Waste Futures – Green Island Landfill Closure

Groundwater Technical Assessment – October 2024 Update

Dunedin City Council

18 July 2024

→ The Power of Commitment

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1. Introduction

1.1 Background

As part of Dunedin's wider commitment to reducing carbon emissions and reducing waste going to landfill, the Dunedin City Council (Council) has embarked on the Waste Futures Programme to develop an improved comprehensive waste management and diverted material system for Ōtepoti Dunedin. The Waste Futures Programme includes the roll out of an enhanced kerbside recycling and waste collection service for the city from July 2024. The new service will include collection of food and green waste.

To support the implementation of the new kerbside collection service, the DCC are planning to make changes to the use of Green Island landfill site (Figure 1.1) in coming years.

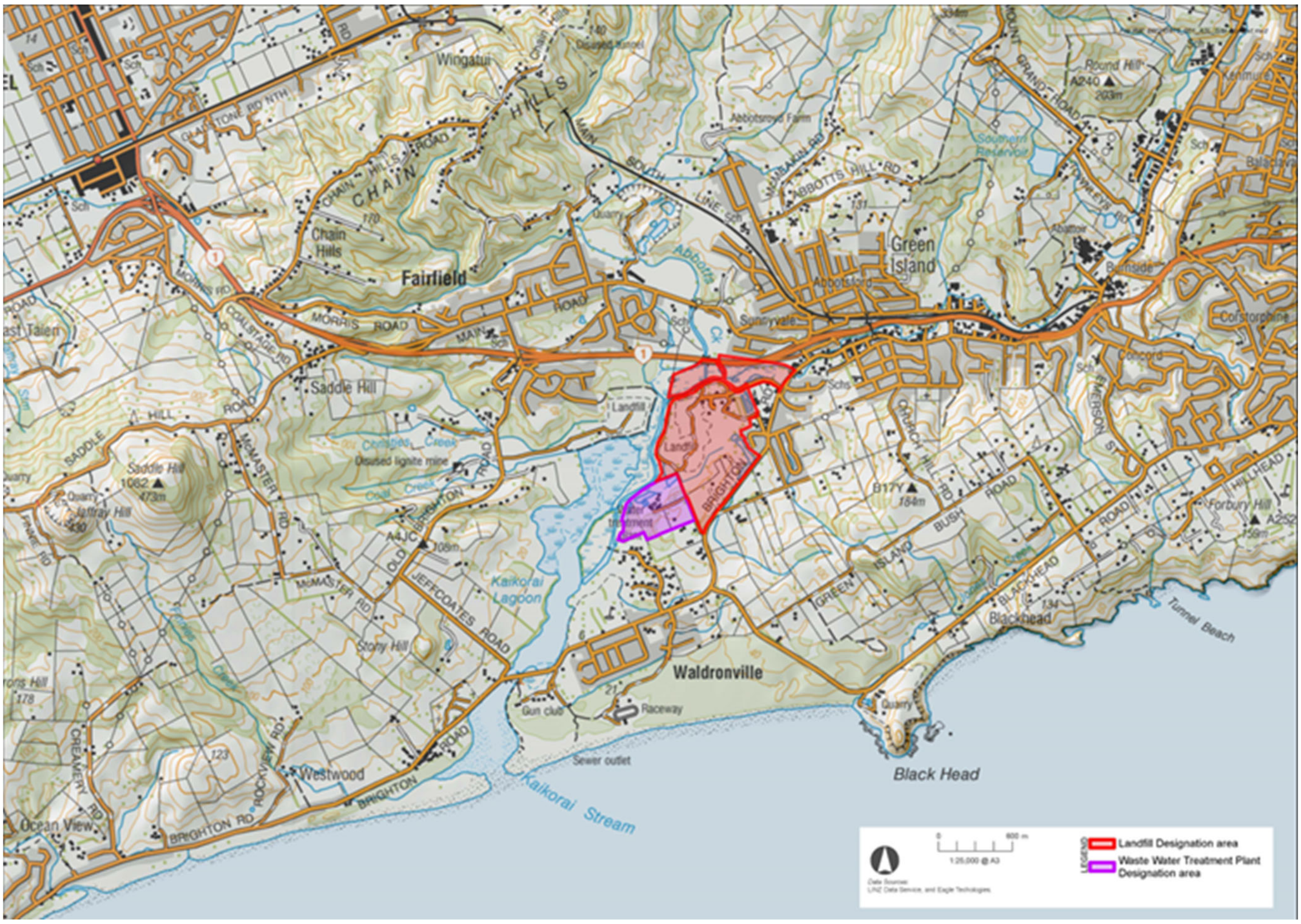


Figure 1.1 Site location

The proposed changes include:

- planning for the closure of the Green Island landfill, which is coming to the end of its operational life
- developing an improved Resource Recovery Park (RRPP) to process recycling, and food and green waste
- providing new waste transfer facilities to service a new Class 1 landfill currently planned for a site south of Dunedin, at Smooth Hill.

The resource consents for the new Smooth Hill landfill were granted in May 2023. Depending on DCC decisions regarding development of Smooth Hill, time needed to undertake baseline monitoring, preparation of management plans, landfill and supporting infrastructure design and construction, DCC anticipate that the new Class I landfill facility, won't be able to accept waste until 2027/2028 at the earliest.

In the interim, DCC therefore plans to continue to use Green Island landfill for waste disposal. Based on Dunedin's current waste disposal rates, it is likely that that the Green Island landfill can keep accepting waste for another six years (until about 2029). Between now and then, and as it continues to fill up, the landfill will be closed and capped in stages. When the landfill closes completely, there will be opportunities for environmental enhancements and public recreational use around the edge of the site. Examples could be planting restoration projects and new walking and biking tracks beside the Kaikorai Estuary. Long term use and public access to the landfill site post closure will be determined in consultation with Te Rūnanga o Ōtākou, the local community and key stakeholders.

As current Otago Regional Council resource consents needed to operate a landfill at Green Island expire in October 2023, the DCC are now applying to ORC for replacement resource consents to continue to use the landfill until it closes completely, and waste disposal can be transferred to a new landfill facility. The replacement consents relate to ground disturbance, flood defence and discharges to land, water, and air. The site is subject to an operative designation (D658) in the Proposed Second-Generation Dunedin City District Plan (2GP) for the purpose of Landfilling and Associated Refuse Processing Operations and Activities.

The development of the new RRPP and waste transfer facilities at Green Island does not form part of the replacement consent applications. Resource consents for the development and operation of the RRPP were submitted in March 2024 and are under consideration by ORC..

This groundwater technical assessment has been prepared to support the resource consent application for the continued operation and closure of Green Island Landfill. This report has been updated in October 2024 to include new information and to respond to s92 questions from the ORC. This version of the report replaces the original Groundwater report issued in March 2023.

1.2 Purpose of this report

The purpose of this report is as follows:

- Provide a description of the groundwater environment, existing management of groundwater and leachate discharges, and environmental monitoring data.
- Provide a technical assessment of the potential effects on groundwater and connected surface water flows from the proposed extension of landfill operations and closure management.
- Provide an assessment of the effects of leachate leakage on groundwater quality.
- Provide recommendations for mitigation measures to minimise the effects on the environment and monitoring conditions to confirm the effectiveness of the recommended mitigation measures.

Note: the potential effects of site stormwater on downstream surface water flows and quality are discussed in the *Surface Water Technical Report* (GHD 2024) and referenced in this report. This Surface Water Report has also been updated in October 2024 with additional information and in response to s92 questions from the ORC.

This report should be read in conjunction with the following reports:

- Green Island Landfill Design Report (GHD, 2023)
- Surface Water Report (GHD, 202), including Appendix B, Annual Monitoring Plan 2022-2023.
- Green Island Landfill Geotechnical Factual Report (GHD, 2023)
- Green Island Landfill Liquification and Stability Assessment (GHD, 2023)
- Human Health & Environment Risk Assessment (GHD, 2024)

These reports provide supporting information and context which the surface water assessment relies upon. Where appropriate, a summary of critical information is summarised in this report with crossed references to the relevant technical report.

In addition, the assessment undertaken in this report is based on a review of previous investigations, including those undertaken as part of the 1994 resource consent application. This information has been supplemented with additional site investigations undertaken by GHD to support the design and consenting process (documented in the *Geotechnical Factual Report* (GHD 2023). The information obtained from the desktop review and site investigations has been used to undertake an assessment of potential impacts to groundwater and connected surface water, associated with the proposed extension and ultimate closure of Green Island Landfill.

1.3 Current landfill operation and management

1.3.1 Current Consents

The operation of the Green Island Landfill, including associated waste processing operations and facilities, is currently subject to 14 existing resource consents granted by Otago Regional Council (ORC). The consents cover landfill operation activities relating to discharges to land, water, and air, taking and/or diverting water, and disturbance of a contaminated site. All consents expire on 1 October 2023.

The current consents limit the extent of landfilling through the combination of a maximum 38 ha landfill footprint, conditions limiting the deposit of waste to 270 m^3/day and 100,000 m^3/year[1], and the 2023 term of the consents. The consent conditions do not impose any specific limit on the overall finished height, shape, or contour of the landfill. However, the plans included in the 1994 resource consent applications show a finished landfill surface rising to a maximum height of 25 m above mean sea level (amsl).

The consent conditions also require the consents are exercised in accordance with a Landfill Work Programme (LWP) prepared by the consent holder, which is to be reviewed annually or at such lesser frequency as the consent authority may approve. Among other matters, the LWP is required to describe present projections and intentions for landfill operations, and the sequencing of works.

1.3.2 Landfill Development and Management Plan

A Landfill Development and Management Plan (LDMP) was developed following the issuing of the consents to serve the purpose of the LWP. The LDMP is to document site-specific procedures, including monitoring and contingency actions to be implemented to ensure the landfill achieves the conditions set out in the resource consents. The LDMP is structured into the sections set out below:

1. **Introduction –** the existing resource consents, designation, and status and review of the LDMP.
2. **Site Management –** management structure, responsibilities, requirements for staff training, and community liaison.
3. **Landfill Development** – including design principles, landfill capacity, and the filling programme and sequence.
4. **Site Operations** – including controls and procedures for access control, stormwater management, leachate management, LFG management, greenwaste mulching and composting, salvage and management of diverted materials, roading and traffic management, waste acceptance and placement, waste cover, and control of nuisances.
5. **Environmental Monitoring** – including monitoring, recording, and reporting for surface water, groundwater, LFG, leachate, odour, and weather.
6. **Emergency Management** – including procedures for management of fires, hazardous waste/materials, leachate and LFG escape, extreme weather/flooding, machinery failure, accidents, and earthquakes.
7. **Closure, Reinstatement, and Aftercare** – including final capping, continued operation and maintenance of landfill infrastructure, and ongoing monitoring.

The LDMP was first provided to ORC in 1994 following the issuing of the consents and was subsequently updated in 2004, and 2007. The most recent LDMP, which reflects the current approach to landfill operation and management was provided to ORC in February 2023.

1.3.3 Landfill Operations Plan

The landfill is currently operated by Waste Management NZ Ltd. under contract to the Council. Waste Management NZ Ltd. are required to maintain a Landfill Operations Plan (LOP) which reflects the LDMP and more specifically addresses day-to-day management landfill operational matters.

The LDMP (February 2023) and LOP (October 2018) will be updated after the granting of any replacement resource consents to ensure that they align with the final approved consent documentation, and any resource consent conditions.

2. Environmental Setting

2.1 Introduction

A review of the environmental setting was undertaken to inform the technical assessment (Section 3). This review includes a factual summary of information relevant to the conceptual understanding of the groundwater system and baseline parameters used in the modelling assessment. Assessment and interpretation of the site data is included in the following sections.

2.2 Site Description

The Green Island Landfill site is located in the suburb of Green Island, approximately 8.8 km by road southwest of Central Dunedin. The landfill site comprises a total area of 75.6 Ha. The site is generally bound by State Highway 1 to the north, the Kaikorai Stream and Estuary to the west, the Green Island Wastewater Treatment Plant (GIWWTP) to the southwest, Brighton Road to the south, and the Clariton Ave residential area and Brighton Road industrial area to the east.

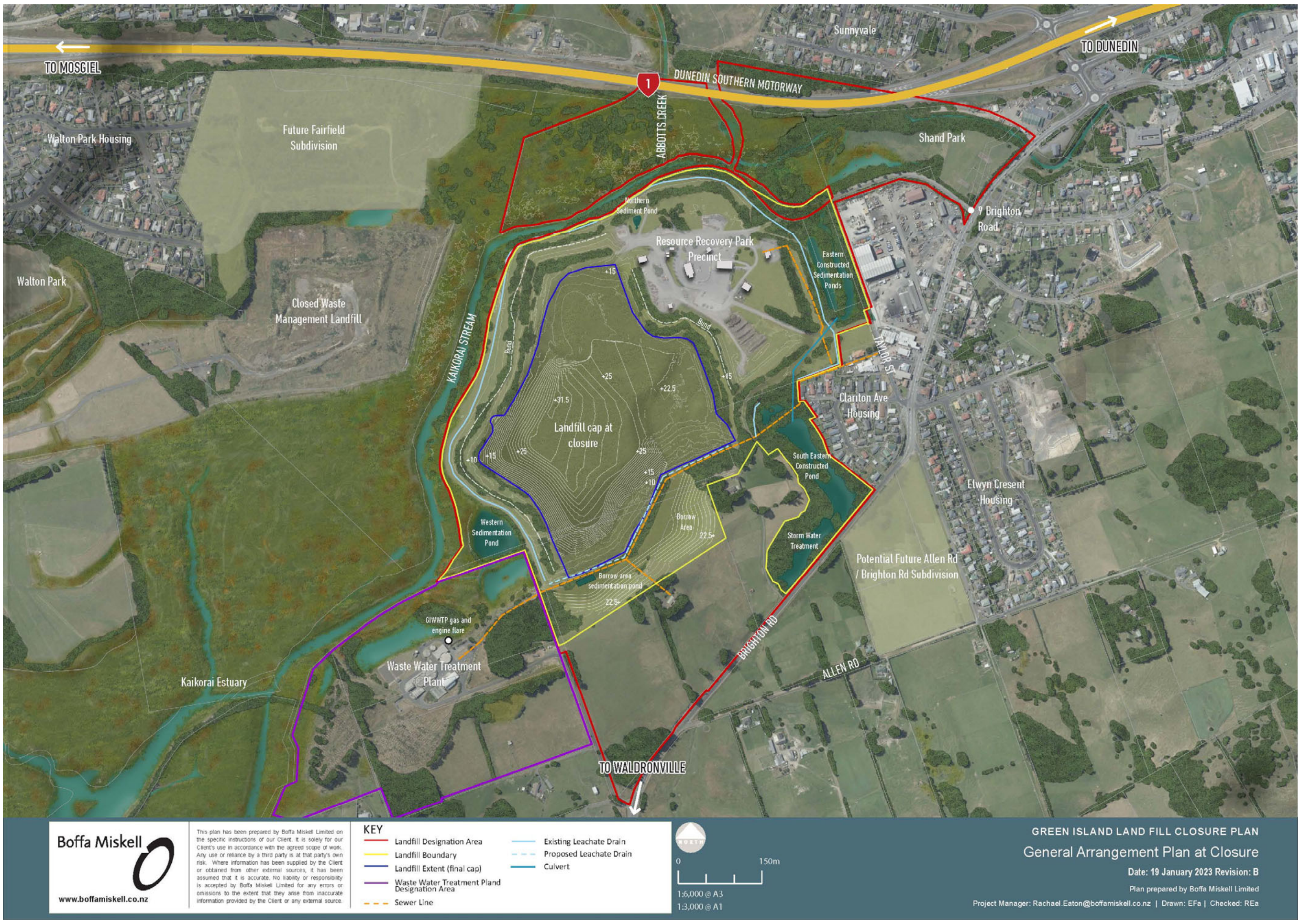


Figure 2.1 Site Layout

The margins of the Kaikorai Stream and Estuary bordering the landfill to the north and west are identified as a Regionally Significant Wetland in the Regional Plan: Water; and an Area of Significant Biodiversity Value, and a Wāhi Tupuna of cultural significance to mana whenua in the 2GP. Low lying areas around the stream and estuary are also identified as being within a Hazard 2 Flood overlay at risk of flooding in the 2GP.

2.2.1 History

The historical placement of waste and its distribution across the site is described in detail in Appendix D. The following provides a summary of the waste filling history that is relevant to the future engineering design and closure management presented herein.

Waste disposal first occurred at the Green Island site in 1954 with the disposal of industrial waste and the site has been used for waste disposal since that time. A number of other sites have been used over the decades across the Dunedin region including the “Maxwell” landfill on the opposite side of the estuary to Green Island landfill. The Maxwell landfill was formally closed to waste disposal in mid-2017 and the Green Island landfill continued as the sole municipal solid waste disposal facility in the Dunedin region after that time. The existing operational consents were granted in 1994.

Landfilling commenced at the south-east corner of the landfill site and has continued north and west over the decades. The eastern portion of the landfill has a relatively shallow depth of waste at around 3 to 6 m thickness and is currently used for facilities and waste transfer station operations. This area is proposed to be developed in the near future to establish the Resource Recovery Park Precinct (RRPP). No further waste disposal will occur in this area.

The main landfill area is located immediately to the west of the facilities area. Waste placement in this area has been confined over recent decades within a constructed soil bund that encircles the landfill on the eastern, northern and western sides adjacent to the estuary. However, prior to berm construction waste had been placed across the whole extent of the area (see Appendix D). In recent years significant waste disposal has progressed north to south. In the northern and eastern areas waste has been placed up to the 1994 design contours (see *Design Report (GHD 2023))* and final capping has been completed. The south western half of the landfill has up to approximately 6 m - 8 m depth of waste placed during the 1990’s, and a further 10 to 15 m of waste can be placed in this area. This is the primary area where future waste placement will occur through to closure of the landfill.

The pre-existing landform for the Green Island landfill was tidal estuary associated with the upper reaches of the Kaikorai Estuary (Figure 2.2). Abbotts Creek flows into Kaikorai Stream to the north of the site with the Kaikorai Stream flowing to the east then south in the Kaikorai Estuary. The 1942 aerial photograph shows a very similar Kaikorai Stream alignment to present. Several small channels are evident on the tidal mudflats, these drain towards the estuary at the southwest corner of the site. The 1942 photo also shows some evidence of land disturbance (to the south) and drains or trenches that predate the landfill activities.

Waste was originally end dumped directly onto the estuarine muds and up against the south eastern estuary edge where the pre-existing landform rises gently to the southeast. As discussed above, a soil bund was constructed around the north, west and south-western sides of the landfill to confine the waste from the adjacent Kaikorai Stream. The current landfill has an access track on the outside of the bund along with a leachate trench which is part of the leachate collection system and perimeter groundwater monitoring wells.

The leachate trench was installed on the outside of the soil bund in the mid-1990’s. This perimeter control is not present along the southern side of the landfill against the rising ground of the hillside *(see Drawing 12547621-01-G102, Appendix A Design Report (GHD 2023*). The main wastewater trunk sewer follows the existing southern extent of existing landfill, flowing to the GIWWTP located 200 m southwest of the landfill site. A surface water drain follows the alignment of the sewer creating a valley that intercepts runoff from the landfill and directs it to the leachate collection system.

Figure 2.2 1942 Aerial photo showing pre existing landform.

2.2.2 Leachate management

The perimeter bund and leachate trench was installed on the outside of the soil bund in 1994 and commissioned in 1995. The leachate trench intersects contaminated groundwater (landfill leachate mixed with groundwater) seeping from the site. The leachate collection system comprises the gravel interception trench with the HDPE liner (on outer side) and the slotted PVC drainage pipe, together with a manhole and pump station configuration (Figure 2.3). Figure 2.4 shows details of the gravity leachate trench drain arrangement between pump stations and manholes. The manholes are located at the ends of each PVC collector pipe, allowing inspection and cleaning of the pipes to occur. Impacted groundwater is then conveyed by gravity to nine individual pump stations, which then pump into a 125 mm dia. rising main, which conveys the leachate and groundwater to the main sewer and ultimately GIWWTP. The rising main has a discharge into the sewer at each end, one approximately 79 m south of PS1 and the other approximately 80 m south of PS8. Hence, the riser pumps in both clockwise and/or anti-clockwise direction before being discharged to the sewer line. PS9 discharges directly to the sewer main in the southern valley.

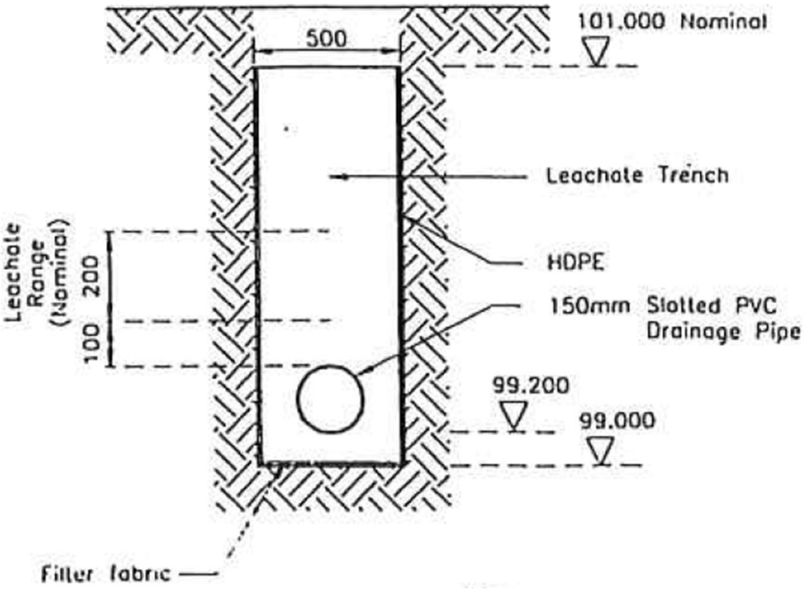


Figure 2.3 Leachate drain schematic (City Consultants, 1997)

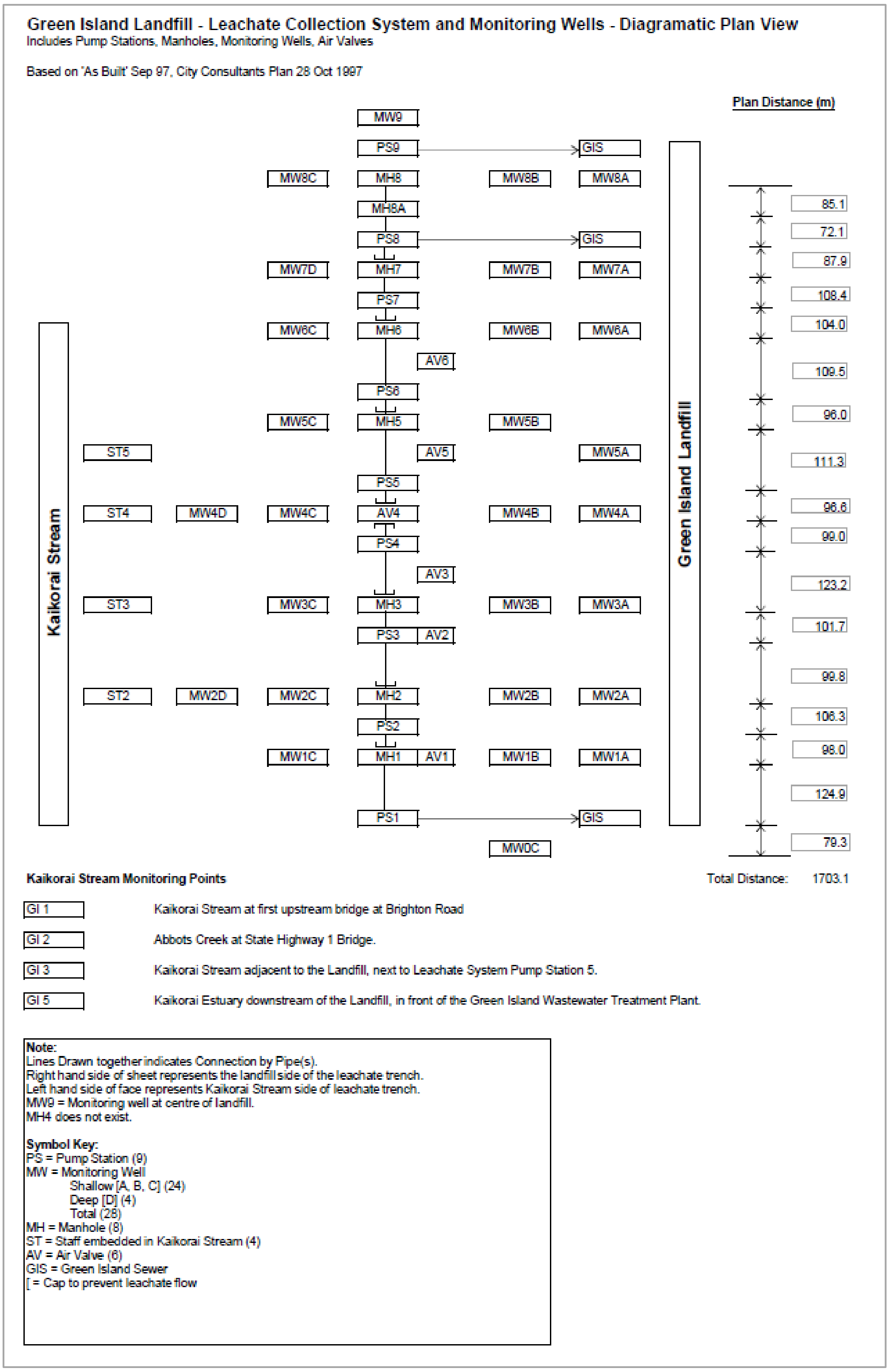
The trench creates a hydraulic barrier for groundwater and leachate migration offsite. The HDPE liner aids in reducing the volume of water entering the trench from the Kaikorai Stream but does not completely prevent inflows. The continuous dewatering of the trench is required to maintain this barrier, with the pump stations set to maintain water levels at low levels to create the hydraulic gradient which directs flow to the trench. The leachate pumps are automated to start when the pumpwell reaches a “Pump ON” level, and then stop when the level reaches a “Pump OFF” level. The pumpstations also have alarms for the following conditions (high level alarm, pump running low level and power loss). Flow rate through the pump is measured continuously, as are the pump run hours. Consent conditions require regular monitoring of groundwater levels adjacent to the trench to confirm the hydraulic gradient (discussed in sections 2.5.3).

The trench is installed in the Upper Kaikorai Estuary Member (UKEM) (see section 2.4) comprising fine sands and silt. However, landfill refuse was recorded as overlying the UKEM in over half of the trench profiles during construction (Barry Douglas, 2022) with a maximum thickness of landfill recorded of 2.6 m. Borehole data from the recent drilling investigation (see section 2.4.2) confirmed similar profiles.

The leachate trench is absent along the southern edge of the landfill where waste is placed against the base of the slope that rises to the east. Management of leachate in this area is currently via a shallow surface drain which conveys the leachate (and any shallow groundwater seepage) to PS1. It is also noted that there is a 90 m gap in the trench between MH8 and PS9. This gap aligns with a short ridge of land that extended into the estuary based on historical maps and photos. Based on the geological map this ridge is inferred to be mudstone.

A culvert located on the eastern side of the landfill between the South Eastern Constructed wetland and the Eastern Constructed Wetland has recently been identified as a pathway for leachate seepage, which has been confirmed from water quality monitoring and a culvert inspection (discussed in the *Surface Water Report, 2024*). These results and proposed mitigation are discussed further in the *Design Report* (GHD 2023). As at October 2024 work is underway to repair this culvert and work is expected to be complete by end of March 2025.

Additional perforated leachate drains have been installed over intermediate cover soils in the southern portion of the landfill and in the northern sector of waste placed in 2019-2022. These drains direct leachate to the perimeter leachate collection trench. These drains installed within the landfill are described in the *Design Report (GHD 2023)* and shown on Drawings 12547621-01-C204 (*Design Report – Appendix A).*



Green Island Landfill - Leachate Collection System and Monitoring Wells - Diagramatic Plan View
Includes Pump Stations, Manholes, Monitoring Wells, Air Valves

Based on 'As Built' Sep 97, City Consultants Plan 28 Oct 1997

Kaikorai Stream Monitoring Points

GI 1	Kaikorai Stream at first upstream bridge at Brighton Road
GI 2	Abbots Creek at State Highway 1 Bridge.
GI 3	Kaikorai Stream adjacent to the Landfill, next to Leachate System Pump Station 5.
GI 5	Kaikorai Estuary downstream of the Landfill, in front of the Green Island Wastewater Treatment Plant.

Note:
Lines Drawn together indicates Connection by Pipe(s).
Right hand side of sheet represents the landfill side of the leachate trench.
Left hand side of face represents Kaikorai Stream side of leachate trench.
MW9 = Monitoring well at centre of landfill.
MH4 does not exist.

Symbol Key:
PS = Pump Station (9)
MW = Monitoring Well
    Shallow [A, B, C] (24)
    Deep [D] (4)
    Total (28)
MH = Manhole (8)
ST = Staff embedded in Kaikorai Stream (4)
AV = Air Valve (6)
GIS = Green Island Sewer
[= Cap to prevent leachate flow

Figure 2.4 Well and pump station arrangement, leachate collection system

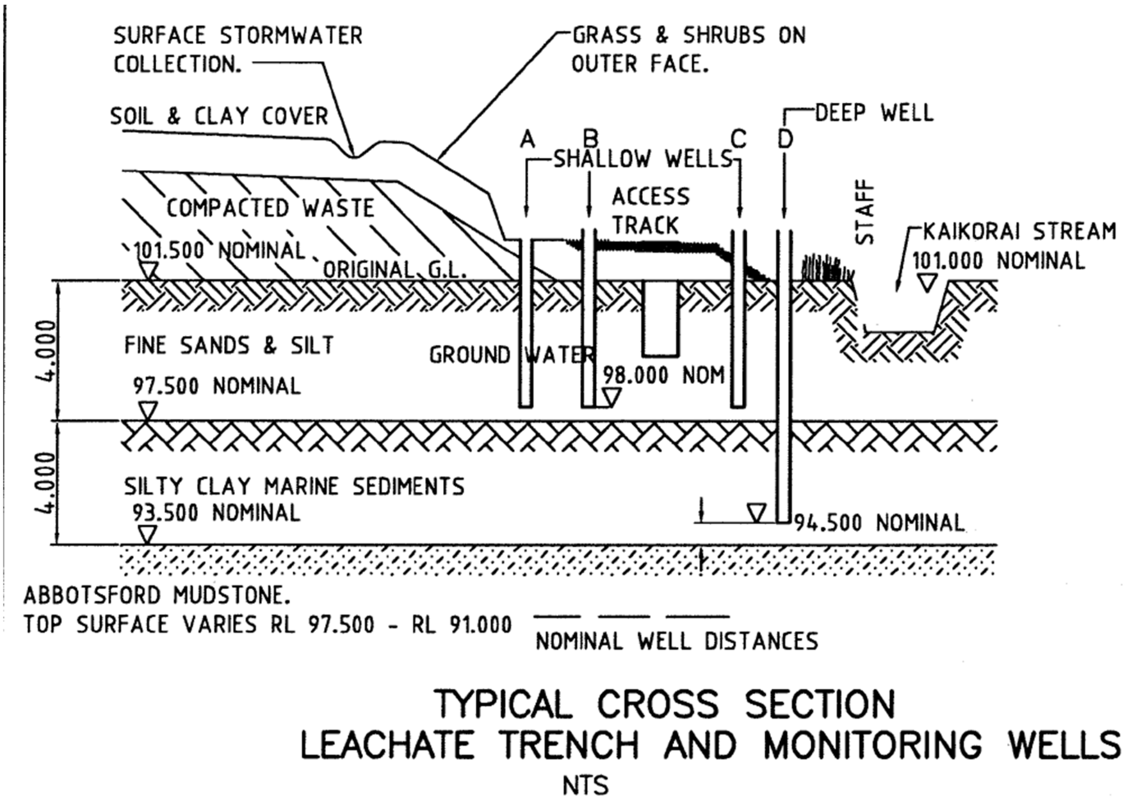


Figure 2.5 Typical cross section of leachate collection system (MWH, 2004

2.2.3 Leachate volumes

Pump flow rates and pump hours are recorded within each pump station continuously. The volume of leachate pumped from each pump station to the rising main (weekly total) was reviewed as part of this assessment. Based on this record, a box and whisker plot of the combined flow rate (to all pump stations) averaged on a weekly basis is presented in Figure 2.6. Lower flow rates in the 2020-2021 and 2021-2022 reporting years are likely to be related to below average rainfall during this period (Table 2.1) but may also partly reflect the installation of final capping to part of the landfill which will reduce rainfall seepage into the waste. It is understood that PS1 has in the past received large quantities of stormwater flows from the landfill via open drains, with a recent improvement to the stormwater collection from the landfill (September 2021) resulting in some of these flows now going directly to PS3. Water held in the Northern Leachate Pond (see Drawing 12547621-01-C402) is also diverted to the leachate collection system (at PS5). Table 2.2 lists the median flow rates from the individual pump stations for an average rainfall year (2019-2020) and the past year (2021-2022, below average rainfall).

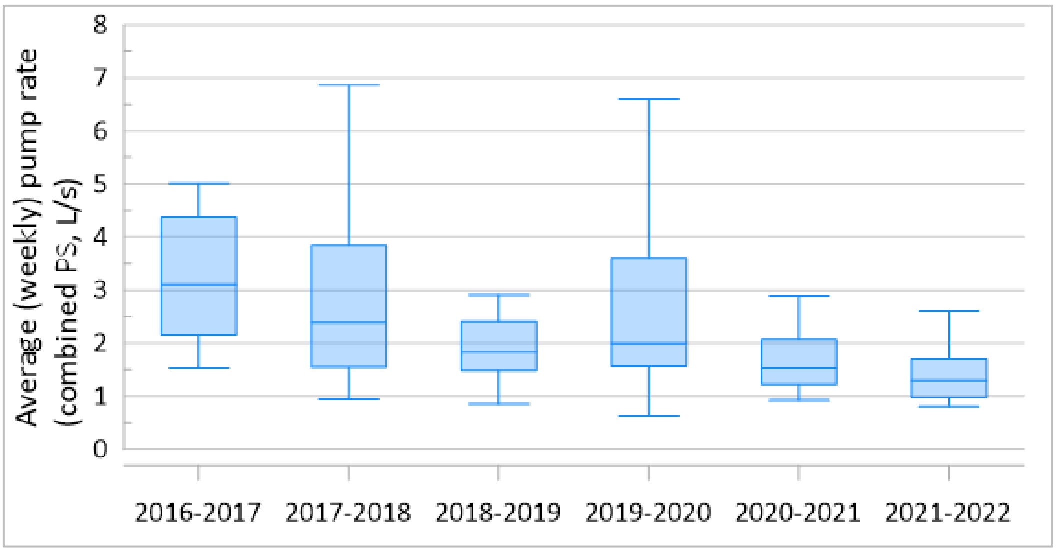


Figure 2.6 Combined flows from pump stations to rising main, reporting year July to June.

Table 2.1 Rainfall recorded at Musselburgh EWS

Year (July- June)	Rainfall total (mm)[1]
2016 – 2017	819.8
2017 – 2018	783.6
2018 – 2019	658.6
2019 – 2020	734.4
2020 -2021	556.6
2021- 2022	476

[1]Average rainfall ~750 mm

Table 2.2 Pump station flows – Median flow rate (reporting year July to June)

Pump station	2019 – 2020 (L/s)	2021 – 2022 (L/s)
PS1	0.76	0.13
PS2	0.04	0.03
PS3	0.04	0.08
PS4	0.15	0.10
PS5	0.31	0.24
PS6	0.25	0.21
PS7	0.20	0.19
PS8	0.16	0.10
PS9	<0.01	<0.01
Combined median flow rate	2.0	1.3

2.3 Hydrology

As discussed above the Kaikorai Stream borders the landfill to the north and west. Summary flow statistics for the Kaikorai Stream are provided below in Table 2.3 (NIWA, 2023[1]). Further details on the surface water environment

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[1] NIWA River Maps online view: **https://shiny.niwa.co.nz/nzrivermaps/** (accessed 09/02/2023)

are provided in the *Surface Water Technical Assessment (GHD, 2023)*. From time to time, the estuary/ river mouth is blocked as a result of sand/debris accumulation from storm events. When this occurs, water backs up in the stream and results in higher stream levels adjacent to the site. Elevated water levels are maintained until the mouth is opened up again, either by natural or mechanical methods.

Table 2.3 Kaikorai Stream Flow Statistics (source NIWA)

Location	Mean flow	Mean Annual Low Flow
Upstream of Abbots Creek confluence	227 L/s	49 L/s
Downstream of Abbots Creek confluence	368 L/s	81 L/s

2.4 Geology

2.4.1 Overview

The site is situated on estuarine sedimentary deposits associated with the Kaikorai Estuary (Figure 2.7). These have been characterised as the Kaikorai Estuary Formation (KEF) (BDGC, 2002). KEF was considered to extend to a depth of approximately 11 m in the landfill area, and immediately overlies the Abbotsford Formation mudstone (BDGC, 2002)

The KEF was divided into an upper and lower layer (Member), with the upper member being further divided by BDGC (2020) into two subgroups as shown in Table 2.4. The estuarine sediments are underlain by weak mudstone rocks belonging to the Abbotsford Formation(Adams Geotechnical, 2019; Geotechnical Report (GHD 2023)).

To the southeast of the site, the landfill and underlying alluvium terminate at the toe of a 30m high ridge that has been mapped as the upper part of the Abbotsford Formation sequence (Adams Geotechnical, 2019) as shown in Figure 2.8. The Abbotsford Formation is described as “Grey to dark grey sandstone, siltstone and claystone with some glauconitic mudstone and green sand layers” (McKellar, 1990). Overlying the mudstone is a layer of loess and colluvium (clay -silt soils). The thickness of the colluvium/loess layer is variable, near the base of the ridge (southern valley) the Test pit investigations by Adams Geotechnical indicated that the colluvial layer was generally 1-2 meters thick. Groundwater was not intercepted in any of the test pits (Adams Geotechnical, 2019).

Table 2.4 Description of KEF lithological units (after BDGC, 2002)

Member	Description	Subgroup	Thickness
Upper Kaikorai Estuary Member (UKEM)	Variable thin beds of sand, silty sand, sandy silt, silt, clayey silt and silty clay	Subgroup A -mostly homogeneous fine grained	4.5 m
		Subgroup B – heterogeneous, coarser grain size	
Lower Kaikorai Estuary Member (LKEM)	Massive homogeneous beds of clayey silt, silty clay and silt, and minor (possibly localised) beds of clay, very fine sandy silt and silty very fine sand.	-	6.5 m

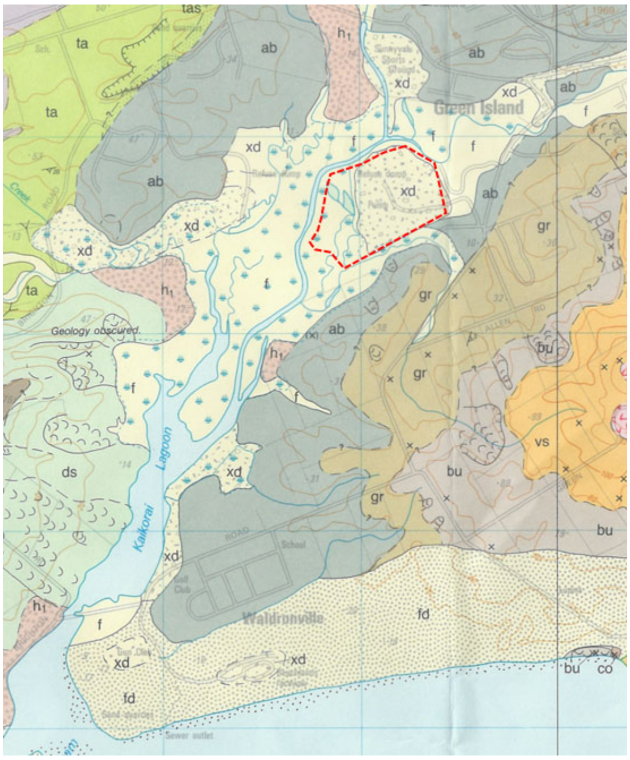

Figure 2.7 *Geological map of Green Island area (McKellar, 1990). Approximate site boundary shown by red dashed line. ab: Abbotsford Formation f: alluvium, xd:fill*

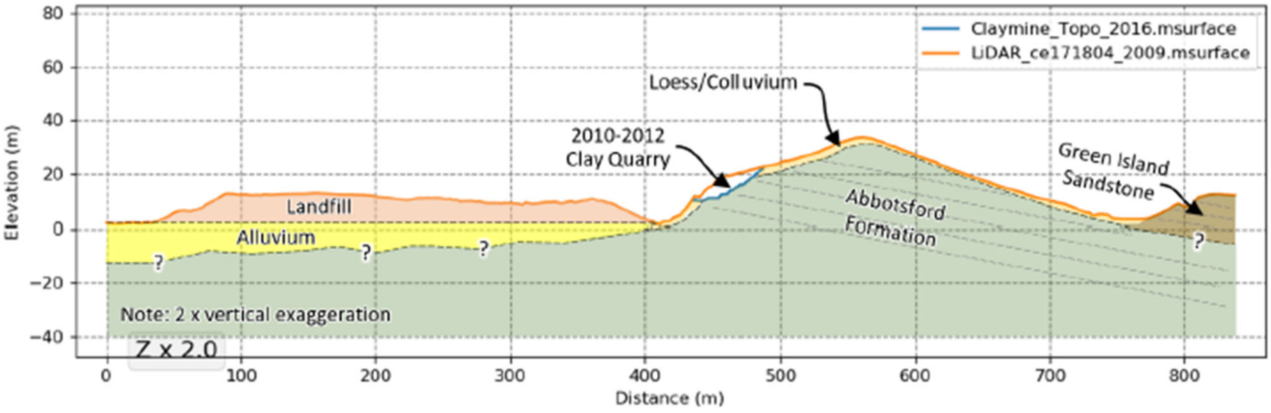

Figure 2.8 ***Interpreted geological cross section from Adams Geotechnical (2019)***

2.4.2 GHD site investigation (2022)

Site investigations were undertaken by GHD to inform the geotechnical and hydrogeological assessments. The results of the site investigation are documented in the *Geotechnical Factual Report* (GHD 2023). A brief summary of the geology encountered is included here. The GHD investigation comprised twelve bore holes across the site, with piezometers installed in six of the bore holes. The general geological profile for boreholes on site perimeter is summarised in Table 2.5 below. There was no clear geological distinction between the two subgroups of the Upper Kaikorai Estuary Member (UKEM), therefore we have not adopted this division. In several of the bore holes there was a coarse grained layer (sand and/or gravel) at the contact of the Lower Kaikorai Estuary Member (LKEM) and mudstone. Depending on the location, variable amounts of fill were encountered. At BH104, drilled in the south-eastern part of the site, fill sits directly on mudstone.

Bore locations are included in Appendix B-1.

Table 2.5 Summary geological profile – perimeter (near leachate trench) boreholes (Geotechnical Factual Report, GHD 2023)

Geology	Description	Layer thickness
Fill	Variable waste and soil	variable
UKEM	Silty fine to medium sand, sandy silt	1 – 3 m
LKEM	Organic silt, silty clay	6 – 8.5
Coarse sediments	Sands/gravel	0.5 -1.5
Abbotsford Formation	Grey-brown mudstone, very weak	-

2.5 Hydrogeology

2.5.1 Overview

Prior to the landfill, groundwater within the estuarine deposits (KEF) is likely to have been hydraulically connected to the Kaikorai Stream and other surface water features. As discussed in Section 2.2.1, pumping from the perimeter leachate trench creates a hydraulic barrier between surface water and the shallow aquifer underlying the landfill. The underlying Abbotsford Formation is inferred to be an aquitard due to the very low permeability of the mudstone/siltstone and is effectively an impermeable barrier for downward seepage. Adams Geotechnical (2019) reported permeabilities for the Abbortsford Formation siltstone associated with the capping material borrow pit located to the east of the landfill, between 3.8-7.9 x 10^{-10} m/s.

