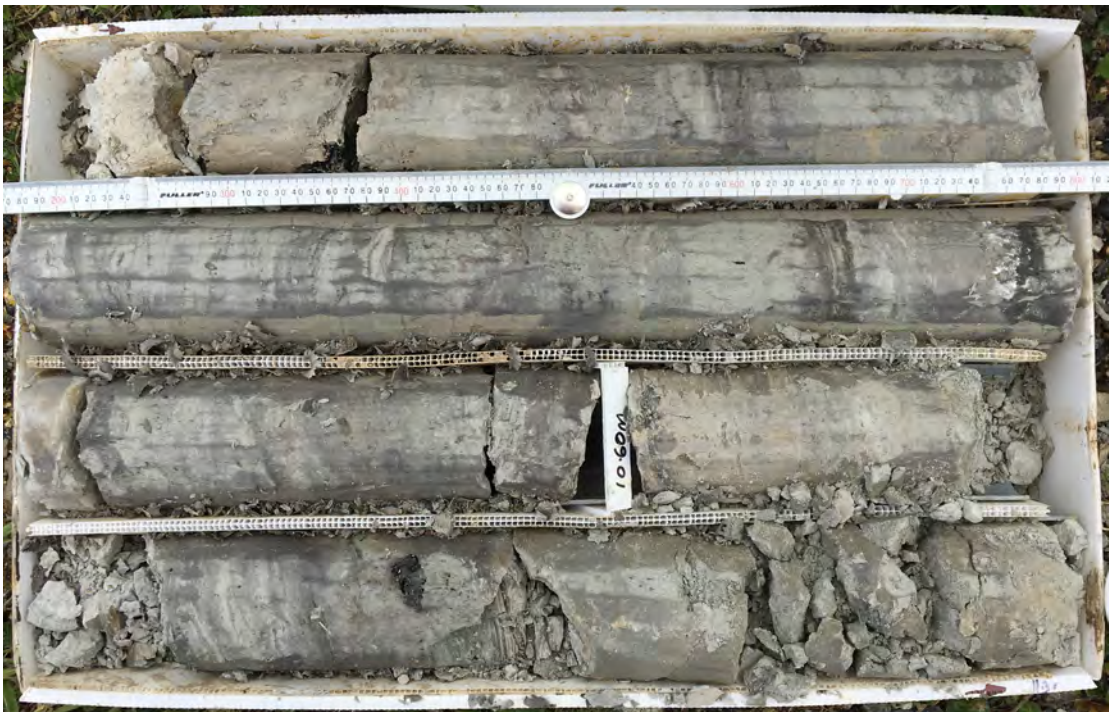
6.90 m to 9.20 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 19.7 m		



9.20 m to 11.30 m

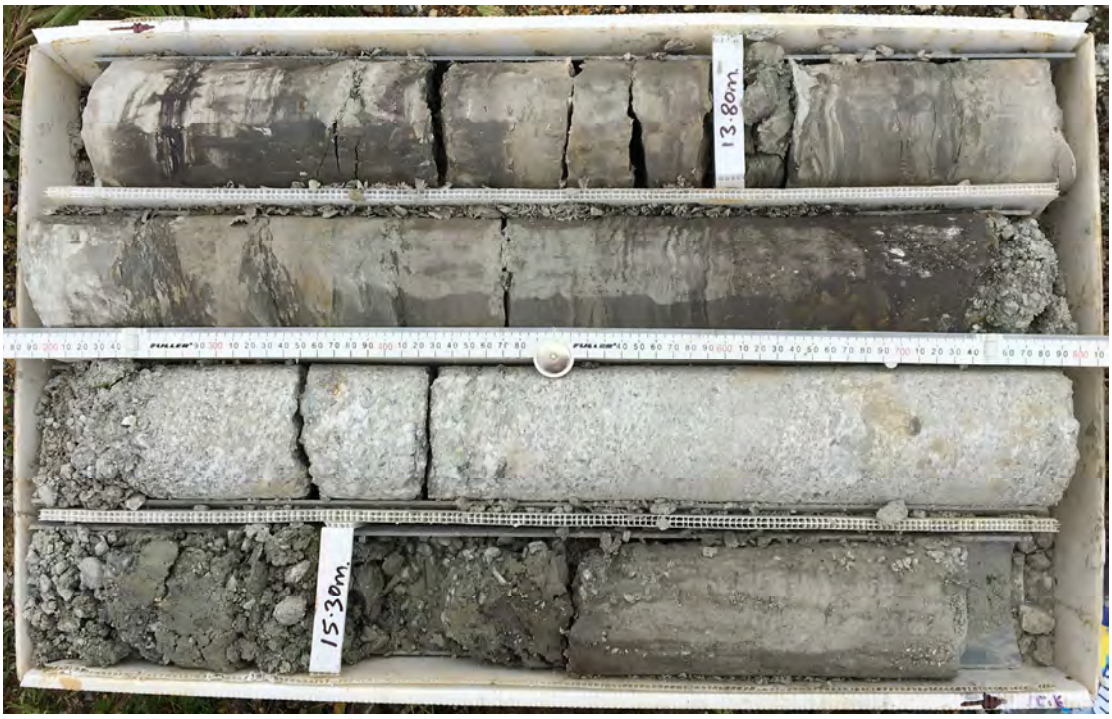
11.30 m to 13.40 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 19.7 m		



13.40 m to 15.60 m

15.60 m to 17.90 m

Report of Photographs

Site Identification: BH203

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	07/11/2019	**Completed**	07/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 19.7 m		

17.90 m to 19.70 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Western Boundary
Job Number: 12506381
Commenced: 24/10/2019 Completed: 24/10/2019

Hole No. : BH209
Sheet : 1 of 1
Hole Length : 10.00m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: Northing: System:
RL: Datum:

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	0	Intermixed: clayey SILT, sandy SILT, and SILT with minor clay; grey and brown. Soft to firm, moist to wet, low to high plasticity; wood fragments throughout (FILL)	FILL	M-W	S-F				PQTT				92			
	0.6	SILT, minor clay, trace find sand; light grey and orange-brown. Very stiff, moist, low plasticity; trace fine gravel sized iron oxide nodules (LOESS) 0.80 - 3.15 m: grey-brown and orange-brown	LOESS	M	VSt				PQTT				100			
	3.15	Gravelly SILT; grey, cream and brown. Very stiff to hard, dry to moist, non-plastic; gravel is fine to medium, rounded to subangular quartz and schist; highly weathered (TARATU FORMATION)	TARATU FORMATION	D-M	VSt-H				PQTT		HW		96			
	3.6	SILT, minor to some clay; grey with orange-brown streaks. Firm to stiff, moist, high plasticity		M	F-St											
	4	Moderately weathered, orange-brown, very thinly to moderately thickly bedded fine-grained SANDSTONE; very weak; no defects 4.80 - 5.30 m: light grey							PQTT				100 86			
	5.3	Moderately weathered, brown and orange-brown CONGLOMERATE; extremely weak; no defects; matrix supported; clasts are fine to medium, rounded to subangular, quartz and schist gravel; silty sand matrix. Soil description: gravelly silty sand							PQTT		MW		100 60			
	5.9	Moderately weathered, orange-brown, very thinly to moderately thickly bedded fine-grained SANDSTONE; very weak; no defects														
	6.65	Slightly weathered, grey, laminated to moderately thinly bedded fine-grained SANDSTONE; very weak; no defects							PQTT				100 100			
	7.3	Slightly weathered, brown with occasional orange-brown and white, moderately thinly to moderately thickly bedded, fine to medium-grained SANDSTONE; very weak; no defects; minor fine quartz and schist gravel														
	7.8	Slightly weathered, brown and orange-brown CONGLOMERATE; extremely weak; no defects; clast supported; silty sand matrix; clasts are fine to coarse, rounded to subangular, quartz and schist gravel. Soil description: silty, sandy, fine to coarse gravel							PQTT		SW		100 0			
	10	End of Hole @ 10.00m,Target Depth.							PQTT				94 0			

Notes and Comments:
End of Hole @ 10.00m, Target Depth.
Groundwater not encountered

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Tracked Rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH209

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	24/10/2019	**Completed**	24/10/2019
Site	Western Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.0 m		

Box 1 of 5: 0.00 m to 2.40 m

Box 2 of 5: 2.40 m to 4.70 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH209

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	24/10/2019	**Completed**	24/10/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.0 m		

Box 3 of 5: 4.70 m to 7.15 m

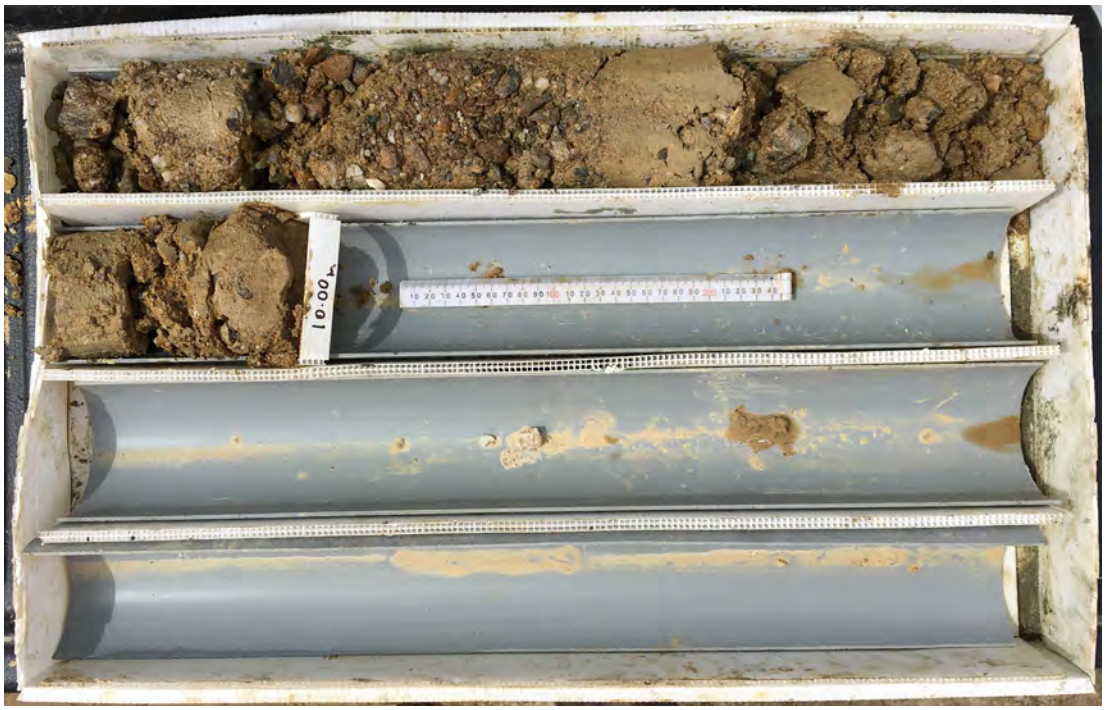
Box 4 of 5: 7.15 m to 9.20 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH209