2.5.2 Hydraulic Conductivity

Groundwater investigations undertaken as part of the 1992 EIA (Beca, 1992), included permeability testing in three boreholes at various depths. The results indicated an average hydraulic conductivity for the estuarine sediments of 4 x 10^{-6} m/s above 4 m depth and 6 x 10^{-7} m/s for greater than 4 m depth.

Hydraulic conductivity estimates of the differing geological units at the site, determined from hydraulic testing during the GHD site investigation (Appendix A) are presented in Table 2.6. The testing resulted in a range of hydraulic conductivity values; this reflects the heterogeneity created by the depositional environment. There are likely to be discrete channels of higher permeability materials (where active stream channels were located), with both horizontal (due to the direction of deposition) and vertical anisotropy[2] (due to the layering of sediments) likely.

While investigations beneath the landfill waste are necessarily limited it is expected that the permeability of the estuarine sediments is likely to be reduced beneath the landfill footprint due to the compression of the sediments from the weight of the landfill.

Table 2.6 Hydraulic conductivity summary

Geology	Monitoring wells*	Hydraulic Conductivity Range (m/s)	Adopted Hydraulic Conductivity (m/s)
Upper Kaikorai Estuary Member (UKEM)	MW1C, MW5C, MW6C	8.4 x 10^{-7} to 2.8 x 10^{-6}	1 x 10^{-6}
Lower Kaikorai Estuary Member (LKEM)	BH100, BH101, BH103, BH108, MW2D,	6.2 x 10^{-10} to 3.3 x 10^{-6}	1 x 10^{-7}
Abbotsford Formation	BH104	< 1 x 10^{-9}	1 x 10^{-9}

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[2] Where the hydraulic conductivity of sediments is different in two directions. Ie. in the horizontal direction compared to the vertical direction, in layered sedimentary units the vertical to horizontal hydraulic conductivity ratio is commonly 0.1.

2.5.3 Groundwater monitoring

2.5.3.1 Monitoring network

Monitoring of water levels and water quality is undertaken on a routine basis in accordance with the conditions of the current consents. The monitoring programme includes sampling of surface water, groundwater and leachate. A review of the surface water quality data is presented in the *Surface Water Technical Assessment* (GHD, 2023), and surface water quality will only be discussed here where relevant to the groundwater assessment. The groundwater monitoring network comprises:

- Eight lines of groundwater monitoring wells transecting the leachate collection trench, as shown in **Error! Reference source not found.**.
- Each Well Line is located at mid-distance between two pump stations and each line comprises three shallow wells, MWA through to MWC, with the exception of Line 7, where MWC is absent (noting that the majority of these are founded in the UKEM geological unit).
- At each Well Line, monitoring wells MWA and MWB are located on the landfill side of the leachate trench, approximately 20 m and 5 m from the trench respectively.
- Monitoring well MWC is located between the trench and the Kaikorai Stream / eastern sedimentation pond / eastern boundary.
- Along each Well Line, an inspection manhole is located at the point the Well Line intersects the leachate trench, between monitoring wells MWB and MWC.
- On three of the Well Lines (Well Line 2, 4 and 7), deep wells are also present and monitored, located between the leachate collection trench and the stream. They are described as MWD (and founded in the LKEM geological unit).
- An additional bore, MW0C located at the end of the leachate trench collection system at Well Line 0, to the south of PS1 is also monitored.
- A further monitoring well, MW9D, had been located towards the centre of the landfill, but was lost due to landfilling activities in 2015.

Bore locations are included in Appendix B. A schematic of the monitoring Wells Lines is shown in Figure 2.9.

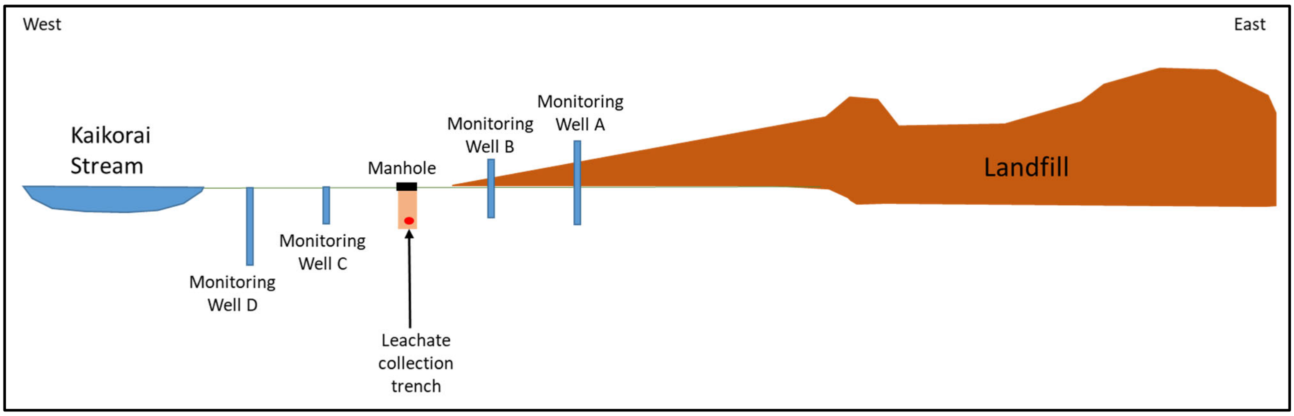


Figure 2.9 Schematic of monitoring well transect

2.5.3.2 Groundwater levels

The leachate collection system was designed to create a hydraulic barrier by reducing groundwater levels in the trench and drawing groundwater from both sides of the trench (i.e. landfill and stream side, although the stream side inflows were designed to be retarded by the installation of a HDPE liner on the stream side of the trench). Groundwater levels are checked on a monthly basis to monitor the hydraulic gradient. The water level monitoring consistently shows that the lowest groundwater levels (in monitoring wells) occur adjacent to the trench (MWC wells). These results are shown in the Green Island annual monitoring report (GHD, 2022 and attached to the Surface Water Report (GHD 2023)) with a selection representing winter, spring, summer, and autumn, included in Appendix B. These groundwater levels have been monitored monthly and reported annually to the ORC since the commencement of these consents in 1994.

Long term groundwater level records were reviewed as part of this assessment. Groundwater level data is available for the period from 1995 to 2003 and from 2015 to present. In general:

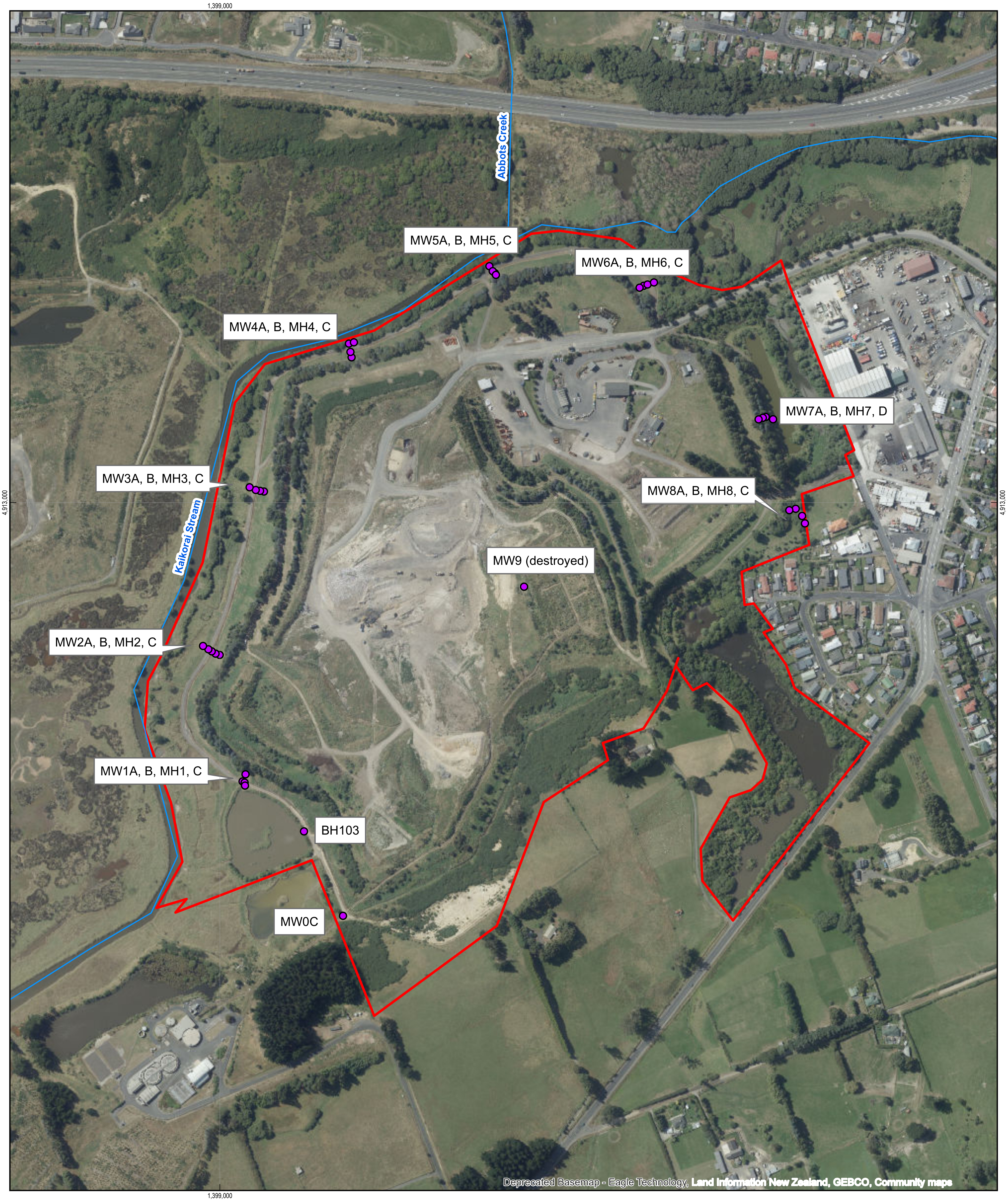
- Groundwater levels fluctuate within a range for each well, with no long-term trend in groundwater levels evident (with the exception of MW4D discussed below, Figure 2.11); and
- Seasonal variation is evident in the record for some wells (e.g. MW3C and MW6C, Figure 2.12). Groundwater levels are generally lowest in drier periods (summer-autumn), with groundwater highs occurring winter/spring and large rainfall events (e.g. January 2021).

Groundwater levels in MW4D showed an increasing trend from 1997 to 2003 (Figure 2.11). Due to the increasing groundwater head, the monitoring well casing was extended higher above ground to ensure no leakage of groundwater from the top of the casing (artesian conditions). The increasing artesian conditions are likely to be a function of the weight of the landfill squeezing and compressing the underlying estuarine sediments. Observed changes in groundwater level (shown in Figure 2.11) appear to correlate well with wate placement in this sector of the landfill. There is some uncertainty about the datum used for 2015-2016 measurements[3], however the data shows that groundwater levels appear to have stabilised around 1.7- 2.2 m RL (NZVD[4]) in recent years. MW4D was drilled to a depth of 10.5 m depth. There is no bore log available for the well, but the geology encountered in a nearby borehole, BH100 (*Geotechnical Factual Report* GHD,2023), suggests that MW4D is screened over a sand and gravel layer present between the base of the LKEM and mudstone.

---

[3] Note throughout this report two datums are used. On older figures/drawings a DCC Design Datum of AMSL +100m is used (hence a 1994 flood level of 103.3m). More recent data and the design drawings for this study use NZVD2016 as the datum and are referred to through this report as “amsl”

[4] Elevation of MW4D converted to NZVD based on correction factor of -(0.388 m + 100 m), from height of mark AG1B **AG1B: W 6 (linz.govt.nz)**



Legend

● Monitoring Well
River
🟥 Site Boundary

Paper Size A3
0 20 40 80 120 160
Metres
Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

Dunedin City Council
Green Island Landfill

Monitoring Well Locations

Job Number 12613624
Revision A
Date 11 Jul 2024

Figure 2.10

G:\51\12613624\GIS\Maps\Working\12613624_Monitoring wells.mxd

Level 3 138 Victoria Street Christchurch 8141 New Zealand **T** 64 3 378 0900 **F** 64 3 377 8575 **E** chcmail@ghd.com **W** www.ghd.com

Data source: Google Earth Pro; Imagery as at April 2019, DCC; GHD_DCC_Urban_Imagery_2013, Data (GILF_SIte_BoundarGHD_20180818, GILF_River_GHD_20180818, GILF_Location_from_esdat_GHD_20180818). Created by:icrankshaw

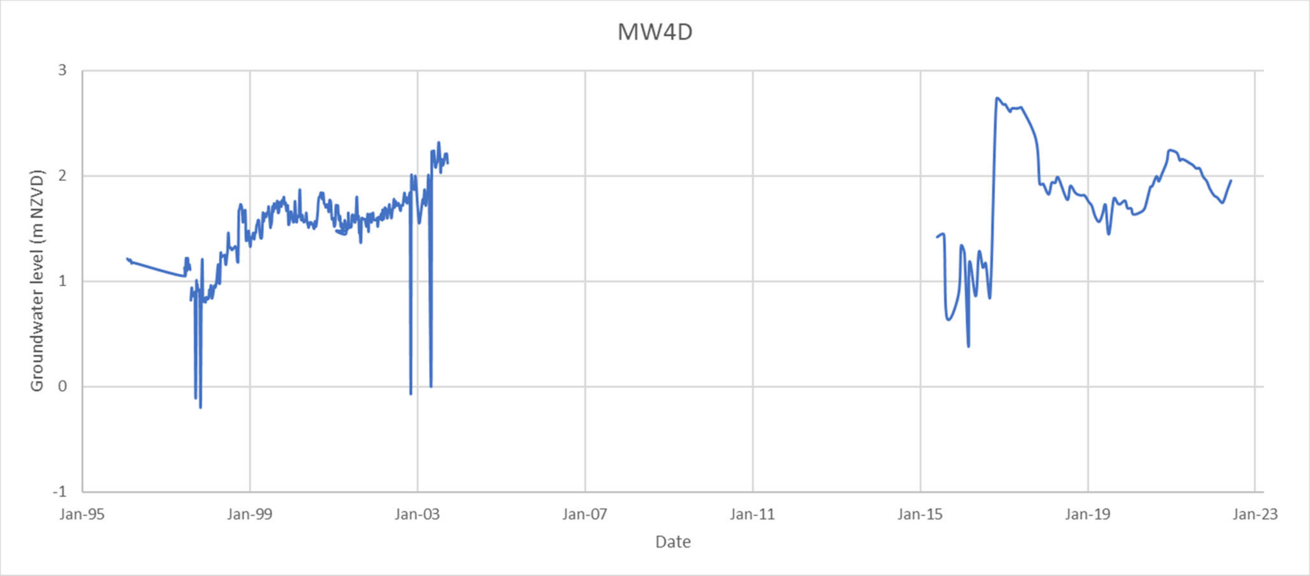


Figure 2.11 Groundwater levels measured in MW4D

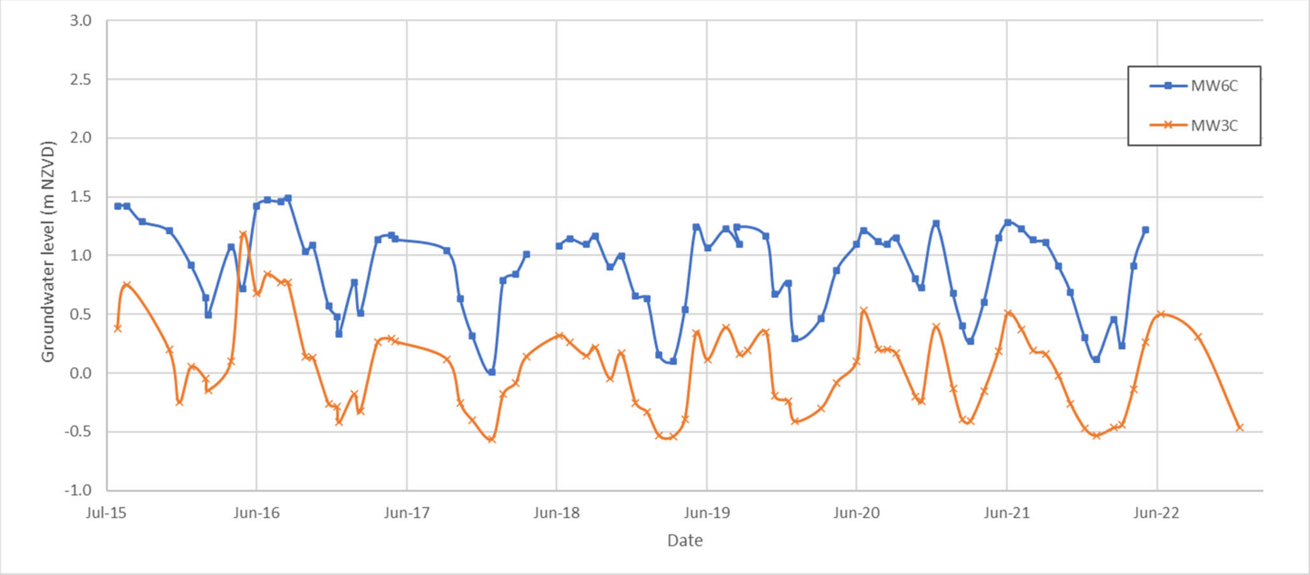


Figure 2.12 Groundwater levels measured in MW3C and MW6C – 2015 to 2022

2.5.3.3 Groundwater quality

Groundwater quality is monitored on a quarterly basis in accordance with the consenting conditions, and results are reported in annual monitoring report, the most recent being the 2022-2023 report (GHD, 2023). The annual report provides a full summary of water quality trends and comparison against relevant standards/guidelines. A brief overview of the data is provided below with selected monitoring plots included in Appendix C.

In general, the monitoring wells inside the leachate trench (A and B series) are likely to be impacted by leachate. However, some of the wells on the outside of the trench also show the influence of landfill waste. A review of the site history and waste distribution was undertaken (included as Appendix D) which identified areas where waste has been placed outside of the leachate trench. The likely extent of waste on the outside of the trench is shown on Figure 2.13. Based on this review, the following "C" wells are likely to be within or influenced by historical waste materials; 8C, 7C, 6C, 4C, and 3C. Of the "D" wells, 7D is only 7 m deep and may be within waste. Monitoring well 4D, at 10.5 deep, is likely to be screened below the waste materials.

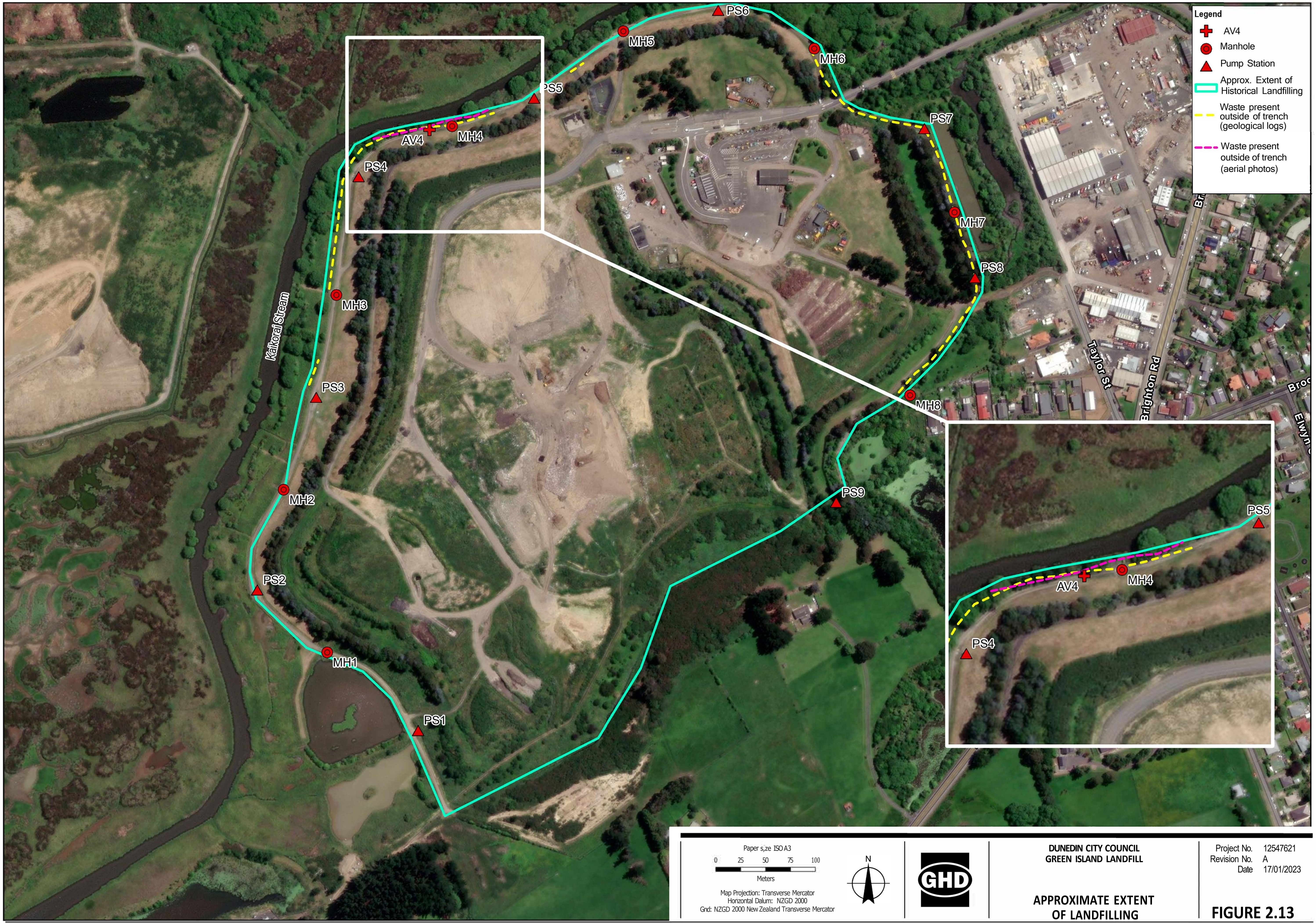
The impact of waste outside of the trench is managed through operation of the leachate collection system, which pulls groundwater (and any leachate) from both sides of the trench. This is discussed further in Section 4.

Water quality trends

A review of water quality data was undertaken to inform the conceptual understanding of the groundwater system and interactions with leachate/water. The water quality trends and patterns for relevant parameters are summarised below in Table 2.7. Water quality plots are provided in Appendix C.

Table 2.7 Water quality trends in groundwater

Parameter	Groundwater trends
Electrical Conductivity	Elevated in all monitoring wells relative to typical background groundwater Deep wells – highest in 2D and 4D (also higher chloride in these wells) Shallow wells – no clear pattern between A/B/C wells
Dissolved oxygen	Dissolved oxygen in groundwater is low with many samples <20% oxygen saturation, in contrast most surface samples are > 50% . The Eastern Constructed Wetland and South Eastern Constructed Wetland exhibit a wide variation in dissolved oxygen content.
Ammoniacal nitrogen	Generally elevated in groundwater relative to surface water with the exception of Eastern Constructed Wetland; Deep wells – highest in 2D (range of 14-23 mg/L) and 4D (0.8-10.5 mg/L), compared to 7D (<1.3 mg/L) C wells – elevated in 5C (14-21 mg/L), 2C (9-13 mg/L) and 4C (5.3-9.8 mg/L), the rest of the C monitoring wells recorded concentrations <5 mg/L
Chromium	Most groundwater concentrations < 0.002 mg/L, the exception is MW5C with chromium between 0.0052 – 0.012 mg/L (historical range) Groundwater chromium concentration is generally lower than site surface water (such as W and E Sediment Ponds) but elevated compared to Kaikorai Stream
Boron	Boron concentration highest in 1C (~4 mg/L), 5C (~3 mg/L) and 4C (~2 mg/L). Deep well concentrations is highest in 7D (~1.4 mg/L), 4D and 2D <0.8 mg/l Boron elevated in Eastern Constructed wetland (up to 9 mg/L), estuary concentration up to 1.8 mg/L, rest <1 mg/L (note boron analysis not undertaken in GI1, GI2, GI3, GI5)
Arsenic	Highest groundwater concentrations measured in 2D. Most results < 0.005 mg/L with the exception of 6C and 7D Groundwater and site surface water concentrations in similar range
Iron	Elevated in groundwater, in particular 1C, 4C, 2C, 6C, 5C, and deep monitoring wells. Highest concentrations recorded in 2D (116 mg/L) Iron concentration in groundwater an order of magnitude higher than site surface water and two orders of magnitude higher than Abbots Creek/Kaikorai Stream (GI1-GI5)



Map Projection: Transverse Mercator
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DUNEDIN CITY COUNCIL
GREEN ISLAND LANDFILL

APPROXIMATE EXTENT OF LANDFILLING

Project No. 12547621
Revision No. A
Date 17/01/2023

FIGURE 2.13

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Major ion chemistry

The major ion chemistry for selected water samples is shown graphically in a piper (trilinear) plot (Figure 2.14). The piper plot shows relative proportions of the major anion and cation species within the water samples and is used to display the differences (or similarities) between different water types. The plot shows the following water types:

- Sodium bicarbonate type – leachate
- Sodium chloride – groundwater and estuary
- Mixed water types – pump station and ponds
- Magnesium bicarbonate – groundwater (MW3C and MW8C)

The piper plot shows that the samples from PS3 are an intermediate water type between leachate and groundwater. This is unsurprising given that the leachate trench intercepts both groundwater and landfill leachate. The Eastern and Western Sediment Pond samples also show an intermediate chemistry. These ponds are influenced by stormwater runoff from the landfill.

Groundwater from monitoring wells potentially influenced by waste (see above review of waste distribution) show a more varied water chemistry compared to the three wells unlikely to be influenced by landfill waste (MW2C, 2D, 4D, BH103). Major ion chemistry is not available for Kaikorai Stream (SW sample sites GI1-5), however a sample from the estuary at low tide is most similar to monitoring well MW4C. The estuary sample is likely to be influenced by activities in the wider catchment.

Isotopic Analysis

Isotopic analysis of samples from pump stations (leachate/groundwater mix), selected surface water and groundwater wells is undertaken in accordance with the consent, and the results and interpretive isotopes are included in the annual monitoring report. The relative proportions of stable isotopes can change through chemical processes, such as evaporation, diffusion, or chemical reactions, and can be used to understand mixing of different water types. The following isotopes are analysed:

- Oxygen-18 in water from leachate (δ18O-H2O), relative to Vienna standard mean ocean water.
- Hydrogen-2 in water from leachate (δD- H2O), relative to Vienna standard mean ocean water.
- Carbon-13 in dissolved inorganic carbon from leachate (δ13C- DIC), relative to Vienna Pee Dee Belemite.
- Nitrogen-15 in ammonium from leachate (δ15N-NH4+), relative to atmospheric nitrogen (from October 2019).

The data below are presented relative to the local Meteoric Water Line[5]. A number of biogeochemical and physical processes can result in waters plotting above or below the MWL.

The isotopic analysis indicates the following:

- ^{13}C concentrations have been relatively stable with no one sampling location deviating greatly. A slight net increase in ^{13}C concentrations can be observed in the surface water and monitoring well MW4D data sets. The enriched ^{13}C data for leachate is a by-product of methane producing bacteria which use the lighter ^{12}C to form CH_4 (Hackley & Liu, 1996).
- The record for $^{15}N\text{-}NH_4^+$ isotope analysis is relatively short (data available from October 2019). There is some variability in the date but no clear pattern or trends in the available data set.

The isotopic signature for hydrogen and oxygen shows

- Groundwater from MW2D and 4D plot close together and generally within ±5% of the Dunedin Meteoric Water line.
- The majority of the surface water data plots with in MWL ±5% lines.
- The majority of the leachate data points sit as a cluster above the Dunedin MWL -5% line.
- Isotopic signature of pump station samples (leachate/groundwater) suggest a mature stage of leachate methanogenesis (interaction with older waste).

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[5] The Global Meteoric Water Line (MWL) describes the global annual average relationship between hydrogen and oxygen isotope (2H and 18O) ratios in natural meteoric waters (water derived from precipitation). The Dunedin MWL has been adapted for local conditions by North and Frew (2006).

The isotope data indicates that leachate is not influencing deep groundwater or surface water. The oxygen/hydrogen isotopic signature of the leachate is relatively distinct, plotting well above the Dunedin MWL compared to other samples.

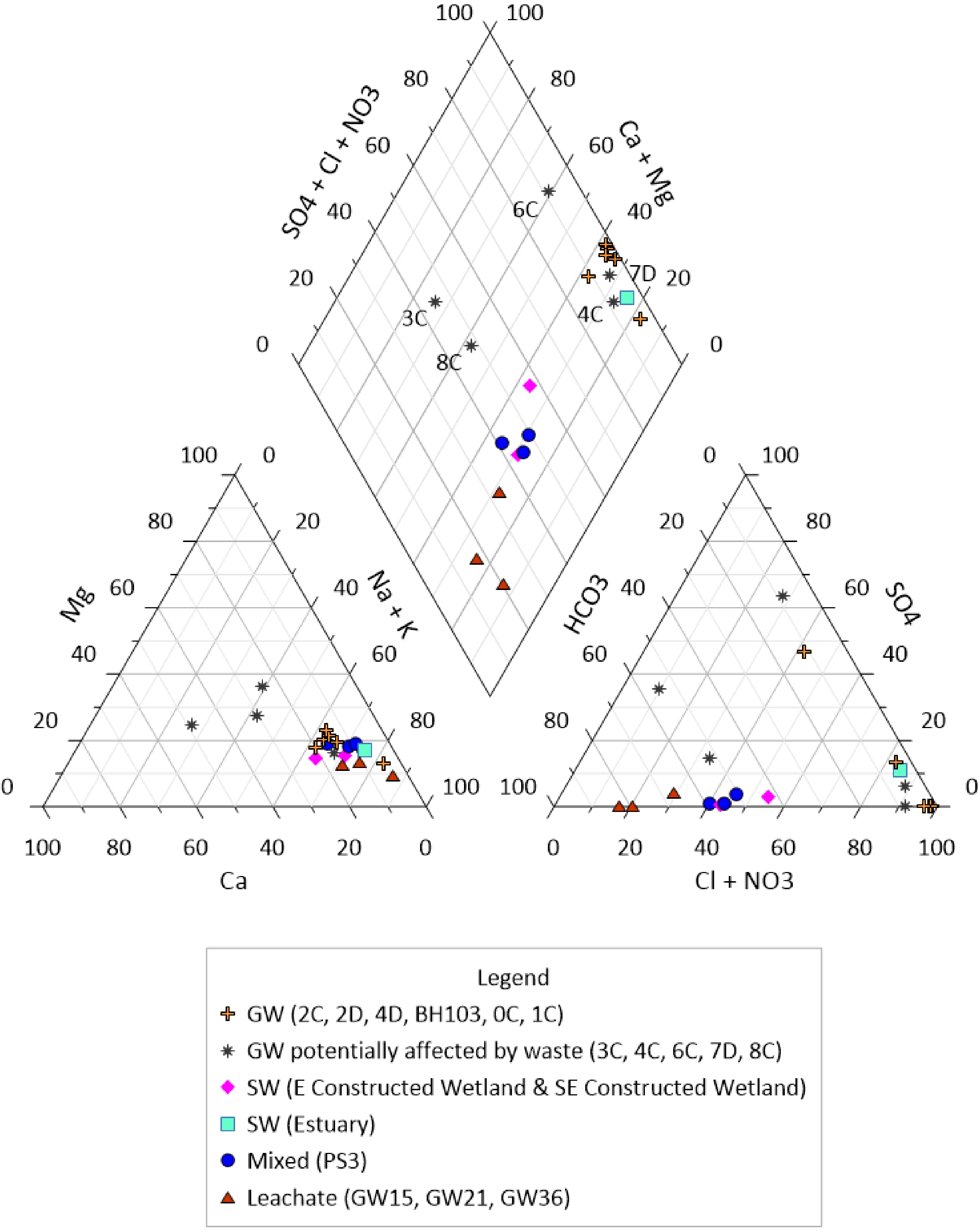

Figure 2.14 Relative proportion of major ions in GILF water samples

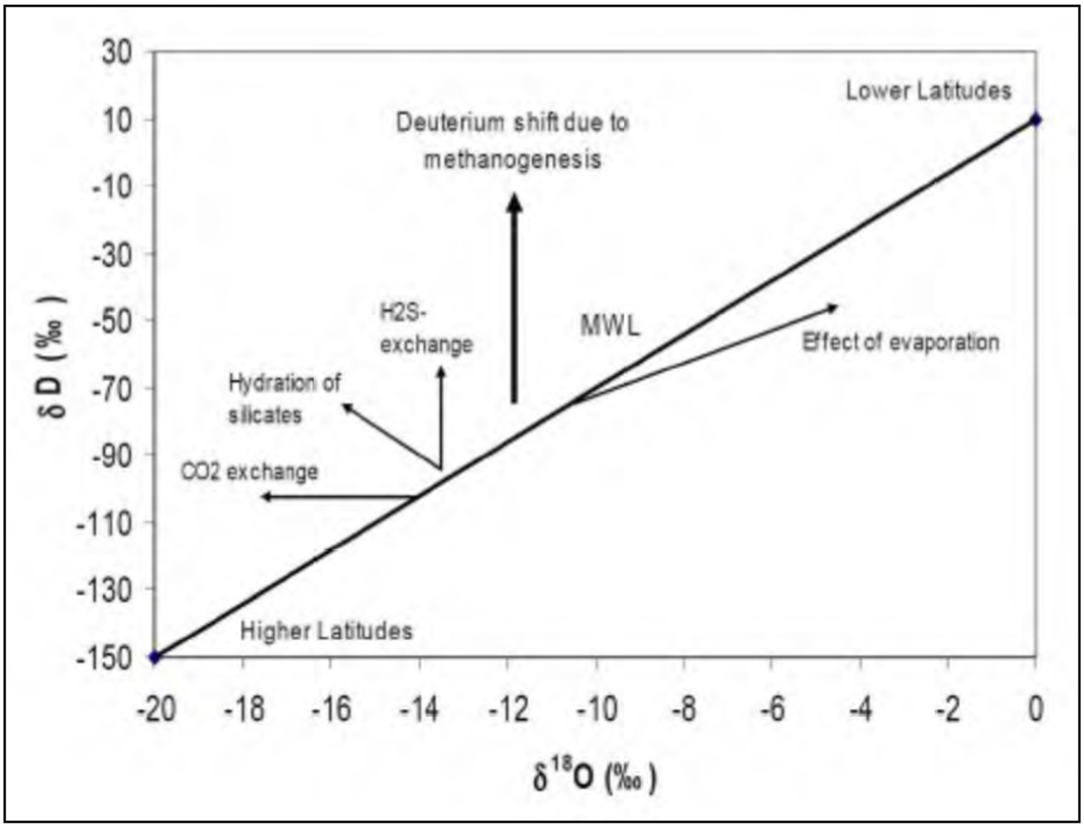

Figure 2.15 ***Deviations from the Meteoric Water Line caused by various biogeochemical and physical processes (from North and Frew , 2006)***

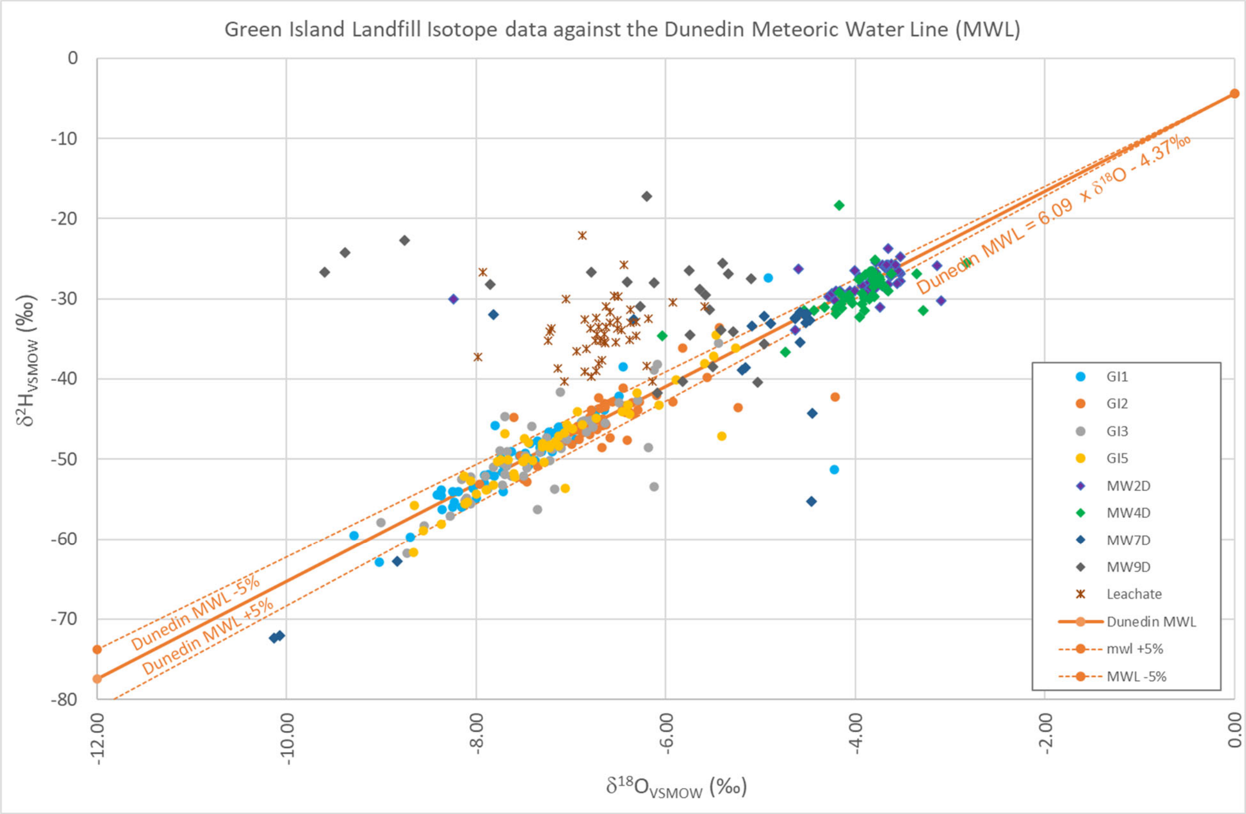

Figure 2.16 ***Green Island Landfill Isotope data against the Dunedin Meteoric Water Line (MWL)***

PFAS

Additional water sampling was undertaken for the presence of Persistent Organic Pollutants (POP), specifically PFOS and PFOA (i.e. perfluoroalkyl and polyfluoroalkyl substances[6]). The sampling was undertaken as landfills and industrial activities are a known sources of these contaminants. Water samples were collected from the perimeter groundwater monitoring wells, surface water monitoring sites, sedimentation ponds, and the leachate collection system. The results from the groundwater samples are provided in Table 2.8 below and the location of the sampling sites are shown in **Error! Reference source not found.**, with the full set of results provided in Appendix C of the *Surface Water Report (2024)*.

Table 2.8 PFAS and PFOA Concentrations in GW monitoring wells

Site	January 2023		April 2023		August 2023	
	Total PFOS (µg/L)	PFOA (µg/L)	Total PFOS (µg/L)	PFOA (µg/L)	Total PFOS (µg/L)	PFOA (µg/L)
MW0C	<0.001	<0.001	0.0012	<0.0005	0.004	0.0008
MW1C	<0.001	<0.001	0.0009	<0.0005	<0.0004	<0.0005
MW2C	<0.001	<0.001	<0.0004	<0.0005	0.0078	<0.0005
MW2D	<0.001	<0.001	<0.0004	<0.0005	0.0026	<0.0005
MW3C	0.0073	0.011	0.0082	0.0192	0.0092	0.0127
MW4C	<0.001	<0.001	<0.0004	<0.0005	<0.0004	<0.0005
MW4D	<0.001	<0.001	0.0012	0.0008	0.0009	<0.0005
MW5C	<0.001	0.0088	<0.0004	0.0121	0.002	0.011
MW6C	<0.001	<0.001	<0.0004	<0.0005	0.0024	0.0033
MW7D	<0.001	<0.001	<0.0004	<0.0005	<0.0004	<0.0005
MW8C	0.0019	<0.001	0.0024	0.008	0.002	<0.0005
PS3 (leachate)	0.057	0.11	0.0886	0.248	0.1	0.162
GI1 (SW)	0.001	0.0011	-	-	0.0008	<0.0005
GI3 (SW)	0.0012	0.0012	-	-	0.0009	<0.0005
GI5 (estuary)	<0.001	<0.001	0.0047	0.0006	0.0009	0.0007

The concentrations of Total PFOS in the perimeter groundwater wells are at low concentrations and are below the 95% species protection limits of 0.13 ug/L, defined in the PFAS National Environmental Management Plan Version 2.0 – known as NEPM V2.0).

There was no clear pattern in the concentration and occurrence of PFAS in groundwater and the distribution of waste (particularly in areas where historic waste is present outside of the trench). The two monitoring wells (MW4C and MW7D) where PFAS has not been detected, are located in areas identified as being potentially influenced by historic waste. Conversely, monitoring wells MW1C and MW2C, which are inferred to be located outside of historic waste, contained PFAS compounds at low concentrations. The low level PFAS contamination in areas outside of historic deposition activities or in deep wells (MW4D) may relate to historic activities within the landfill and catchment prior to the installation of the leachate trench. PFAS concentration in surface water (Kaikorai Stream GI1, GI3 and GI5) are in a similar range to or greater than most groundwater samples with a significant amount of the PFAS present originating from upstream of the landfill. This is discussed further in the Surace Water report.

The concentration of Total PFOS and PFOA obtained from leachate at Pump Station 3 (PS3), which is representative of leachate mixed with groundwater, was consistent for all sampling events, with concentrations recorded at least an order of magnitude above the groundwater samples. If leachate was migrating beyond the

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[6] Synthetic chemicals found in many manufactured products

leachate trench it would be reasonable to expect that the concentrations of these chemicals in the groundwater perimeter wells would be similar to the mixed leachate PS3 sample.

Summary of water quality data

The water chemistry data shows the influence of landfill waste on groundwater quality. In areas where historical waste is known to be present outside of the leachate trench, the groundwater quality shows a mixed major ion signature with elevated contaminants.

The major ion chemistry clearly shows mixing of groundwater and landfill leachate in water pumped from the leachate trench.

The depositional environment, and relatively recent (in geological terms) change from estuarine to a freshwater setting influences the groundwater chemistry. In estuarine and shallow marine sediments elevated chloride, alkalinity and boron is likely due to the influence of sea water. Ammoniacal nitrogen (Ammoniacal-N) and iron are elevated in many of the groundwater samples, including monitoring wells unlikely to be influenced by waste. The elevated ammoniacal-N and iron in background groundwater may reflect the influence of the organic material in the estuarine sediments (KEF) and reducing conditions in the aquifer. Electrical conductivity is elevated in all samples, reflecting the influence of leachate and/or brackish water in the Kaikorai estuary.