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	24/10/2019	**Completed**	24/10/2019
Site	Southern Boundary	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 10.0 m		



Box 5 of 5: 9.20 m to 10.0 m (EOH)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern gully base
Job Number: 12506381
Commenced: 4/11/2019 Completed: 6/11/2019

Hole No. : BH211A
Sheet : 1 of 3
Hole Length : 25.20m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396598 Northing: 787965 System: TAIETM2000
RL: 107 Datum: NZVD2009

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result
107	0	0.00 - 0.35 m: CORE LOSS (inferred at top of run)					
	0.35	SILT, minor fine to medium sand, trace clay; grey, orange-brown and dark grey intermixed. Stiff to very stiff, moist, low plasticity (FILL)	FILL	M	St-VSt		
106	0.7	SILT, trace to minor fine to medium sand; grey and orange-brown. Very stiff, moist, low plasticity; trace to minor iron-oxide nodules (LOESS)	LOESS	M	VSt		
	1.6	1.60 - 1.80 m: CORE LOSS (inferred depth)					
105	1.8	SILT (continued from 0.7 m)					
		Sandy SILT, minor fine gravel; orange-brown and grey. Very stiff to hard, moist, non-plastic; sand is fine to medium; gravel is angular to rounded quartz and schist; completely weathered breccia (HENLEY BRECCIA)		M	VSt-H		
		2.40 - 2.80 m: firm to stiff			F-St		
104		2.80 - 3.20 m: very stiff			VSt		
	3.2	3.20 - 3.70 m: CORE LOSS					
103	3.7	SILT; dark grey. Firm to stiff, moist, low plasticity; completely weathered siltstone		M	F-St		
	4.2	Gravelly SAND; grey. Moist; sand is fine to coarse; gravel is fine, angular to subrounded, quartz and schist; completely weathered breccia		M	VSt-H		
102	4.6	4.60 - 5.20 m: CORE LOSS					
	5.2	Gravelly SAND (continued from 4.2 m)		M	VSt-H		
	5.4	Highly weathered, orange-brown and grey, moderately thickly bedded BRECCIA; extremely weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to medium, angular to rounded, quartz and schist gravel. Soil description: gravelly sand	HENLEY BRECCIA				
101	6.2	Slightly weathered, light grey and white, moderately thickly bedded SILTSTONE; very weak to weak; no defects					
	6.75	Slightly weathered, light grey and white BRECCIA; weak to moderately strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel					
100							
99							
98		8.80 - 9.90 m: very weak to weak					
97							

Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	PQTT				78			
	PQTT				75			
	PQTT		CW		62			
	PQTT				100			
	PQTT				59			
			HW		25			
	PQTT				100			
					93			
	PQTT		SW		100			
					70			
	PQTT				100			
					79			

Notes and Comments:
End of Hole @ 25.20m, Target Depth.
Groundwater at 2.81 m bgl in shallow piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern gully base
Job Number: 12506381
Commenced: 4/11/2019 Completed: 6/11/2019

Hole No. : BH211A
Sheet : 2 of 3
Hole Length : 25.20m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396598 Northing: 787965 System: TAIETM2000
RL: 107 Datum: NZVD2009

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
96	11	9.90 - 11.80 m: weak to moderately strong Slightly weathered, light grey and white BRECCIA; weak to moderately strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel *(continued from layer starting at 6.8m)*	HENLEY BRECCIA						PQTT		SW		100 92			
95	11.8 12	Slightly weathered, grey SILTSTONE; very weak; no defects; trace to minor fine gravel, content decreases with depth							PQTT				100 60			
94	13	Slightly weathered, brown, SILTSTONE; very weak; no defects; possible lithified topsoil							PQTT				97 90			
93	13.65 14	13.50 - 13.65 m: grey Slightly weathered, grey, fine to coarse grained SANDSTONE; very weak to weak; no defects							PQTT				100 87			
92	15	Slightly weathered, grey and white BRECCIA; weak to moderately strong; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel							PQTT				100 46			
91	16.1	Slightly weathered, grey, fine to coarse grained SANDSTONE; very weak; no defects							PQTT				100 35			
90	16.6 17	Slightly weathered, grey and white BRECCIA; very weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to medium, angular to subrounded, quartz and schist gravel							PQTT				100 84			
89	17.6 18	Slightly weathered, grey, fine to medium grained SANDSTONE; very weak; no defects							PQTT				100 86			
88	18.3 19	Slightly weathered, grey and white BRECCIA; moderately strong to strong; no defects; clast supported; fine to coarse sand matrix; clasts are fine to medium, angular to subrounded, quartz and schist gravel							PQTT				100 71			
87	19.1	Slightly weathered, grey and white BRECCIA; very weak to weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel														

Notes and Comments:
End of Hole @ 25.20m, Target Depth.
Groundwater at 2.81 m bgl in shallow piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 June 2020

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern gully base
Job Number: 12506381
Commenced: 4/11/2019 Completed: 6/11/2019

Hole No. : BH211A
Sheet : 3 of 3
Hole Length : 25.20m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396598 Northing: 787965 System: TAIETM2000
RL: 107 Datum: NZVD2009

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
86	21		Slightly weathered, grey and white BRECCIA; very weak to weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel *(continued from layer starting at 19.1m)*	HENLEY BRECCIA						PQTT		SW		96 51			
			21.00 - 25.20 m: occasional cobble-sized clast														
85	22		22.00 - 25.20 m: clast supported							PQTT				100 63			
			22.65 - 23.00 m: moderately strong to strong														
84	23									PQTT				100 36			
83	24		24.00 - 24.40 m: moderately strong to strong														
82	25									PQTT				92 68			
			End of Hole @ 25.20m,Target Depth.														
81	26																
80	27																
79	28																
78	29																
77																	

Notes and Comments:
End of Hole @ 25.20m, Target Depth.
Groundwater at 2.81 m bgl in shallow piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 June 2020

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern gully base
Job Number: 12506381
Commenced: 4/11/2019 Completed: 6/11/2019

Hole No. : BH211B
Sheet : 1 of 3
Hole Length : 25.20m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396598 Northing: 787965 System: TAIETM2000
RL: 107 Datum: NZVD2009

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result
107	0	0.00 - 0.35 m: CORE LOSS (inferred at top of run)					
	0.35	SILT, minor fine to medium sand, trace clay; grey, orange-brown and dark grey intermixed. Stiff to very stiff, moist, low plasticity (FILL)	FILL	M	St-VSt		
	0.7	SILT, trace to minor fine to medium sand; grey and orange-brown. Very stiff, moist, low plasticity; trace to minor iron-oxide nodules (LOESS)	LOESS	M	VSt		
106	1						
	1.6	1.60 - 1.80 m: CORE LOSS (inferred depth)					
105	1.8	SILT (continued from 0.7 m)					
	2	Sandy SILT, minor fine gravel; orange-brown and grey. Very stiff to hard, moist, non-plastic; sand is fine to medium; gravel is angular to rounded quartz and schist; completely weathered breccia (HENLEY BRECCIA)		M	VSt-H		
		2.40 - 2.80 m: firm to stiff			F-St		
104	3	2.80 - 3.20 m: very stiff			VSt		
	3.2	3.20 - 3.70 m: CORE LOSS					
103	3.7	SILT; dark grey. Firm to stiff, moist, low plasticity; completely weathered siltstone		M	F-St		
	4						
	4.2	Gravelly SAND; grey. Moist; sand is fine to coarse; gravel is fine, angular to subrounded, quartz and schist; completely weathered breccia		M	VSt-H		
	4.6	4.60 - 5.20 m: CORE LOSS					
102	5						
	5.2	Gravelly SAND (continued from 4.2 m)		M	VSt-H		
	5.4	Highly weathered, orange-brown and grey, moderately thickly bedded BRECCIA; extremely weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to medium, angular to rounded, quartz and schist gravel. Soil description: gravelly sa	HENLEY BRECCIA				
101	6						
	6.2	Slightly weathered, light grey and white, moderately thickly bedded SILTSTONE; very weak to weak; no defects					
	6.75	Slightly weathered, light grey and white BRECCIA; weak to moderately strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel					
100	7						
99	8						
98	9	8.80 - 9.90 m: very weak to weak					
97	10						

Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	PQTT		CW		78			
	PQTT				75			
	PQTT				62			
	PQTT				100			
	PQTT		HW		59			
					25			
	PQTT				100			
					93			
	PQTT		SW		100			
					70			
	PQTT				100			
					79			

Notes and Comments:
End of Hole @ 25.20m, Target Depth.
Groundwater at 13.0 m bgl in deep piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 June 2020

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern gully base
Job Number: 12506381
Commenced: 4/11/2019 Completed: 6/11/2019

Hole No. : BH211B
Sheet : 2 of 3
Hole Length : 25.20m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396598 Northing: 787965 System: TAIETM2000
RL: 107 Datum: NZVD2009

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
96	11		9.90 - 11.80 m: weak to moderately strong Slightly weathered, light grey and white BRECCIA; weak to moderately strong; no defects; clast supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel *(continued from layer starting at 6.8m)*	HENLEY BRECCIA						PQTT		SW		100 92			
										PQTT				100 60			
95	11.8 12		Slightly weathered, grey SILTSTONE; very weak; no defects; trace to minor fine gravel, content decreases with depth							PQTT				97 90			
			Slightly weathered, brown, SILTSTONE; very weak; no defects; possible lithified topsoil														
94	13									PQTT				100 87			
	13.65		13.50 - 13.65 m: grey														
93	14		Slightly weathered, grey, fine to coarse grained SANDSTONE; very weak to weak; no defects														
			Slightly weathered, grey and white BRECCIA; weak to moderately strong; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel							PQTT				100 46			
92	15																
91	16									PQTT				100 35			
	16.1		Slightly weathered, grey, fine to coarse grained SANDSTONE; very weak; no defects														
	16.6		Slightly weathered, grey and white BRECCIA; very weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to medium, angular to subrounded, quartz and schist gravel							PQTT				100 84			
90	17																
	17.6		Slightly weathered, grey, fine to medium grained SANDSTONE; very weak; no defects														
89	18									PQTT				100 86			
	18.3		Slightly weathered, grey and white BRECCIA; moderately strong to strong; no defects; clast supported; fine to coarse sand matrix; clasts are fine to medium, angular to subrounded, quartz and schist gravel														
88	19																
	19.1		Slightly weathered, grey and white BRECCIA; very weak to weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel							PQTT				100 71			
87																	

Notes and Comments:
End of Hole @ 25.20m, Target Depth.
Groundwater at 13.0 m bgl in deep piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

Report ID: GENERAL_LOG || Project: 12506381 GINT LOGS SMOOTH HILL.GPJ || Library: GHD - NZGD.GLB || Date: 4 June 2020

Project : Smooth Hill Landfill Consenting
Client : Dunedin City Council
Site : Eastern gully base
Job Number: 12506381
Commenced: 4/11/2019 Completed: 6/11/2019

Hole No. : BH211B
Sheet : 3 of 3
Hole Length : 25.20m
Scale @ A4 : 1:50
Logged : MF
Processed : MF
Checked : JHS

Easting: 396598 Northing: 787965 System: TAIETM2000
RL: 107 Datum: NZVD2009

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistancy / Relative density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR SCR RQD (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
86	21		Slightly weathered, grey and white BRECCIA; very weak to weak; no defects; matrix supported; matrix is fine to coarse sand; clasts are fine to coarse, angular to subrounded, quartz and schist gravel *(continued from layer starting at 19.1m)*	HENLEY BRECCIA						PQTT		SW		96 51			
			21.00 - 25.20 m: occasional cobble-sized clast														
85	22		22.00 - 25.20 m: clast supported							PQTT				100 63			
			22.65 - 23.00 m: moderately strong to strong														
84	23									PQTT				100 36			
83	24		24.00 - 24.40 m: moderately strong to strong														
82	25									PQTT				92 68			
			End of Hole @ 25.20m,Target Depth.														
81	26																
80	27																
79	28																
78	29																
77																	

Notes and Comments:
End of Hole @ 25.20m, Target Depth.
Groundwater at 13.0 m bgl in deep piezo (25/11/19)

Refer to explanation sheets for abbreviation and symbols

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: Track mounted rig
Shear Vane Id:

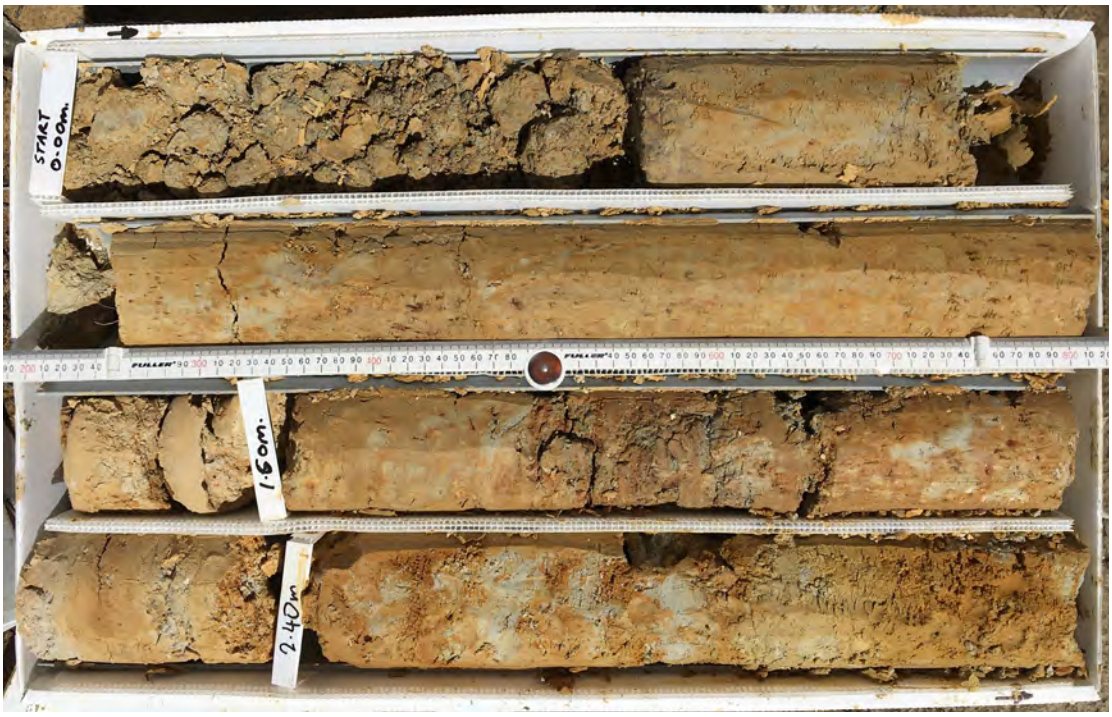
Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)

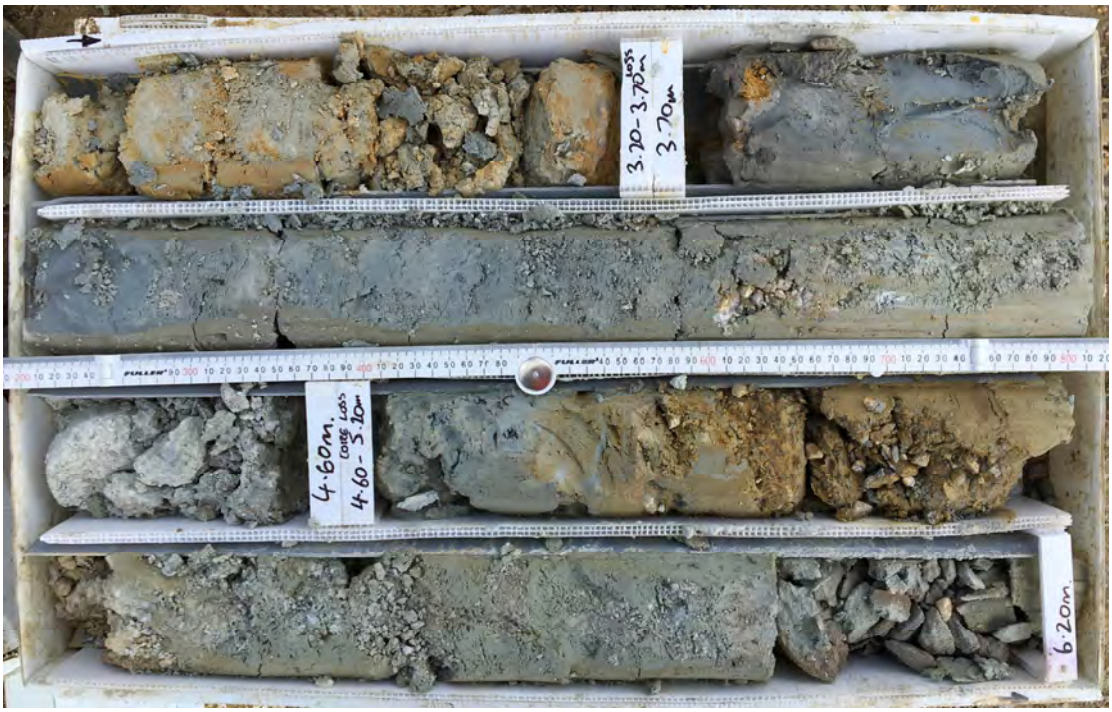
Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m – 25.2 m		