2.5.4 Leachate levels

Leachate levels were measured in the landfill by dipping existing gas wells and groundwater monitoring wells within the landfill footprint. The leachate survey was completed in August 2022 by a site contractor. These data are included in Appendix D and shown in Figure 2.17. There is some variability in leachate measurements, this is likely due to the heterogeneity of the fill. As of August 2022, the leachate level in the centre of the landfill is on average 16 or 17 amsl over completed areas of landfill and cap, with two wells over 20 m amsl.

2.6 Other groundwater users

Bore records and bore and water take consents listed on ORC webmaps[7] were reviewed for a 2 km radius surrounding the site. Two water takes were identified, one upgradient of the site at Blackhead quarry and the other for Maxwells Landfill (previously operated by Waste Management) (Figure 2.18).

Two bore consents were identified, one of the bore consents (RM14.355.01) is described as “proposed”. The other (RM22.311.01) is described as “decommissioned”. Details on the RM22.311.01 consent indicates that bore (ORC well number CE17/0153) was drilled in March 2023. The bore was drilled to a depth of 32 m (Table 2.9) and appears to have been dry.

Forty-nine bore records were identified in the area of interest, as summarised in Table 2.10. The site is not located within a mapped aquifer or groundwater protection zone[8].

Table 2.9 Summary log of CE17/0153[9] located to the south of GILF

Depth	
0 - 8	Clay boulders, grey, dry
8 – 12.5	Clay boulders, brown, damp
12.5 – 23	Rock, grey, damp
23 - 30	Volcanic clay, brown, dry
30 - 32	Rock, grey, dry

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[7] https://maps.orc.govt.nz/OtagoMaps/

[8] https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-policies/water

[9] **View Well | Well summary (teurukahika.nz)**

Table 2.10 ORC Bore records within 2 km radius of the site

Well type	Count	Comments
Monitoring / Investigation	13	
Dewatering	1	Green Island WWTP
Domestic / stockwater	2	Proposed – RM14.355.01, one decommissioned (RM22.311.01)
Other	33	Green Island Landfill investigation bores /monitoring wells

Paper Size ISO A3
0 10 20 30 40
Meters

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

N

Dunedin City Council
Green Island Landfill

Leachate head measured in landfill

Project No. **12547621**
Revision No. **A**
Date **17/1/2023**

Figure 2.17

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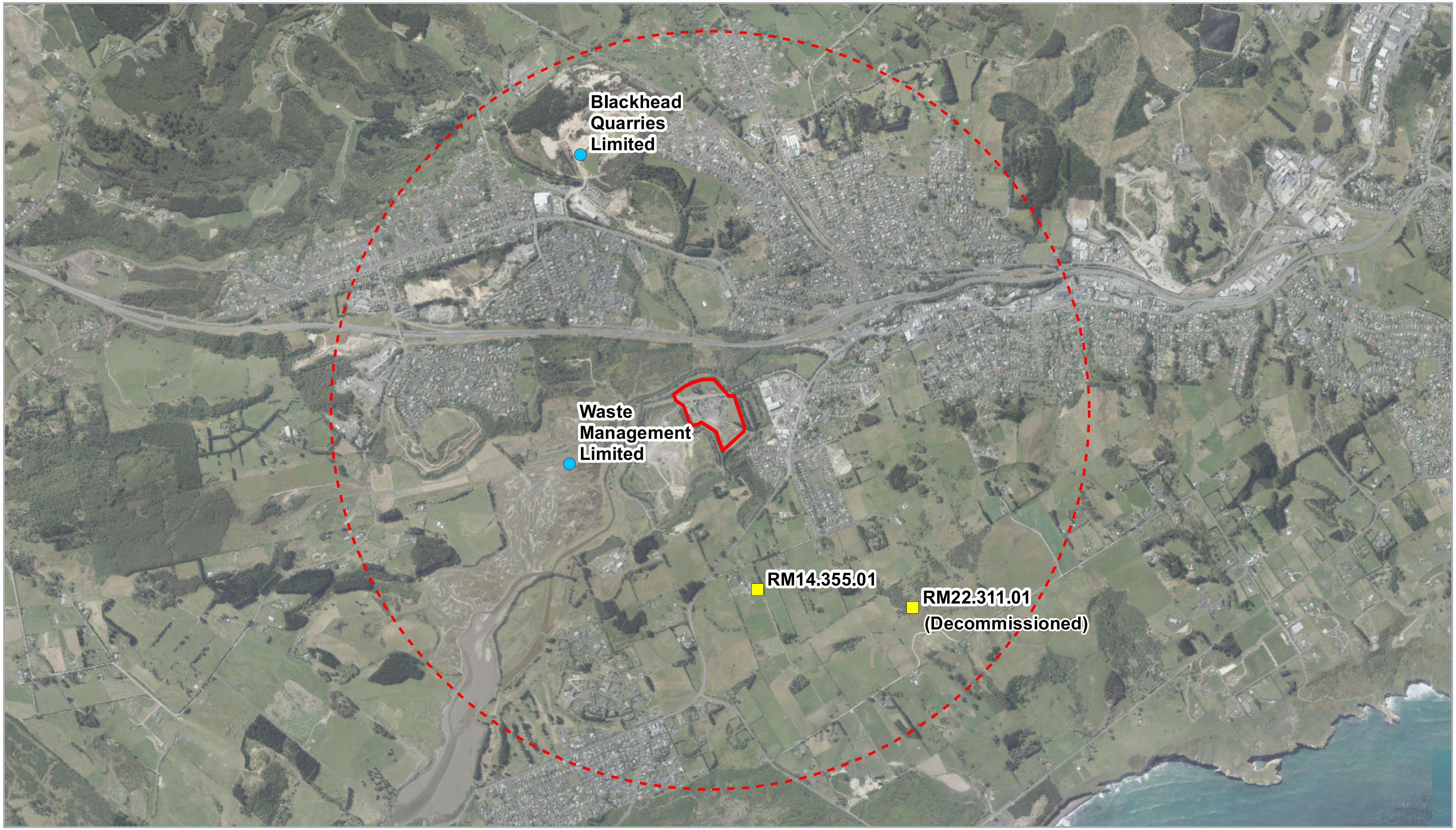
Print date: 19 Jan 2023 - 11:18

Data source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors. Created by: icrankshaw



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

Legend

●	Water takes	▭	RRPP Site Boundary
🟨	Bore consents	⬚	2 km Radius

GHD

DCC
Waste Futures - Green Isand RRPP

WATER TAKES AND BORE CONSENTS WITHIN 2 KM RADIUS

Project No. 12613624
Revision No. A
Date 15/07/2024

FIGURE 2.18

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Data source: General Topo - LINZ 2020; Aerial imagery - LINZ 2020 (Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors);. Created by: icrankshaw

3. Technical assessment

The following section documents the conceptual understanding of the groundwater system, interaction of groundwater with the landfill leachate and the leachate collection system, and interaction with surface water. This conceptual understanding, site data and investigation results, have been used to assess the effect of the proposed activities. The technical assessment includes:

- An assessment of rainfall infiltration through the current and proposed cap (HELP modelling)
- An assessment of leachate head within the fill (2D SEEP/W groundwater modelling)
- An assessment of the effectiveness of the leachate trench in intercepting leachate (SEEP/W)
- Groundwater – surface water interaction

Detailed summaries of the modelling assessments are provided in and Appendix F (HELP modelling) Appendix G (Seep/W).

3.1 Conceptual model

The conceptual understanding of the groundwater system is summarised below and shown in Figure 3.1. and Figure 3.2. The model is based on published information, routine monitoring, and previous site investigations, in summary:

- Infiltration of rainfall into the landfill, generation of leachate as water comes into contact with waste;
- Migration of leachate down and outwards towards the edge of the landfill;
- Abstraction of groundwater and leachate from leachate trench, water chemistry confirms mixing of water types;
- Groundwater quality influenced by historical waste deposition; this includes areas outside of the trench (e.g MW4C). However, continuous pumping from the leachate trench maintains the hydraulic gradient and pulls the impacted groundwater towards the trench (and away from surface water);
- Stream depletion effects limited by presence of HDPE liner on stream side of trench. However, some abstraction of shallow groundwater from the outer edge of the site (and stream water) is likely to occur;
- Reduced permeability of the estuarine sediments below the landfill footprint due to compression of soft sediments.
- Upward hydraulic gradient in LKEM restricting migration of leachate into deeper layers under the trench collection system; and
- Underlying mudstone forms an aquitard limiting deeper flow paths and restricting flow to the south (southern valley) where it occurs at/near the surface.

A groundwater contour map (Figure 3.3) has been created to show the relative groundwater level across the site. Within the landfill, this shows the leachate head in the fill material. The leachate interception trench reduces the groundwater-leachate level either side of the trench as shown by the inset. The data used to create this map are included in Appendix B.

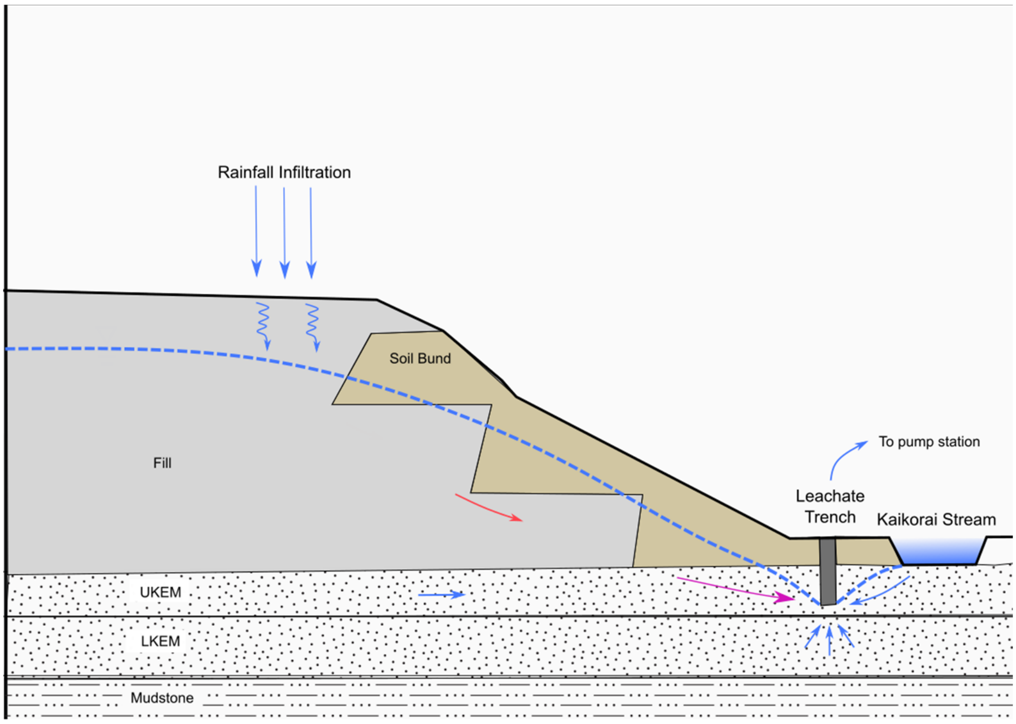


Figure 3.1 Conceptual model – North and west margins of the landfill

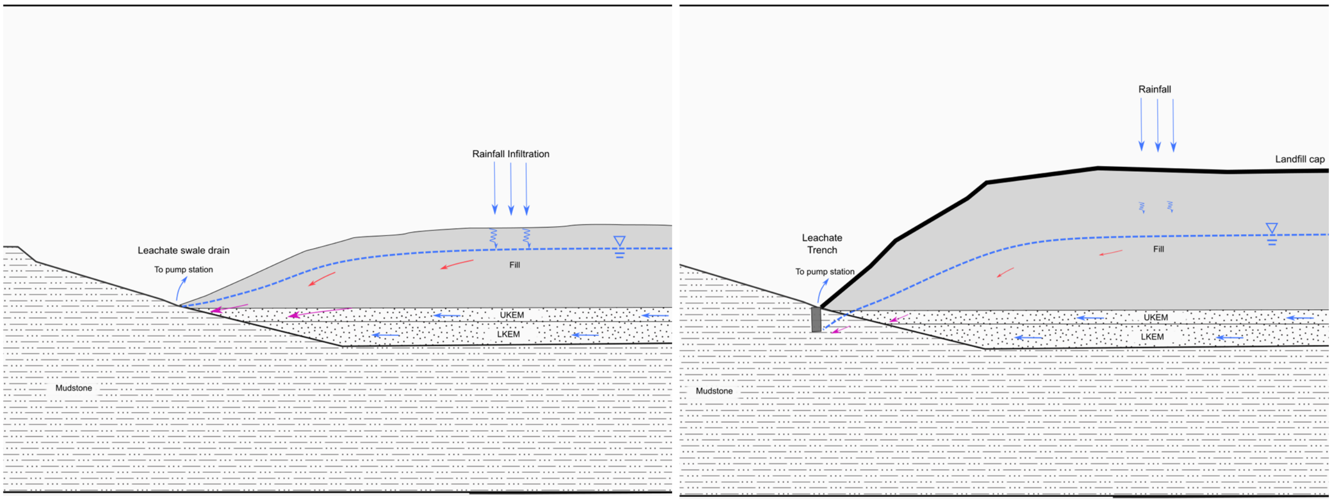
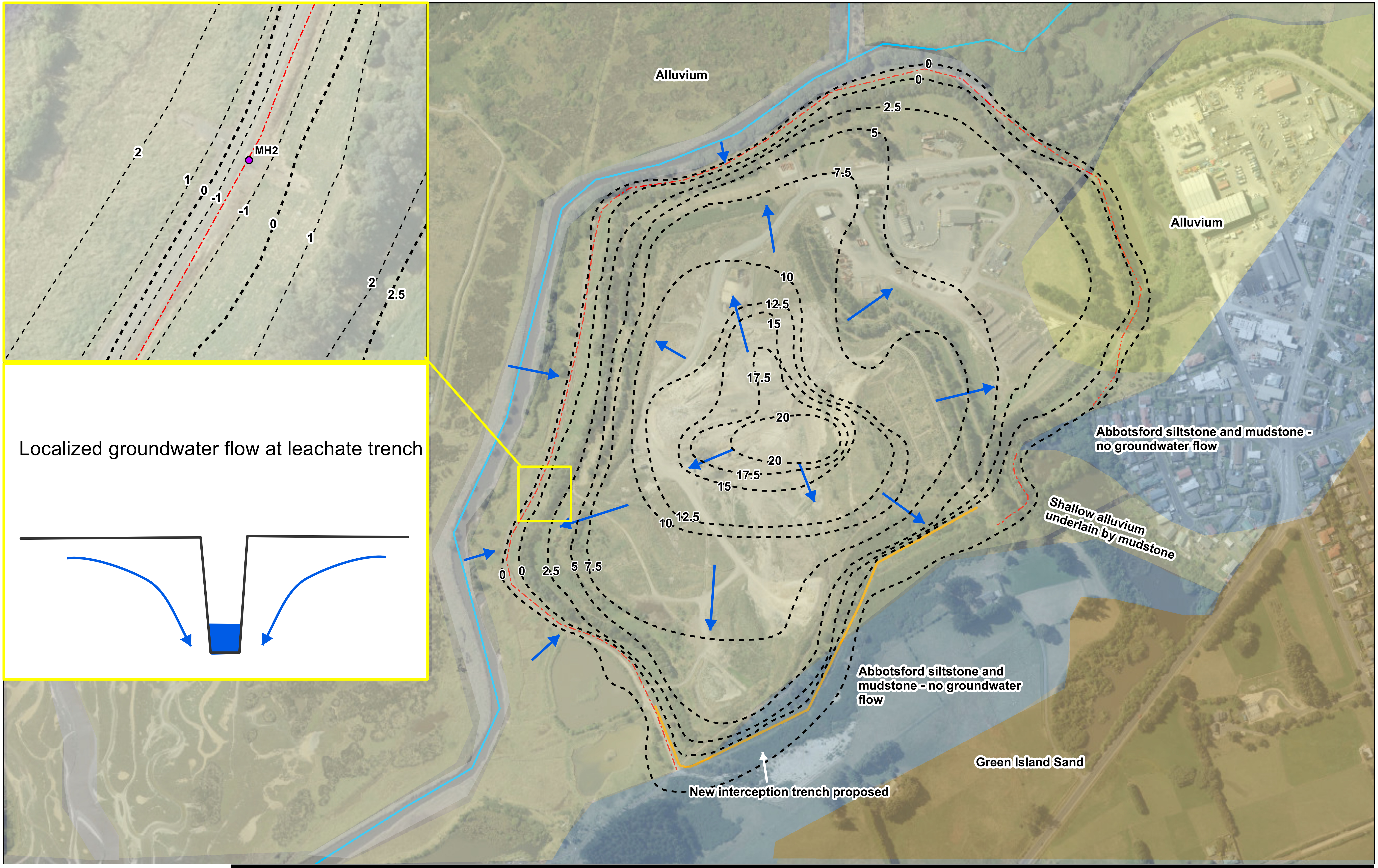


Figure 3.2 Conceptual model – southern valley (current and future)



Legend

- - - - Inferred groundwater/ leachate contour (mRL NZVD)
→ Groundwater flow direction
-·-·- Leachate interception drain
— Leachate swale drain
— Kaikorai stream

Paper Size ISO A3
0 25 50 75 100
Meters

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

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Dunedin City Council
Green Island Landfill

Groundwater contour map

Project No. **12613624**
Revision No. **A**
Date **22/07/2024**

Figure 3.3

G:\51\12613624\GIS\Maps\Working\12547621_GW Contour map_v2.mxd
Print date: 23 Jul 2024 - 08:49

Data source: Eagle Technology, GNS Science
Deprecated Basemap - Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors. Created by: icrankshaw

3.2 Review of flow paths

As discussed in Section 2.2.1 the landfill was formed on fine grained estuarine sediments and organic matter of the Kaikorai estuary. The 1942 aerial photograph shows a defined channel for Abbots Creek / Kaikorai Stream around the edge of the current site footprint. The photograph shows small channels across the estuarine sediments flowing from the centre to the southwest corner of the site. While there is no recent evidence of alternative Kaikorai Stream flow path, it is likely that the main stream channel moved around, with the general flow direction from the northeast towards the south west. Therefore, monitoring wells in the southwest corner of the site could be considered to be downgradient of the historical drainage, and any preferential flow paths (if present).

Monitoring wells in the southwest corner of the site include MW1C (4.6 m deep) and MW0C (4.9 m deep) both likely installed in the UKEM. A piezometer (BH103) installed as part of the 2022 geotechnical investigation provides further coverage along the downgradient side of the site. BH103 is screened in the LKEM, between 8.1-10.1 m depth. The major ion chemistry (Section 2.5.3.3) of BH103 is consistent with other deep wells (2D and 4D) with very high chloride, elevated ammoniacal-N and iron, related to the estuarine organic sediments in a low DO environment. MW0C and MW1C shows some variability compared to the deep groundwater samples, with a greater proportion of sulphate, but do not show a leachate signature.

3.3 Groundwater sensitivity and monitoring

Our review of water take consents and bore records (see section 2.6) confirms that groundwater is not used for supply near the site or downgradient due to the low yielding aquifer conditions (clay and rock). On that basis, groundwater is not considered to be a sensitive receptor in accordance with the WasteMINZ landfill guidelines. In addition, the site is bordered to the south by mudstone and siltstone forming a barrier to groundwater flow.

Groundwater monitoring is undertaken along the site boundary. With monitoring wells either side of the leachate interception trench. The current and proposed groundwater monitoring is generally in accordance with the WasteMINZ landfill guidelines (2023). The absence of groundwater monitoring wells along the southern valley (section between MW9 and MW0) reflects the characterisation of the geological environment (noted as comprising extensive deposits of mudstone of the Abbotsford Formation) and the absence of a known or mapped aquifer. As discussed in Section 2.4 the hill country to the southeast of the landfill is comprised of mudstone, therefore groundwater flow towards the south and coast is unlikely. The mudstone and overlying siltstone has been the source of capping material for the landfill.

As part of the proposed leachate improvement at the landfill, DCC propose to extend the leachate interception trench into the valley to reduce leachate levels in the landfill and avoid leachate being conveyed via the surface drainage. This trench will provide additional hydraulic separation from the wider groundwater environment.

3.4 Modelling assessment

The modelling assessment utilised two different methods:

- HELP (Hydrologic Evaluation of Landfill Performance)
- SEEP/W 2D groundwater model

Rainfall infiltration through the landfill cap 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 landfill 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 liners. The modelled leakage (infiltration) through the current and future landfill cap was included in the SEEP/W modelling assessment. The HELP modelling assessment is included in Appendix F. HELP can also be used to calculate leachate leakage through the base of the landfill, however this is typically applied to lined landfills. Given the complex history of the Green Island Landfill site and absence of a modern landfill liner system, it was considered that the SEEP/W was more suitable for representing the interaction between the landfill, including the leachate volumes and head level within the landfill, and the receiving environment.

The groundwater assessment included 2D modelling using Geostudio 2021 SEEP/W finite element modelling software. Modelling was undertaken to estimate the seepage into the leachate trench and to simulate the leachate head within the landfill.

Two SEEP/W cross-sections were created to model the landfill. The location of the cross-section lines is shown in Figure G.1 (Appendix G). The models were created based on a drone survey provided by DCC. Each model was initially run under steady-state conditions to simulate the interpreted baseline groundwater conditions. Models were calibrated to:

– Measured leachate head within the landfill (average level); and
– Combined pump station flows (from leachate collection trench), under dry weather conditions.

Steady state model scenarios were then run to simulate future conditions at closure, in particular, capping of the landfill and installation of a leachate collection trench in the southern valley. The Line 2 future scenarios include additional filling as outlined in the *Design Report* (GHD 2023). Details of the model set up and assumptions are provided in Appendix G. Model scenarios are included in Table 3.1 below.

Table 3.1 Model scenarios

Scenario Number	Hydraulic conductivity of cap		Description
	Currently uncapped*	Capped areas (north/central, applies- Section Line 1 only)	
Current	-	-	Leachate trenches operational
Current (trench off)	-	-	Trench” turned off”
1A	1 x 10^{-7} m/s	1 x 10^{-8} m/s	Leachate trenches operational
1B	1 x 10^{-7} m/s	1 x 10^{-8} m/s	Trench” turned off”
1C	1 x 10^{-7} m/s	1 x 10^{-8} m/s	Trench operational, Sea level rise (+ 0.5 m) applied to river boundary.
2A	1 x 10^{-8} m/s (all areas)		Leachate trenches operational
2B	1 x 10^{-8} m/s (all areas)		Trench” turned off”
2C	1 x 10^{-8} m/s (all areas)		Trench operational, Sea level rise (+ 0.5 m) applied to river boundary.
3A	1 x 10^{-9} m/s (all areas)		Leachate trenches operational

3.4.1 Results

The results of the modelling for the base case (current) and future simulations are summarised in Table 3.2.

The modelling indicates flows to the leachate trench of approximately 1 L/s, this does not include the flows reporting to pump stations 5 to 8, which are expected to flow into the trench at a lower rate (per metre of trench) than the sections modelled. However, the results are in line with the current recorded flows (section 2.2.3).

The modelled leachate head for the base case scenarios are similar to field measurements, although the very high leachate in the centre of the landfill could not be simulated. It is likely that the high leachate levels reflect the heterogeneity of the landfill materials resulting in pockets/areas of higher leachate.

Table 3.2 Summary modelling results – leachate trench flow rate and leachate head

Scenario	Model Section	Perimeter leachate drain flow rate for length of trench modelled* (L/s)	Southern Valley leachate drain flow rate for length of trench modelled* (L/s)	Modelling leachate head in fill (m RL)
Current	Line 1	0.5		16
	Line 2	0.5		10.2
1A	Line 1	0.5	0.1	15.4
	Line 2	0.4	0.2	9.8
1C	Line 1	0.6	0.1	15.4
	Line 2	0.5	0.2	9.9
2A	Line 1	0.5	0.1	14
	Line 2	0.4	0.1	9.3
2C	Line 1	0.6	0.1	14
	Line 2	0.4	0.1	9.3
3A	Line 1	0.3	0.01	4
	Line 2	0.2	0.02	3

**Flow rate (per metre) multiplied by length of trench represented by each section:*

Line 1 – Perimeter trench, 400 m, Southern Valley trench (150 m)

Line 2 – Perimeter trench, 620 m, Southern Valley trench (300 m)

The relative proportion of flows from each side of the trench was calculated from the model. For Section 1, the modelling results indicate that approximately 70% of the flow to the trench comes from the landfill (and underlying groundwater) and 30% from the direction of the stream. Stream depletion rates are estimated to be < 0.1 L/s.

If the leachate trench pumps were to fail for an extended period (i.e. several weeks), the modelling shows a reversal of flow over time with flow from the landfill into the stream eventually at an estimated rate of 0.5-0.8 L/s (combined rate). This equates to approximately 0.2% of the mean flow in the Kaikorai Stream, downstream of Abbotts Creek confluence.

By undertaking a simple mass mixing model approach the potential impact on water quality in the Kaikorai Stream from a prolonged loss of the hydraulic containment can be estimated (Table 3.3). At mean flow, using the mixing model approach, the Ammoniacal-N concentration would increase by an order of magnitude when compared to existing background concentrations, whilst at low flows the concentration would be higher still.

Table 3.3 Simple mass mixing model for GW Ammoniacal-N discharge to Kaikorai Stream

Leachate impacted groundwater	**Value**	
Groundwater discharge (mean) (m^3/day)	69.1	
PS3 Ammoniacal -N (g/m^3)	323	
Kaikorai Stream	**Mean Flow Conditions**	**Low Flow Conditions**
Stream Flow (below Abbots Creek) (m^3/day)	31,795	6,998
Background Ammoniacal-N (g/m^3)	0.05	0.05
Mixed Concentrations if Discharge Occurred		
Mixed Ammoniacal concentration (g/m^3)	0.75	3.2

It is understood that when on occasions blockages have occurred in the gravity leachate lines taking leachate to the pumpstations, , it has taken weeks for leachate levels to rise within the trench (pers comm. L Coe). The monthly water level monitoring data from the perimeter wells and leachate manholes that has been collected over the years provides a good evidentiary basis for showing that the trench has been effective in maintaining a hydraulic barrier. It is designed to enable gravity flow of leachate along the trench to a pump station, with the ability of leachate to bypass a pump station in the event of an isolated pump shut down. In addition, it is unlikely that the entire system would fail at once for a prolonged period of time, where remedial actions were not able to be instated to maintain the hydraulic barrier. Therefore, the effects to surface water as shown by the model scenario are unlikely to be realised for short term failures.

The Section Line 2 model indicates a very small flow from groundwater to the stream (0.01 L/s) this is interpreted to be from the estuarine sediments adjacent to and under the stream bed. The stream is located ~70 m from the trench, therefore while the trench appears be effective at intercepting leachate from the landfill, it does not result in stream depletion and does not influence groundwater levels immediately adjacent to the stream.

A summary of the key finding from the modelling assessment is provided below in Table 3.4.

Table 3.4 Modelling summary

Feature	Summary
Cap permeability	Decrease in leachate flow rate and leachate head level when a lower permeability cap is applied. This effect is most pronounced when a cap hydraulic conductivity (K) of 10^{-9} m/s is applied. The difference between leachate flow and head for the K 10^{-7} and 10^{-8} m/s scenarios is small.
River side leachate trench	The trench is effective at drawing down leachate levels and intercepting flows to the stream. When the trench drainage boundary condition is “turned off” for modelling purposes, the flow rate to stream is estimated to be between 0.5-0.8 L/s. Modelled flow rates are similar to dry weather trench pump rates
Southern valley trench	Estimated flow rates to the proposed trench are 0.2-0.3 L/s (0.03 L/s for low permeability cap scenario)
Surface water interaction	The modelling indicates that stream water (and shallow groundwater) is intercepted by the leachate trench. Stream depletion rates are estimated to be in the order of 0.1 L/s for Section 1. Stream depletion rates are higher in the sea level rise scenarios due to the higher water levels. However, the Section 2 model indicates flow (at a very low rate, 0.01 L/s) into the stream from shallow groundwater adjacent to the stream. This is much lower than the modelled flow to the stream (0.3-0.5 L/s) if the trench was “turned off” showing that the trench is effective at intercepting leachate. The small inflow (0.01 L/s) to the stream under operating conditions is interpreted to represent groundwater seeping from the stream bed and adjacent river bank. Due to the distance of the trench to the stream, the operation of the leachate trench does not influence groundwater levels immediately adjacent to the stream.

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4. Assessment of effects on the environment

4.1 Introduction

The proposed filling and closure of the Green Island Landfill has the potential to affect water quantity and quality. An assessment of effects addressed in this technical assessment includes:

- Effects to groundwater levels and flow;
- Effects to surface water flows;
- Effect of climate change and sea level rise; and
- Effects to water quality.

The water quality assessment is focussed on groundwater quality with consideration of surface water interaction. Surface water quality is primarily addressed in *Surface Water Technical Assessment* (GHD, 2024).

4.2 Effect to groundwater and surface water levels and flows

The leachate collection system operates by drawing down water levels in the trench, this intercepts any leachate flowing from the landfill but also draws groundwater from the area outside of the trench. It is likely that this groundwater is hydraulically connected with surface water in the Kaikorai Stream, with the potential for groundwater abstraction to have a stream depleting effect.

The modelling assessment presented in Section 3 and Appendix F, indicates that approximately 30% of the water pumped from the leachate trench is derived from groundwater / connected surface water on the outside of the trench, in areas where the trench is close to the stream. This volume is estimated to be <0.5 L/s for the entire trench length. For areas further from the active stream channel, eg PS3, the modelling indicates no effect of the leachate trench operation on stream flows.

Overall, the assessment indicates the effect of the leachate trench abstraction on surface water flows is negligible when compared to the stream flows, even during low flow conditions, and volume of water in the estuary.

The underlying KEF and Abbotsford Formation are not used for groundwater supply. Therefore, the abstraction of groundwater and localised reduction in groundwater levels around the landfill perimeter does not affect any groundwater users.

4.3 Effect of climate change and sea level rise

Modelling was undertaken to assess the effect of higher river levels on the leachate collection system. The modelling incorporated a higher road level (as recommend in the Design Report) and a higher river level (increase by 0.5 m). The model results indicated slightly higher inflows to the leachate collection system, this increase is well within the operating range of the leachate collection system, which can accommodate much higher stormwater flows.

4.4 Effects to water quality

This assessment has shown the perimeter leachate collection system is effective at creating a hydraulic barrier and intercepting leachate flowing from the landfill. It also draws groundwater from outside of the gravel leachate trench, this is of particular importance in areas where waste is present outside of the trench (from historic activities). This abstraction prevents the movement of potentially contaminated groundwater from outside the leachate trench, into surface water. As discussed in the *Surface Water Assessment,* surface water monitoring shows that there are no discernible adverse effects on surface water quality from the existing landfill activities.

The review of ORC water takes and bore records did not identify any groundwater users close to or downgradient of the site. Furthermore, the ORC has not mapped the area as a groundwater resource. Therefore, on that basis groundwater is not considered to be a sensitive receptor.

The modelling assessment was used to assess the effect on groundwater flow rates and flow paths should pumping from the leachate trench cease for a prolonged period resulting in discharge to surface water. This modelling scenario is considered very unlikely in reality, as there would be a time lag for leachate levels to rise in the trench before the modelled flow rate was achieved. Furthermore, it is considered unlikely that all pump stations would be out of action for an extended period given historical performance and additional mitigation measures that are proposed in the *Design Report*. However, for the purposes of this assessment, if leachate migration to surface water was occurring (at a rate of 0.5 – 0.8 L/s) we would expect to see a measurable change in water quality between the surface water monitoring points GI2 and GI3 (during low flow conditions) due to the very high contaminant load in the landfill leachate (as described in section 3.2). Instead, the water quality at the downstream GI3 is generally better than GI2. This further supports the conclusions of modelling assessment that the leachate trench is effective at intercepting landfill leachate.

The proposal includes the installation of a leachate collection trench in the southern valley, this will intercept leachate flowing from the southern side of the landfill. However, there will still be a gap in the leachate trench between MH8 and PS9. This area of the landfill sits directly on a ridge of Abbotsford Formation. The mudstone forms an effectively impermeable barrier to flow, therefore leachate migration off site is unlikely.

4.4.1 Effects on recreational use

While the post closure use of the site is still to be confirmed, the applicant does not intend to re-use or apply impacted groundwater to land (via irrigation). Therefore, the groundwater quality will not impact any future recreation use of the site and surrounding area. With regards to surface water quality, The Human Health Risk Assessment (HHRA) (GHD,2024b) concluded that discharges from the site into the receiving environment of the Kaikorai Stream generally represent a low risk to human users of the waterway and the aquatic environment.

4.5 Effects on other groundwater users

The surrounding area is not used for groundwater supply due to the low permeability geology, with the only two consented groundwater takes (within a 2 km radius of the site) located upgradient of the site (quarry and landfill). Groundwater is not utilised to the south of the site due to low permeability ground conditions. As noted above, the effect of the proposed dewatering activities of groundwater are expected to be limited to the area within the leachate perimeter trench with no effect on any other groundwater users.

5. Recommendations

5.1 Monitoring

It is recommended that a condition of consent for the provision of a Groundwater Monitoring Plan is included, which would include the following:

- Details of all monitoring locations (groundwater and surface water),
- Details of the monitoring well construction details, elevation, screened interval
- A detailed sampling and analysis plan
- The practice and procedures for groundwater monitoring will be included in the Landfill Development Management Plan (LDMP)

For both groundwater monitoring and surface water monitoring it is recommended to continue with the monitoring programme in line with the current consent conditions, with the following exceptions:

- It is recommended that isotopic analysis is removed as a consent condition. The current consent requires quarterly sampling for analysis of environmental isotopes. It is considered that isotopic analysis does not significantly improve the understanding of the groundwater/surface water system, and given the long delay (months) between collection of samples and reporting of results, chemical analysis is likely to provide a more timely indication of leachate mobility.
- It is recommended that the requirement to install a deep groundwater well within the landfill is removed as a consent condition. The installation of a deep well has the potential to create preferential flow paths from fill to the underlying geology.
- It is recommended that deep well BH103 is added to the routine monitoring schedule to provide geographical coverage of the (historic) downgradient side of the site.

The following total peak and average daily flow rates are proposed as a consent condition for the leachate collection system. These maximum rates allow for both groundwater and diverted stormwater during potentially extended periods of rainfall:

- Peak rate – 20 L/s (1,728 m^3/day)
- Average rate - 5 L/s (432 m^3/day or 157,680 m^3/year).

It is recommended that the following water level and quality monitoring is undertaken (Table 5.1).

A comparison to the existing monitoring schedule is outlined in Table 5.2. The proposed changes simplify the current monitoring program, with all water types having the same quarterly and annual analytical suites. Some analytes have been removed from the schedule, as these analytes (i.e. faecal coliforms, volatile fatty acids) were considered not to be useful for detecting leachate migration into the environment.

Table 5.1 Recommended monitoring

Frequency	Measurement/Analyte	Locations
Monthly	Groundwater levels	A / B / C / D wells, BH103, pump stations and manholes.
Quarterly[1]	pH Electrical Conductivity Dissolved oxygen Boron Nitrate Nitrogen Ammoniacal Nitrogen Chloride PFAS/PFOA[3]	- C and D wells - BH103 - Representative sample from the leachate trench (PS3) - Surface water (GI1, GI2, GI3, GI 5 and estuary) within three hours of low tide - Western sediment pond - South western pond - Eastern sediment pond

Frequency	Measurement/Analyte	Locations
		- South eastern constructed wetland - Eastern constructed wetland
Annual	Major Ions (Sodium, Potassium, Magnesium, Calcium, Bicarbonate, Sulphate and Chloride) Dissolved Reactive Phosphorous Metals[2] (Aluminium Arsenic, Cadmium, Chromium, Iron, Lead, Manganese, Mercury, Nickel, Zinc) Volatile Organic Compounds (VOC) Semi Volatile Organic Compounds (SVOC) Cyanide Chemical oxygen demand (COD) Biological oxygen demand (BOD) PFAS/PFOA (after three years of monitoring on quarterly basis)	- C and D wells - BH103 - Representative sample from the leachate trench (PS3) - Representative sample of leachate (from gas well in landfill) - Surface water (GI1, GI2, GI3, GI 5 and estuary) within three hours of low tide - Western sediment pond - South western pond - Eastern sediment pond - South eastern constructed wetland - Eastern constructed wetland

[1] Reduced frequency to 6 monthly, two years post closure

[2] Metal analysis – dissolved metals in groundwater and leachate trench (PS3), total metals in surface water samples.

[3] Reduced frequency to annual after 3 years

Water quality results are to be documented and reviewed and assessed on receipt, with full analysis and reporting in the annual monitoring report due 1 October every year. The annual monitoring report is to include a discussion on any water quality trends and the effectiveness of the leachate trench in intercepting landfill leachate.

Post closure it is recommended that the monitoring programme is reviewed and updated to reflect the changes to the landfill.

Table 5.2 *Comparison between current and proposed monitoring schedule*

Schedule	**Surface Water**			**Groundwater**			**PS3 (Leachate)**		
	Current	Proposed Additional	Proposed Removed	Current	Proposed Additional	Proposed Removed	Current	Proposed Additional	Proposed Removed
Monthly				Groundwater levels					
Quarterly	pH Electrical Conductivity Chloride Dissolved Oxygen Ammoniacal Nitrogen Nitrate Nitrogen	PFAS/PFOA	Total Organic Carbon Isotope Analysis Dissolved Metals, (annual only) Total Cyanide (annual only)	pH Electrical Conductivity	Dissolved oxygen Boron Nitrate Nitrogen Ammoniacal Nitrogen Chloride PFAS/PFOA	Isotope Analysis	Isotope Analysis	pH Electrical Conductivity Dissolved Oxygen Boron (previously measured annually) Nitrate Nitrogen Ammoniacal Nitrogen Chloride PFAS/PFOA	Isotope Analysis
Annual		Major Ions (Sodium, Potassium, Magnesium, Calcium, Bicarbonate, Sulphate and Chloride) Metals (Aluminium Arsenic, Cadmium, Chromium, Iron, Lead, Manganese, Nickel, Zinc, Mercury) Volatile Organic Compounds (VOC) Semi Volatile Organic Compounds (SVOC) PFAS/PFOA Cyanide Chemical Oxygen Demand (COD) Biological Oxygen Demand (BOD)		BOD Major Ions (Sodium, Potassium, Magnesium, Calcium, Bicarbonate, Carbonate, Sulphate and Chloride) Cation Anion Ratio pH Conductivity Ammoniacal Nitrogen Nitrate nitrogen Dissolved Iron Dissolved Lead Dissolved Zinc Dissolved Oxygen	PFAS/PFOA Cyanide Chemical oxygen demand (COD) Mercury Nickel Cadmium Chromium Aluminium Volatile Organic Compounds (VOC) Semi Volatile Organic Compounds (SVOC)	Total Organic Carbon	Major Ions (Sodium, Potassium, Magnesium, Calcium, Bicarbonate, Carbonate, Sulphate and Chloride) Cation anion ratio pH Electrical Conductivity COD and BOD Ammoniacal nitrogen Nitrate nitrogen Dissolved Oxygen Dissolved Reactive Phosphorus (DRP) Total Organic Carbon Acid soluble metals, including: Aluminium, Arsenic, Barium Cadmium, Chromium, Copper, Iron, Lead, Nickel, Manganese, Zinc Total Mercury Total Cyanide Volatile Organic Compounds (VOC) Semi Volatile Organic Compounds (SVOC)	PFAS/PFOA	Barium Sulphide Total phenols Faecal Coliforms OCP Polychlorinated Biphenyls Volatile fatty acids

6. Conclusions

This technical groundwater assessment has involved a review of historical data, including the historic distribution of waste, site monitoring data, and recent site investigation data. This information was used to inform a groundwater modelling assessment to estimate the seepage into the leachate collection trench and to simulate the leachate head within the landfill. In summary:

- The leachate collection trench is effective in intercepting landfill leachate and drawing groundwater from areas of waste outside the trench;
- The chemical signature of waters pumped from the leachate trench show that it is a mix of groundwater and leachate;
- The future modelling scenarios indicate a small reduction in leachate head in recently capped area (northern part of the landfill) and an increase of leachate head in areas receiving additional fill;
- Modelling indicates that the leachate trench in the southern valley will intercept leachate coming from the landfill and aid to lower leachate levels within the landfill and enhance leachate collection;.
- Potential for a small increase in dry weather flows in the leachate collection system from the additional fill placement and installation of the southern valley trench;
- With the continuing operation of the leachate collection system (including the extension of the trench into the southern valley), and maintenance of the groundwater hydraulic barrier, no discernible effect on surface water quality is expected; and
- The effect on surface water flows from groundwater abstraction is negligible.
- Groundwater is not considered to be a sensitive receptor as groundwater is not utilised for supply in the surrounding area due to the low permeability geology.
- There is no evidence of groundwater flow occurring to the southeast, under the landfill and towards the coast.

7. References

Adams Geotechnical (2019): Green Island Landfill Clay cover System. Borrow South Investigations. Report C301-J1810-D005-v1. Issued 11 June 2019.

Barry J Douglas Geological Consultants, 2002, Green Island Landfill Leachate Collection Trench Geological Report

Beca Steven, 1992. Environmental Impact Assessment of the Extended Green Island Sanitary Landfill.

City Consultants, 1997: Green Island Landfill Leachate Monitoring, Drawing 5526/234.

GHD, 2022. Green Island Landfill, Annual Monitoring Report 2021-2022. Report prepared for Dunedin City Council, September 2022.

GHD(A), Feb 2023. Waste Futures – Green Island Landfill Closure – Design Closure Report

GHD(B), Feb 2023. Waste Futures – Green Island Landfill Closure – Surface Water Technical Assessment

GHD(C), Feb 2023. Waste Futures – Green Island Landfill Closure – Factual Geotech Report

GHD (2024a) Addendum Report – Updated Groundwater and Surface Water PFAS results for Green Island landfill and Surface Water Management (30 April 2024)

GHD (2024b) Green Island Landfill Interim Human Health and Environment Risk Assessment. Report prepared for Dunedin City Council , 20 May 2024.

Hackley, K., C. Liu, et al. (1996). “Environmental Isotope Characteristics of Landfill Leachates and Gases.” Ground Water 34(5): 827-836.

McKellar, I.C. 1990: Miscellaneous map of New Zealand – southwest Dunedin urban 1:25 000. Map (1 sheet) and notes (64 p) Wellington, Department of Scientific and Industrial Research.

MWH 2004; DCC Landfill Annual Survey Plans – July 2004. Green Island Landfill – Leachate Collection & Environmental Monitoring System. Drawing 006116-19-01, Sheet G11, Rev C. Dated 01 July 2004.

North, J. C. & Frew, R. D. 2007. Isotopic Characterisation of Leachate from Seven New Zealand Landfills. In: LEHMANN, E. C. (ed.) Landfill Research Focus. New York: Nova Science.

Tonkin & Taylor, 2020, Green Island Landfill Perimeter Bund Assessment. Prepared for Dunedin City Council, July 2020.

WasteMINZ (2023) Technical guidelines for disposal to land Revision 3.1. Waste Management Institute New Zealand, September 2023.

8. 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 Dunedin City Council as set out in Section 1 of this report. GHD otherwise disclaims responsibility to any person other than Dunedin City Council and Council officers, consultants, the hearings panel and submitters associated with the resource consent and notice of requirement process for the Green Island Landfill Closure 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.*

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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

GHD has relied on information from a number of sources, including but not limited to the following:

Environmental Impact Assessment (Beca, 1992)

Green Island Landfill Leachate Collection Trench Geological Report (Barry J Douglas Geological Consultants, 2002 – herein referred to as BDGC, 2002)

Green Island Landfill Gas Management Project. Stage 1: Investigation Works. URS, 2007.