0.00 m to 2.80 m

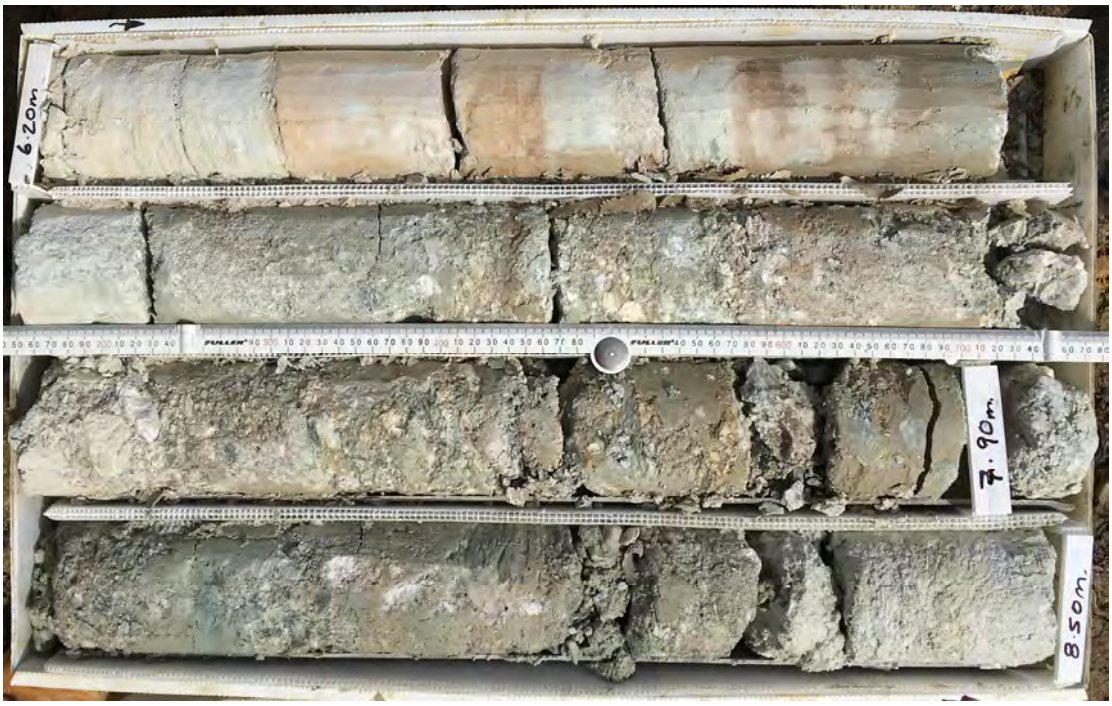


2.80 m to 6.20 m

Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



6.20 m to 8.50 m

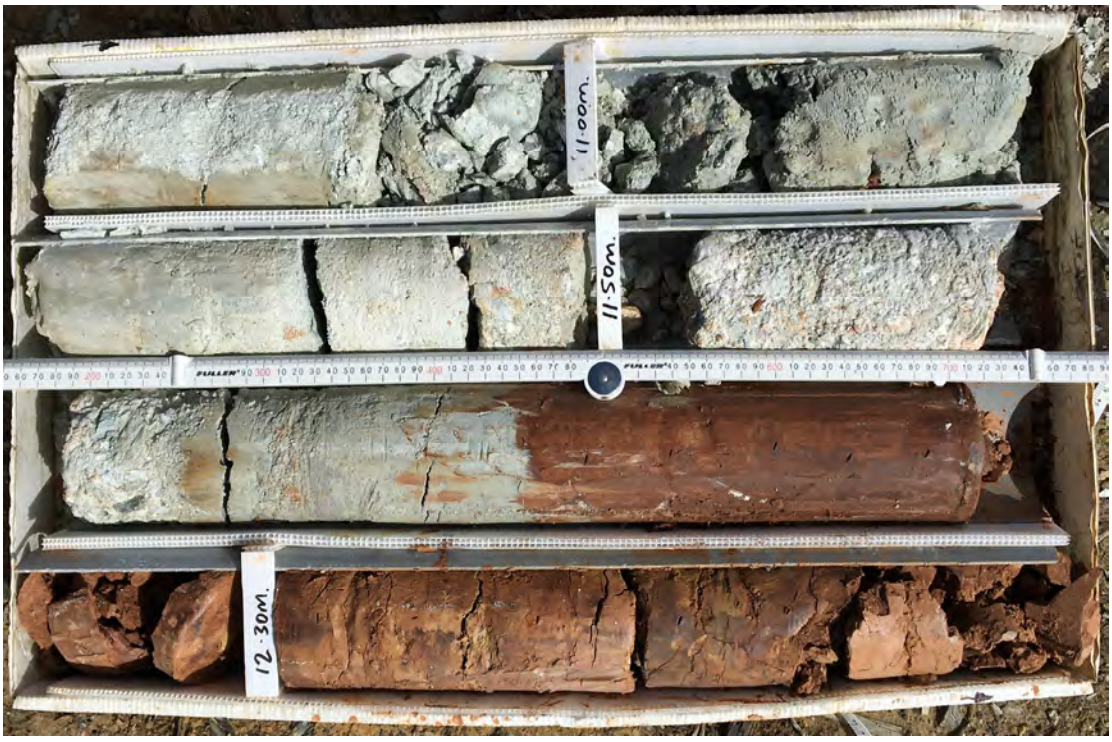
8.50 m to 10.70 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



10.70 m to 12.80 m

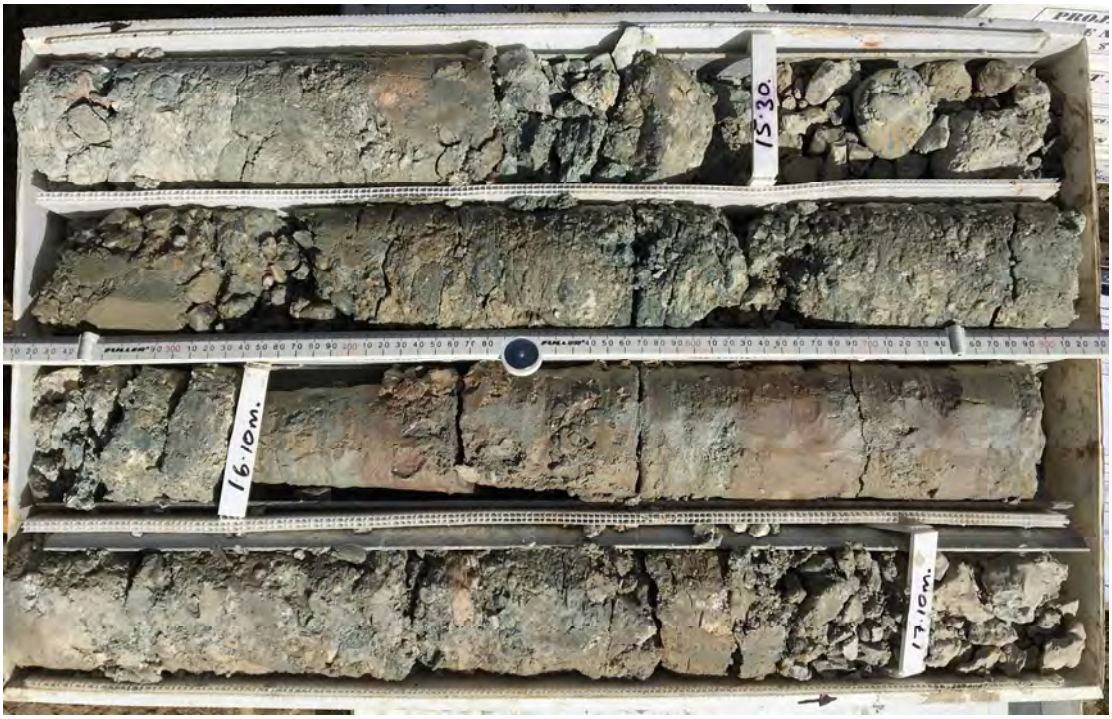
12.80 m to 14.90 m

CLIENTS | PEOPLE | PERFORMANCE

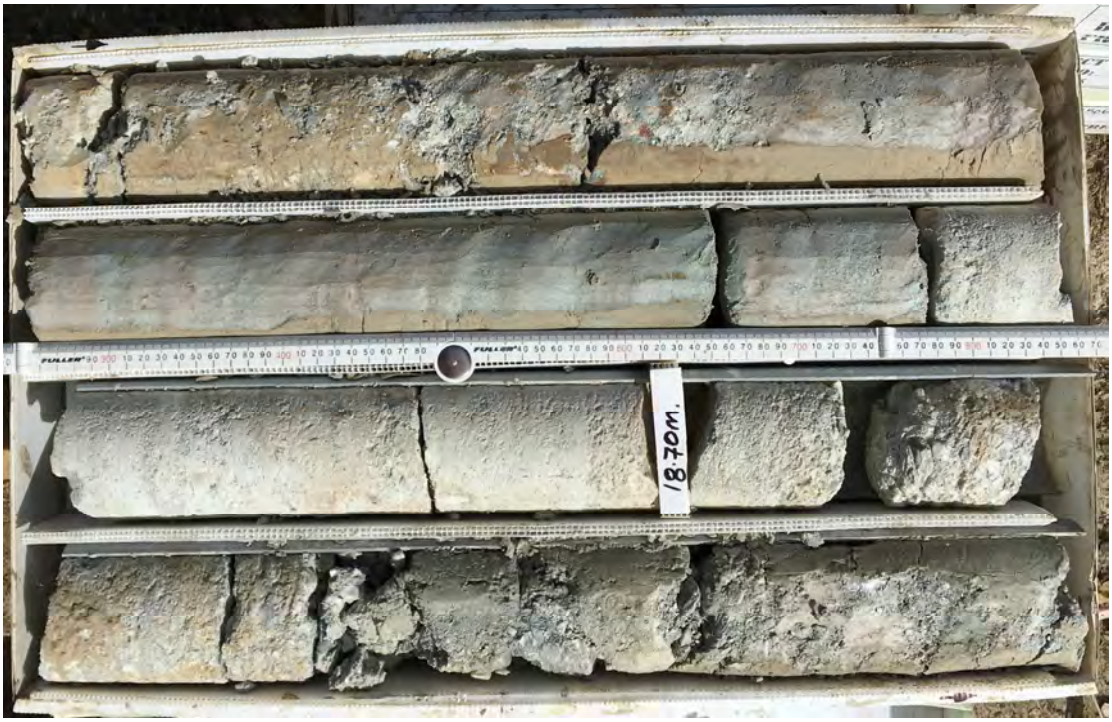
Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