Bund stability report (T&T, 2020)

Leachate collection summary (DCC) and associated plans

Claymine Assessment (DCC) and associated plans

GILF & RRRP master plan (Stantec 2020)

Green Island Annual monitoring reports prepared by GHD, 2022

Appendices

Appendix A

Hydraulic conductivity testing

A-1 Hydraulic conductivity testing

Rising and falling head tests of existing monitoring wells and new bore holes were undertaken in November and December 2022 to estimate the hydraulic conductivity of the underlying shallow aquifer. Up to two sets of rising and falling head tests were completed in each well, however due to the slow groundwater response in the low permeability sediments, less tests were completed in some wells. The raw data was initially processed and reviewed graphically and then, if test results were considered suitable (e.g. not too many fluctuations, and suitable measured response and recovery time), data were interpreted with Aqtesolv software using Bouwer and Rice (1976) and Hvorslev (1951) solutions.

The hydraulic conductivity estimate for monitoring wells MW2D is based on historical data from 1997, when the well was purged and groundwater levels recovered over a few weeks.

The results of the hydraulic conductivity testing are summarised in Table A.1, full results are provided in Table A.2 with analysis plots following.

Table A.1 Summary of hydraulic conductivity testing

Geology	Monitoring wells*	Hydraulic Conductivity Range (m/s)	Adopted Hydraulic Conductivity (m/s)
Upper Kaikorai Estuary Member (UKEM)	MW1C, MW5C, MW6C	8.4×10^{-7} to 2.8×10^{-6}	1×10^{-6}
Lower Kaikorai Estuary Member (LKEM)	BH100, BH101, BH103, BH108, MW2D, MW8C	6.2×10^{-10} to 3.3×10^{-6}	1×10^{-7}
Abbotsford Formation (AM)	BH104	$< 1 \times 10^{-9}$	1×10^{-9}

*Logs not available for older MW monitoring wells, inferred geology based on recent drilling investigation.

Wells BH102, MW0C, MW2C, MW3C, MW4C, MW4D likely screened over two layers

Test in BH104 does not recover fully (<85% recovery) – results approximately only.

Table A.2 Hydraulic conductivity testing

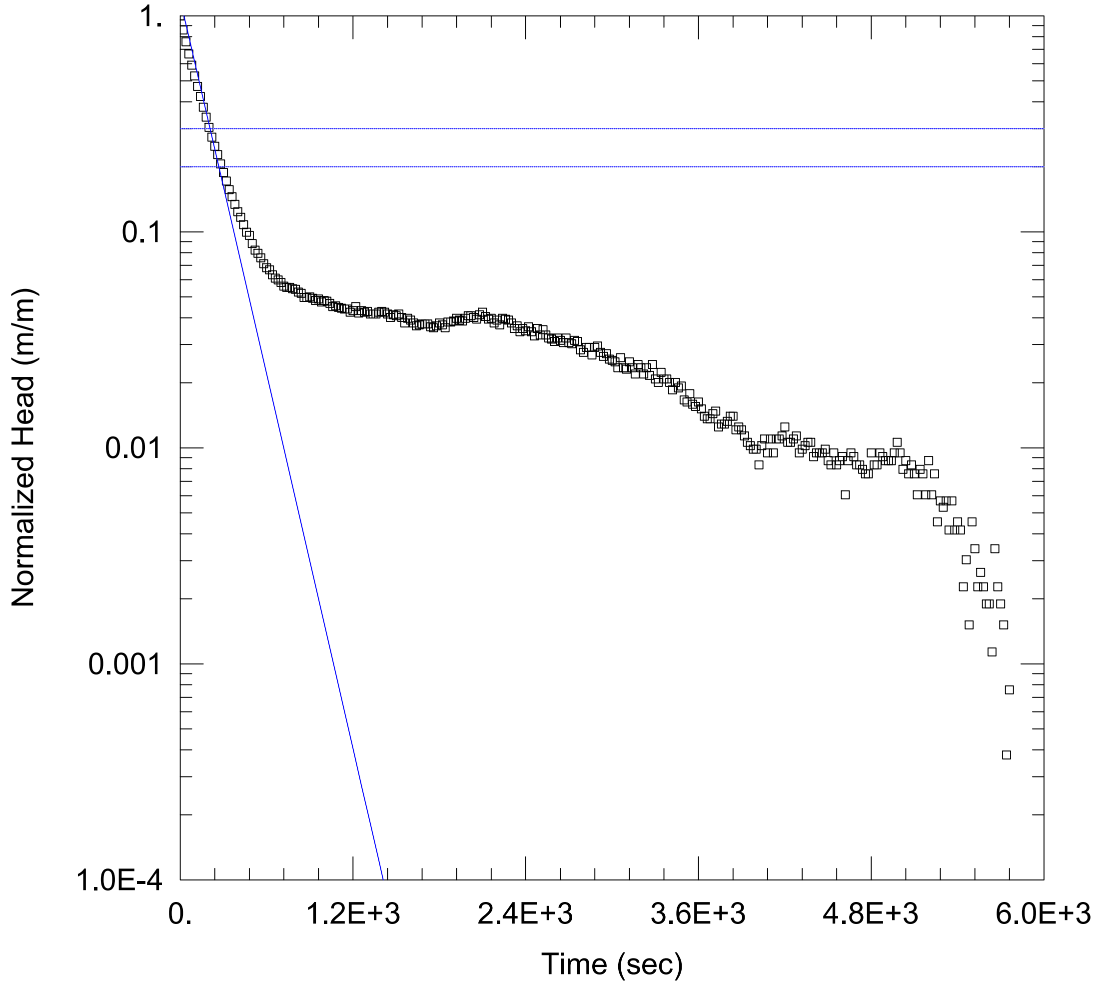
Monitoring wells	Screen lithology	Hydraulic test methodology*	Solution	Hydraulic Conductivity (m/s)	Comment
MW0C	Likely screened over two layers	FHT	Bouwer-Rice	1.9×10^{-7}	
		RHT	Bouwer-Rice	3.3×10^{-7}	
		FHT	Bouwer-Rice	1.8×10^{-7}	
		RHT	Bouwer-Rice	3.4×10^{-7}	
		FHT	Hvorslev	2.3×10^{-7}	
		RHT	Hvorslev	4.6×10^{-7}	
		FHT	Hvorslev	1.9×10^{-7}	
		RHT	Hvorslev	4.0×10^{-7}	
MW1C	UKEM	FHT	Bouwer-Rice	1.9×10^{-6}	
		RHT	Bouwer-Rice	8.4×10^{-7}	
		FHT	Bouwer-Rice	9.6×10^{-7}	
		RHT	Bouwer-Rice	1.1×10^{-6}	
		FHT	Hvorslev	1.5×10^{-6}	
		RHT	Hvorslev	8.8×10^{-7}	
		FHT	Hvorslev	1.0×10^{-6}	
		RHT	Hvorslev	1.3×10^{-6}	
MW2C	Likely screened over two layers	FHT	Bouwer-Rice	3.9×10^{-7}	
		FHT	Bouwer-Rice	4.0×10^{-7}	
		FHT	Hvorslev	5.3×10^{-7}	
		FHT	Hvorslev	5.0×10^{-7}	
MW2D	LKEM	RHT following purging	Bouwer-Rice	6.2×10^{-10}	Taken from purged data (weekly dip readings) in 1997 used for an estimate
		RHT following purging	Hvorslev	7.2×10^{-10}	
MW3C	Likely screened over two layers	FHT	Bouwer-Rice	1.1×10^{-7}	
		RHT	Bouwer-Rice	1.3×10^{-7}	
		FHT	Bouwer-Rice	1.2×10^{-7}	

Monitoring wells	Screen lithology	Hydraulic test methodology*	Solution	Hydraulic Conductivity (m/s)	Comment
		RHT	Bouwer-Rice	9.6 x 10^{-8}	
		FHT	Hvorslev	1.6 x 10^{-7}	
		RHT	Hvorslev	1.1 x 10^{-7}	
		FHT	Hvorslev	1.5 x 10^{-7}	
		RHT	Hvorslev	1.0 x 10^{-7}	
MW4C	Likely screened over two layers	FHT	Bouwer-Rice	6.6 x 10^{-7}	
		FHT	Bouwer-Rice	6.8 x 10^{-7}	
		FHT	Hvorslev	7.7 x 10^{-7}	
		FHT	Hvorslev	8.0 x 10^{-7}	
MW4D	Likely screened over two layers	FHT	Bouwer-Rice	1.2 x 10^{-7}	Appears to be influenced by pumping or other unaccounted for factor, potentially tidal
		RHT	Bouwer-Rice	1.1 x 10^{-7}	
		FHT	Hvorslev	6.7 x 10^{-7}	
		RHT	Hvorslev	2.0 x 10^{-7}	
MW5C	UKEM	FHT	Bouwer-Rice	1.5 x 10^{-6}	
		RHT	Bouwer-Rice	1.0 x 10^{-6}	
		FHT	Bouwer-Rice	1.1 x 10^{-6}	
		RHT	Bouwer-Rice	1.3 x 10^{-6}	
		FHT	Hvorslev	2.0 x 10^{-6}	
		RHT	Hvorslev	1.2 10^{-6}	
		FHT	Hvorslev	1.4 x 10^{-6}	
		RHT	Hvorslev	1.6 x 10^{-6}	
MW6C	UKEM	FHT	Bouwer-Rice	1.0 x 10^{-6}	
		RHT	Bouwer-Rice	2.3 x 10^{-6}	
		FHT	Bouwer-Rice	9.3 x 10^{-7}	
		RHT	Bouwer-Rice	2.5 x 10^{-6}	
		FHT	Hvorslev	1.3 x 10^{-6}	
		RHT	Hvorslev	2.3 x 10^{-6}	

Monitoring wells	Screen lithology	Hydraulic test methodology*	Solution	Hydraulic Conductivity (m/s)	Comment
		FHT	Hvorslev	1.1×10^{-6}	
		RHT	Hvorslev	2.8×10^{-6}	
BH100	LKEM	RHT	Bouwer-Rice	2.4×10^{-6}	
		FHT	Bouwer-Rice	3.3×10^{-6}	
		RHT	Bouwer-Rice	2.2×10^{-6}	
		RHT	Hvorslev	2.5×10^{-6}	
		FHT	Hvorslev	2.3×10^{-6}	
		RHT	Hvorslev	2.9×10^{-6}	
BH101	LKEM	FHT	Bouwer-Rice	3.3×10^{-7}	
		FHT	Bouwer-Rice	2.7×10^{-7}	
		RHT	Bouwer-Rice	6.6×10^{-7}	
		FHT	Hvorslev	3.9×10^{-7}	
		FHT	Hvorslev	3.6×10^{-7}	
		RHT	Hvorslev	6.6×10^{-7}	
BH102	Screened over two layers	FHT	Bouwer-Rice	5.4×10^{-7}	
		RHT	Bouwer-Rice	2.8×10^{-7}	
		FHT	Bouwer-Rice	4.0×10^{-7}	
		RHT	Bouwer-Rice	2.8×10^{-7}	
		FHT	Hvorslev	6.6×10^{-7}	
		RHT	Hvorslev	2.6×10^{-7}	
		FHT	Hvorslev	4.5×10^{-7}	
		RHT	Hvorslev	2.7×10^{-7}	
BH103	LKEM	RHT	Bouwer-Rice	2.1×10^{-8}	
		RHT	Hvorslev	3.0×10^{-8}	
	Mudstone	RHT	Bouwer-Rice	7.0×10^{-10}	Does not recover to 85% of displacement. Approximate only.
		RHT	Hvorslev	8.0×10^{-10}	
BH108	LKEM	FHT	Bouwer-Rice	3.1×10^{-8}	

Monitoring wells	Screen lithology	Hydraulic test methodology*	Solution	Hydraulic Conductivity (m/s)	Comment
		RHT	Bouwer-Rice	2.2 x 10^{-8}	
		FHT	Hvorslev	3.4 x 10^{-8}	
		RHT	Hvorslev	1.5 x 10^{-8}	

**FHT/RHT = Falling/rising head test undertaken using displacement slug*



BH100 - FHT02

Data Set: G:\...\BH100_FHT02_BR.aqt
Date: 12/07/22 Time: 10:47:15

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH100
Test Date: 17/11/2022

AQUIFER DATA

Saturated Thickness: 7.57 m
Anisotropy Ratio (Kz/Kr): 1.

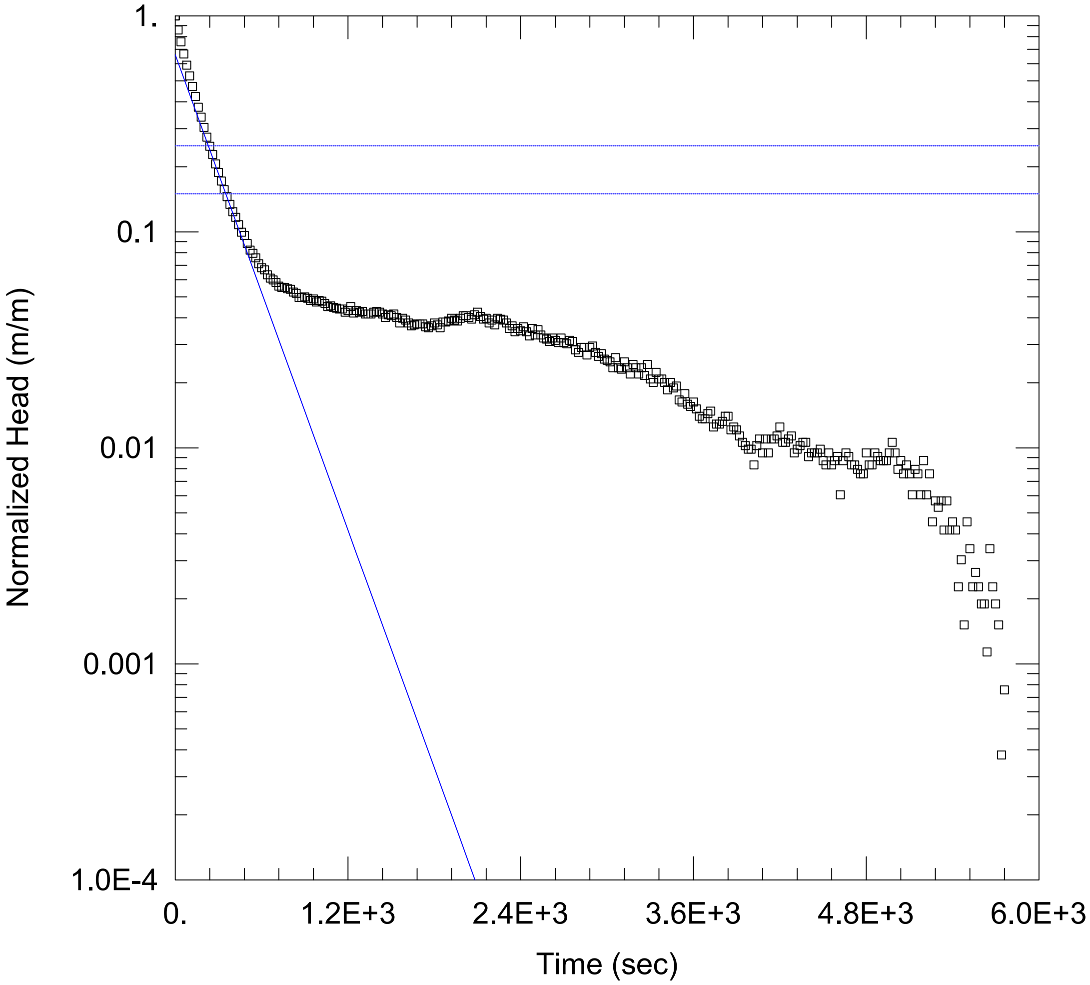
WELL DATA (BH100)

Initial Displacement: 0.264 m
Static Water Column Height: 7.57 m
Total Well Penetration Depth: 7.43 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.253E-6 m/sec
y0 = 0.3146 m



BH100 - FHT02

Data Set: G:\...\BH100_FHT02_H.aqt
Date: 12/07/22 Time: 10:48:01

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH100
Test Date: 17/11/2022

AQUIFER DATA

Saturated Thickness: 7.57 m
Anisotropy Ratio (Kz/Kr): 1.

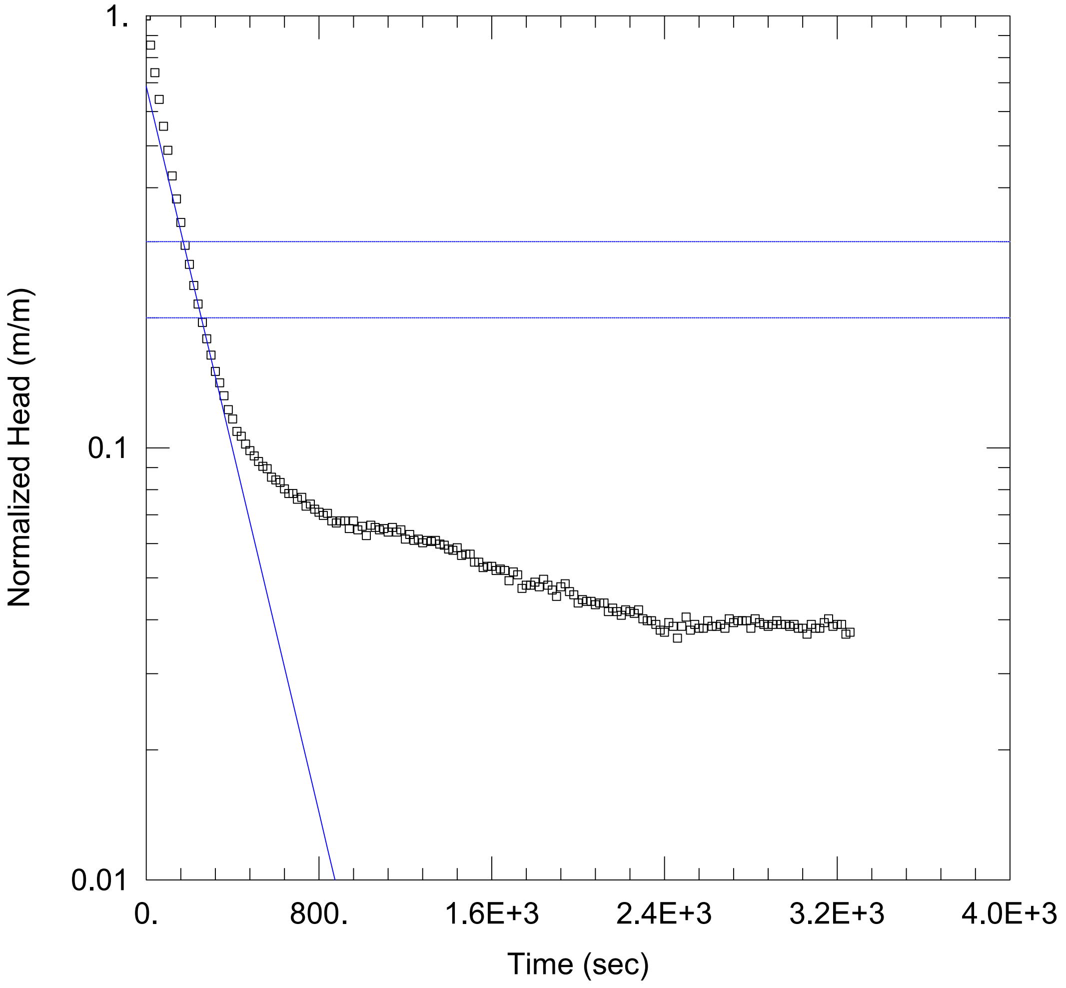
WELL DATA (BH100)

Initial Displacement: 0.264 m
Static Water Column Height: 7.57 m
Total Well Penetration Depth: 7.43 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.282E-6 m/sec
y0 = 0.1742 m



BH100 - RHT01

Data Set: G:\...\BH100_RHT01_BR.aqt
Date: 12/08/22
Time: 10:07:42

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH100
Test Date: 17/11/2022

AQUIFER DATA

Saturated Thickness: 7.57 m
Anisotropy Ratio (Kz/Kr): 1.

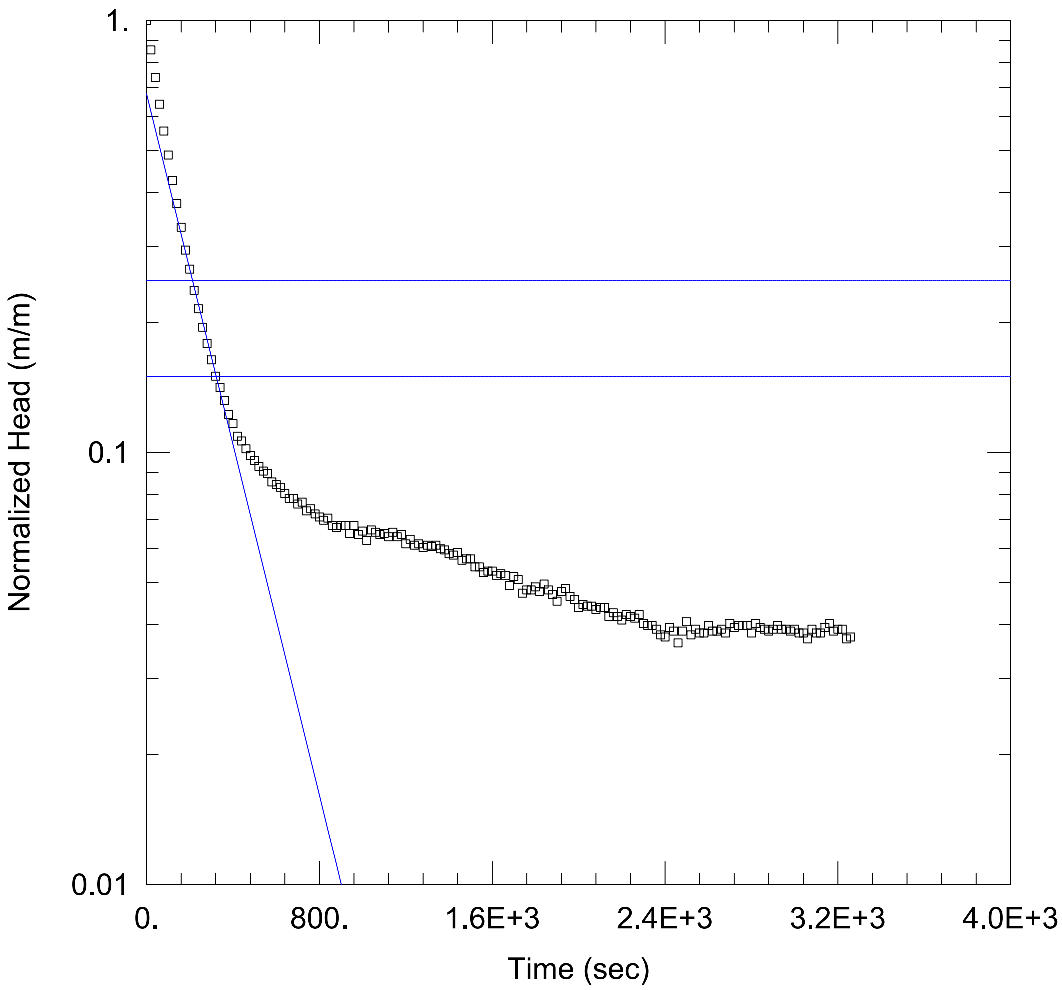
WELL DATA (BH100)

Initial Displacement: 0.2538 m
Static Water Column Height: 7.57 m
Total Well Penetration Depth: 7.43 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.365E-6 m/sec
y0 = 0.1742 m



BH100 - RHT01

Data Set: G:\...\BH100_RHT01_H.aqt
Date: 12/07/22 Time: 10:48:55

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH100
Test Date: 17/11/2022

AQUIFER DATA

Saturated Thickness: 7.57 m
Anisotropy Ratio (Kz/Kr): 1.

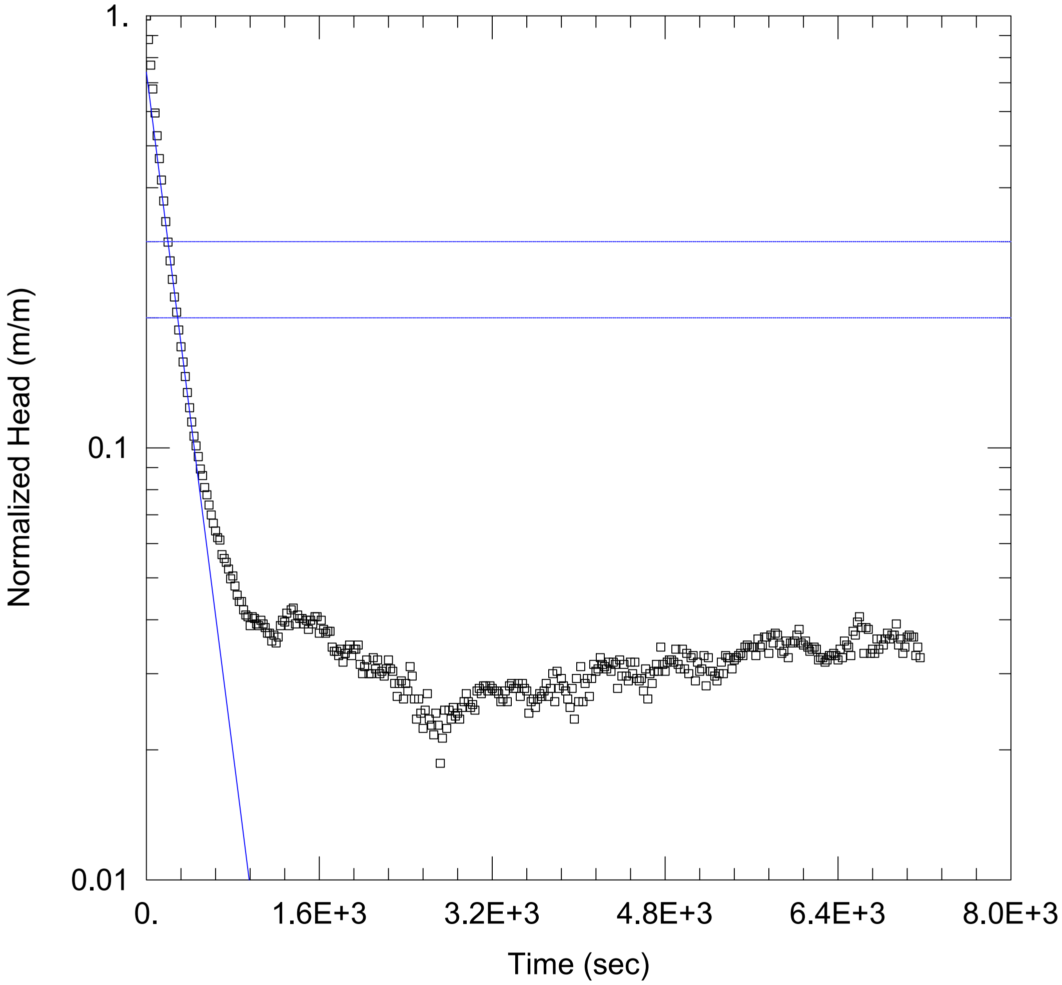
WELL DATA (BH100)

Initial Displacement: 0.2538 m
Static Water Column Height: 7.57 m
Total Well Penetration Depth: 7.43 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.524E-6 m/sec
y0 = 0.1716 m



BH100 - RHT02

Data Set: G:\...\BH100_RHT02_BR.aqt
Date: 12/07/22
Time: 10:49:30

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH100
Test Date: 17/11/2022

AQUIFER DATA

Saturated Thickness: 7.57 m
Anisotropy Ratio (Kz/Kr): 1.

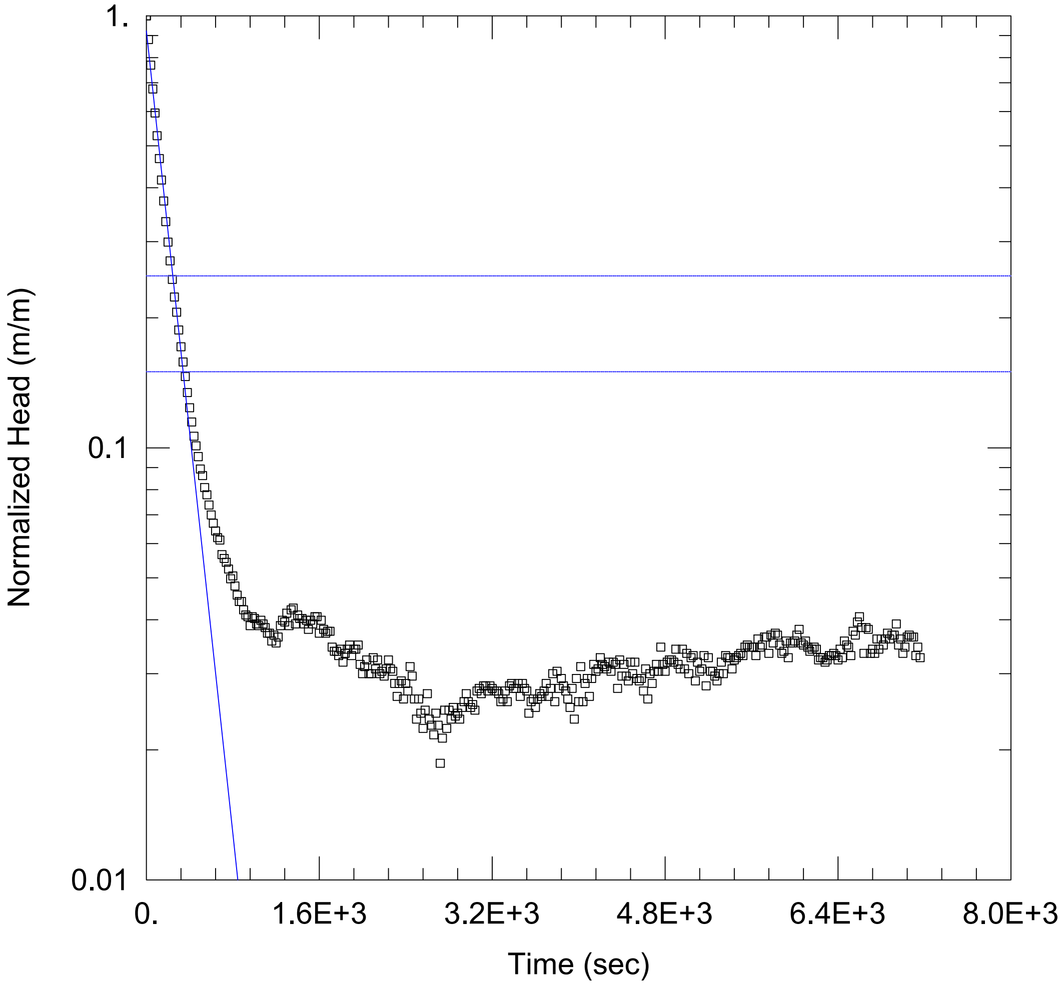
WELL DATA (BH100)

Initial Displacement: 0.2632 m
Static Water Column Height: 7.57 m
Total Well Penetration Depth: 7.43 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.212E-6 m/sec
y0 = 0.1949 m



BH100 - RHT02

Data Set: G:\...\BH100_RHT02_H.aqt
Date: 12/07/22 Time: 10:50:20

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH100
Test Date: 17/11/2022

AQUIFER DATA

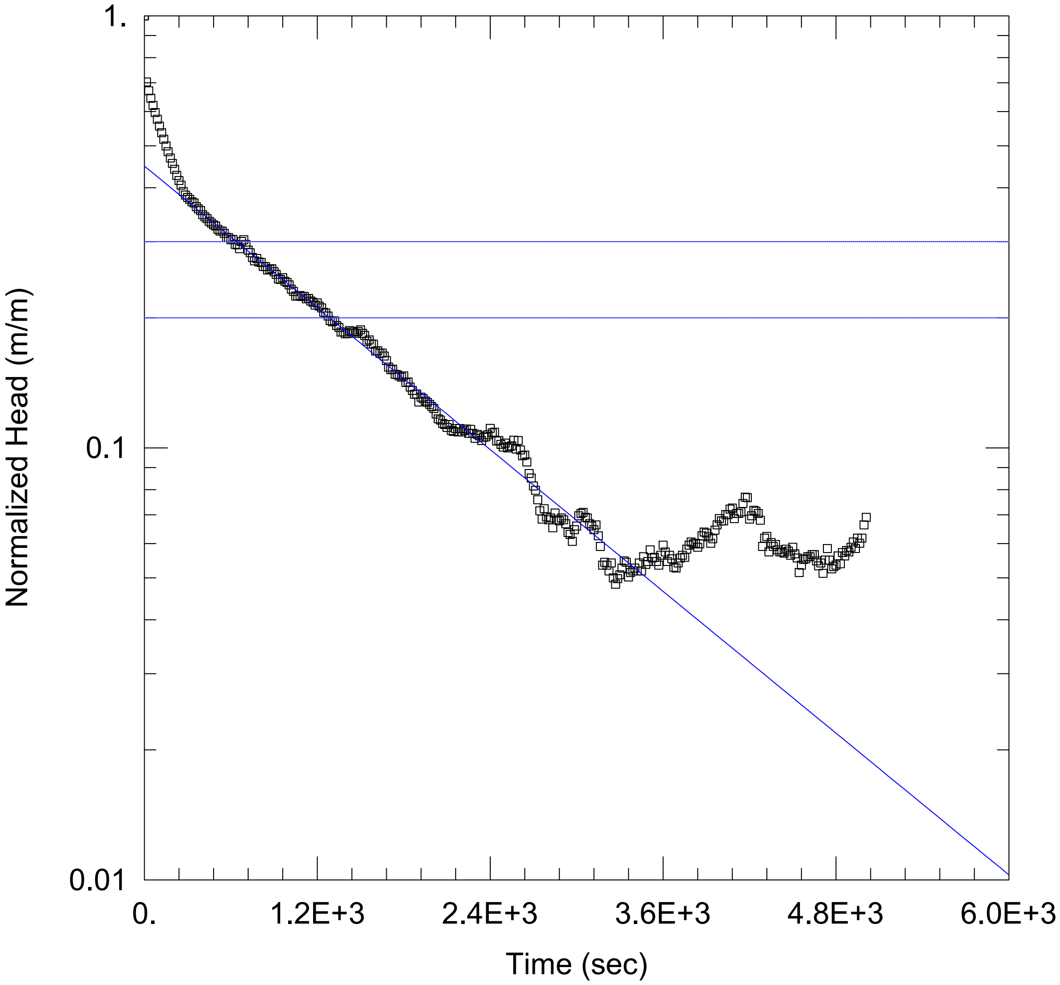
Saturated Thickness: 7.57 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH100)

Initial Displacement: 0.2632 m
Total Well Penetration Depth: 7.43 m
Casing Radius: 0.025 m
Static Water Column Height: 7.57 m
Screen Length: 2. m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 2.889E-6 m/sec
y0 = 0.2429 m



BH101 - FHT01

Data Set: G:\...\BH101_FHT01_BR.aqt
Date: 12/07/22 Time: 10:51:45

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH101
Test Date: 16/11/2022

AQUIFER DATA

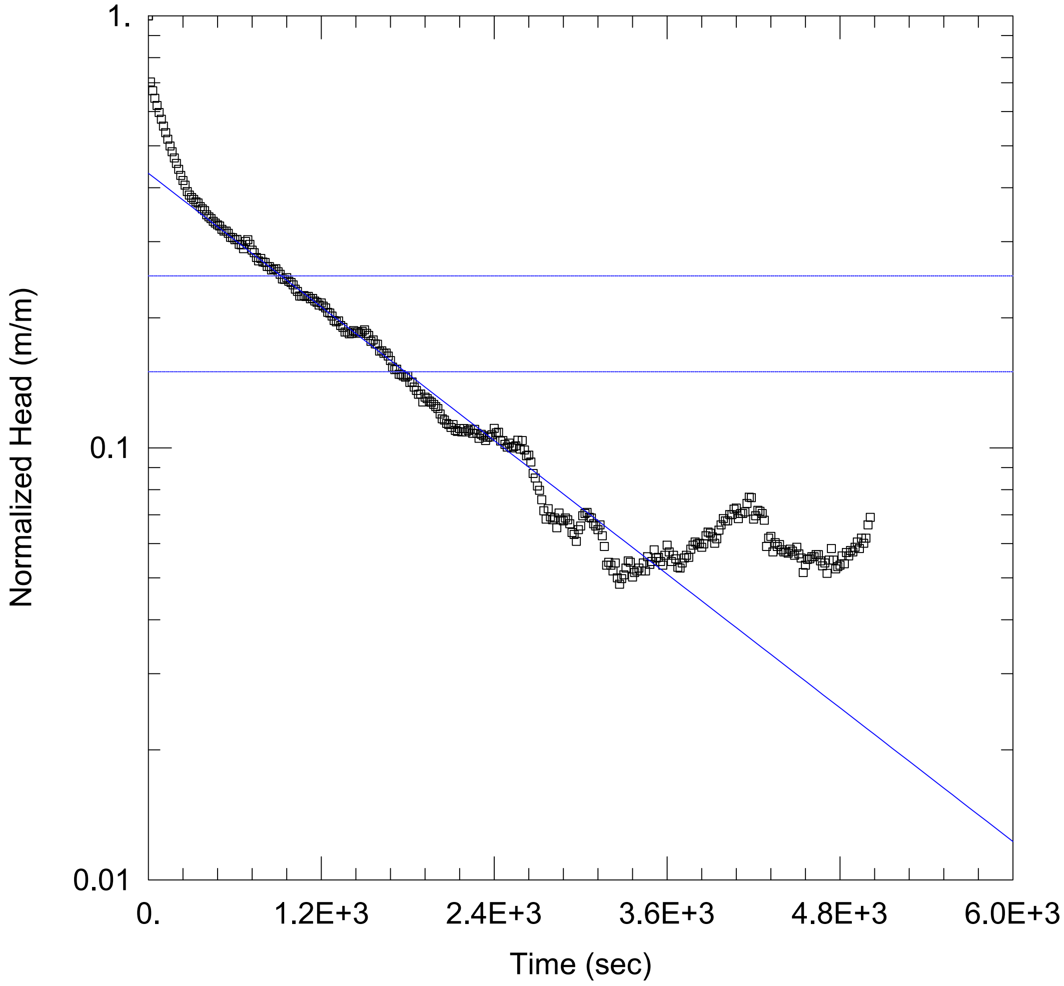
Saturated Thickness: 6.55 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH101)

Initial Displacement: 0.484 m
Static Water Column Height: 6.55 m
Total Well Penetration Depth: 6.55 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 3.273E-7 m/sec
y0 = 0.2173 m



BH101 - FHT01

Data Set: G:\...\BH101_FHT01_H.aqt
Date: 12/07/22 Time: 10:52:20

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH101
Test Date: 16/11/2022

AQUIFER DATA

Saturated Thickness: 6.55 m
Anisotropy Ratio (Kz/Kr): 1.

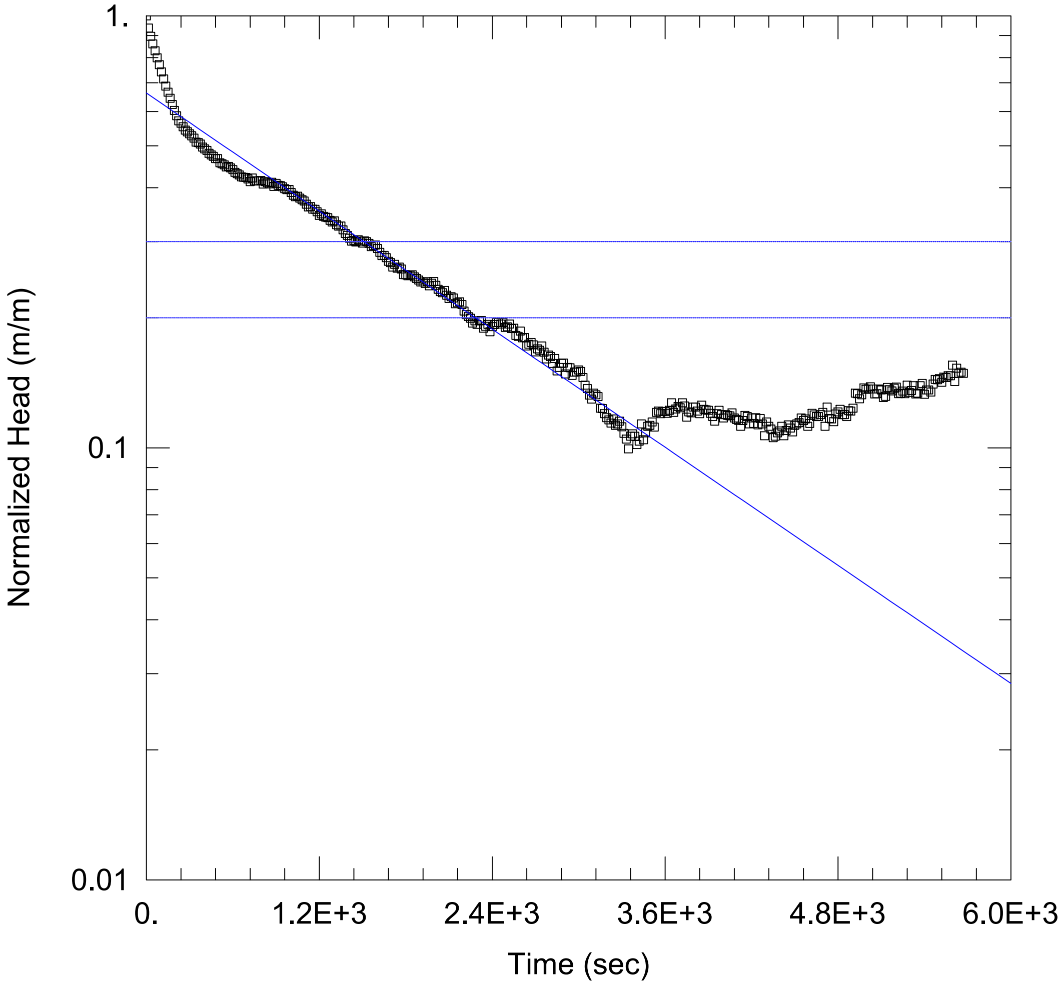
WELL DATA (BH101)

Initial Displacement: 0.484 m
Static Water Column Height: 6.55 m
Total Well Penetration Depth: 6.55 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 3.85E-7 m/sec
y0 = 0.2091 m



BH101 - FHT02

Data Set: G:\...\BH101_FHT02_BR.aqt
Date: 12/07/22 Time: 10:56:34

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH101
Test Date: 16/11/2022

AQUIFER DATA

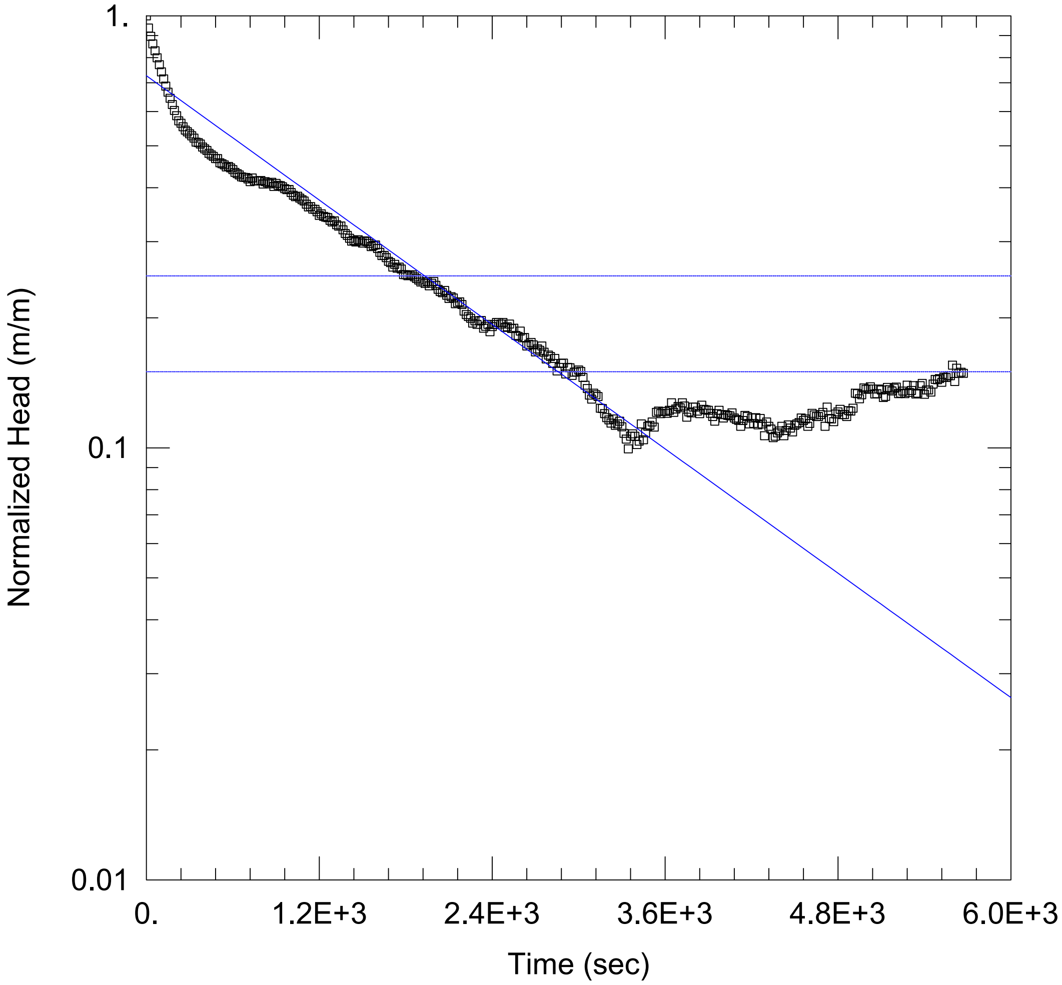
Saturated Thickness: 6.55 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH101)

Initial Displacement: 0.361 m
Static Water Column Height: 6.55 m
Total Well Penetration Depth: 6.55 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.726E-7 m/sec
y0 = 0.2391 m



BH101 - FHT02

Data Set: G:\...\BH101_FHT02_H.aqt
Date: 12/07/22 Time: 10:57:36

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH101
Test Date: 16/11/2022

AQUIFER DATA

Saturated Thickness: 6.55 m
Anisotropy Ratio (Kz/Kr): 1.