14.90 m to 17.20 m

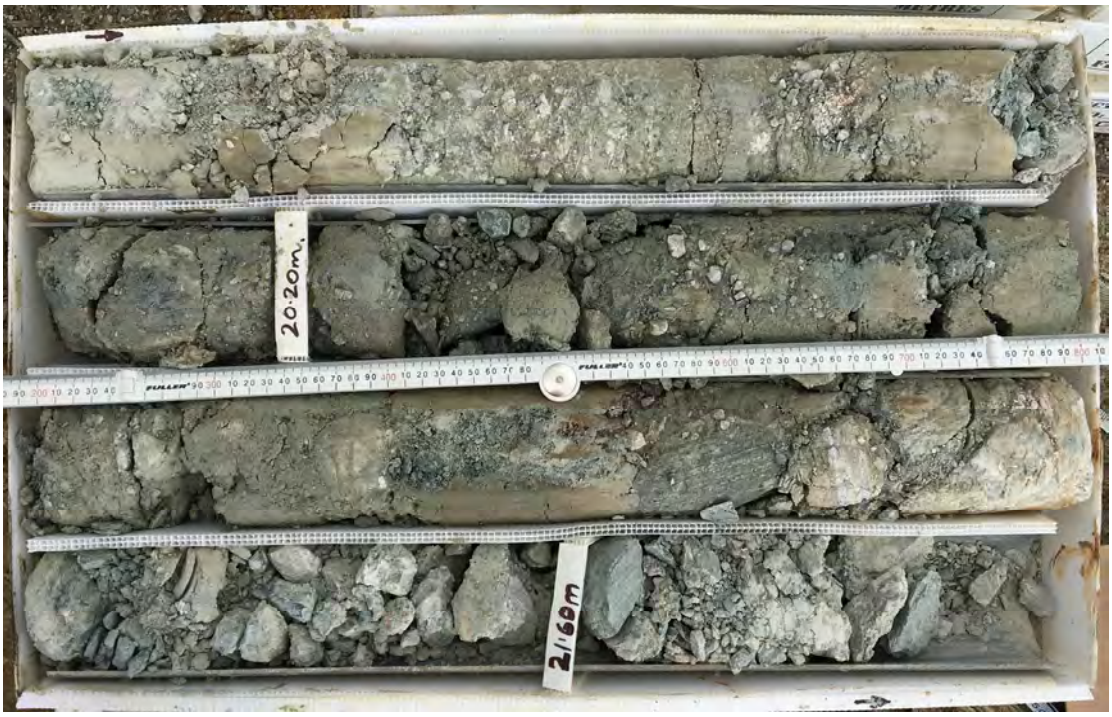


17.20 m to 19.50 m

Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



19.50 m to 21.70 m

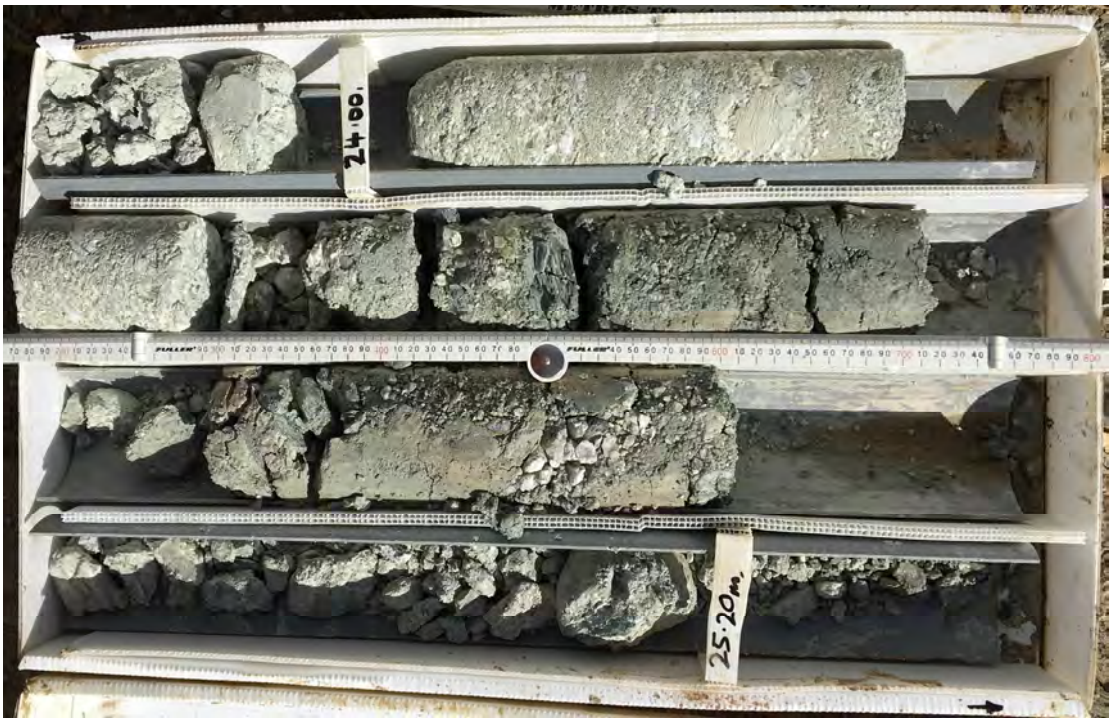
21.70 m to 23.90 m

CLIENTS | PEOPLE | PERFORMANCE

Report of Photographs

Site Identification: BH211

Project	Waste Futures WS3 – Smooth Hill	**Commenced**	04/11/2019	**Completed**	06/11/2019
Site	Smooth Hill	**Logged By**	MF		
Job #	12506381	**Checked By**			
Client	Dunedin City Council	**Core Depth**	0.0 m to 25.2 m		



23.90 m to 25.20 m (EOH)

Appendix C – Technical Appendix

Technical Appendix

1. Introduction

This technical appendix outlines the assessment of leachate generation and leakage for the proposed Smooth Hill landfill, and has been prepared to support both the landfill design and an assessment of environmental effects (AEE), as presented in the following reports:

- GHD, 2020. Waste Futures – Smooth Hill Landfill. Concept Design Report.
- GHD, 2020. Waste Futures – Smooth Hill Landfill. Assessment of Effects to Groundwater.

1.1 Landfill Design

The flow balancing of the landfill leachate collection system requires that the following hydraulic aspects are considered in the design of the proposed Smooth Hill landfill:

- Flow capacity of the leachate drainage pipework.
- In-landfill storage basin capacity.
- Leachate pump station capacity and rising main size.
- Leachate above ground storage (prior to discharging off site).

Additionally, restricting the maximum leachate head to less than 300 mm is a minimum requirement for leachate collection systems within the WasteMINZ technical guidelines for disposal to land (WasteMINZ, 2018).

To inform the hydraulic design, leachate generation and reporting times to the leachate collection system have been estimated for storm events of varying rainfall intensity.

1.2 Assessment of Environmental Effects

The following aspects of the proposed Smooth Hill Landfill are required to be understood to inform assessment of potential environmental effects:

- Likely volume of leachate leaking to ground, as a function of landfill area, stages of development and expected liner performance.
- The landfill water balance during construction and after closure, including runoff, evapotranspiration and leachate generation.

2. Leachate Assessment Methodology

2.1 Introduction

The leachate assessment comprised analysis of the following:

1. Seasonal and average leachate generation and leakage, to support landfill cover design and assessment of environmental effects (AEE), with this analysis described in Section 2.2.
2. Storm event leachate generation and flow to the leachate collection system to support hydraulic design of the collection system, with this analysis described in Section 2.3.

2.2 HELP Modelling and Landfill Leachate Balance

Leachate generation, leakage to ground and leachate head above the liner was assessed using the Hydrologic Evaluation of Landfill Performance (HELP) software (Berger and Schroeder, 2013). HELP 3.95D is a quasi-two-dimensional hydrologic model for conducting water balance analysis of landfills and cover systems. The model utilises weather, soil and design data to account for the effects of surface storage, runoff, infiltration, evapotranspiration, soil moisture, lateral subsurface drainage, vertical drainage and leakage through soil and geo-membrane liners.

Four different landfill profiles were modelled to assess leachate generation and leakage. The water balance estimated for each were applied for the five landfill stages to provide the whole of landfill water balance at different times through the landfill operational lifecycle.

The results of this assessment provide information to support landfill capping design, and assessment of environmental effects.

2.2.1 Landfill Profile and Cover

Four landfill profiles, in different phases of landfill development, were considered in predicting the landfill water balance:

- Open waste.
- Daily cover.
- Intermediate cover.
- Final cap.

A liner only profile (prior to placement of waste) was not modelled with HELP, as all rainfall is assumed to report to the leachate collection system. Average annual rainfall of 809.5 mm was adopted for this profile from the results of the weather generator model (discussed further in Section 2.2.3).

All landfill profiles comprised a landfill liner, discussed further in Section 2.2.2, overlain by a 300 mm gravel drainage layer and municipal waste. A municipal waste thickness of 100 mm was adopted for open waste, daily cover and intermediate cover landfill phases. A municipal waste thickness of 1,400 mm was adopted for the final cap phase, to represent the final average waste thickness across the landfill. The profile characteristics adopted are presented in attached Table A 1. Soil values of total pore volume, field capacity and wilting point were adopted from published USDA soil textures (Schroeder et al., 1994), however saturated hydraulic conductivity was modified for a number of the soil units. Justification for the adopted soil textures and saturated hydraulic conductivity is presented in Table 1.

Table 1: Justification for adopted soil texture and saturated hydraulic conductivity

Landfill profile	Soil Unit	Adopted USDA Soil Texture[1]	USDA saturated hydraulic conductivity (cm/s)	Adopted saturated hydraulic conductivity (cm/s)	Justification
Open Waste	Upper Municipal Waste Layer (Layer 1)	21 - Gravel	$3x10^{-1}$	$3x10^{-3}$	Poor soil moisture retention expected due to high heterogeneity and poor compaction. Plastics in the waste are also likely to channel the drainage, limit the spreading of infiltration, and restrict the wetting of the waste[2]. Adopted saturated hydraulic conductivity therefore similar, but slightly greater than, that of municipal waste.
Daily Cover	Daily Cover (Layer 1)	9 – Silt Loam (slightly compacted)	$1.9x10^{-4}$	$1x10^{-3}$	On site top soil described as silt with trace to minor clay, however lower soil moisture retention characteristics and increased saturated hydraulic conductivity adopted as site won material will have significant open macro-pores allowing water transmission. Slight compaction.
Intermediate Cover	Intermediate Cover (Layer 1)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-4}$	On site loess largely described as silt with trace to some clay to silty clay. Increased adopted saturated hydraulic conductivity to account for lower clay content. Minor compaction and contouring.
Final Cap	Topsoil (Layer 1 & 2)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-4}$	On site loess largely described as silt with trace to some clay to silty clay. Increased adopted saturated hydraulic conductivity to account for lower clay content. Minor compaction and contouring.
	Barrier Clay (Layer 3)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$5x10^{-6}$	On site loess largely described as silt with trace to some clay to silty clay. Increased adopted saturated hydraulic conductivity to account for lower clay content. Moderate compaction.

Landfill profile	Soil Unit	Adopted USDA Soil Texture[(1)]	USDA saturated hydraulic conductivity (cm/s)	Adopted saturated hydraulic conductivity (cm/s)	Justification
	Soil (Layer 4)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-4}$	Represents layer 1 of intermediate cover which will be present before placement of final cap.
All Profiles (Landfill Waste and Liner)	Municipal Waste	18 - Municipal Waste (312 kg/m^3)	$1x10^{-3}$		No changes to USDA soil texture characteristics.
	Drainage Layer	21 – Gravel	$3x10^{-1}$		No changes to USDA soil texture characteristics.
	FML Geomembrane	35 – High Density Polyethylene (HDPE)	$2x10^{-13}$		No changes to USDA soil texture characteristics.
	GCL	17 – Bentonite Mat	$3x10^{-9}$	$5x10^{-9}$	Adopted saturated hydraulic conductivity increased slightly to match GRI-GCL3 requirement for a typical GCL.
	Clay	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-6}$	On site loess largely described as silt with trace to some clay to silty clay. Adopted saturated hydraulic conductivity anticipated to be achieved using site won loess materials.

1) Schroeder et al., 1994.

2) Berger and Schroeder, 2013.

2.2.2 Landfill Liner and Slope

The landfill liner, as presented in the profiles in attached Table A 1, is proposed to comprise a 600 mm clay base layer, overlain by a 5 mm geosynthetic clay liner (GCL) and 1.5 mm flexible membrane liner (FML).

The following landfill liner defects and condition, were adopted within the HELP model with regards to the FML:

- FML comprised a high density polyethylene.
- Pinhole density: 2 / hectare.
- Installation defects: 25 / hectare.
- Installation quality: Poor.

Two liner slope scenarios were modelled for each landfill profile (Table 2), which reflect different liner slopes between benched (low gradient) and battered (high gradient) areas of the landfill. For each slope scenario, the average distance to the leachate drain was adopted. For each stage of the landfill development, it was assumed that at any given point in time the bench to batter ratio would be approximately 3:7, with this being generally consistent with the whole of landfill distribution of liner slopes.

Table 2: Landfill Stage and Scenario

Stage	Scenario	Average Flow Path Distance to Leachate Drain (m)	Liner Slope	Area (m^2)
1	**1**	270	4%	32,600
	2	150	25%	70,542
2	**1**	270	4%	27,000
	2	140	25%	66,788
3	**1**	270	4%	23,000
	2	160	25%	50,276
4	**1**	190	4%	26,200
	2	150	25%	55,123
5	**1**	200	7%	10,700
	2	200	25%	69,768

2.2.3 Weather and Rainfall Runoff

Synthetic weather files were generated for a 50 year period using a weather generator model (WGEN), a stochastic model used to generate daily weather variables. Taulis and Milke (2005) from the University of Canterbury developed climate parameters for Dunedin, Otago, which were used within the Weather Generator to generate inputs for:

- Evapotranspiration
- Precipitation
- Air Temperature
- Solar Radiation

In developing the HELP climate data, the following user defined parameters and values were also included:

- Maximum leaf area index:
    - 3.5 was adopted for all landfill phases
- Evaporative zone depth:
    - 1 cm was adopted for open waste
    - 15 cm was adopted for daily cover, intermediate cover and final cap

The evaporative zone depth was reduced for the open waste profile to account for rapid infiltration of rainfall through the shallow layers of municipal waste, which is expected to be very heterogeneous and poorly compacted, resulting in poor soil moisture retention. Plastics in the waste are also likely to channel the drainage, limit the spreading of infiltration, and restrict the wetting of the waste (Berger and Schroeder, 2013). For the same reason, a 10 cm thick drainage layer was specified as layer 1 of the open waste soil profile (attached Table A 1).

Rainfall runoff within the HELP model is determined through application of a runoff curve number. The parameters utilised for determination of the curve number include soil texture, surface slope, compaction, surface vegetation and average surface flow path length. The adopted criteria for each landfill phase and stage are presented in attached Table A 2 and Table A 3, respectively. Sensitivity analysis was undertaken to assess whether changes in surface slope of the intermediate and final cap profiles influenced the HELP model water balance. The analysis indicated that there was very little difference in water balance with slope changes between a 5% and 33% slope. A 33% slope was therefore adopted for all intermediate and final cap landfill profiles (attached Table A 2). A 0.1% slope was adopted for open waste and waste with daily cover to simulate an approximately flat surface (attached Table A 2).

2.2.4 Landfill Development Stages and Landfill Leachate Balance

Water balances for the five stages of landfill development (Drawing No. 51-12506381-01-C201) were determined, considering progressive development from Stage 1 to Stage 5. For each stage of the landfill development, with the exception of the completed and closed landfill, a worst case scenario of open landfill area is assumed, with the operational areas of the landfill comprising the following:

- 10,000 m^2 of exposed liner.
- 2,500 m^2 of exposed landfill waste with no cover.
- 11,500 m^2 of exposed landfill waste with daily cover.
- Intermediate and final cap areas varying depending on the total footprint each stage of landfill development.

2.3 Storm Event Leachate Reporting Times

The time for leachate to report to the leachate drainage system was modelled using Geostudio 2018 SEEP/W finite element numerical modelling software. This allowed for analysis of rainfall infiltration through open (un-covered) waste material, and estimation of the time for leachate to reach the drainage layer.

Model set up is described in Table 3.

Table 3: Model Set Up

Parameter	Adopted Value	Justification
Model dimensions	0.1 m wide x 14 m thick	Width chosen to ensure sufficient mesh density Average thickness of waste layer in landfill
Waste Hydraulic Conductivity	2.15 x 10^{-3} m/s	High permeability of recently placed waste (Uniform Sand - SEEP/W Database)
Waste Volumetric Water Content Function	Uniform Sand Function (SEEP/W Database)	Low residual water content
Drainage Layer Hydraulic Conductivity	3 x 10^{-3} m/s	Particle size density (PSD) hydraulic conductivity analysis of drainage layer aggregate.
Drainage Layer Volumetric Water Content Function	Uniform Sand (SEEP/W Database)	Low residual water content
Rainfall Boundary Condition	Water rate for each rainfall event (detailed in Table 4)	HIRDS* rainfall intensity data
Drainage Layer Boundary Condition	0 m water pressure head	Simulates leachate removal from the drainage layer

* High Intensity Rainfall Design System (HIRDS) v4 Depth Duration Frequency (DDF) for site coordinates.

Table 4: Rainfall rate from HIRDSv4 DDF rainfall depths

10 Year Annual Recurrence Interval (ARI)	Rainfall depth (mm)
2 Hour	27.5
12 Hour	65.1
48 Hour	115

The following assumptions were adopted for the model:

- No evaporation or runoff was allowed for (100% of rainfall was assumed to infiltrate into the waste).
- The average final landfill waste thickness was adopted (14 m).
- The model assumes the waste is homogeneous.

3. Results

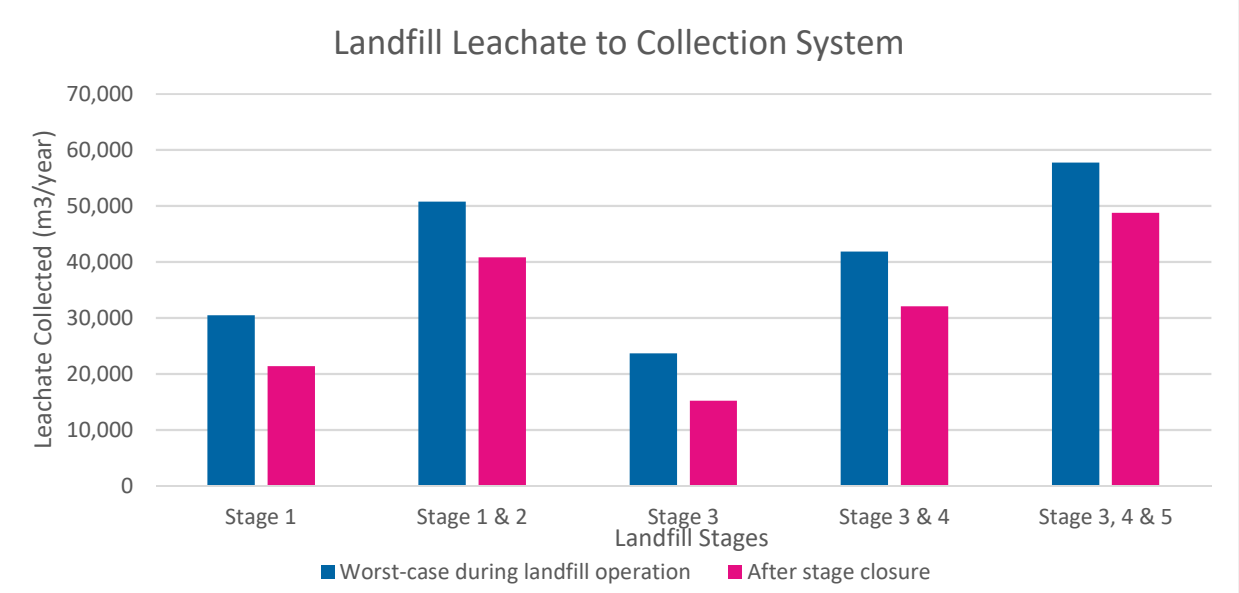
3.1 HELP Modelling

HELP model outputs from each model profile and stage are detailed in attached Table A 4 and Table A 5, and are further discussed in the sections below.

3.1.1 Leachate Generation

Attached Table A 6 presents the HELP model results of leachate collected through the drainage layer for the worst case landfill state, comprising a combination of landfill profiles including exposed liner, open waste, intermediate waste and final cap. Attached Table A 7 presents the HELP model results for leachate collection for closed landfill stages modelled using final cap profile only. A summary of the leachate predicted to be collected during operation and after stage closure is presented in Figure 1. There are two drainage collection systems for the proposed landfill, which separate the leachate collection in Stages 1 and 2 from leachate collection in Stages 3, 4 and 5.

Figure 1: HELP Model landfill leachate collection



The predicted leachate volumes reported to the collection systems during operation will not occur concurrently as each landfill stage will be closed before the next one is opened (ie. when stage 2 is operational, stage 1 will be closed and covered with final cap). The largest leachate volumes are likely to occur during operation of stage 5, with a total predicted leachate volume of approximately 98,525 m^3/year for the whole landfill. Approximately 57,699 m^3/year of this will be generated from operational stage 5 and closed stages 3 and 4. The remaining leachate of approximately 40,826 m^3/year will be generated from closed stages 1 and 2.

After complete landfill closure, the total leachate predicted from all five stages is approximately 89,588 m^3/year, with around 40,826 m^3/year reporting to the drainage system for stages 1 and 2, and around 48,762 m^3/year reporting to the drainage system for stages 3, 4 and 5.

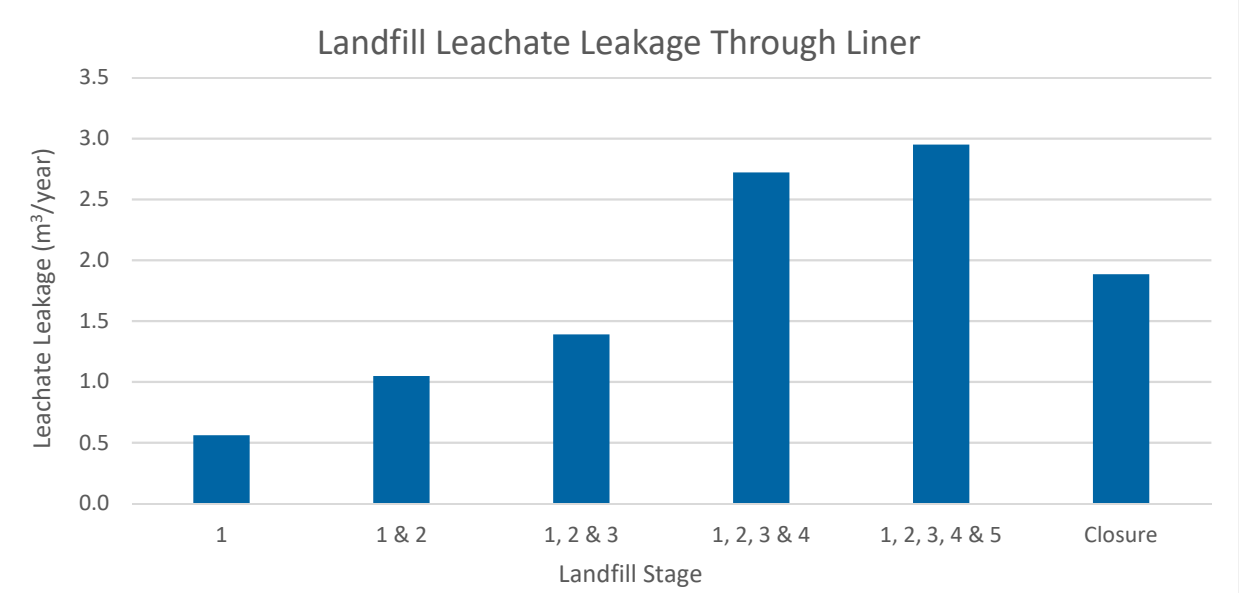
3.1.2 Leachate Leakage

Attached Table A 8 and Table A 9 present the areas considered for leachate generation, and the results of leachate leakage through the landfill liner, respectively, comprising a combination of landfill profiles including exposed liner, open waste, intermediate waste and final cap. A summary of the predicted

leachate leakage through the liner during development of the landfill and after closure is presented in Figure 2.