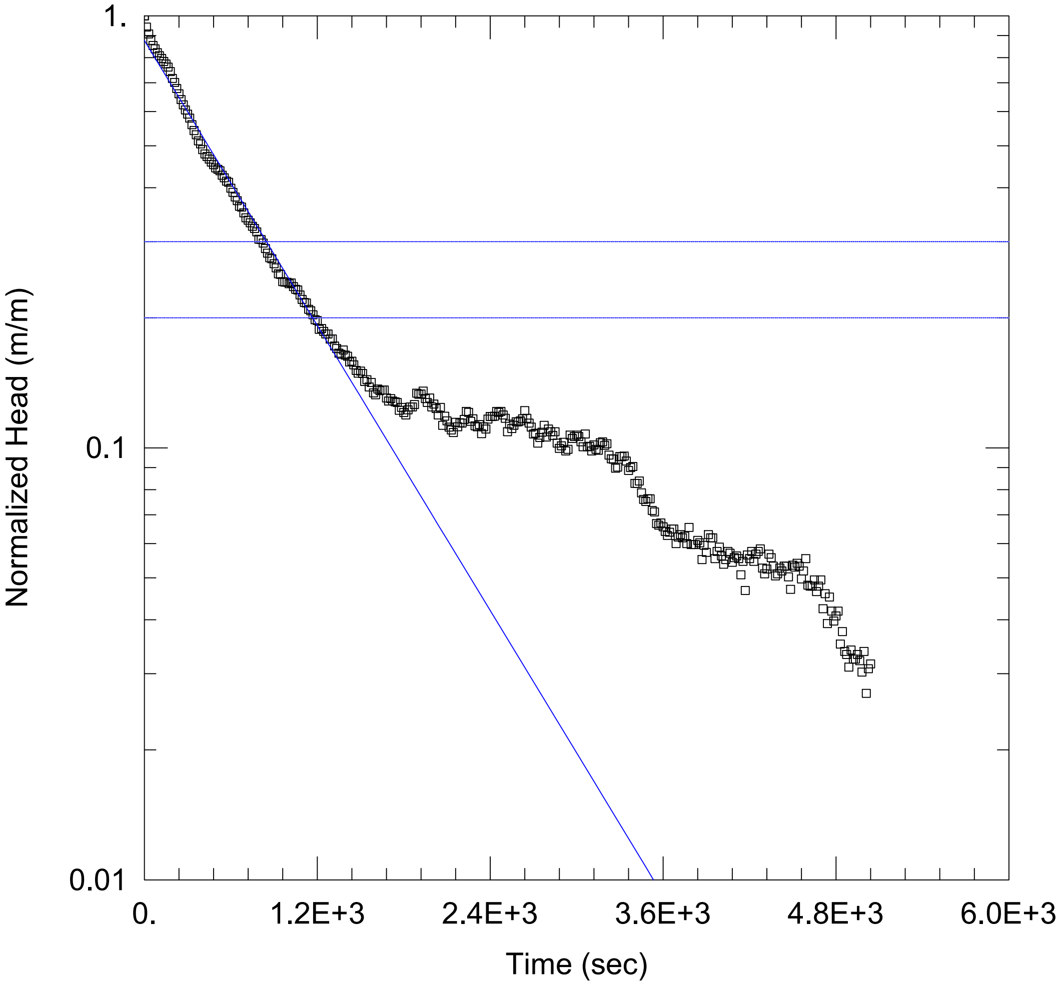
WELL DATA (BH101)

Initial Displacement: 0.361 m
Static Water Column Height: 6.55 m
Total Well Penetration Depth: 6.55 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 3.583E-7 m/sec
y0 = 0.2623 m



BH101 - RHT02

Data Set: G:\...\BH101_RHT02_BR.aqt
Date: 12/07/22
Time: 10:58:12

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH101
Test Date: 16/11/2022

AQUIFER DATA

Saturated Thickness: 6.55 m
Anisotropy Ratio (Kz/Kr): 1.

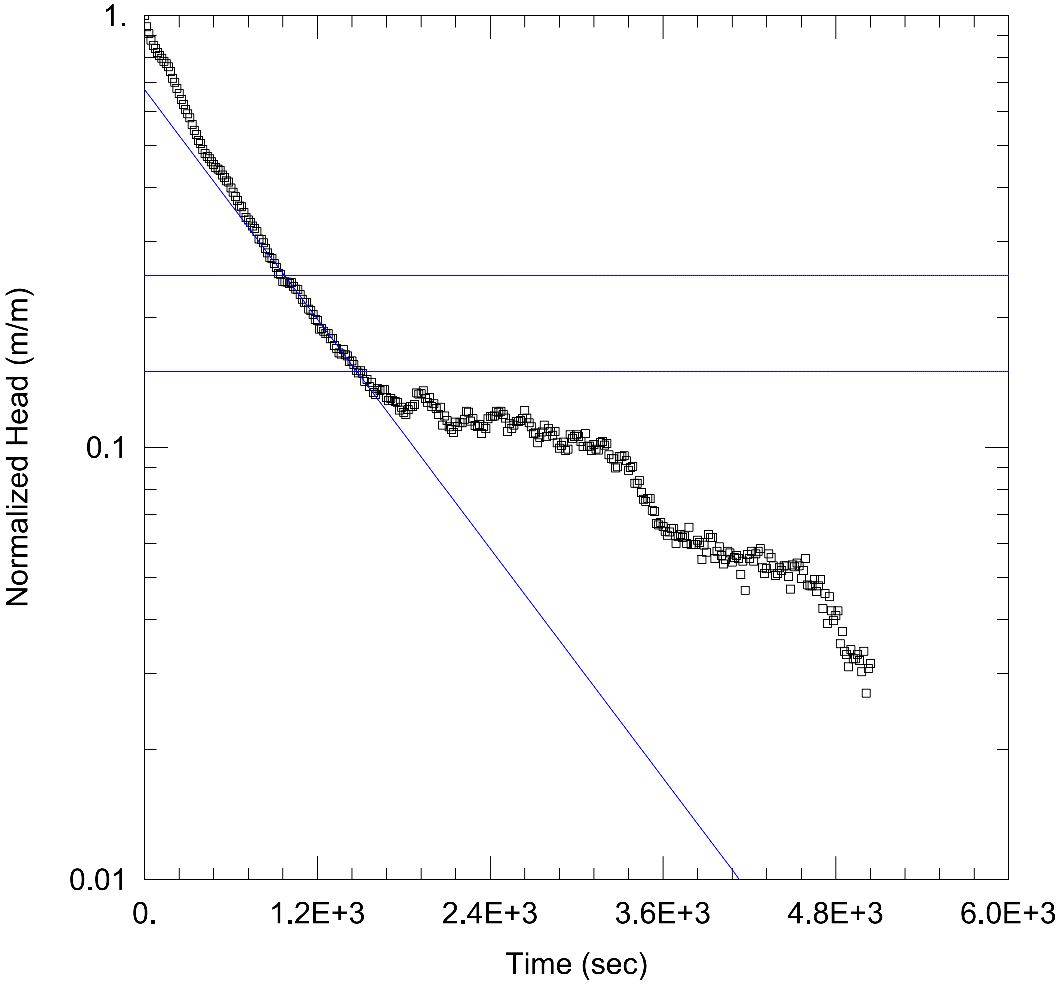
WELL DATA (BH101)

Initial Displacement: 0.37 m
Static Water Column Height: 6.55 m
Total Well Penetration Depth: 6.55 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 6.578E-7 m/sec
y0 = 0.3243 m



BH101 - RHT02

Data Set: G:\...\BH101_RHT02_H.aqt
Date: 12/07/22 Time: 10:58:36

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH101
Test Date: 16/11/2022

AQUIFER DATA

Saturated Thickness: 6.55 m
Anisotropy Ratio (Kz/Kr): 1.

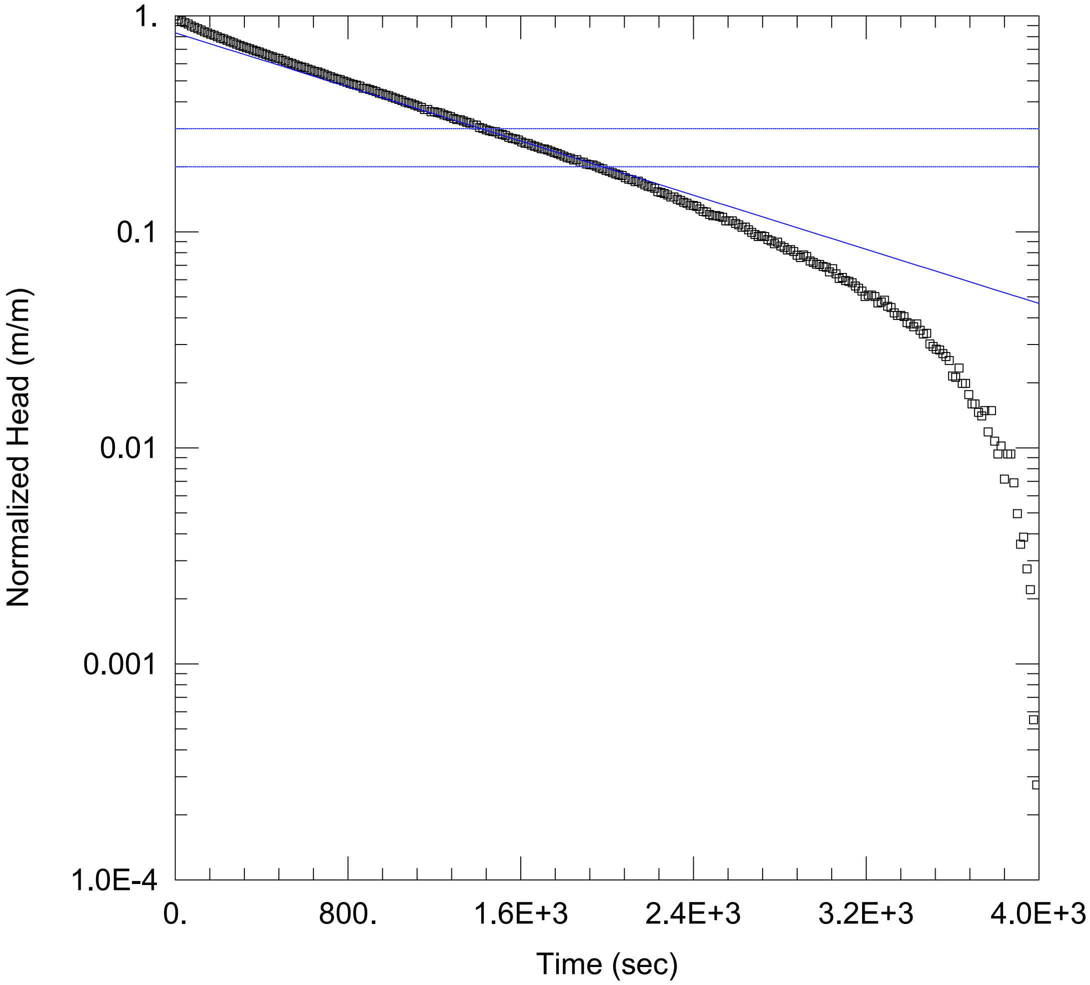
WELL DATA (BH101)

Initial Displacement: 0.37 m
Total Well Penetration Depth: 6.55 m
Casing Radius: 0.025 m
Static Water Column Height: 6.55 m
Screen Length: 2. m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 6.61E-7 m/sec
y0 = 0.2493 m



BH102 - FHT01

Data Set: G:\...\BH102_FHT01_BR.aqt
Date: 12/07/22 Time: 11:05:39

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH102
Test Date: 15/11/2022

AQUIFER DATA

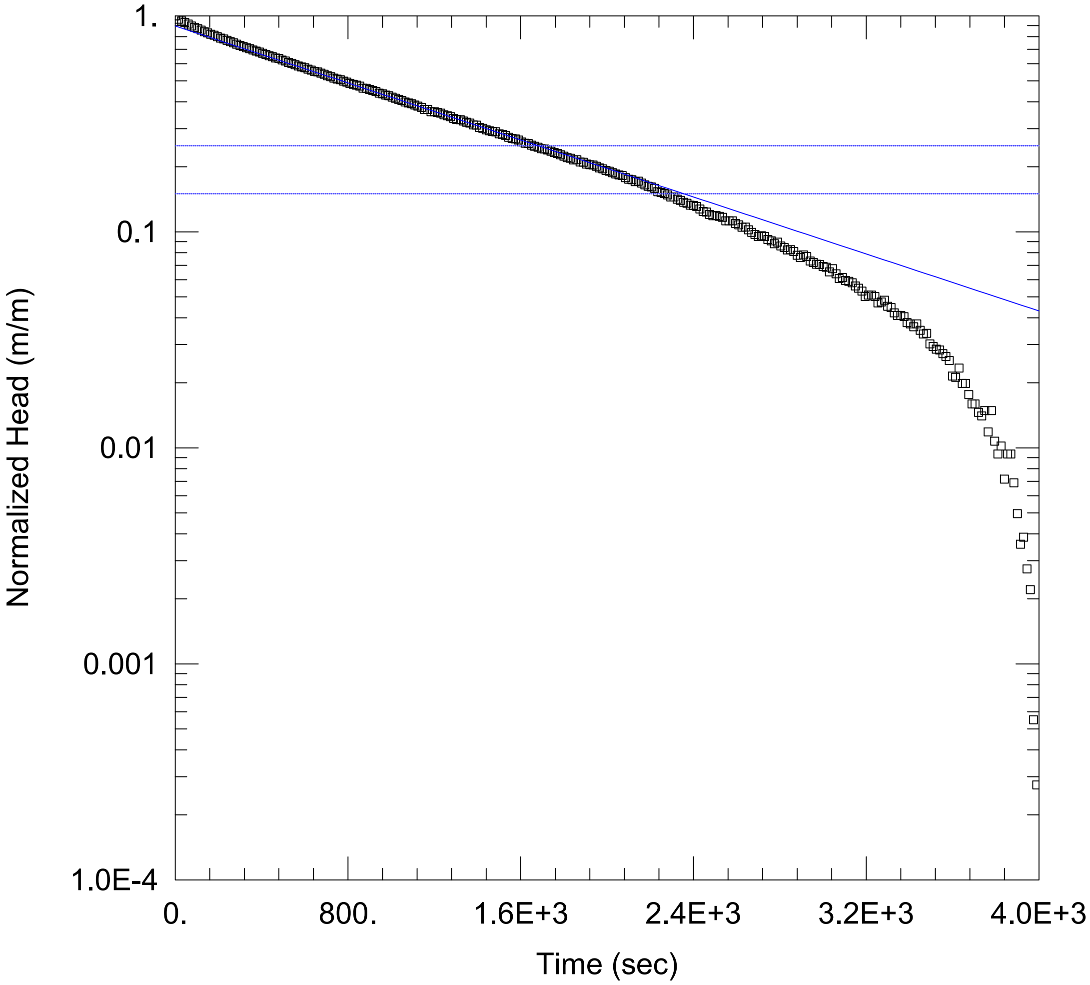
Saturated Thickness: 3.89 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH102)

Initial Displacement: 0.3631 m Static Water Column Height: 3.89 m
Total Well Penetration Depth: 3.7 m Screen Length: 1. m
Casing Radius: 0.025 m Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 5.364E-7 m/sec y0 = 0.3027 m



BH102 - FHT01

Data Set: G:\...\BH102_FHT01_H.aqt

Date: 12/07/22 Time: 11:06:29

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH102
Test Date: 15/11/2022

AQUIFER DATA

Saturated Thickness: 3.89 m Anisotropy Ratio (Kz/Kr): 1.

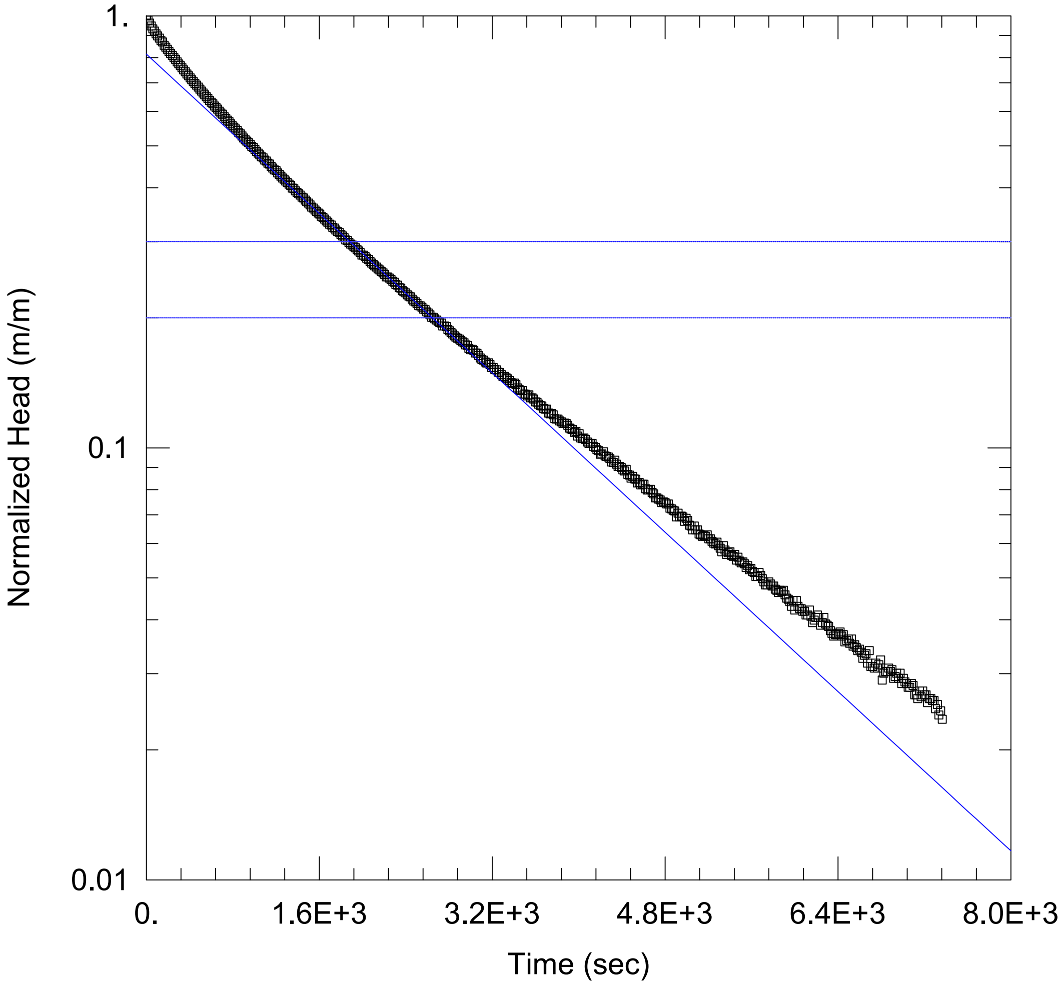
WELL DATA (BH102)

Initial Displacement: 0.3631 m
Total Well Penetration Depth: 3.7 m
Casing Radius: 0.025 m
Static Water Column Height: 3.89 m
Screen Length: 1. m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 6.571E-7 m/sec y0 = 0.3258 m



BH102 - FHT02

Data Set: G:\...\BH102_FHT02_BR.aqt
Date: 12/07/22 Time: 11:04:56

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH102
Test Date: 15/11/2022

AQUIFER DATA

Saturated Thickness: 3.89 m
Anisotropy Ratio (Kz/Kr): 1.

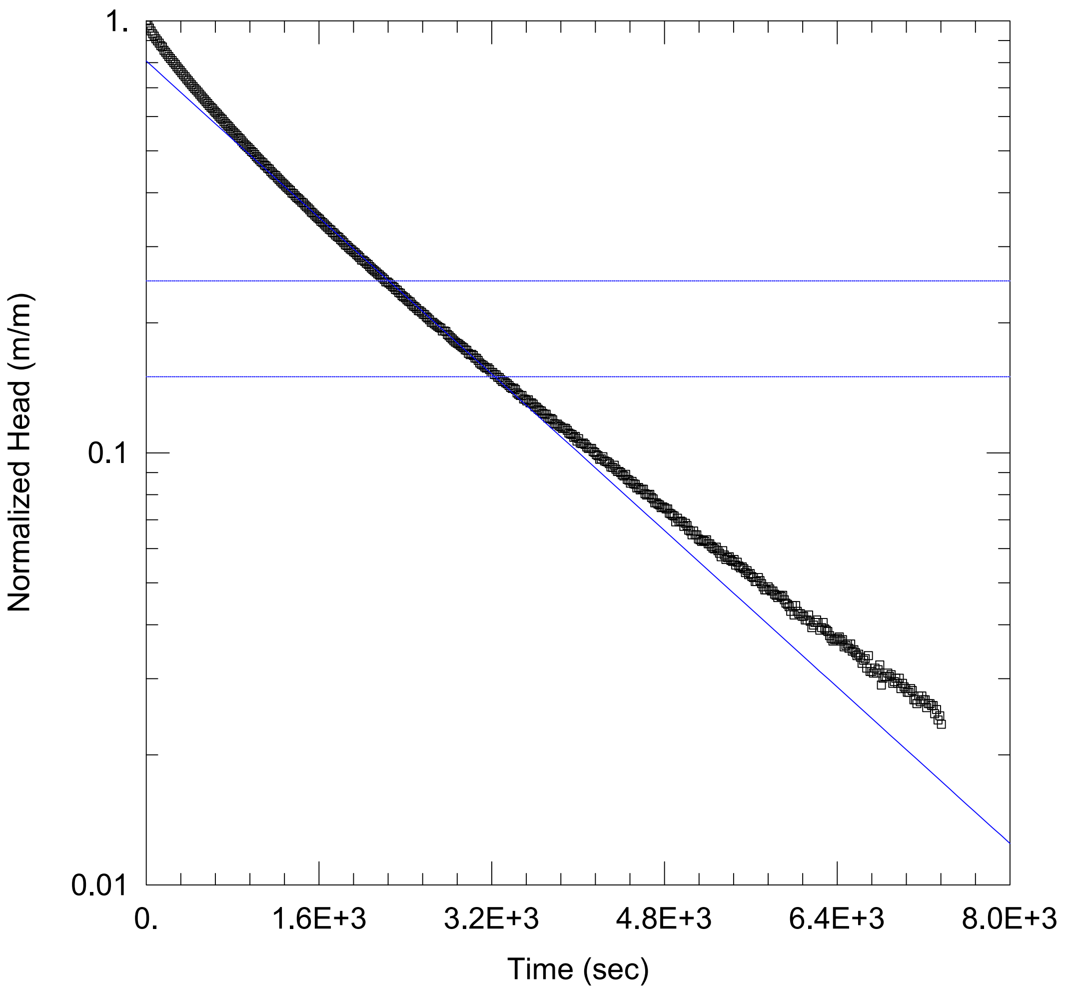
WELL DATA (BH102)

Initial Displacement: 0.3655 m
Static Water Column Height: 3.89 m
Total Well Penetration Depth: 3.7 m
Screen Length: 1. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.948E-7 m/sec
y0 = 0.2979 m



BH102 - FHT02

Data Set: G:\...\BH102_FHT02_H.aqt
Date: 12/07/22 Time: 11:07:09

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH102
Test Date: 15/11/2022

AQUIFER DATA

Saturated Thickness: 3.89 m
Anisotropy Ratio (Kz/Kr): 1.

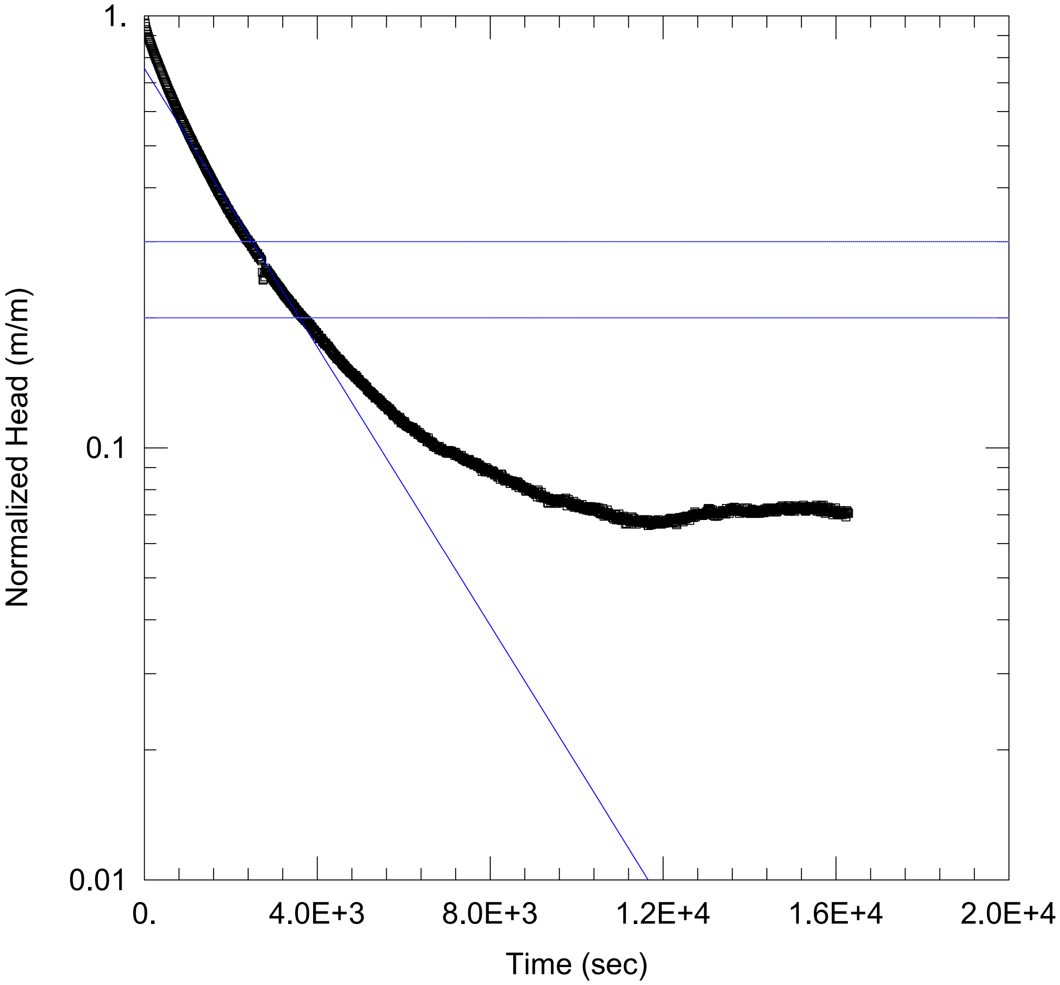
WELL DATA (BH102)

Initial Displacement: 0.3655 m
Static Water Column Height: 3.89 m
Total Well Penetration Depth: 3.7 m
Screen Length: 1. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 4.51E-7 m/sec
y0 = 0.2949 m



BH102 - RHT01

Data Set: G:\...\BH102_RHT01_BR.aqt
Date: 12/07/22 Time: 11:08:30

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH102
Test Date: 15/11/2022

AQUIFER DATA

Saturated Thickness: 3.89 m Anisotropy Ratio (Kz/Kr): 1.

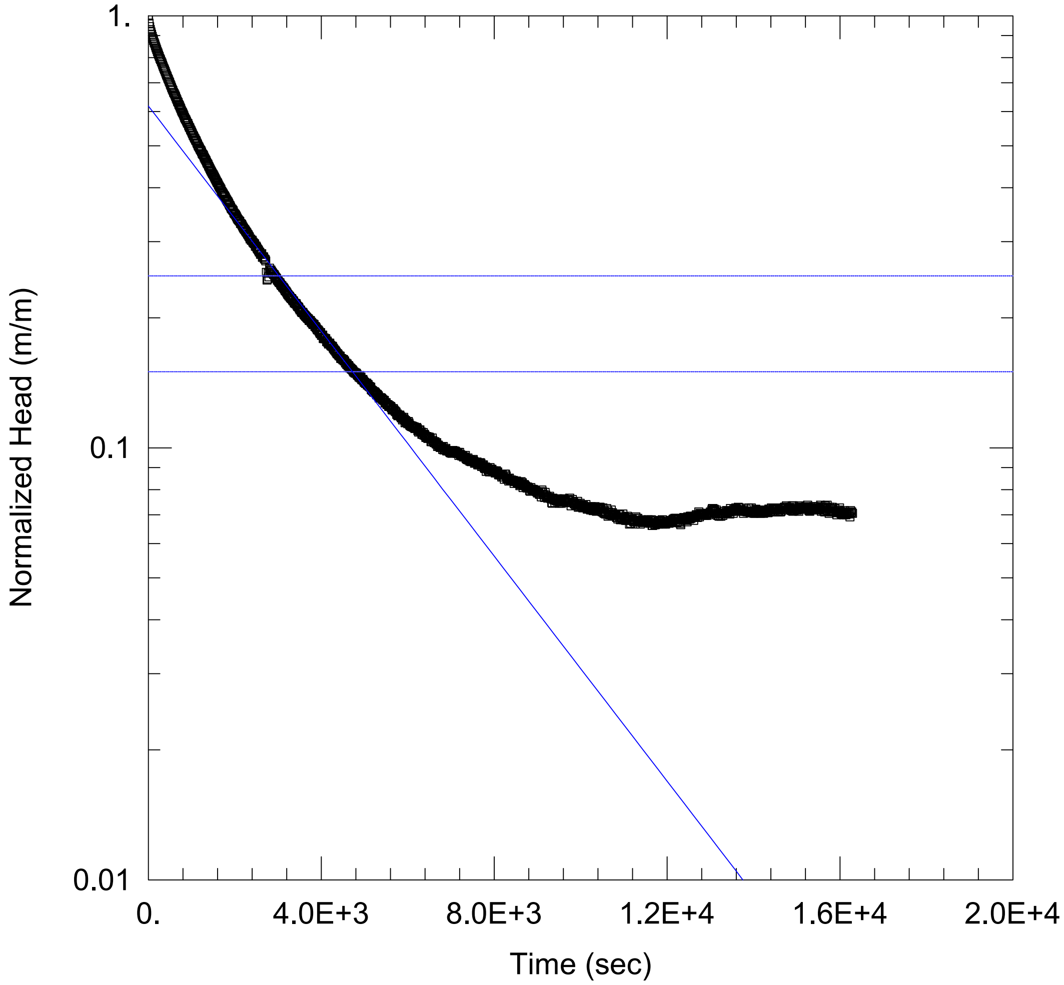
WELL DATA (BH102)

Initial Displacement: 0.3843 m Static Water Column Height: 3.89 m
Total Well Penetration Depth: 3.7 m Screen Length: 1. m
Casing Radius: 0.025 m Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 2.76E-7 m/sec y0 = 0.2902 m



BH102 - RHT01

Data Set: G:\...\BH102_RHT01_H.aqt
Date: 12/07/22 Time: 11:09:14

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH102
Test Date: 15/11/2022

AQUIFER DATA

Saturated Thickness: 3.89 m
Anisotropy Ratio (Kz/Kr): 1.

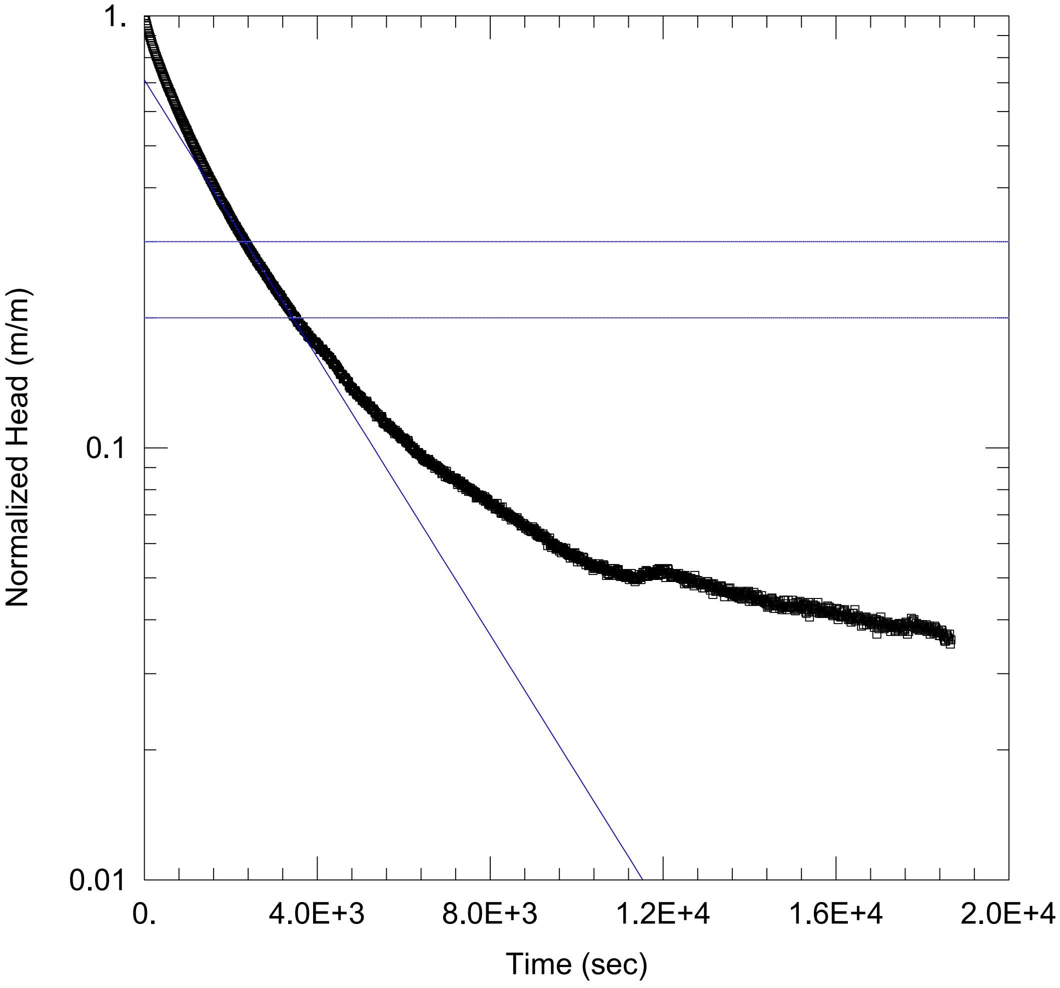
WELL DATA (BH102)

Initial Displacement: 0.3843 m
Static Water Column Height: 3.89 m
Total Well Penetration Depth: 3.7 m
Screen Length: 1. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.594E-7 m/sec
y0 = 0.2375 m



BH102 - RHT02

Data Set: G:\...\BH102_RHT02_BR.aqt
Date: 12/07/22 Time: 11:10:06

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH102
Test Date: 15/11/2022

AQUIFER DATA

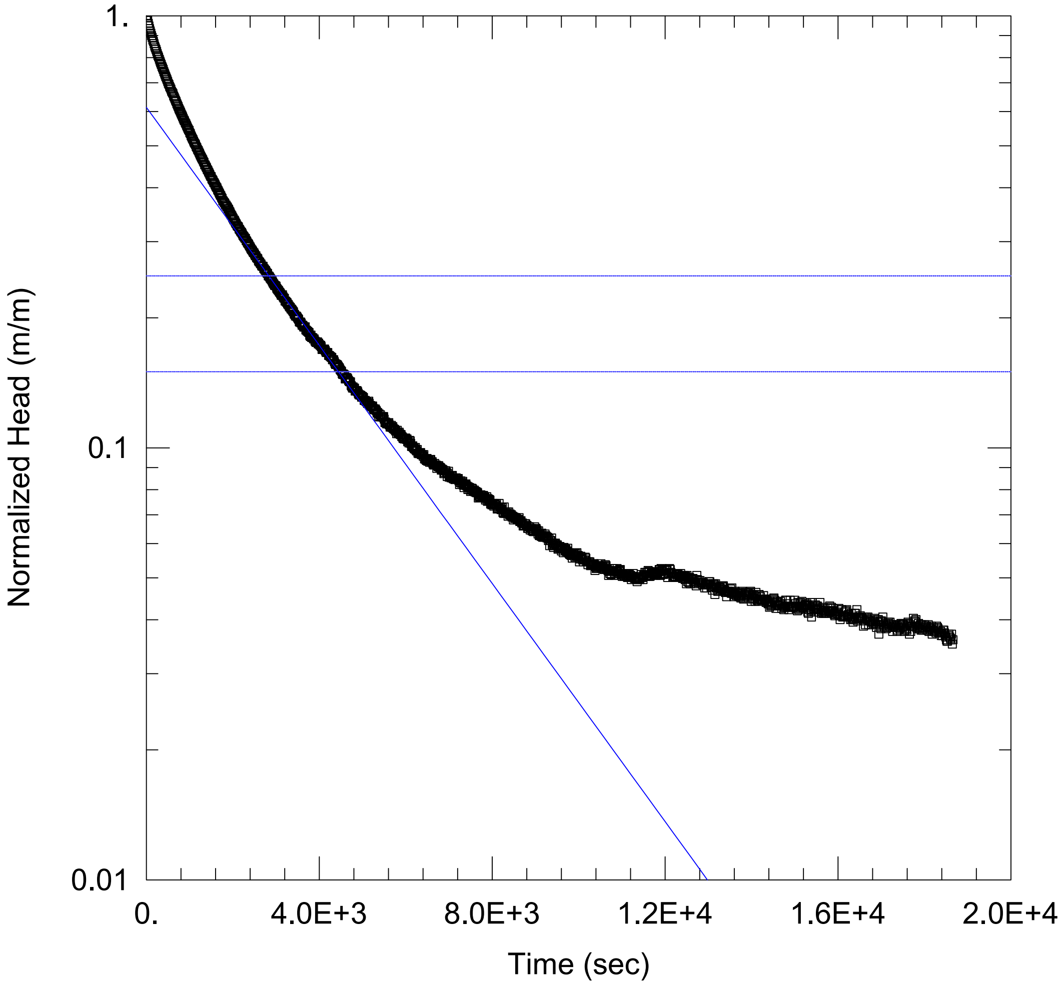
Saturated Thickness: 3.89 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH102)

Initial Displacement: 0.3672 m
Static Water Column Height: 3.89 m
Total Well Penetration Depth: 3.7 m
Screen Length: 1. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.75E-7 m/sec
y0 = 0.2607 m



BH102 - RHT02

Data Set: G:\...\BH102_RHT02_H.aqt
Date: 12/07/22 Time: 11:10:37

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH102
Test Date: 15/11/2022

AQUIFER DATA

Saturated Thickness: 3.89 m
Anisotropy Ratio (Kz/Kr): 1.

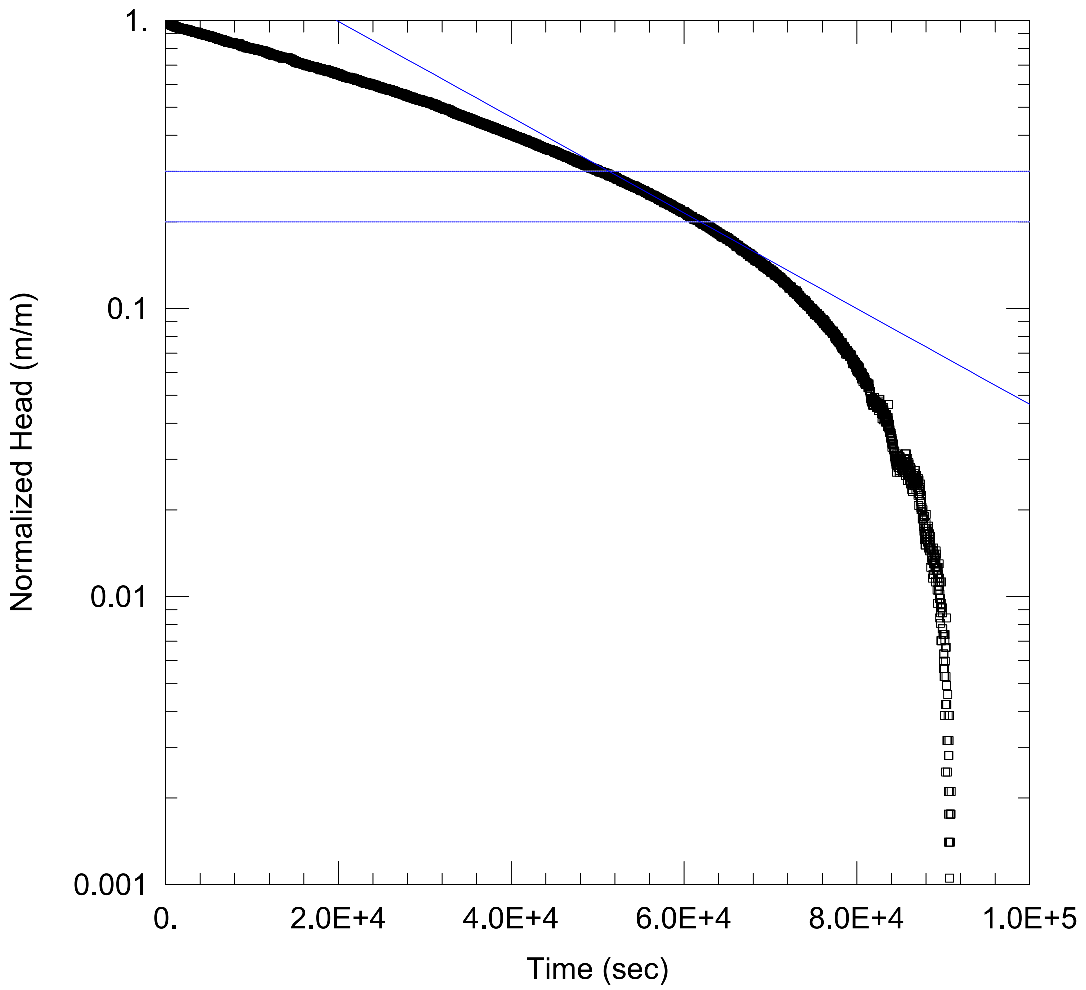
WELL DATA (BH102)

Initial Displacement: 0.3672 m
Total Well Penetration Depth: 3.7 m
Casing Radius: 0.025 m
Static Water Column Height: 3.89 m
Screen Length: 1. m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.744E-7 m/sec
y0 = 0.2254 m



BH103 - RHT01

Data Set: G:\...\BH103_RHT01_BR.aqt

Date: 12/07/22 Time: 11:12:49

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH103
Test Date: 23/11/2022

AQUIFER DATA

Saturated Thickness: 9.65 m Anisotropy Ratio (Kz/Kr): 1.