The maximum leachate leakage is predicted to occur during operation of stage 5, with an estimated leakage rate of 2,950 litres/year (3.0 m^3/year) (generated from operational stage 5 and closed stages 1, 2, 3 and 4). The predicted total leachate leakage from all stages after landfill closure is approximately 1,884 litres/year (1.9 m^3/year).

Figure 2: HELP Model leachate leakage through the landfill liner



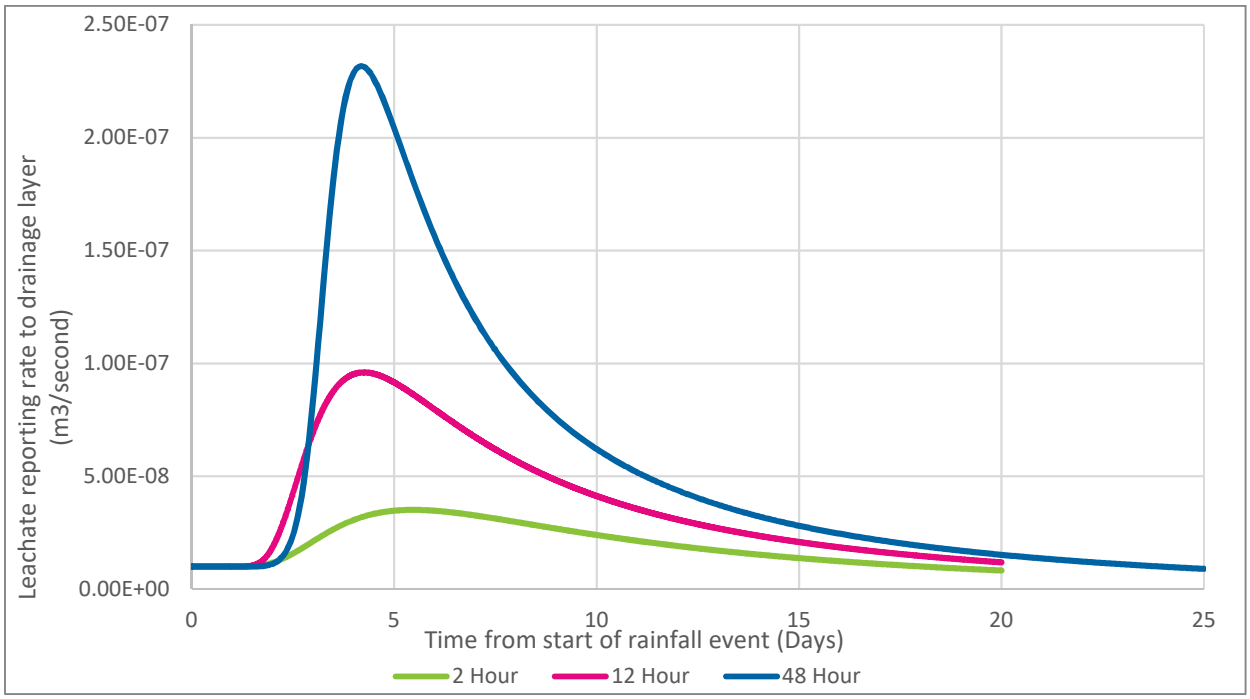
3.1.3 Leachate Head above the Liner

The minimum leachate collection system requirement in the WasteMINZ (2018) technical guidelines states that the leachate head not to exceed 300 mm. The maximum head recorded through the full 50 year HELP model was 164.1 mm under the scenario 1 open waste landfill profile in both stages 1 and 2. The HELP model results in attached Table A 4 indicate that the average predicted head above the liner does not exceed 19.2 mm for the open waste landfill profile. This reduces to maximum average predicted head above the liner of approximately 9.9 mm, 8.3 mm and 7.4 mm for daily cover, intermediate cap and final cap landfill profiles, respectively.

3.2 Storm Event Leachate Reporting Times

The results of the SEEP/W leachate modelling is presented in Figure 3, with Table 5 presenting the percentage of total rainfall reporting to the drainage layer for each of the ARI events. The results indicate that peak leachate reporting rates through 14 m of landfill waste occur approximately 4 to 5 days after the start of each rainfall event for the three ARI events modelled. It is anticipated that rainfall events with varying intensity would also respond within this approximate timeframe for the same thickness of waste. Reporting times would be expected to be faster for a smaller waste layer, and greater for a larger waste layer, due to the respective reduced and increased flow path lengths.

Figure 3: Leachate reporting rate to drainage layer following 10 Year ARI rainfall event



The results also demonstrate that increasing the length of the rainfall event corresponds with increasing reporting rates during peak flow. Infiltration resulting from the two and twelve hour events appears to travel through the waste within approximately 20 days, while infiltration from the 48 hour event took approximately 25 days. Rainfall events that last longer than 48 hours are therefore anticipated to take longer than 25 days to report to the landfill drainage system for a similar waste thickness as that modelled.

Table 5: Percentage of total rainfall reporting to leachate drainage layer through 14 m of waste

10 Year Annual Recurrence Interval (ARI)	Time since commencement of rainfall event											
	1 Hour	4 Hours	12 Hours	1 Day	2 Days	3 Days	4 Days	5 Days	10 Days	15 Days	20 Days	25 Days
2 Hour	0.1 %	0.4 %	1.7 %	2.5 %	5.2 %	9.3 %	16 %	24 %	63 %	86 %	100%	-
12 Hour	0.05 %	0.2 %	0.63 %	1.3 %	2.8 %	8.2 %	19 %	31 %	71 %	90 %	100 %	-
48 Hour	0.03 %	0.1 %	0.36 %	0.7 %	1.4 %	3.9 %	16 %	32 %	73 %	88 %	96 %	100 %

4. References

Berger, K. and Schroeder, P.R. 2013. The Hydrologic Evaluation of Landfill Performance (HELP) Model. User's Guide for HELP-D (Version 3.95D). 6th revised edition for version HELP 3.95D.

Schroeder, P. R., Dozier, T.S., Zappi, P. A., McEnroe, B. M., Sjostrom, J.W., and Peyton, R. L. (1994). "The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3," EPA/600/R-94/168b, September 1994, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.Taulis, M.E. and Milke, M.W. Estimation of WGEN weather generation parameters in arid climates. Ecological Modelling 184: 177-191

Waste Management Institute New Zealand (WasteMINZ), 2018. Technical guidelines for disposal to land. August 2018.

Attachments

Table A 1: HELP Model Soil Profiles

Landfill Stage	Layer No.	Layer Description	Soil Texture Description*	Layer Type**	Layer Thickness (cm)	Saturated Hydraulic Conductivity (cm/s)	Total Pore Volume (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)
Open Waste	1	Municipal Waste	Gravel	VPL	10	3.0E-03	0.397	0.032	0.013
	2	Municipal Waste	Municipal Waste (312 kg/m^3)	VPL	90	1.0E-03	0.671	0.292	0.077
	3	Gravel Drainage	Gravel	LDL	30	3.0E-01	0.397	0.032	0.013
	4	FML	HDPE	GML	0.15	2.0E-13	-	-	-
	5	GCL	Bentonite Mat	BSL	0.5	5.0E-09	0.75	0.747	0.4
	6	Clay	Silty Clay - moderately compacted	VPL	60	1.0E-06	0.452	0.411	0.311
Daily Cover	1	Daily Cover	Silt Loam – slightly compacted	VPL	15	1.0E-03	0.501	0.284	0.135
	2	Municipal Waste	Municipal Waste (312 kg/m^3)	VPL	100	1.0E-03	0.671	0.292	0.077
	3	Gravel Drainage	Gravel	LDL	30	3.0E-01	0.397	0.032	0.013
	4	FML	HDPE	GML	0.15	2.0E-13	-	-	-
	5	GCL	Bentonite Mat	BSL	0.5	5.0E-09	0.75	0.747	0.4
	6	Clay	Silty Clay - moderately compacted	VPL	60	1.0E-06	0.452	0.411	0.311
Intermediate Cover	1	Intermediate Cover	Silty Clay – moderately compacted	VPL	30	1.0E-04	0.452	0.411	0.311
	2	Municipal Waste	Municipal Waste (312 kg/m^3)	VPL	100	1.0E-03	0.671	0.292	0.077
	3	Gravel Drainage	Gravel	LDL	30	3.0E-01	0.397	0.032	0.013
	4	FML	HDPE	GML	0.15	2.0E-13	-	-	-
	5	GCL	Bentonite Mat	BSL	0.5	5.0E-09	0.75	0.747	0.4
	6	Clay	Silty Clay - moderately compacted	VPL	60	1.0E-06	0.452	0.411	0.311
Final Cap	1	Topsoil	Silty Clay Loam – moderately compacted	VPL	10	1.0E-05	0.445	0.393	0.277
	2	Topsoil	Silty Clay Loam – moderately compacted	LDL	5	1.0E-05	0.445	0.393	0.277
	3	Clay cap	Silty Clay – moderately compacted	BSL	60	5.0E-06	0.452	0.411	0.311
	4	Soil	Silty Clay – moderately compacted	VPL	50	1.0E-04	0.461	0.36	0.203
	5	Municipal Waste	Municipal Waste (312 kg/m^3)	VPL	1400	1.0E-03	0.671	0.292	0.077
	6	Gravel Drainage	Gravel	LDL	30	3.0E-01	0.397	0.032	0.013
	7	FML	HDPE	GML	0.15	2.0E-13	-	-	-
	8	GCL	Bentonite Mat	BSL	0.5	5.0E-09	0.75	0.747	0.4
	9	Clay	Silty Clay - moderately compacted	VPL	60	1.0E-06	0.452	0.411	0.311