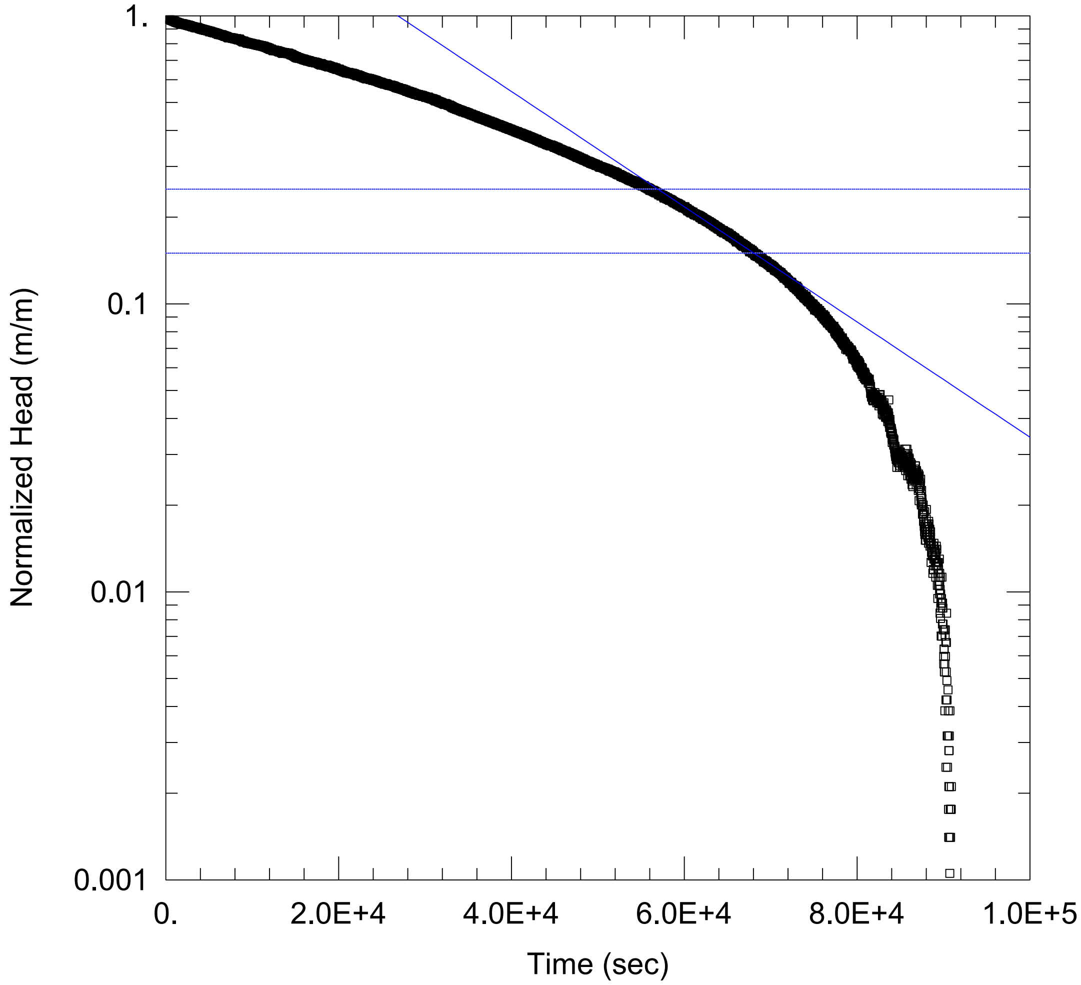
WELL DATA (BH103)

Initial Displacement: 0.2847 m Static Water Column Height: 9.65 m
Total Well Penetration Depth: 10.01 m Screen Length: 2. m
Casing Radius: 0.025 m Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 2.129E-8 m/sec y0 = 0.6076 m



BH103 - RHT01

Data Set: G:\...\BH103_RHT01_H.aqt
Date: 12/07/22 Time: 11:13:26

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH103
Test Date: 23/11/2022

AQUIFER DATA

Saturated Thickness: 9.65 m
Anisotropy Ratio (Kz/Kr): 1.

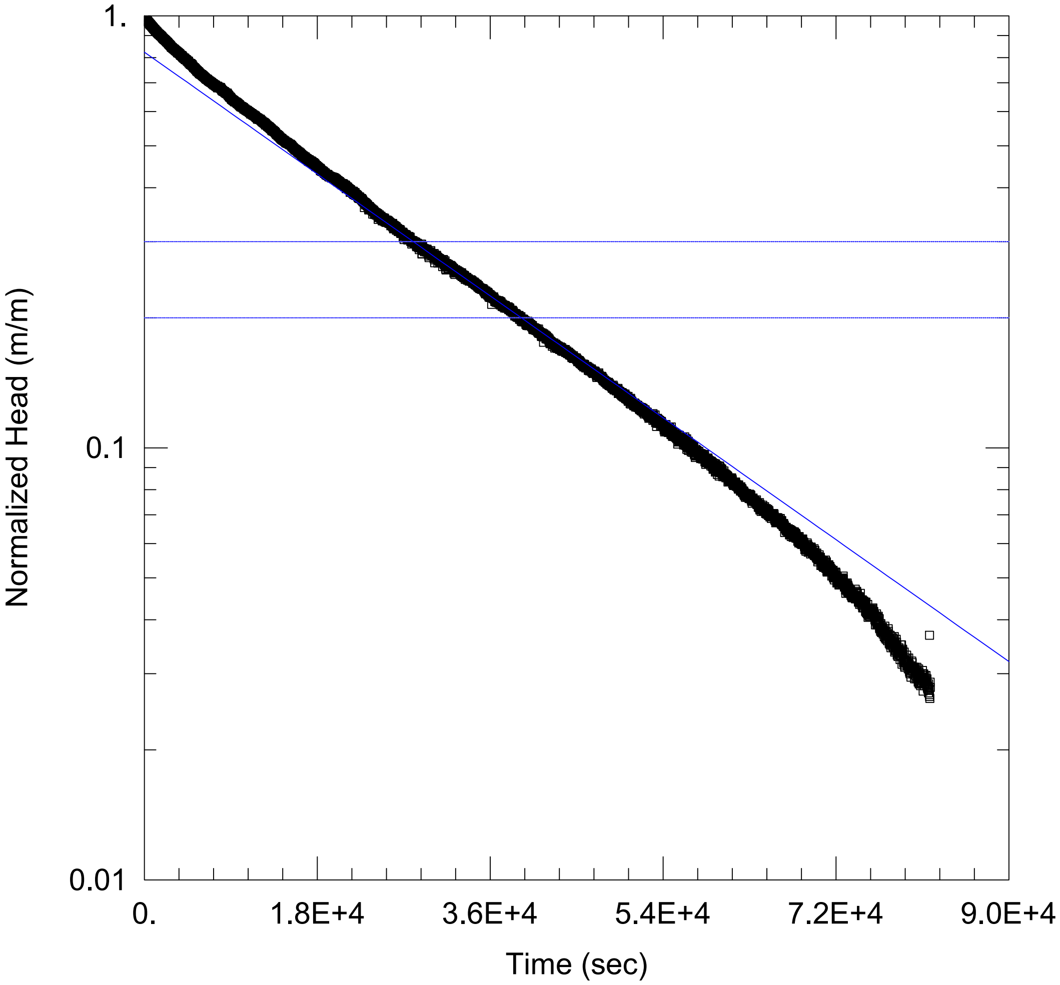
WELL DATA (BH103)

Initial Displacement: 0.2847 m
Static Water Column Height: 9.65 m
Total Well Penetration Depth: 10.01 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.988E-8 m/sec
y0 = 0.9804 m



BH108 - FHT01

Data Set: G:\...\BH108_FHT01_BR.aqt
Date: 12/07/22 Time: 11:14:07

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH108
Test Date: 23/11/2022

AQUIFER DATA

Saturated Thickness: 10.62 m
Anisotropy Ratio (Kz/Kr): 1.

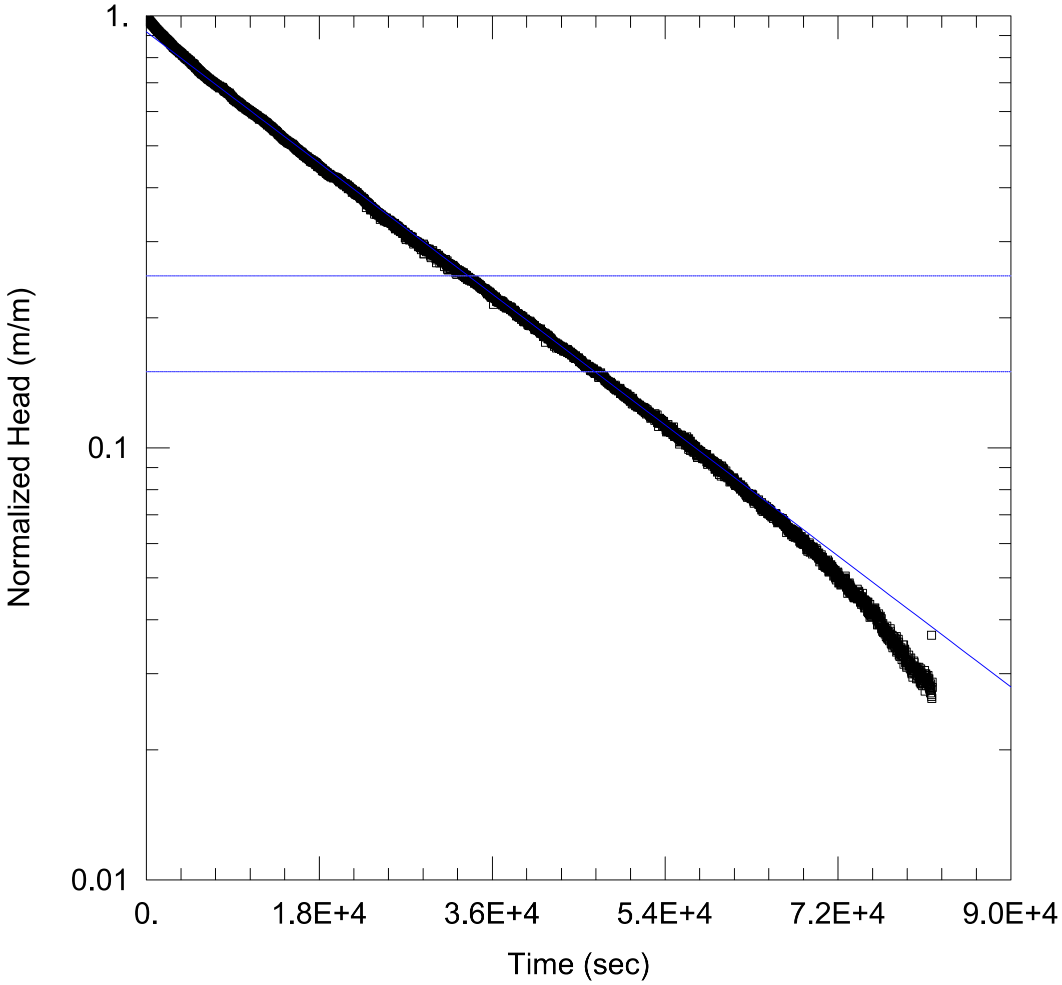
WELL DATA (BH108)

Initial Displacement: 0.3802 m
Static Water Column Height: 10.62 m
Total Well Penetration Depth: 10.49 m
Screen Length: 1. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.152E-8 m/sec
y0 = 0.3132 m



BH108 - FHT01

Data Set: G:\...\BH108_FHT01_H.aqt
Date: 12/07/22 Time: 11:15:04

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH108
Test Date: 23/11/2022

AQUIFER DATA

Saturated Thickness: 10.62 m
Anisotropy Ratio (Kz/Kr): 1.

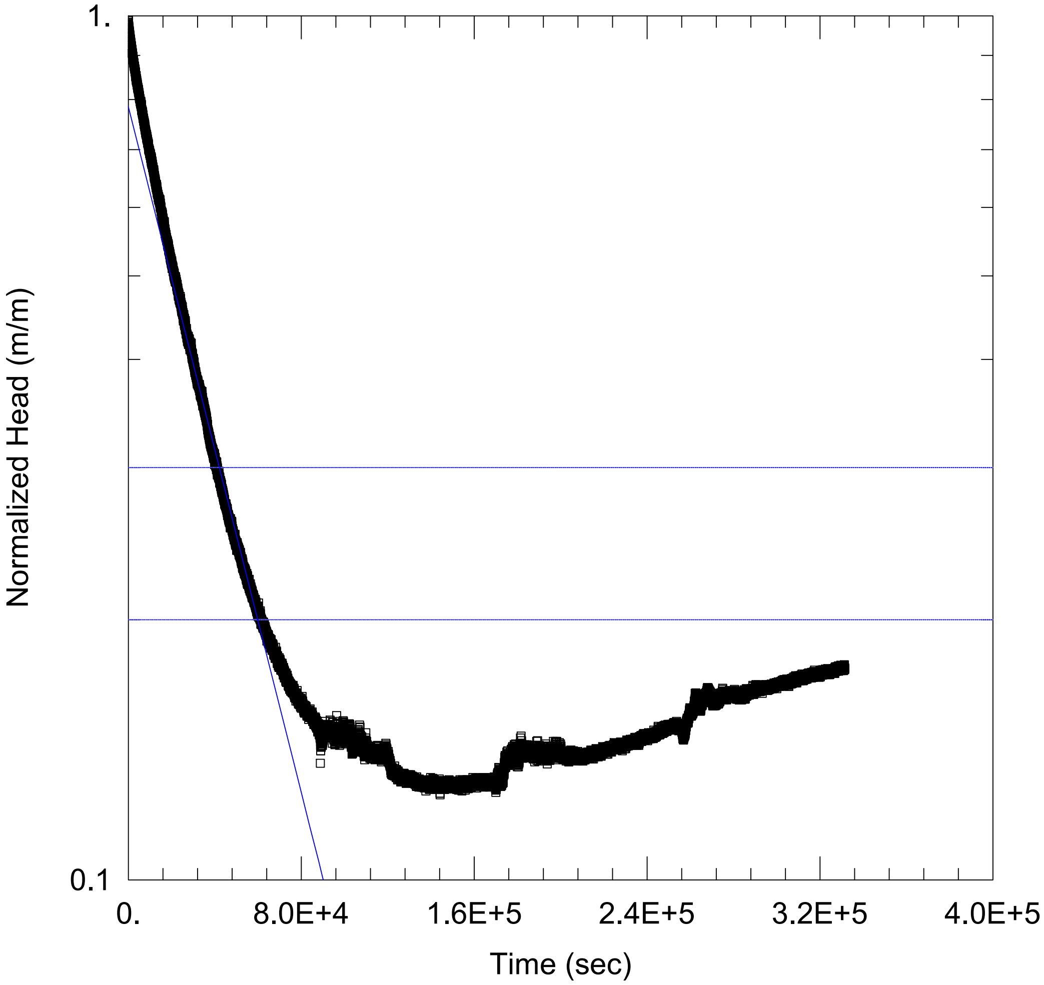
WELL DATA (BH108)

Initial Displacement: 0.3802 m
Static Water Column Height: 10.62 m
Total Well Penetration Depth: 10.49 m
Screen Length: 1. m
Casing Radius: 0.025 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 3.356E-8 m/sec
y0 = 0.3489 m



BH108 - RHT01

Data Set: G:\...\BH108_RHT01_BR.aqt
Date: 12/07/22 Time: 11:15:32

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH108
Test Date: 23/11/2022

AQUIFER DATA

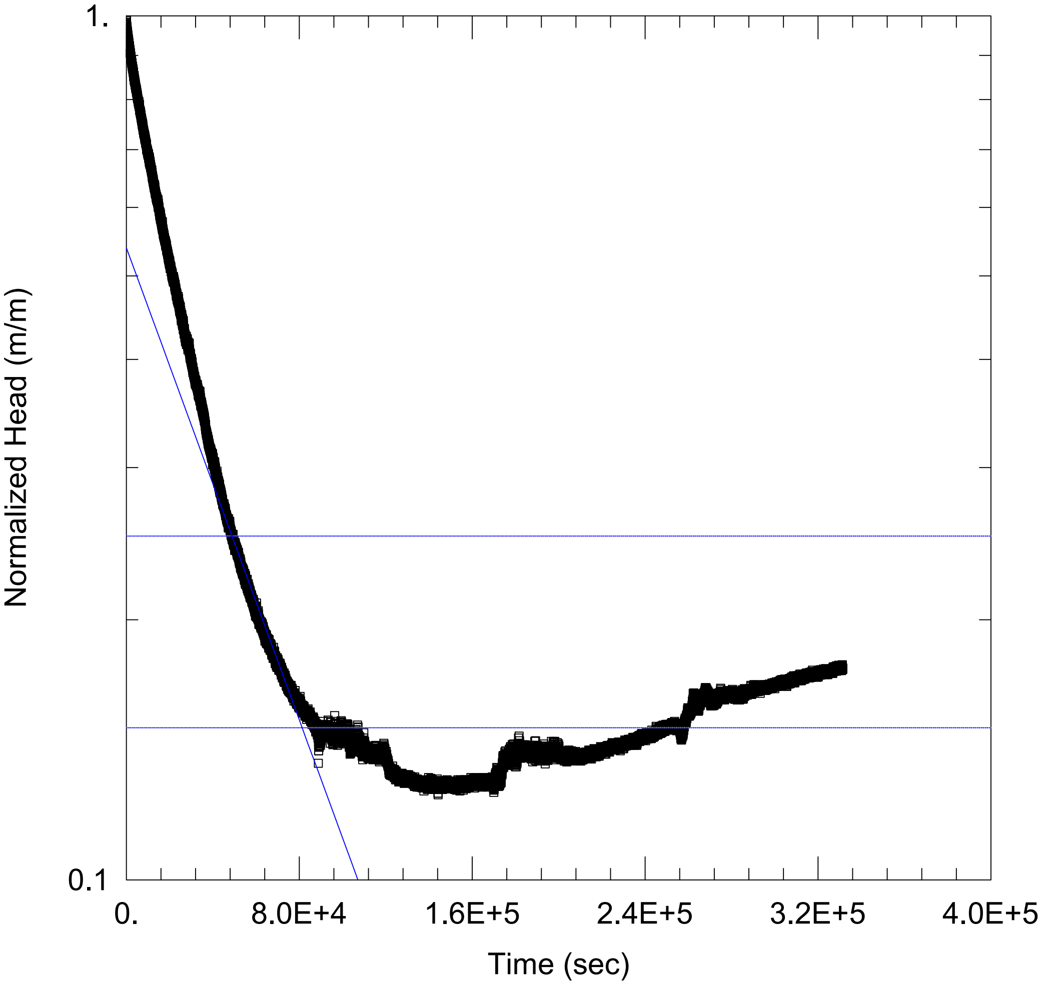
Saturated Thickness: 10.62 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH108)

Initial Displacement: 0.3906 m
Static Water Column Height: 10.62 m
Total Well Penetration Depth: 10.49 m
Screen Length: 1. m
Casing Radius: 0.026 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.157E-8 m/sec
y0 = 0.3064 m



BH108 - RHT01

Data Set: G:\...\BH108_RHT01_H.aqt
Date: 12/07/22 Time: 11:16:29

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: BH108
Test Date: 23/11/2022

AQUIFER DATA

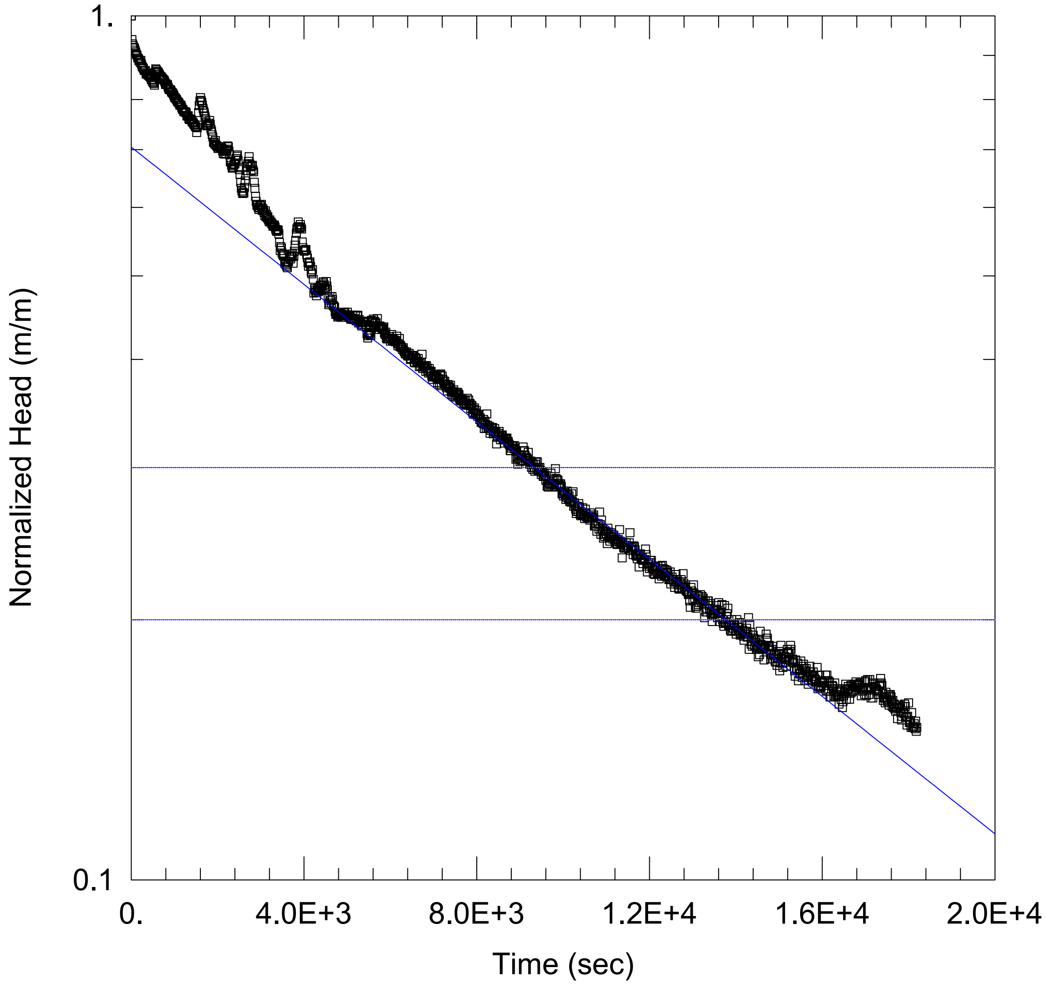
Saturated Thickness: 10.62 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH108)

Initial Displacement: 0.3906 m
Static Water Column Height: 10.62 m
Total Well Penetration Depth: 10.49 m
Screen Length: 1. m
Casing Radius: 0.026 m
Well Radius: 0.063 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 1.471E-8 m/sec
y0 = 0.2105 m



MW0C - FHT1

Data Set: G:\...\MW0C_FHT1_BR.aqt
Date: 12/07/22 Time: 11:17:17

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW0C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 3.27 m
Anisotropy Ratio (Kz/Kr): 1.

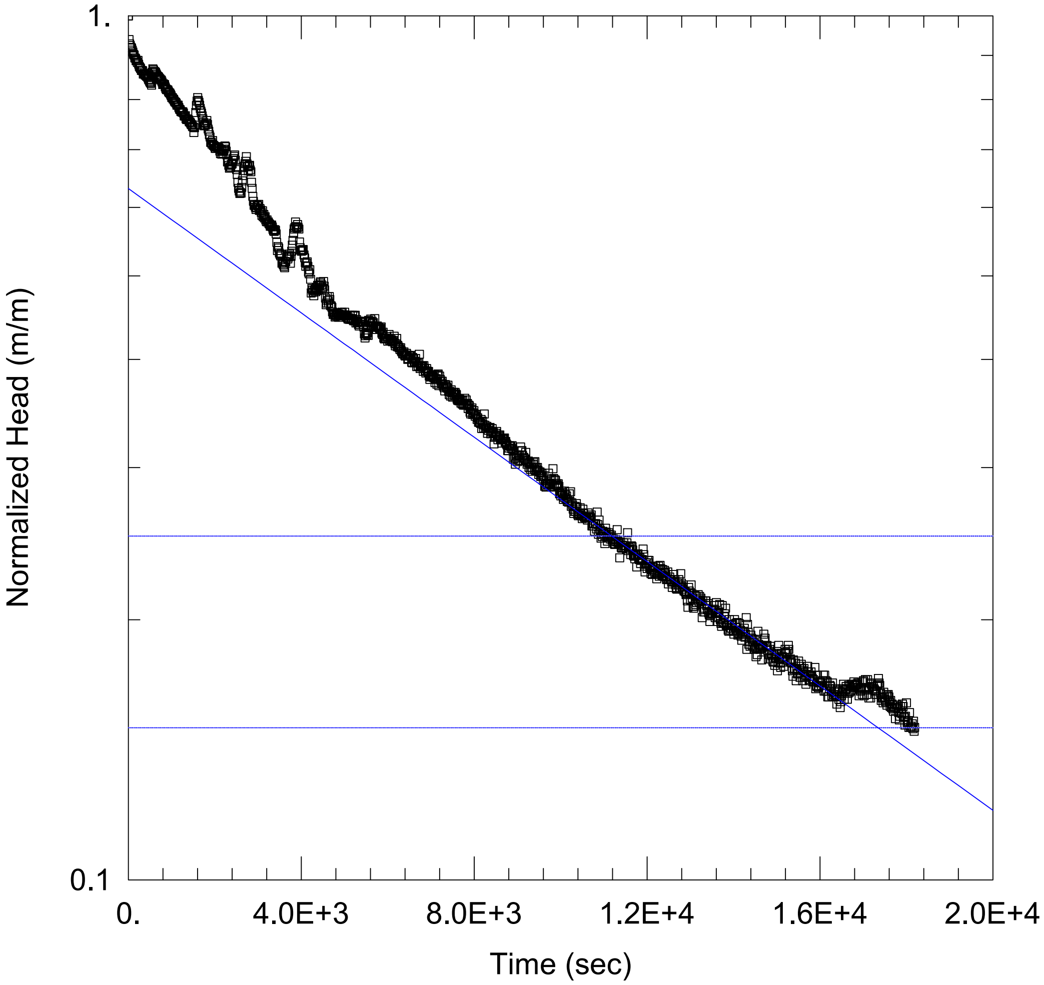
WELL DATA (MW0C)

Initial Displacement: 0.1959 m
Total Well Penetration Depth: 3.3 m
Casing Radius: 0.045 m
Static Water Column Height: 3.27 m
Screen Length: 1. m
Well Radius: 0.131 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.896E-7 m/sec
y0 = 0.1381 m



MW0C - FHT1

Data Set: G:\...\MW0C_FHT1_H.aqt
Date: 12/07/22 Time: 11:19:16

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW0C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 3.27 m
Anisotropy Ratio (Kz/Kr): 1.

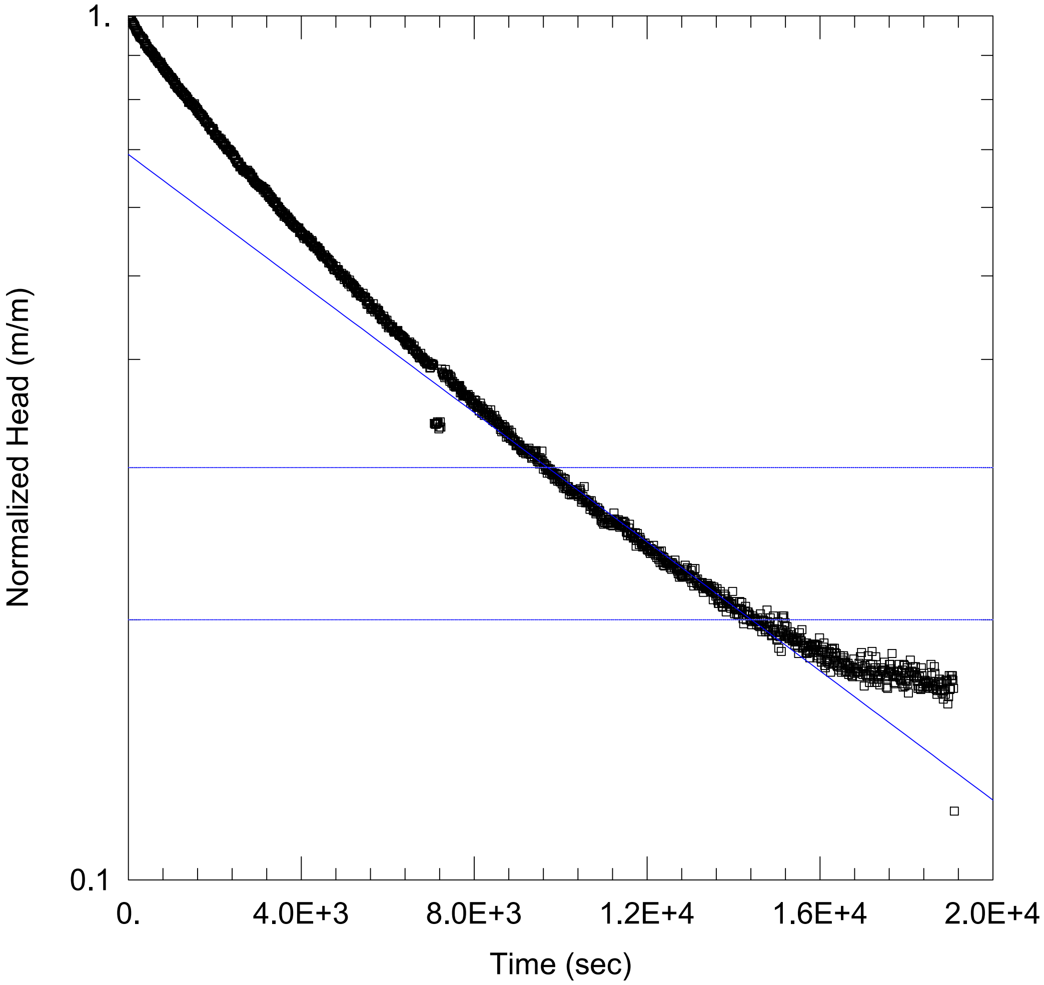
WELL DATA (MW0C)

Initial Displacement: 0.1959 m
Static Water Column Height: 3.27 m
Total Well Penetration Depth: 3.3 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.131 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.29E-7 m/sec
y0 = 0.1236 m



MW0C - FHT2

Data Set: G:\...\MW0C_FHT2_BR.aqt
Date: 12/07/22 Time: 11:19:56

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW0C
Test Date: 10/11/2022

AQUIFER DATA

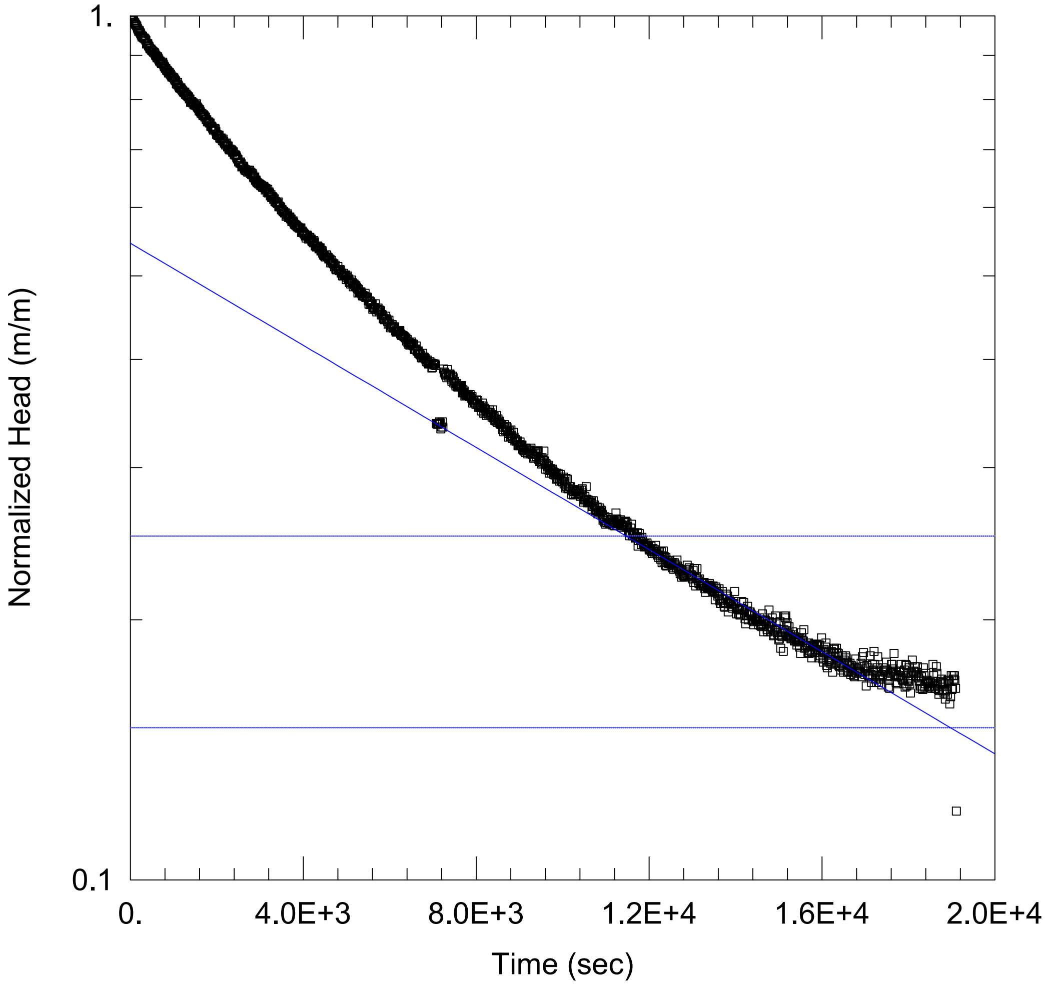
Saturated Thickness: 3.27 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW0C)

Initial Displacement: 0.1915 m
Static Water Column Height: 3.27 m
Total Well Penetration Depth: 3.3 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.131 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.783E-7 m/sec
y0 = 0.1324 m



MW0C - FHT2

Data Set: G:\...\MW0C_FHT2_H.aqt
Date: 12/07/22 Time: 11:20:34

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW0C
Test Date: 10/11/2022

AQUIFER DATA

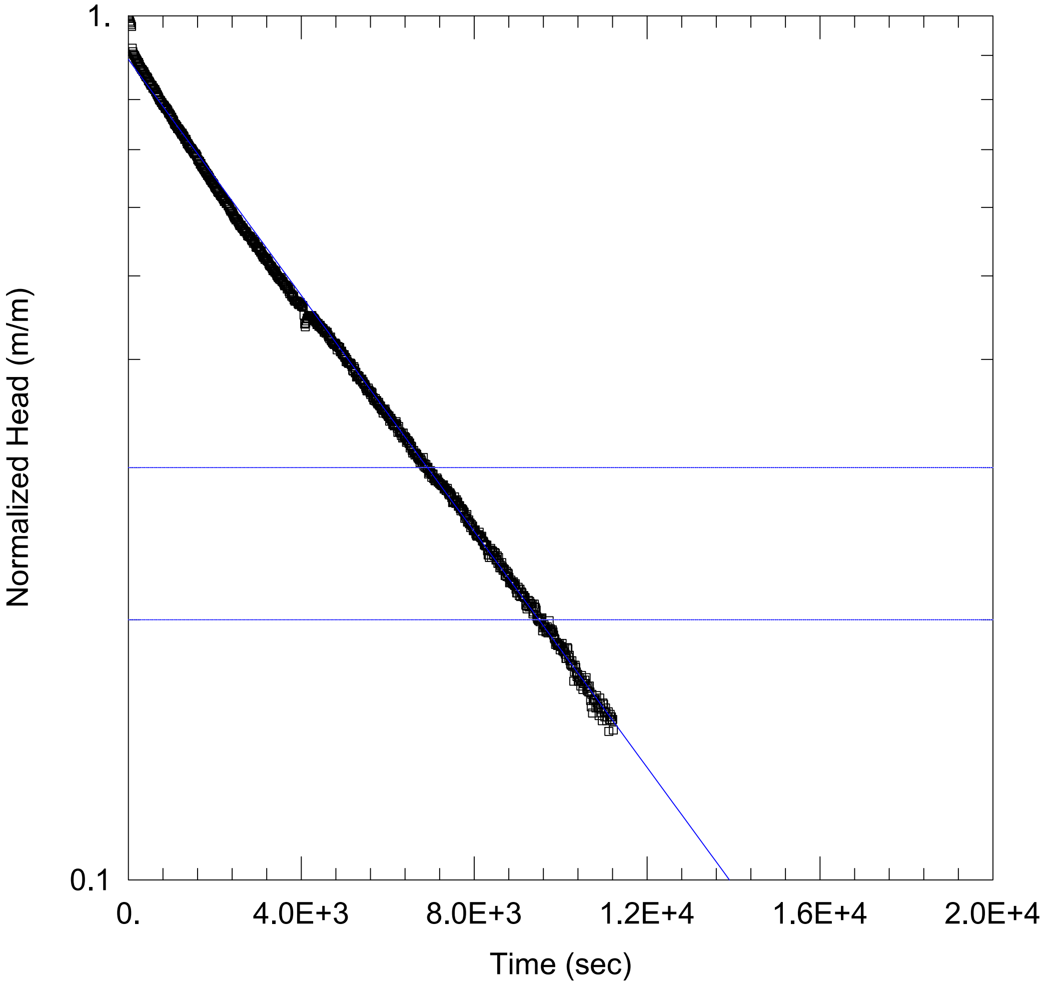
Saturated Thickness: 3.27 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW0C)

Initial Displacement: 0.1915 m
Total Well Penetration Depth: 3.3 m
Casing Radius: 0.045 m
Static Water Column Height: 3.27 m
Screen Length: 1. m
Well Radius: 0.131 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 1.881E-7 m/sec
y0 = 0.1045 m



MW0C - RHT1

Data Set: G:\...\MW0C_RHT1_BR.aqt
Date: 12/07/22 Time: 11:21:06

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW0C
Test Date: 10/11/2022

AQUIFER DATA

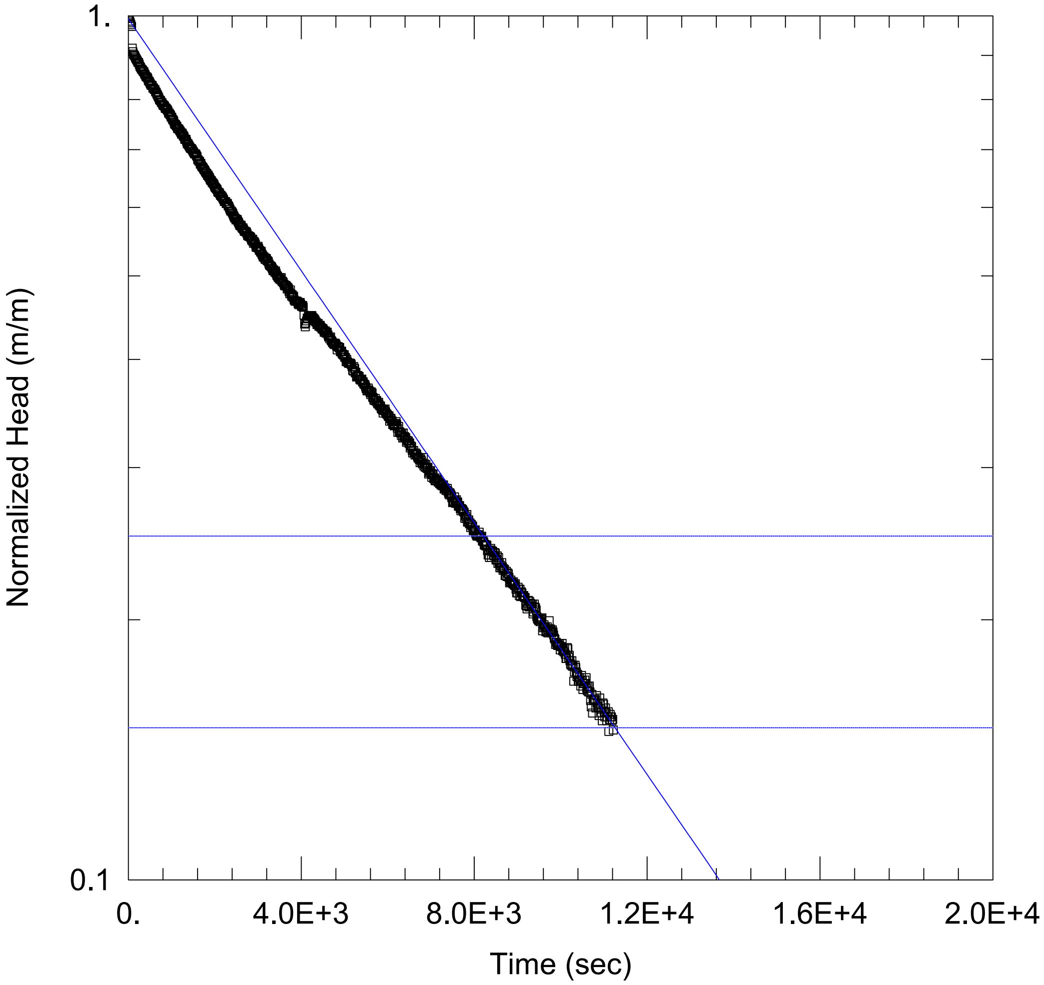
Saturated Thickness: 3.27 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW0C)

Initial Displacement: 0.1885 m
Static Water Column Height: 3.27 m
Total Well Penetration Depth: 3.3 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.131 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 3.259E-7 m/sec
y0 = 0.1678 m



MW0C - RHT1

Data Set: G:\...\MW0C_RHT1_H.aqt
Date: 12/07/22
Time: 11:21:42

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW0C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 3.27 m
Anisotropy Ratio (Kz/Kr): 1.

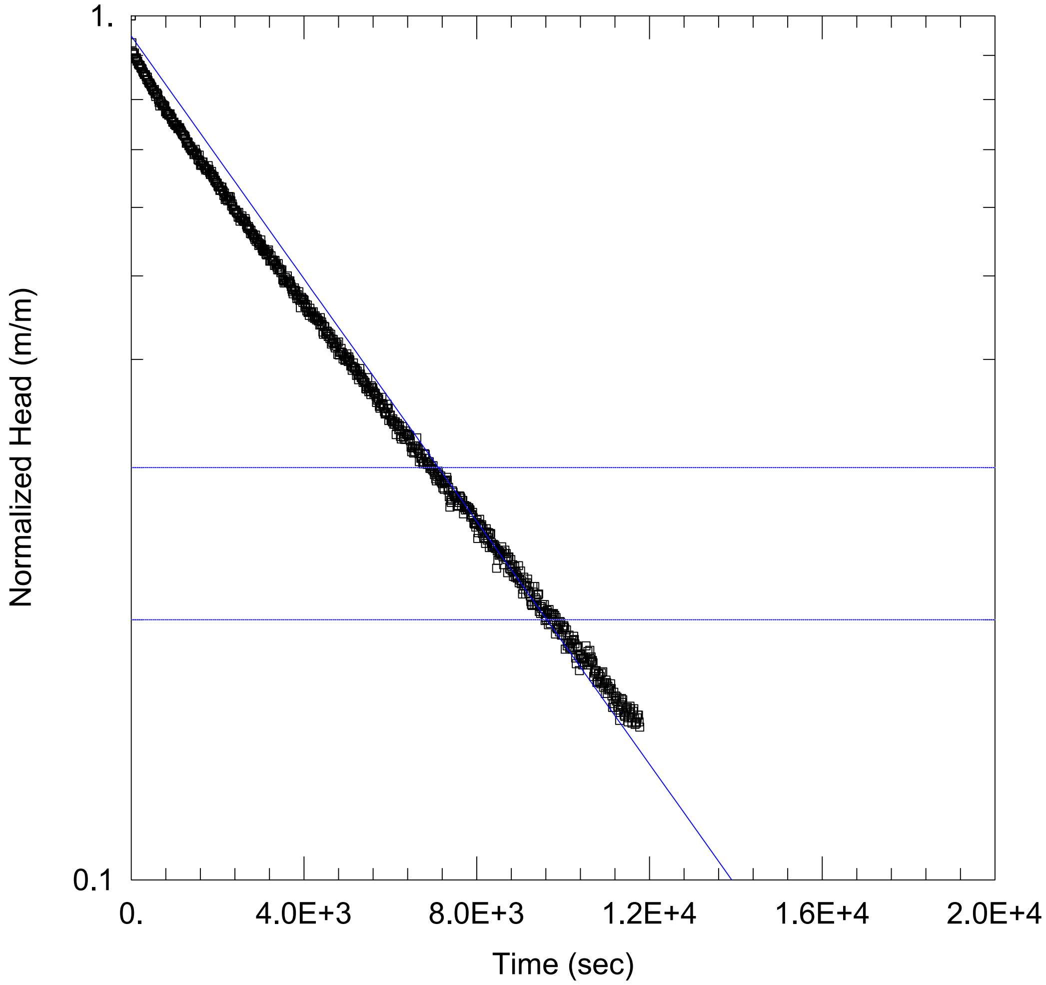
WELL DATA (MW0C)

Initial Displacement: 0.1885 m
Static Water Column Height: 3.27 m
Total Well Penetration Depth: 3.3 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.131 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 4.638E-7 m/sec
y0 = 0.1869 m



MW0C - RHT2

Data Set: G:\...\MW0C_RHT2_BR.aqt
Date: 12/07/22 Time: 11:22:13

PROJECT INFORMATION

Company: DCC
Client: GILF
Project: 12547621
Test Well: MW0C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 3.27 m
Anisotropy Ratio (Kz/Kr): 1.

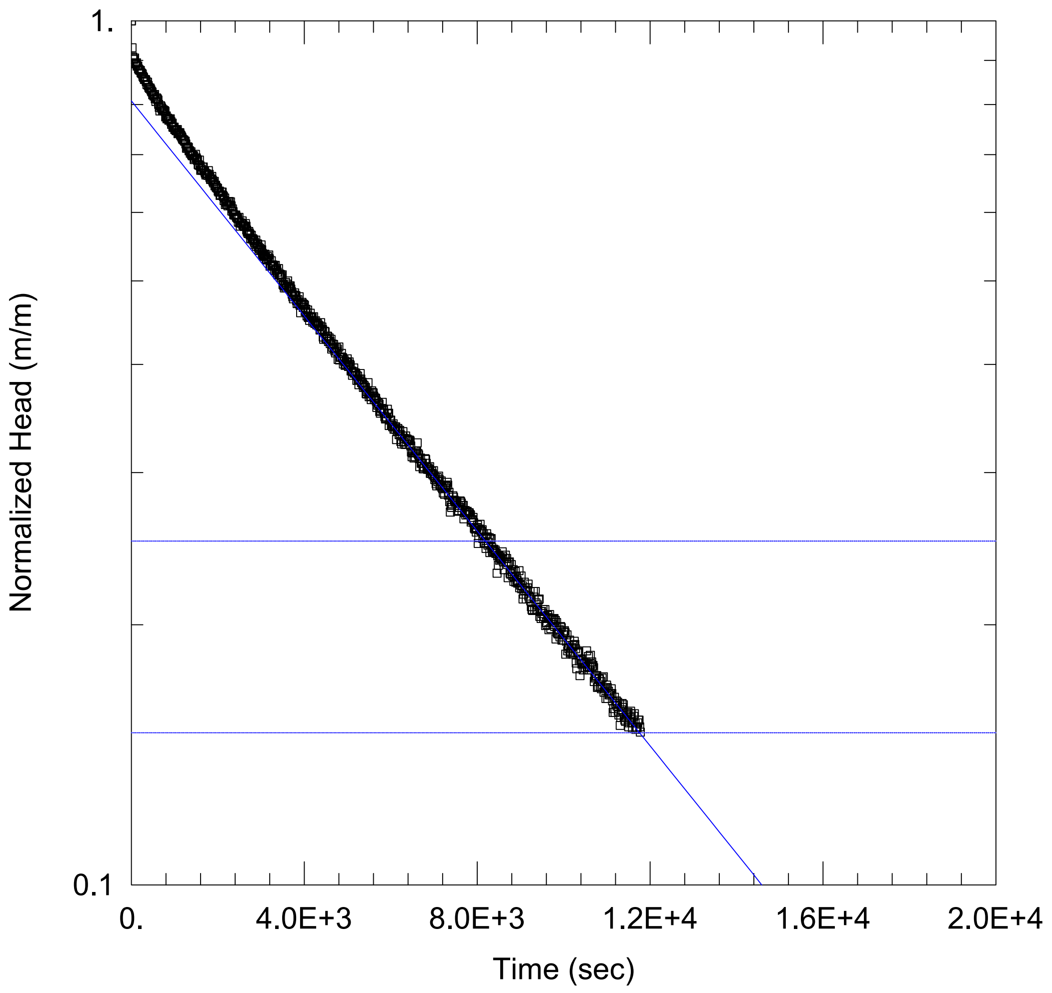
WELL DATA (MW0C)

Initial Displacement: 0.1844 m
Total Well Penetration Depth: 3.3 m
Casing Radius: 0.045 m
Static Water Column Height: 3.27 m
Screen Length: 1. m
Well Radius: 0.131 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.351E-7 m/sec
y0 = 0.1747 m



MW0C - RHT2

Data Set: G:\...\MW0C_RHT2_H.aqt
Date: 12/07/22 Time: 11:23:10

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW0C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 3.27 m
Anisotropy Ratio (Kz/Kr): 1.

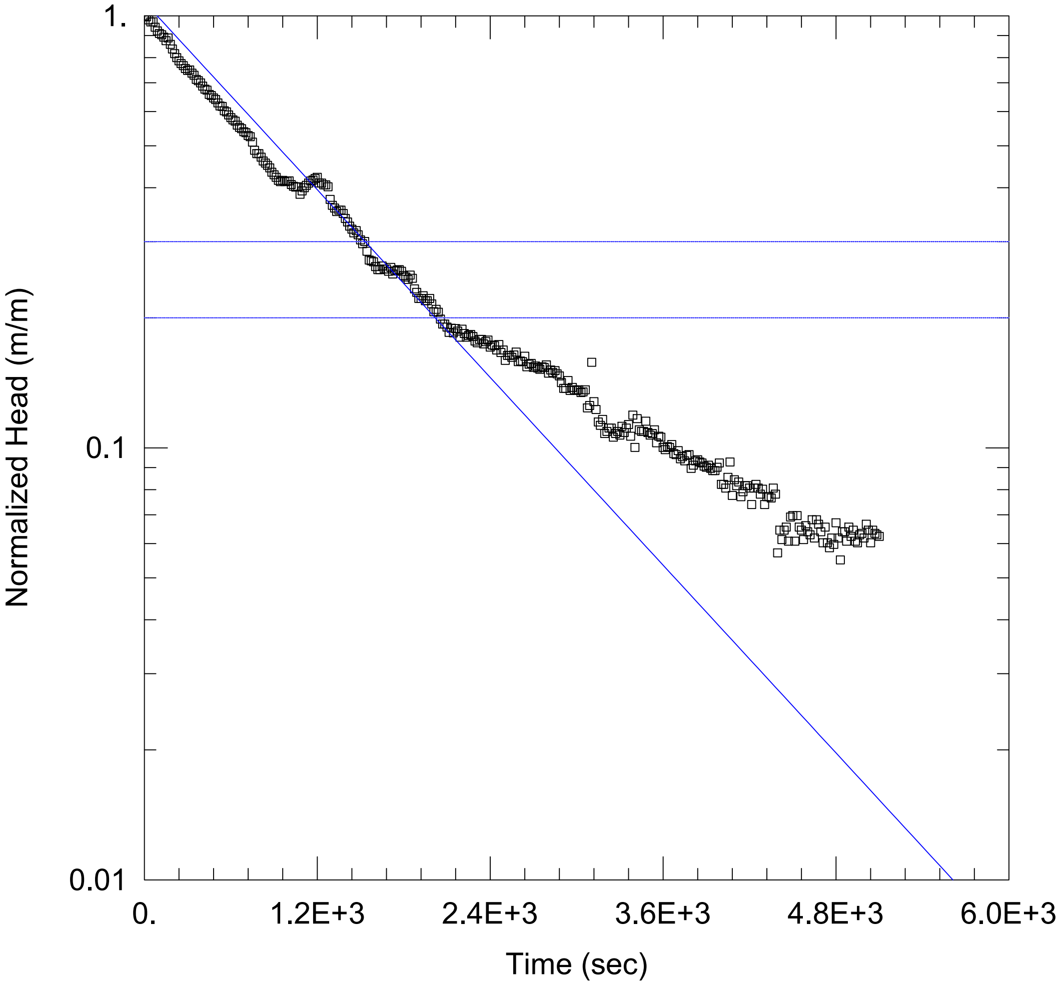
WELL DATA (MW0C)

Initial Displacement: 0.1844 m
Total Well Penetration Depth: 3.3 m
Casing Radius: 0.045 m
Static Water Column Height: 3.27 m
Screen Length: 1. m
Well Radius: 0.131 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 3.959E-7 m/sec
y0 = 0.1489 m



MW1C FHT01

Data Set: G:\...\MW1C_FHT1_BR.aqt

Date: 12/07/22 Time: 11:25:50

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW1C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 4.56 m
Anisotropy Ratio (Kz/Kr): 1.

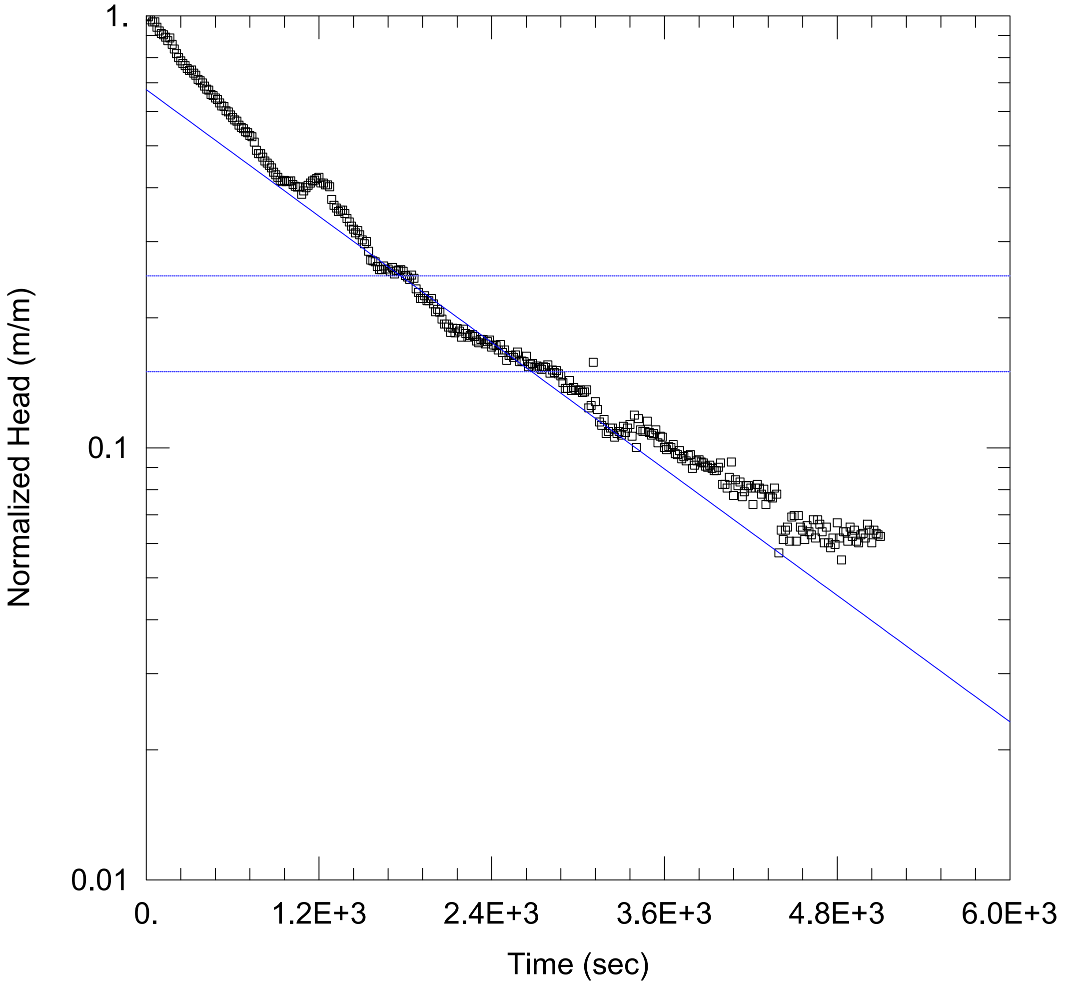
WELL DATA (MW1C)

Initial Displacement: 0.1908 m
Static Water Column Height: 4.56 m
Total Well Penetration Depth: 6.05 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.928E-6 m/sec
y0 = 0.2054 m



MW1C FHT01

Data Set: G:\...\MW1C_FHT1_H.aqt
Date: 12/07/22 Time: 11:26:36

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW1C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 4.56 m
Anisotropy Ratio (Kz/Kr): 1.

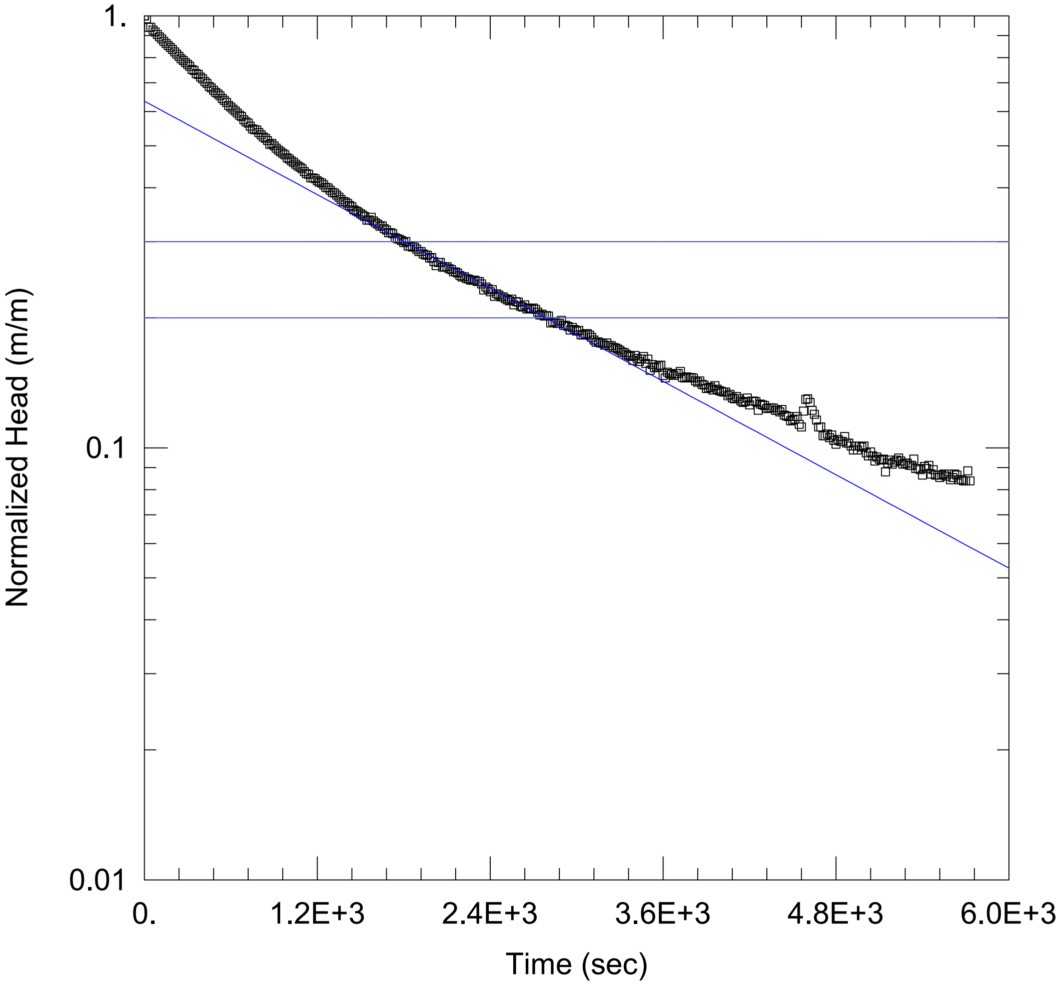
WELL DATA (MW1C)

Initial Displacement: 0.1908 m
Static Water Column Height: 4.56 m
Total Well Penetration Depth: 6.05 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.539E-6 m/sec
y0 = 0.1287 m



MW1C FHT02

Data Set: G:\...\MW1C_FHT2_BR.aqt
Date: 12/07/22 Time: 11:32:11

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW1C
Test Date: 10/11/2022

AQUIFER DATA

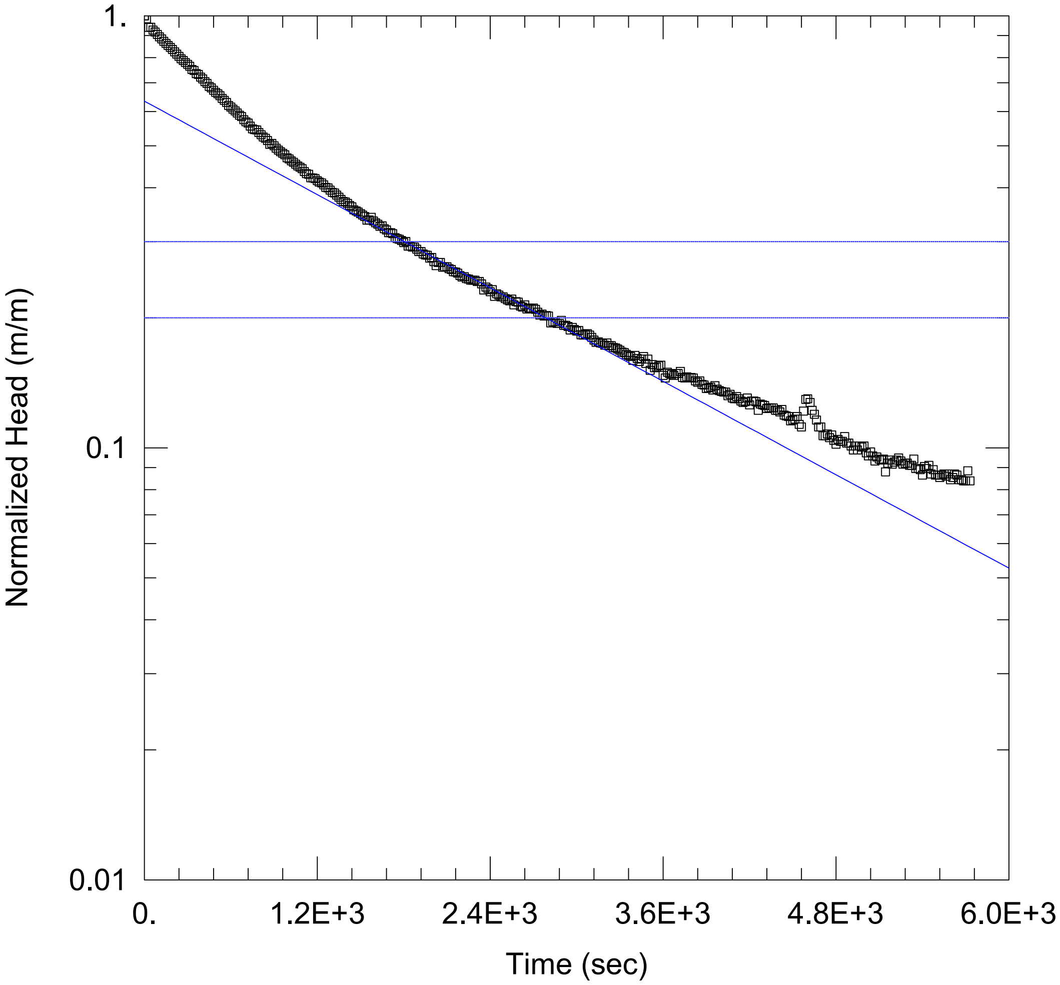
Saturated Thickness: 4.56 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW1C)

Initial Displacement: 0.1932 m
Static Water Column Height: 4.56 m
Total Well Penetration Depth: 6.05 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 9.589E-7 m/sec
y0 = 0.1226 m



MW1C FHT02

Data Set: G:\...\MW1C_FHT2_H.aqt
Date: 12/07/22 Time: 11:34:30

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW1C
Test Date: 10/11/2022

AQUIFER DATA

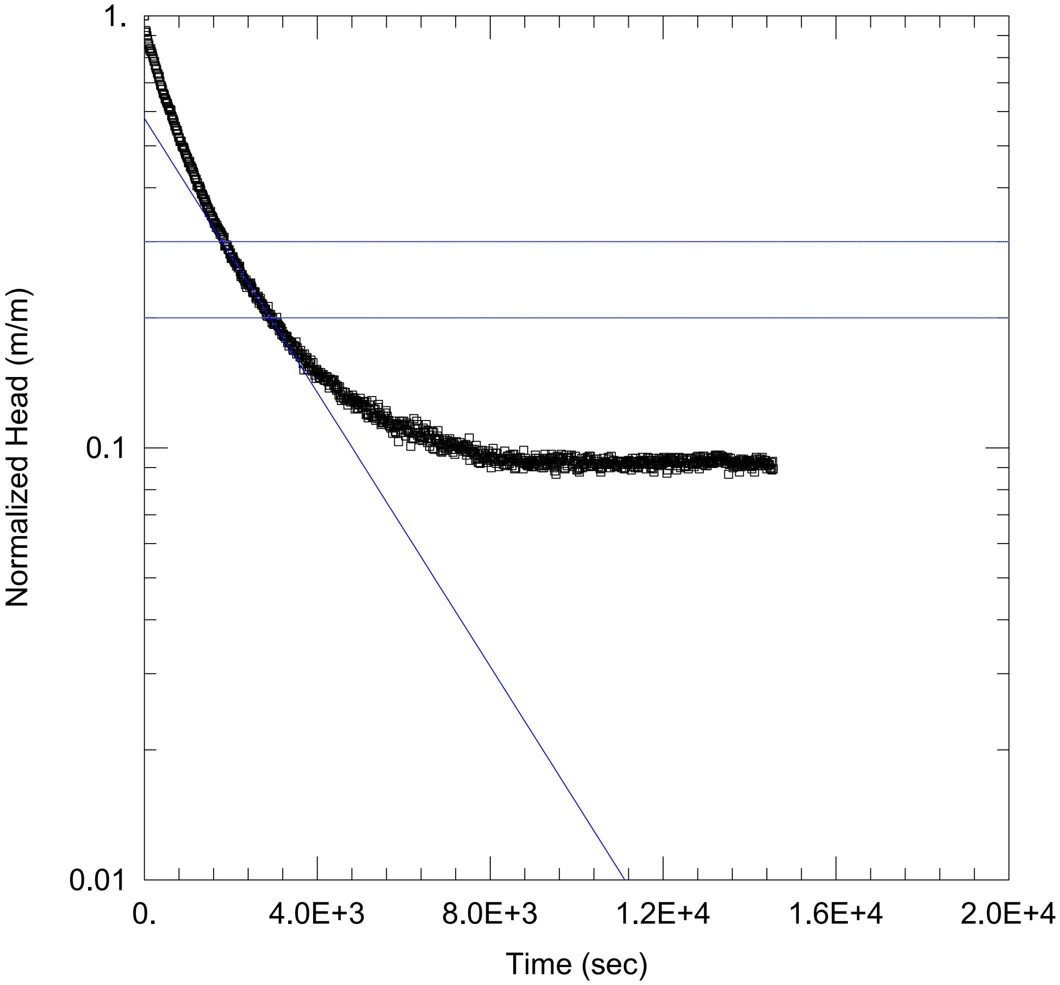
Saturated Thickness: 4.56 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW1C)

Initial Displacement: 0.1932 m
Total Well Penetration Depth: 6.05 m
Casing Radius: 0.045 m
Static Water Column Height: 4.56 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 9.589E-7 m/sec
y0 = 0.1226 m



MW1C RHT01

Data Set: G:\...\MW1C_RHT1_BR.aqt
Date: 12/07/22　Time: 11:28:53

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW1C
Test Date: 10/11/2022

AQUIFER DATA

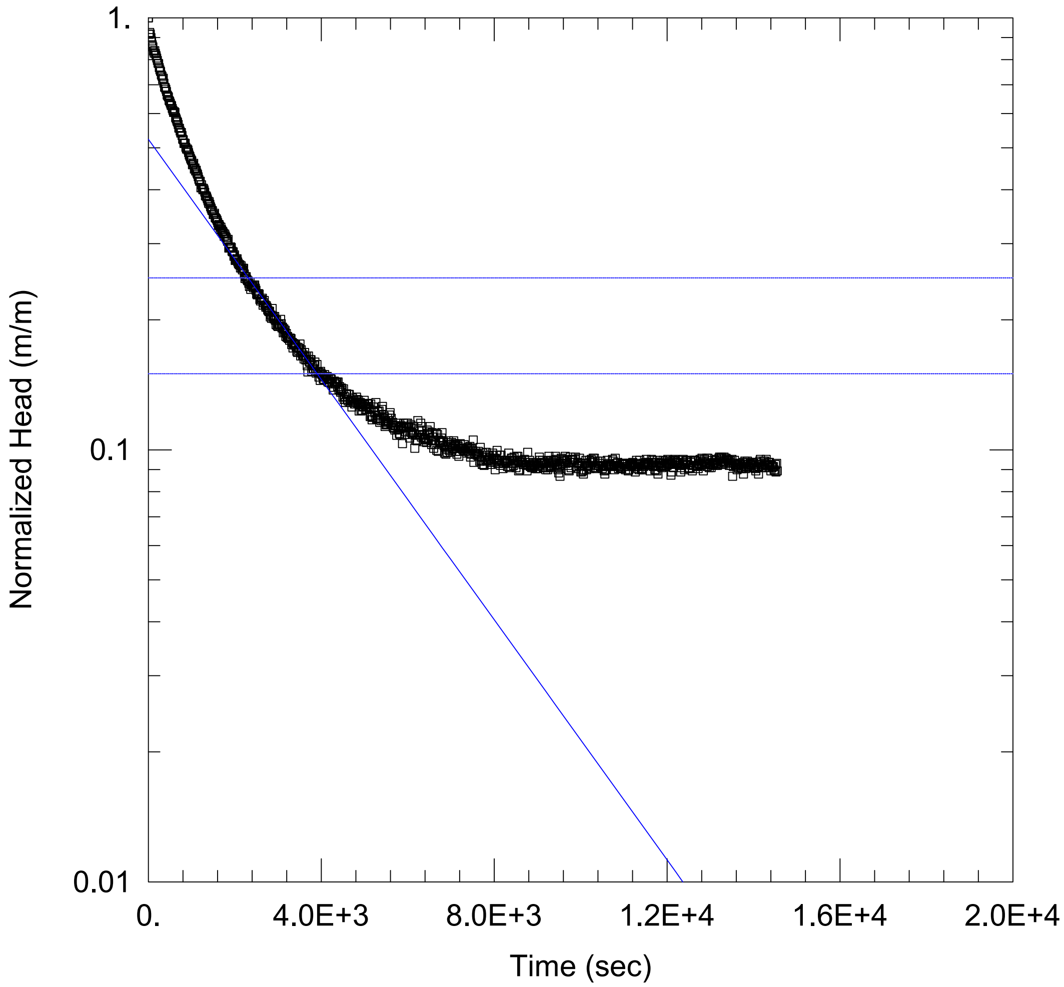
Saturated Thickness: 4.56 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW1C)

Initial Displacement: 0.1935 m
Static Water Column Height: 4.56 m
Total Well Penetration Depth: 6.05 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 8.441E-7 m/sec
y0 = 0.112 m



MW1C RHT01

Data Set: G:\...\MW1C_RHT1_H.aqt
Date: 12/07/22 Time: 11:30:01

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW1C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 4.56 m
Anisotropy Ratio (Kz/Kr): 1.

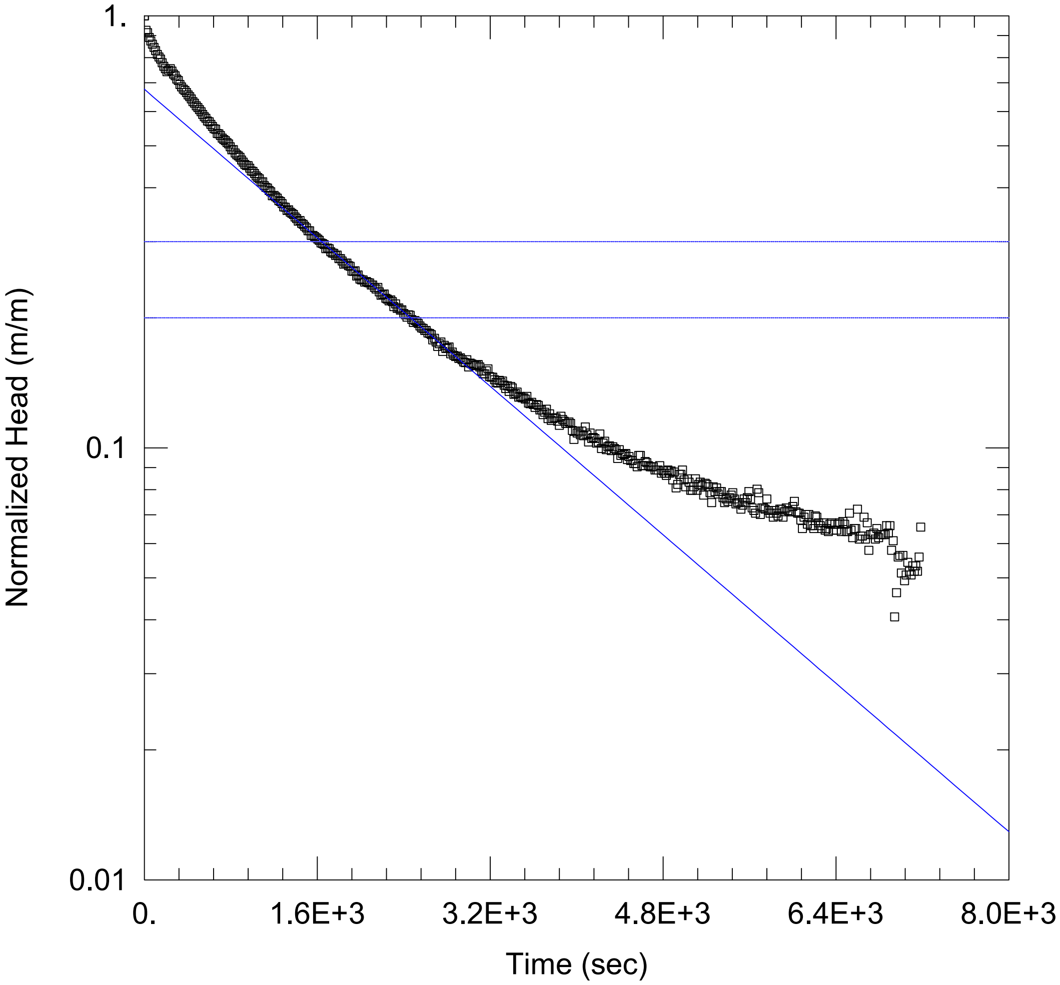
WELL DATA (MW1C)

Initial Displacement: 0.1935 m
Total Well Penetration Depth: 6.05 m
Casing Radius: 0.045 m
Static Water Column Height: 4.56 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 8.775E-7 m/sec
y0 = 0.1013 m



MW1C RHT02

Data Set: G:\...\MW1C_RHT2_BR.aqt
Date: 12/07/22 Time: 11:35:39

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW1C
Test Date: 10/11/2022

AQUIFER DATA

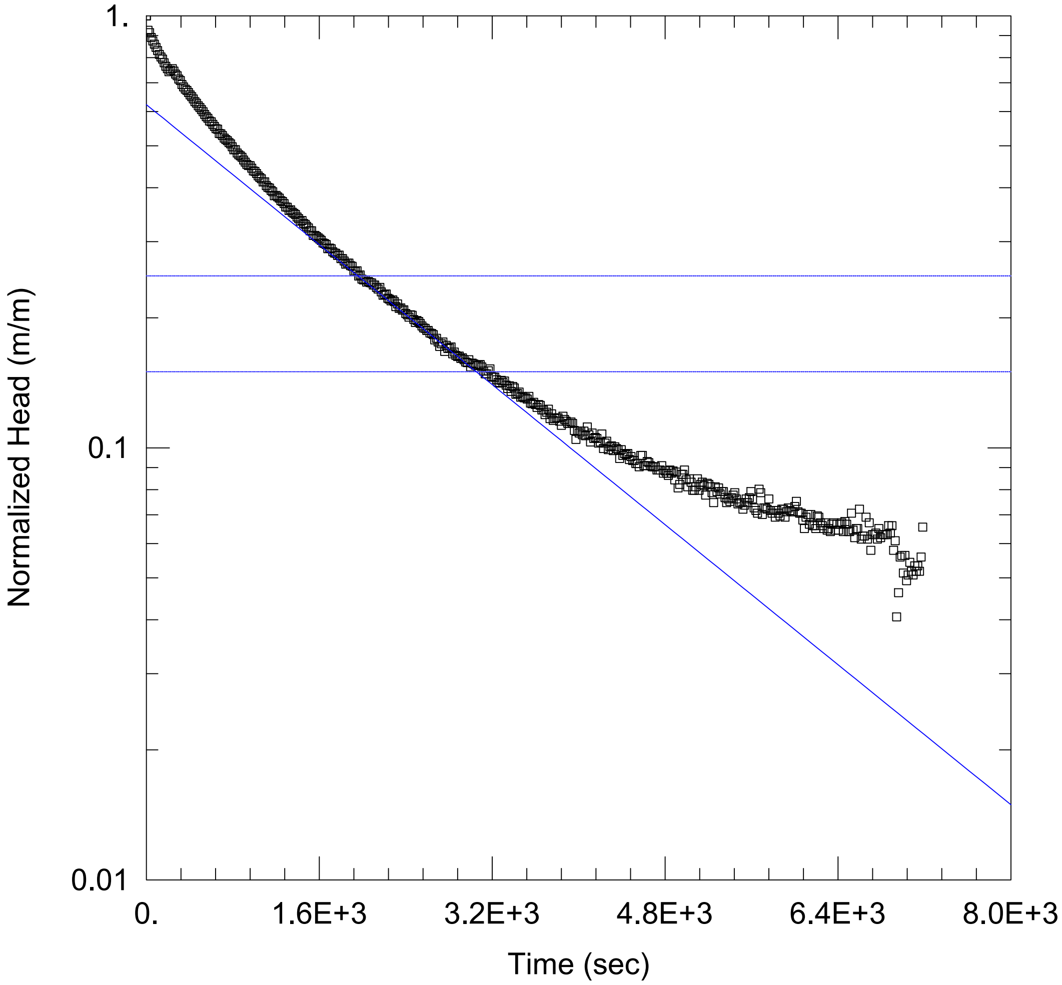
Saturated Thickness: 4.56 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW1C)

Initial Displacement: 0.1969 m
Static Water Column Height: 4.56 m
Total Well Penetration Depth: 6.05 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.144E-6 m/sec
y0 = 0.1331 m



MW1C RHT02

Data Set: G:\...\MW1C_RHT2_H.aqt
Date: 12/07/22
Time: 11:36:30

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW1C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 4.56 m
Anisotropy Ratio (Kz/Kr): 1.

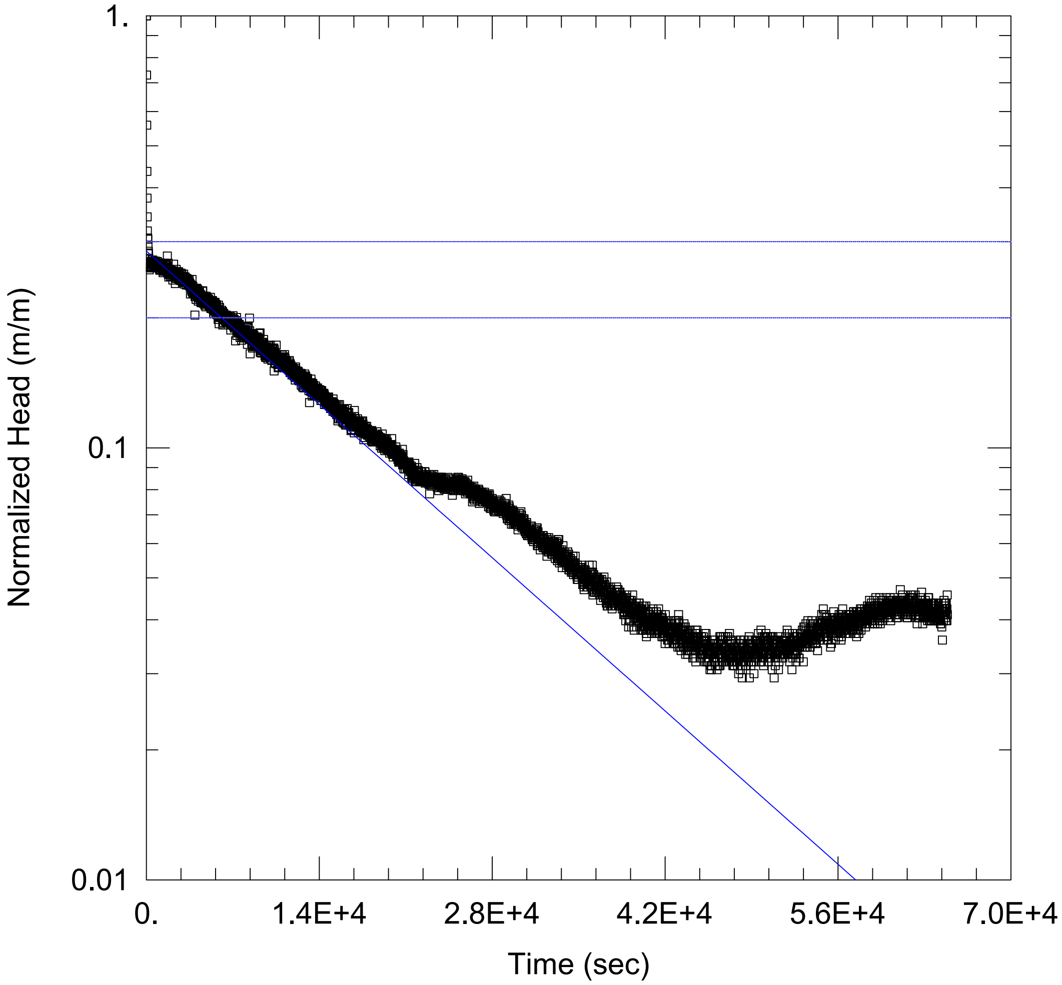
WELL DATA (MW1C)

Initial Displacement: 0.1969 m
Static Water Column Height: 4.56 m
Total Well Penetration Depth: 6.05 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.278E-6 m/sec
y0 = 0.1226 m



MW3C - FHT01

Data Set: G:\...\MW3C_FHT1_BR.aqt
Date: 12/07/22
Time: 11:38:14

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW3C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 1.55 m
Anisotropy Ratio (Kz/Kr): 1.