* U.S. Department of Agriculture (USDA) soil textural classification system reported in Schroeder et al., (1994).[1]

** VPL = Vertical Percolation Layer. LDL = Lateral Drainage Layer. GML = Geomembrane. BSL = Barrier Soil Layer.

[1] Schroeder, P. R., Dozier, T.S., Zappi, P. A., McEnroe, B. M., Sjostrom, J.W., and Peyton, R. L. (1994). "The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3," EPA/600/R-94/168b, September 1994, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Table A 2: Parameters for determination of runoff curve number for each landfill phase

Landfill Stage	Soil Texture	Surface slope	Surface Vegetation
Open Waste	Municipal Waste	0.1%	Bare Soil
Daily Cover	Slightly compacted silt loam	0.1%	Bare Soil
Intermediate Cover	Moderately compacted silty clay	33%	Poor Grass
Final Cap	Moderately compacted silty clay loam	33%	Good Grass

Table A 3: Parameters for determination of runoff curve number for each landfill stage

Stage	Average Surface Flow Path Length (m)
1	150
2	250
3	100
4	300
5	400

Table A 4: HELP Model Leachate Results

				OW	DC	IC	FC	OW	DC	IC	FC	OW	DC	IC	FC
Stage	**Scenario**	**Average Distance to Drain**	**Liner Slope**	**Average Annual Total Leachate Leakage (mm/year) /m²**				**Average Annual Total Leachate Collected from Drainage Layer (mm/year) / m²**				**Average Head on top of FML (mm)**			
1	**1**	270	4%	0.039	0.019	0.016	0.014	538.85	275.64	229.51	207.19	19.237	9.804	8.169	7.368
	2	150	25%	0.003	0.002	0.001	0.001	538.80	275.66	229.52	207.20	1.814	0.925	0.770	0.695
2	**1**	270	4%	0.039	0.020	0.016	0.014	538.94	277.04	232.50	207.43	19.240	9.854	8.275	7.376
	2	140	25%	0.003	0.002	0.001	0.001	538.89	277.06	232.51	207.44	1.693	0.867	0.728	0.649
3	**1**	270	4%	0.039	0.019	0.015	0.014	538.78	274.52	227.05	206.95	19.234	9.764	8.081	7.359
	2	160	25%	0.004	0.002	0.001	0.001	529.73	274.54	227.06	206.96	1.934	0.982	0.813	0.740
4	**1**	190	4%	0.026	0.013	0.011	0.010	538.95	277.53	233.64	207.51	13.539	6.946	5.852	5.193
	2	150	25%	0.003	0.002	0.001	0.001	538.92	277.54	233.65	207.52	1.814	0.931	0.784	0.696
5	**1**	200	7%	0.015	0.008	0.006	0.006	538.97	278.26	235.32	207.79	8.171	4.203	3.557	3.138
	2	200	25%	0.004	0.002	0.002	0.002	538.95	278.26	235.32	207.80	2.419	1.244	1.053	0.929

* OW = Open Waste. DC = Daily Cover. IC = Intermediate Cover. FC = Final Cap.

Table A 5: HELP Model Runoff and Evapotranspiration Results

Stage	Open Waste	Daily Cover	Intermediate Cover	Final Cap	Open Waste	Daily Cover	Intermediate Cover	Final Cap
	Average Annual Total Runoff (mm/year) / m^2				Average Annual Actual Evapotranspiration (mm/year) / m^2			
1	0.649	20.919	92.297	113.975	270.158	512.902	487.663	488.204
2	0.565	19.430	89.101	113.686	270.158	512.993	487.869	488.285
3	0.726	22.125	94.935	114.122	270.158	512.818	487.486	488.257
4	0.537	18.922	87.876	113.628	270.158	513.021	487.954	488.276
5	0.497	18.158	86.056	113.411	270.158	513.061	488.103	488.223

Table A 6: Predicted leachate collected through the drainage layer under worst case operational landfill phases

Landfill Stage	Exposed liner*		Open Waste		Daily Cover		Intermediate Cover		Final Cap		Total Leachate Collected	
	Area (m^2)	Leachate Collected (L/Yr)	Area (m^2)	Leachate Collected (L/Yr)	Area (m^2)	Leachate Collected (L/Yr)	Area (m^2)	Leachate Collected (L/Yr)	Area (m^2)	Leachate Collected (L/Yr)	(L/Yr)	(m^3/Yr)
Stage 1	10,000	8,095,000	2,500	1,347,047	11,500	3,170,064	65,142	14,951,339	14,000	2,900,769	30,464,220	30,464
Stage 1 & 2	10,000	8,095,000	2,500	1,347,259	11,500	3,186,137	90,497	21,041,379	82,433	17,099,792	50,769,567	50,770
Stage 3	10,000	8,095,000	2,500	1,331,103	11,500	3,157,162	43,776	9,939,691	5,500	1,138,275	23,661,231	23,661
Stage 3 & 4	10,000	8,095,000	2,500	1,347,313	11,500	3,191,680	80,299	18,761,901	50,300	10,437,993	41,833,887	41,834
Stage 3, 4 & 5	10,000	8,095,000	2,500	1,347,395	11,500	3,200,023	43,517	10,240,521	167,550	34,816,139	57,699,079	57,699

*100% of rainfall assumed to report from exposed liner. Annual average rainfall of 809.5 mm adopted.

Table A 7: Predicted leachate collected through the drainage layer after landfill stage closure

Stage	Batter Area (m^2)	Base and Bench Area (m^2)	Final Cap Area (m^2)	Leachate Collected	
				(Litres/Yr)	(m^3/Yr)
Stage 1	70,542	32,600	103,142	21,370,776	21,371
Stage 2	66,788	27,000	93,788	19,455,273	19,455
Stage 1 & 2				40,826,049	40,826
Stage 3	50,276	23,000	73,276	15,165,118	15,165
Stage 4	55,123	26,200	81,323	16,875,708	16,876
Stage 3 & 4				32,040,827	32,041
Stage 5	69,768	10,700	80,468	16,720,943	16,721
Stage 3, 4 & 5				48,761,770	48,762
All Stages	**272,709**	**159,288**	**431,997**	**89,587,818**	**89,588**

Table A 8: Areas considered for predicted leachate leakage through landfill liner during landfill development and after closure

Stages	Exposed waste	Exposed waste with Daily Cover	Intermediate Cap	Final Cap
	Area (m^2)			
1	2,500	11,500	65,142	14,000
2	2,500	11,500	58,788	11,000
1 & 2	2,500	11,500	90,457	82,433
3	2,500	11,500	43,776	5,500
1, 2 & 3	2,500	11,500	43,776	202,430
4	2,500	11,500	46,323	11,000
1, 2, 3 & 4	2,500	11,500	80,299	247,230
5	2,500	11,500	32,468	24,000
1, 2, 3, 4 & 5	2,500	11,500	43,517	364,480
Closure	-	-	-	431,997

Table A 9: Predicted leachate leakage through landfill liner during landfill development and after closure

Stage	Exposed waste	Exposed waste with Daily Cover	Intermediate Cap	Final Cap	Total (Litres/year)
	Leachate Leakage (Litres/Yr)	Leachate Leakage (Litres/Yr)	Leachate Leakage (Litres/Yr)	Leachate Leakage (Litres/Yr)	
1	35	79	377	71	562
2	34	80	335	55	505
1 & 2	34	80	518	416	1,050
3	35	81	249	28	393
1, 2 & 3	35	81	249	1,026	1,391
4	25	59	198	41	324
1, 2, 3 & 4	25	59	391	2,246	2,722
5	19	45	107	69	239
1, 2, 3, 4 & 5	19	45	154	2,733	2,950
Closure	-	-		**1,884**	**1,884**

Appendix D – Monitoring Plan

Monitoring of surface water and groundwater is proposed to be undertaken during pre-construction, construction, operation and after landfill closure at the locations and frequency proposed in Table D 1. The location of the groundwater monitoring wells and surface water monitoring points are presented in Drawing 51-12506381-C309. The parameters proposed to be analysed in the water samples are presented in Table 5 in Section 4.2.4 of the main report. Establishment of baseline data will be required for at least 18 months prior to construction commencing The data collected as part of this study will be included as part of the baseline monitoring database and samples will continue to be collected and analysed on a quarterly basis.

Table D 1: Water Monitoring Locations and Frequency

Monitoring Point	Frequency
Groundwater sample from subsoil drainage system prior to discharge to attenuation basin.	Monthly monitoring for the duration of the consent
Groundwater monitoring wells (1) (GW1 – GW6, and BH202 on Drawing 51-12506381-C309)	Quarterly monitoring for the duration of the consent
Surface water monitoring (2) (SW1 – SW6 on Drawing 51-12506381-C309)	Monthly monitoring for the duration of the consent (when flows occur)
Wetland monitoring - Monitoring of wetland features downstream of the landfill (within 100m of the attenuation basin) to identify any long term changes in water levels associated with landfill development	Continues monitoring – data loggers

1) Groundwater monitoring wells to be sampled either by low flow, or purge 3 well volumes followed by a grab sample

2) Sample flowing water only (not stagnant), ensure sample from centre of water column to avoid surface or stream bed sediment/debris.

Parameter trigger levels, and contingency actions should trigger levels be exceeded, will be detailed in the landfill management plan (LMP).

This report has been prepared by Zoë Pattinson, a hydrogeologist with GHD Ltd, under the direction and supervision of Anthony Kirk. Zoë has 7 years experience in consulting and the following qualifications and institutional memberships: BSc Environmental Geoscience. MSc Hydrogeology. Fellow of the Geological Society of London (GSL). International Association of Hydrogeology (IAH). Anthony is a Principal and Technical Director with GHD Ltd, who has over 20 years experience in environmental consulting, and has the following qualifications and institutional memberships: BSc Chemistry and Earth Science. MSc Chemistry. NZ Hydrological Society. International Association of Hydrogeology (IAH).

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Rev01	Z. Pattinson	A. Kirk		S. Douglass		17-08-20

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