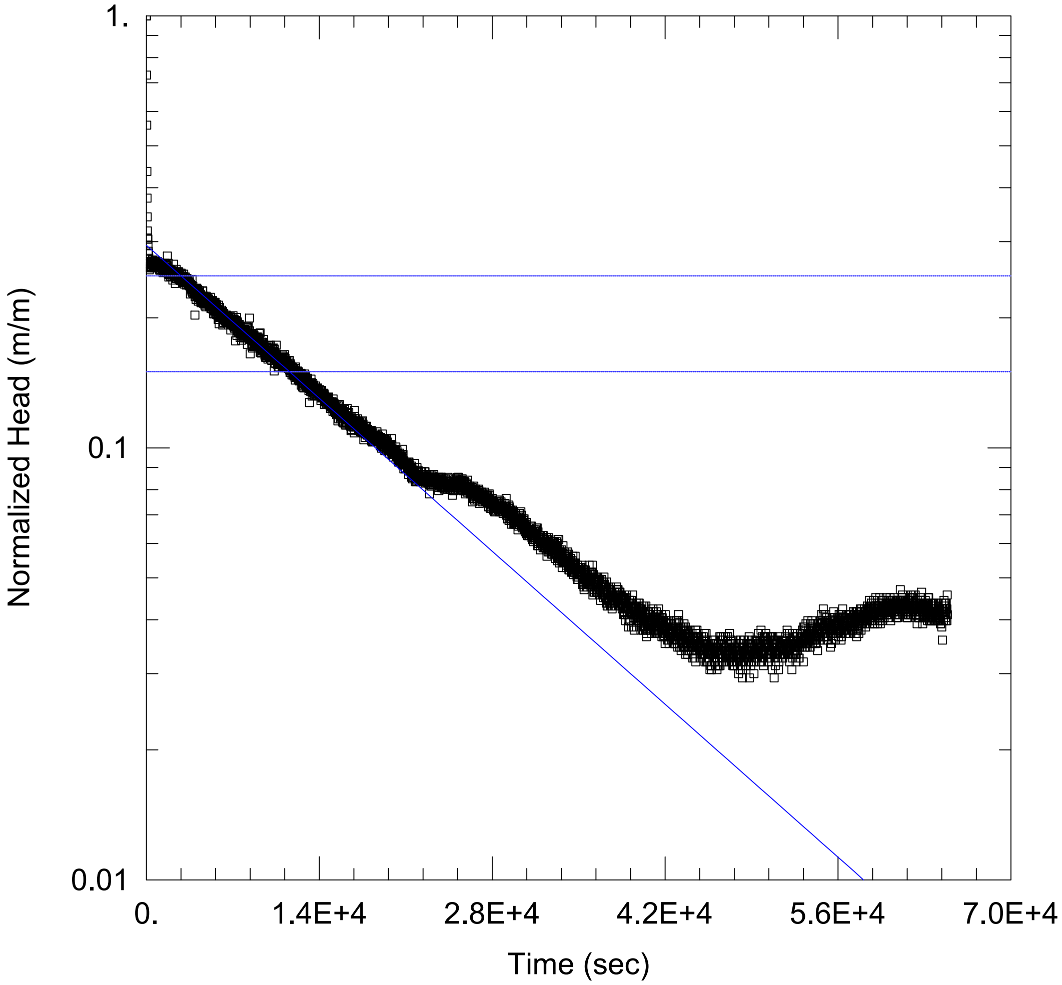
WELL DATA (MW3C)

Initial Displacement: 0.1533 m
Static Water Column Height: 1.55 m
Total Well Penetration Depth: 1.92 m
Screen Length: 1. m
Casing Radius: 0.05 m
Well Radius: 0.13 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.313E-7 m/sec
y0 = 0.04373 m



MW3C - FHT01

Data Set: G:\...\MW3C_FHT1_H.aqt
Date: 12/07/22 Time: 11:38:42

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW3C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 1.55 m
Anisotropy Ratio (Kz/Kr): 1.

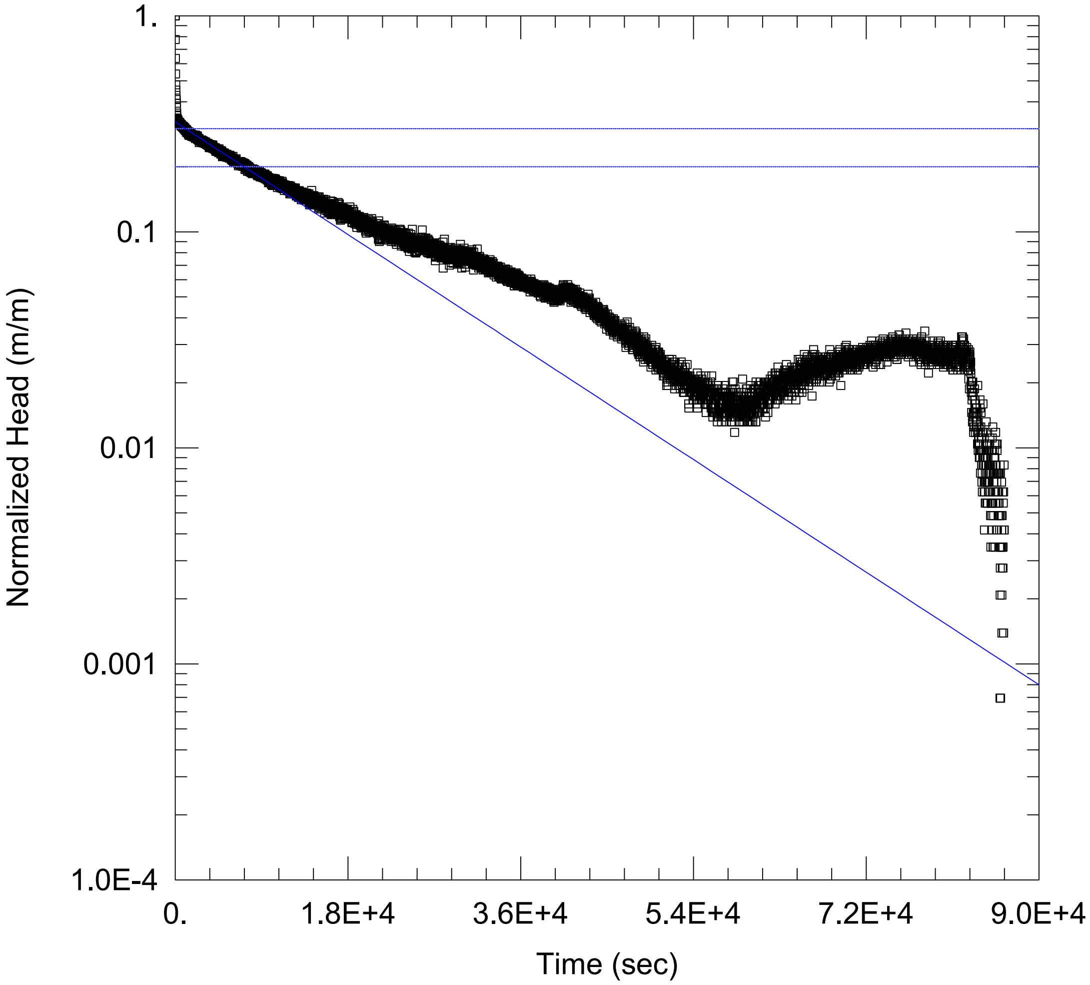
WELL DATA (MW3C)

Initial Displacement: 0.1533 m
Static Water Column Height: 1.55 m
Total Well Penetration Depth: 1.92 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.596E-7 m/sec
y0 = 0.04512 m



MW3C - FHT02

Data Set: G:\...\MW3C_FHT2_BR.aqt
Date: 12/07/22 Time: 11:40:37

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW3C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 1.55 m
Anisotropy Ratio (Kz/Kr): 1.

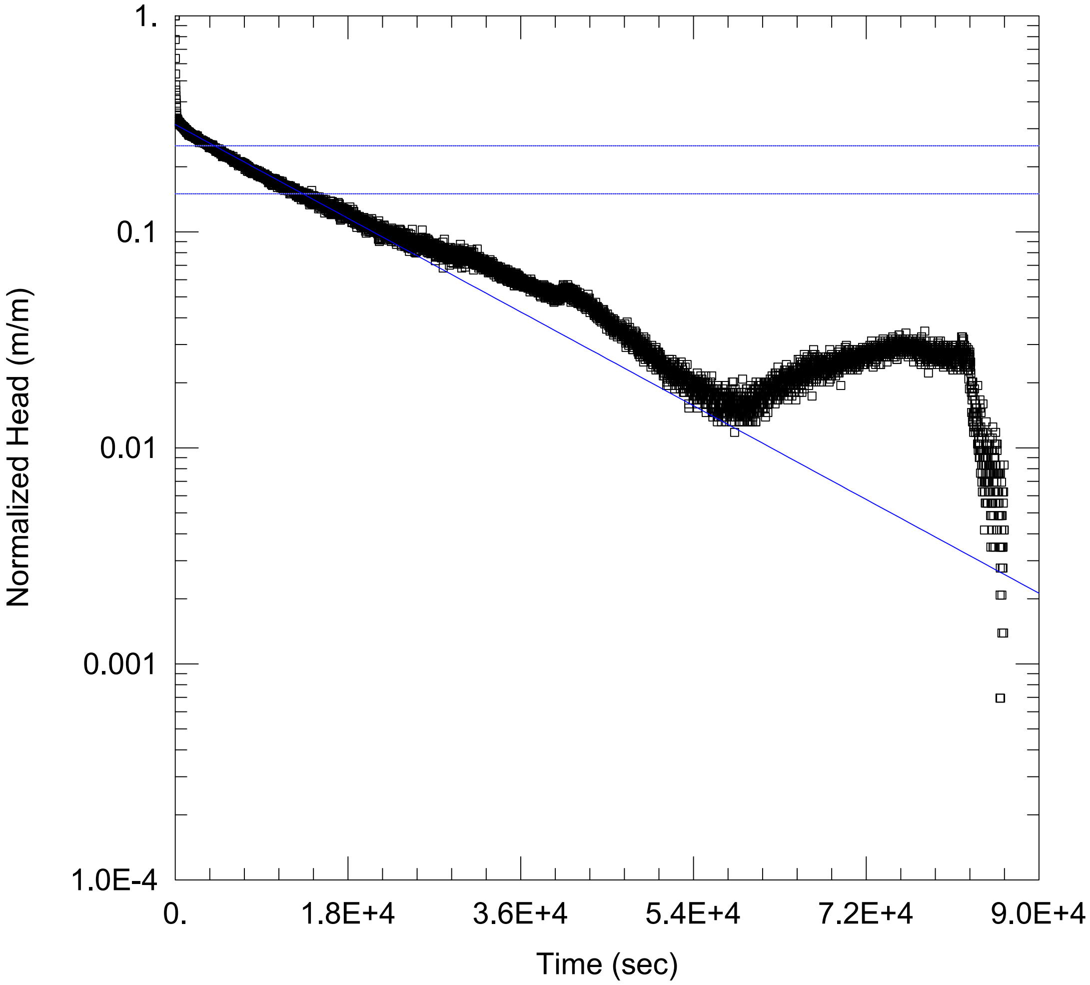
WELL DATA (MW3C)

Initial Displacement: 0.1441 m
Total Well Penetration Depth: 1.92 m
Casing Radius: 0.045 m
Static Water Column Height: 1.55 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.2E-7 m/sec
y0 = 0.04646 m



MW3C - FHT02

Data Set: G:\...\MW3C_FHT2_H.aqt
Date: 12/07/22 Time: 11:41:11

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW3C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 1.55 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW3C)

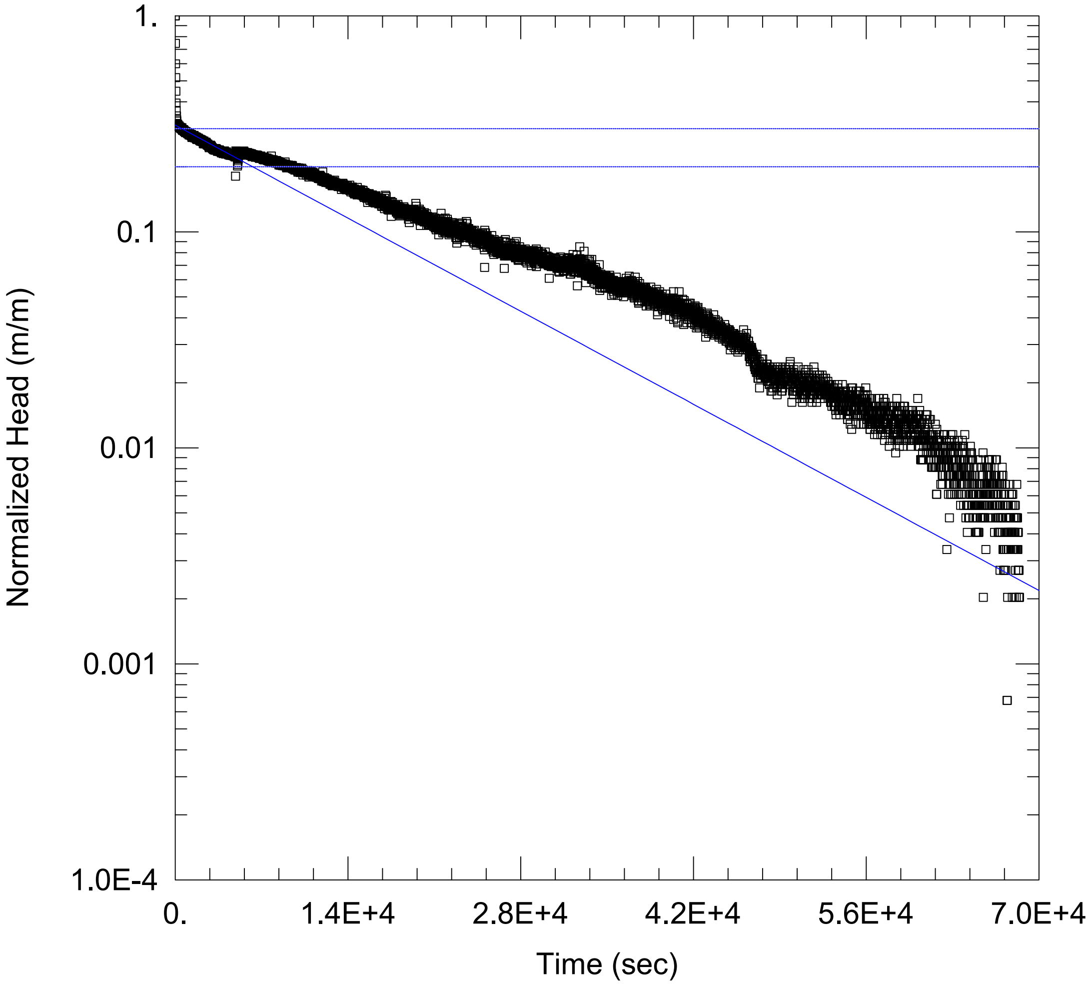
Initial Displacement: 0.1441 m
Total Well Penetration Depth: 1.92 m
Casing Radius: 0.045 m

Static Water Column Height: 1.55 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 1.522E-7 m/sec y0 = 0.04523 m



MW3C - RHT01

Data Set: G:\...\MW3C_RHT1_BR.aqt
Date: 12/07/22 Time: 11:39:24

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW3C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 1.55 m Anisotropy Ratio (Kz/Kr): 1.

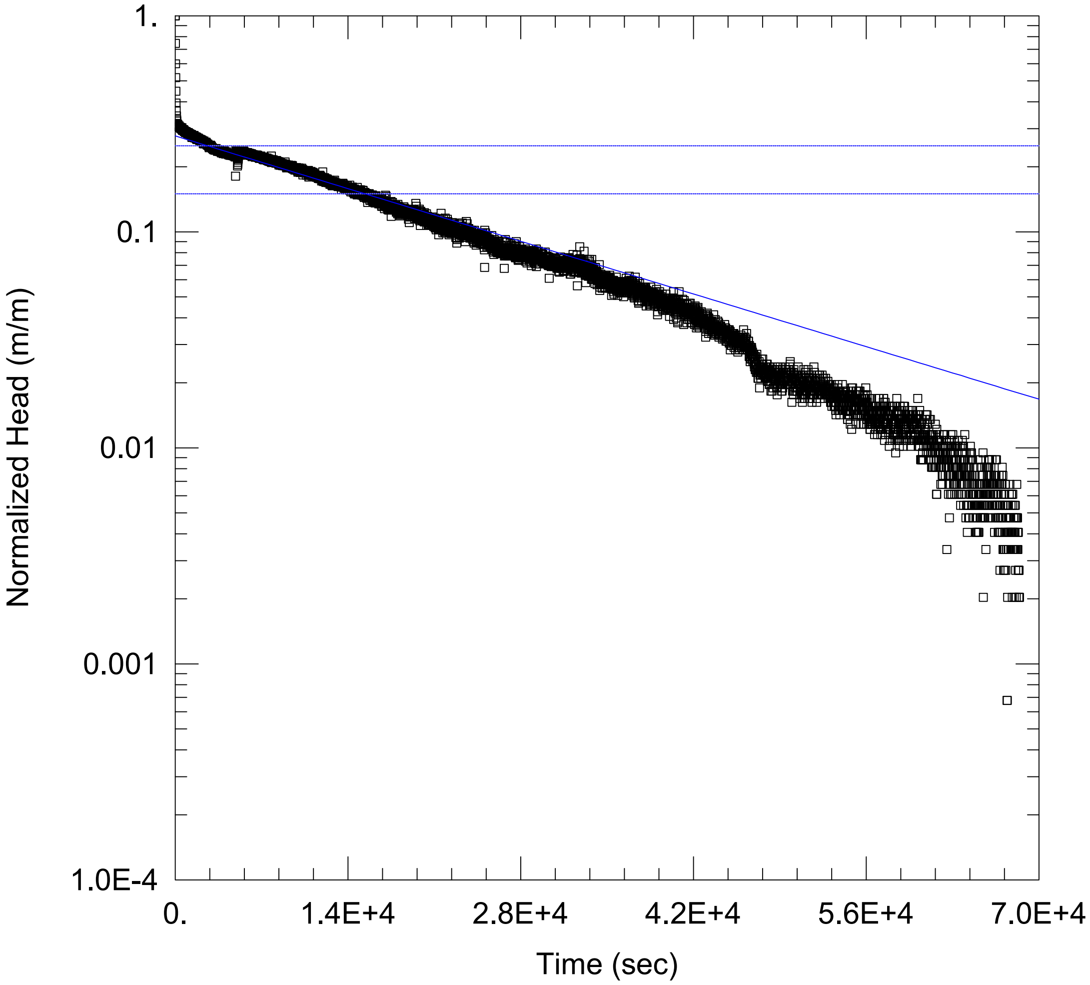
WELL DATA (MW3C)

Initial Displacement: 0.1477 m
Total Well Penetration Depth: 1.92 m
Casing Radius: 0.045 m
Static Water Column Height: 1.55 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 1.276E-7 m/sec y0 = 0.04607 m



MW3C - RHT01

Data Set: G:\...\MW3C_RHT1_H.aqt
Date: 12/07/22 Time: 11:39:51

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW3C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 1.55 m
Anisotropy Ratio (Kz/Kr): 1.

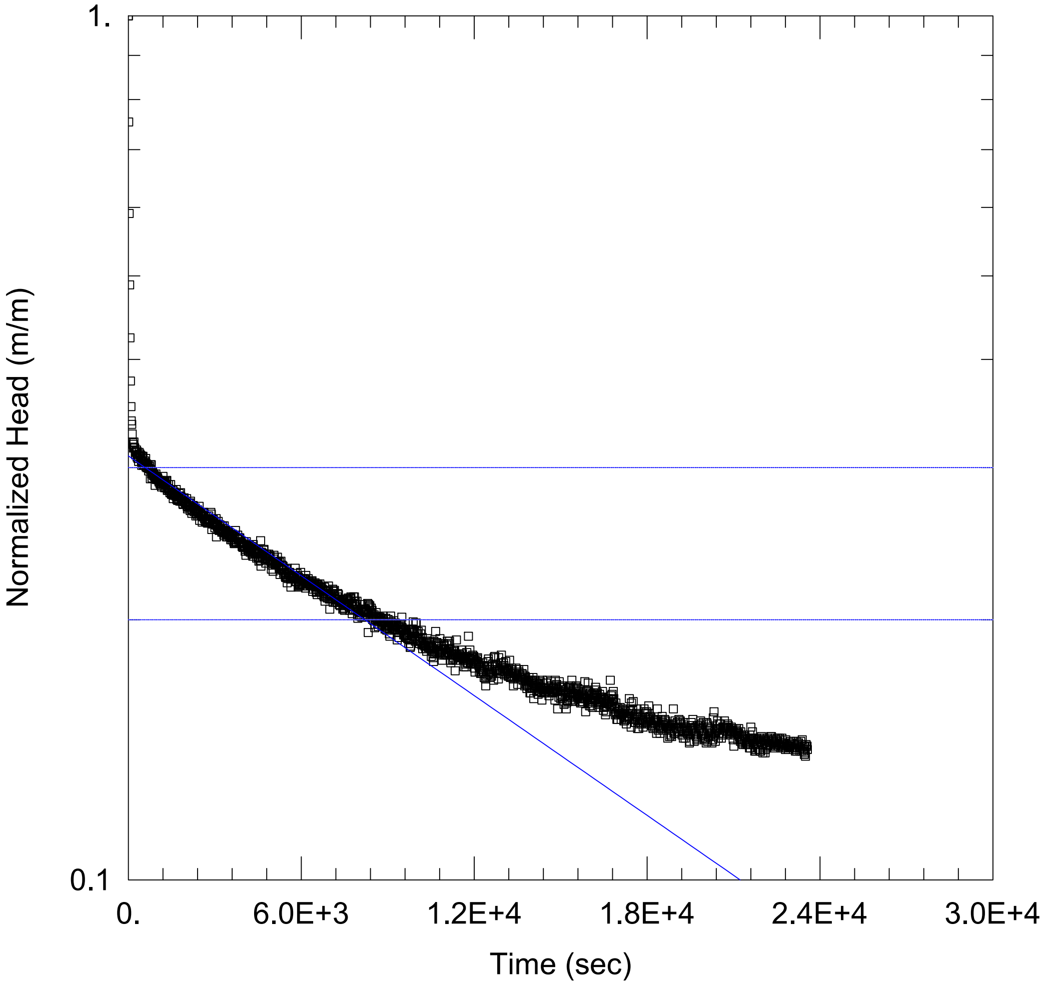
WELL DATA (MW3C)

Initial Displacement: 0.1477 m
Total Well Penetration Depth: 1.92 m
Casing Radius: 0.045 m
Static Water Column Height: 1.55 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.099E-7 m/sec
y0 = 0.04104 m



MW3C - RHT02

Data Set: G:\...\MW3C_RHT2_BR.aqt
Date: 12/07/22
Time: 11:42:41

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW3C
Test Date: 10/11/2022

AQUIFER DATA

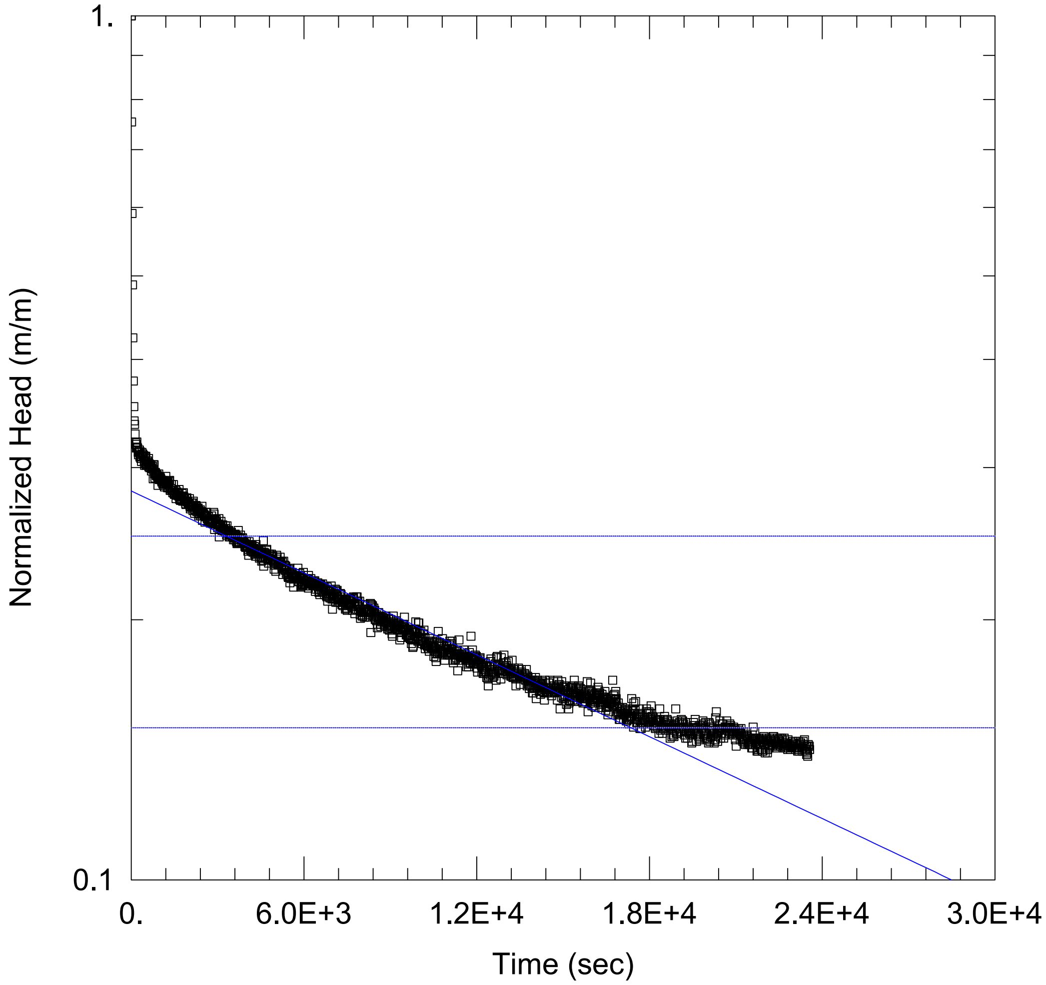
Saturated Thickness: 1.55 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW3C)

Initial Displacement: 0.1604 m
Static Water Column Height: 1.55 m
Total Well Penetration Depth: 1.92 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 9.58E-8 m/sec
y0 = 0.04964 m



MW3C - RHT02

Data Set: G:\...\MW3C_RHT2_H.aqt
Date: 12/07/22
Time: 11:43:36

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW3C
Test Date: 10/11/2022

AQUIFER DATA

Saturated Thickness: 1.55 m
Anisotropy Ratio (Kz/Kr): 1.

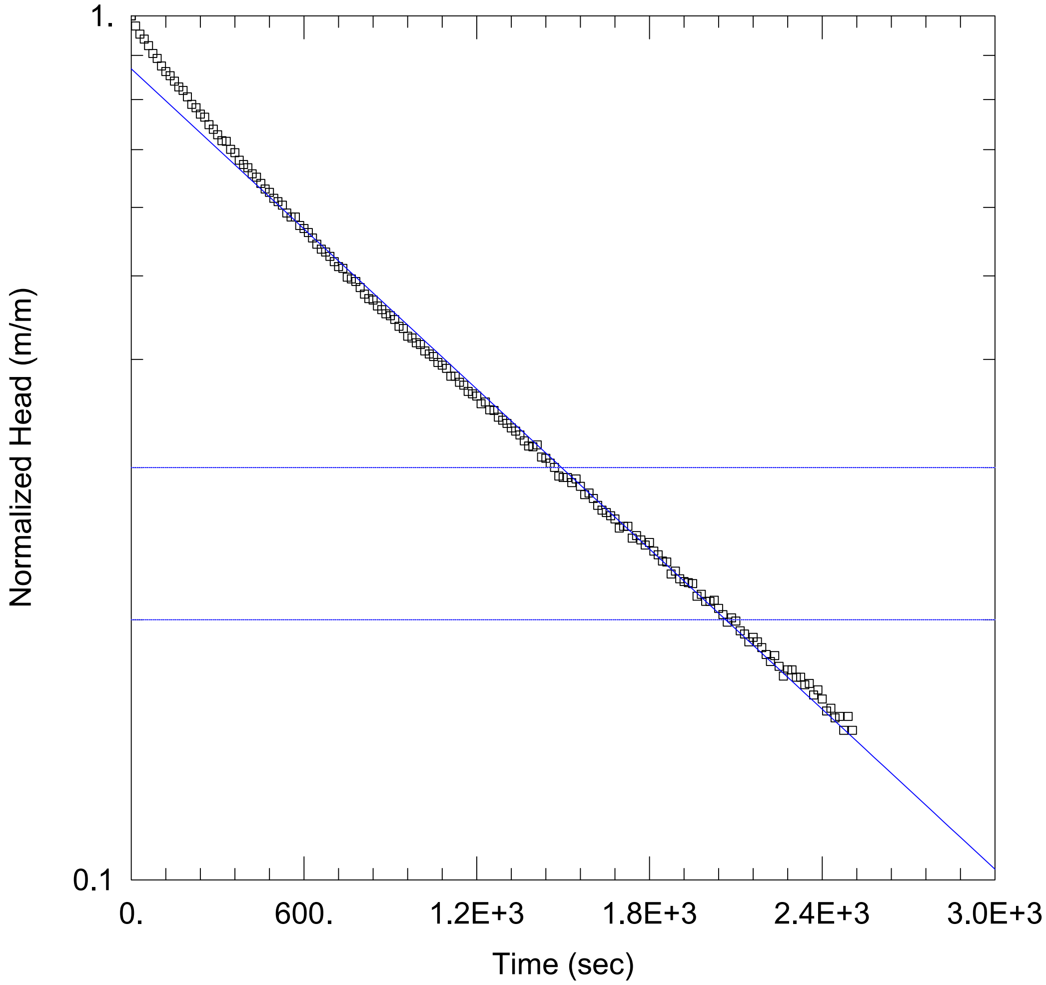
WELL DATA (MW3C)

Initial Displacement: 0.1604 m
Total Well Penetration Depth: 1.92 m
Casing Radius: 0.045 m
Static Water Column Height: 1.55 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 9.972E-8 m/sec
y0 = 0.04522 m



MW5C - FHT01

Data Set: G:\...\MW5C_FHT1_BR.aqt
Date: 12/07/22 Time: 11:46:38

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW5C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 2.71 m
Anisotropy Ratio (Kz/Kr): 1.

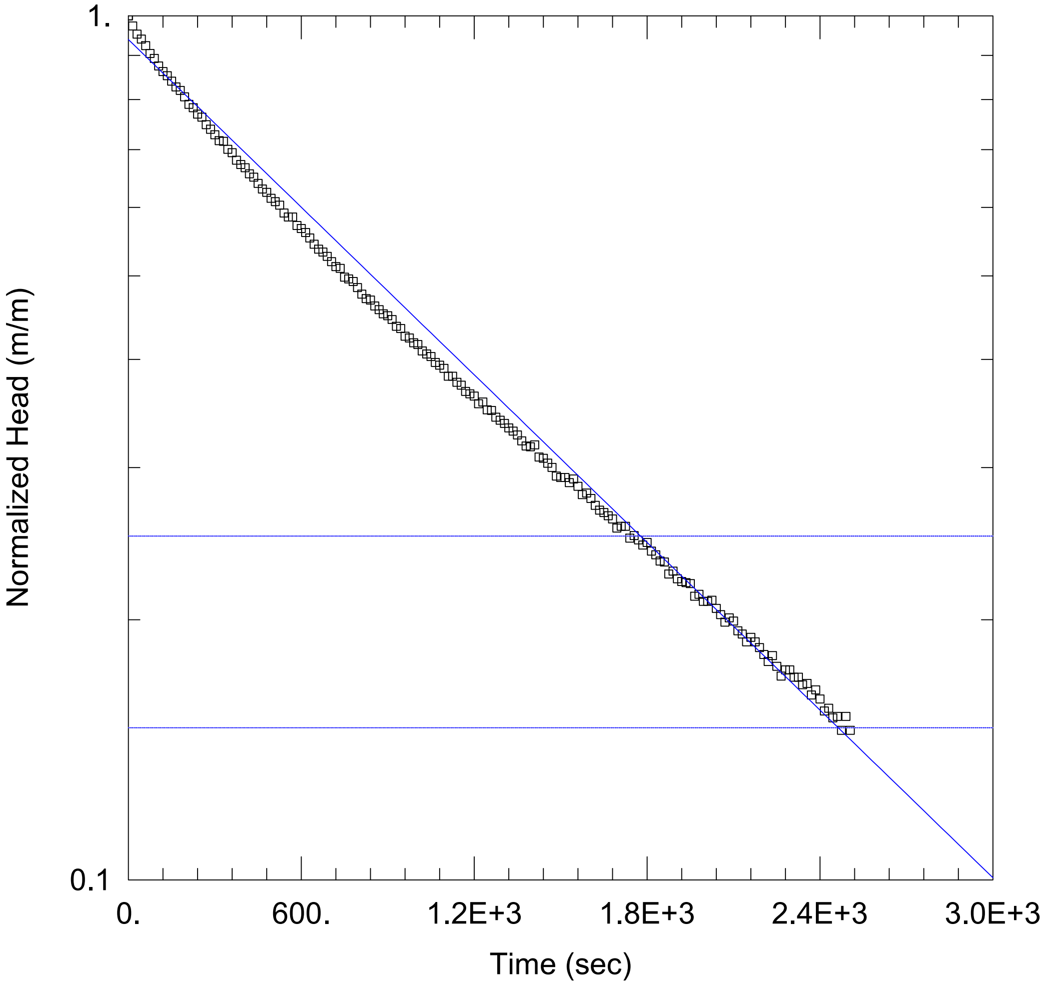
WELL DATA (New Well)

Initial Displacement: 0.1766 m
Total Well Penetration Depth: 3.34 m
Casing Radius: 0.045 m
Static Water Column Height: 2.71 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.465E-6 m/sec
y0 = 0.1533 m



MW5C - FHT01

Data Set: G:\...\MW5C_FHT1_H.aqt
Date: 12/07/22
Time: 11:47:16

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW5C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 2.71 m
Anisotropy Ratio (Kz/Kr): 1.

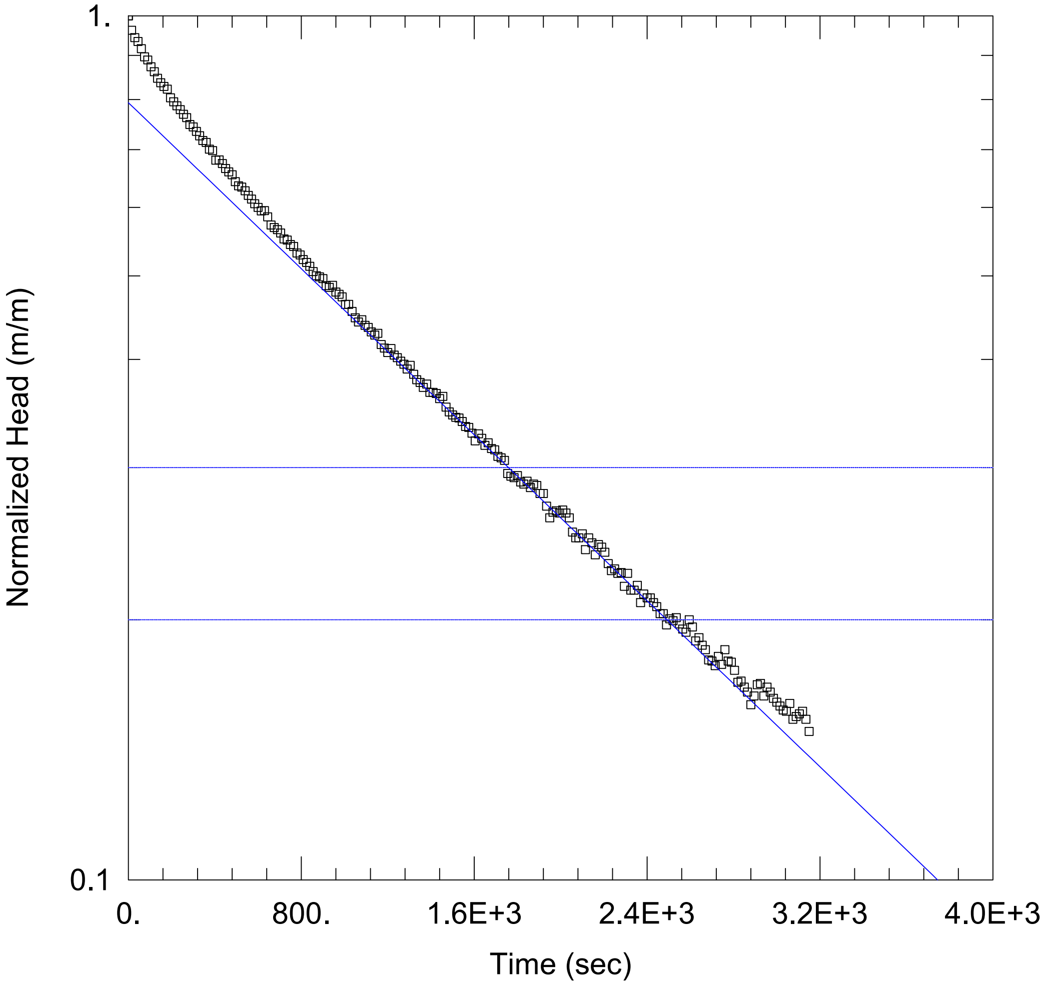
WELL DATA (New Well)

Initial Displacement: 0.1766 m
Static Water Column Height: 2.71 m
Total Well Penetration Depth: 3.34 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.041E-6 m/sec
y0 = 0.1658 m



MW5C - FHT02

Data Set: G:\...\MW5C_FHT2_BR.aqt

Date: 12/07/22 Time: 11:54:24

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW5C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 2.71 m
Anisotropy Ratio (Kz/Kr): 1.

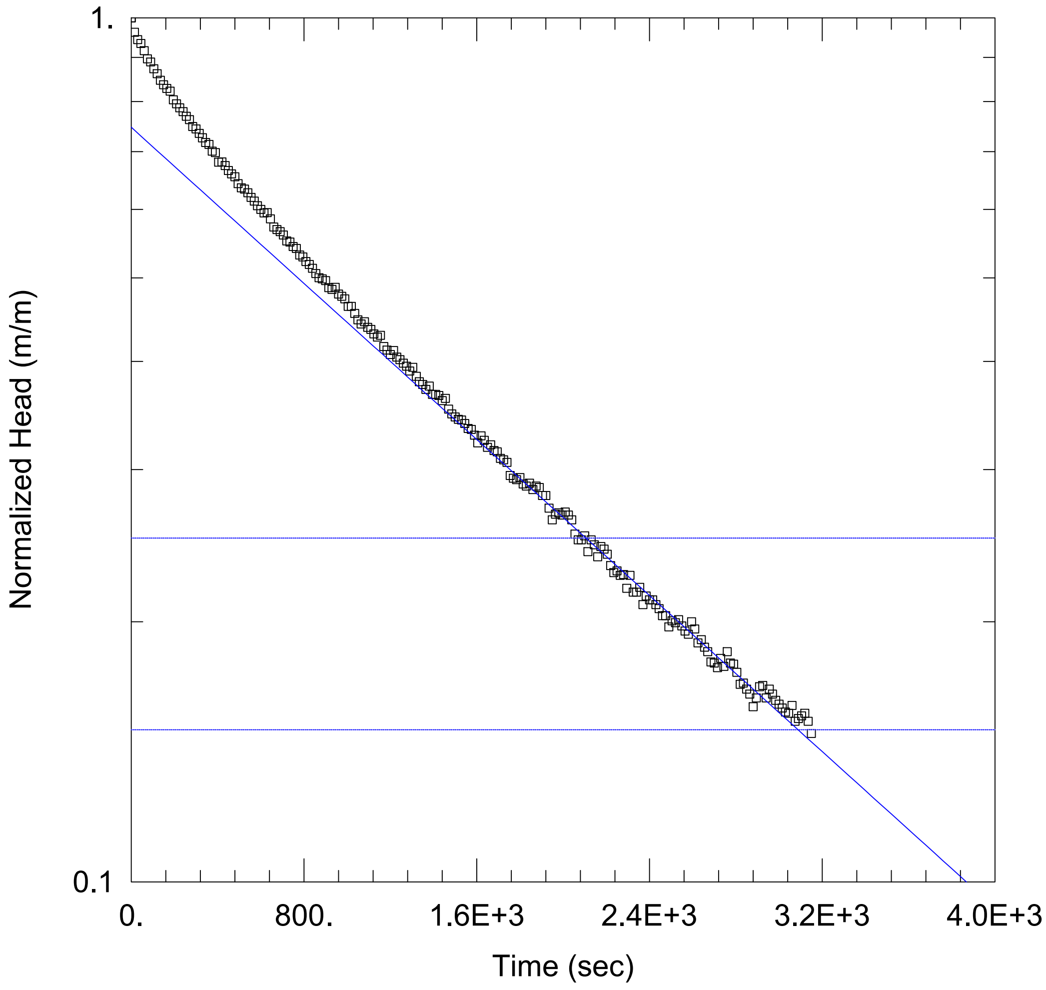
WELL DATA (New Well)

Initial Displacement: 0.1825 m
Static Water Column Height: 2.71 m
Total Well Penetration Depth: 3.34 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.14E-6 m/sec
y0 = 0.1448 m



MW5C - FHT02

Data Set: G:\...\MW5C_FHT2_H.aqt
Date: 12/07/22
Time: 11:54:57

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW5C
Test Date: 14/11/2022

AQUIFER DATA

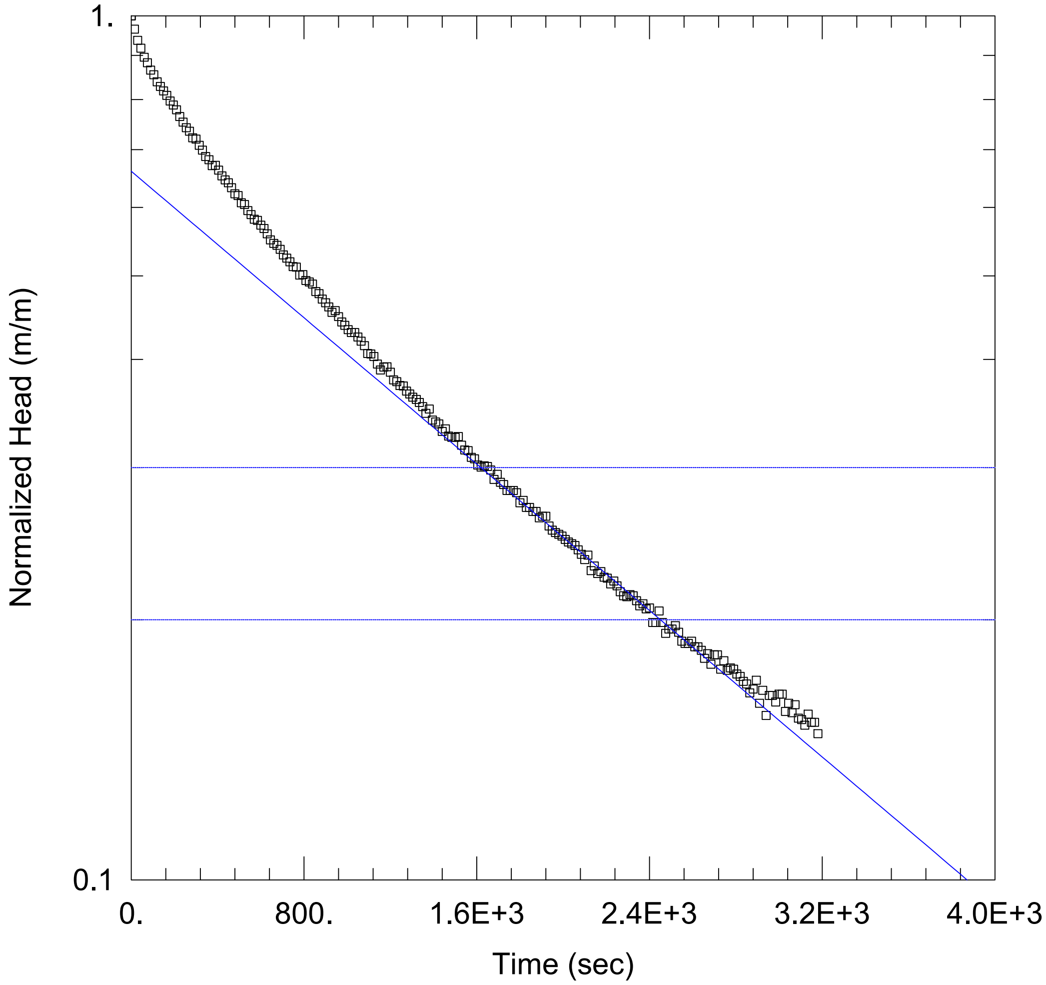
Saturated Thickness: 2.71 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 0.1825 m
Static Water Column Height: 2.71 m
Total Well Penetration Depth: 3.34 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 1.425E-6 m/sec
y0 = 0.1363 m



MW5C - RHT01

Data Set: G:\...\MW5C_RHT1_BR.aqt
Date: 12/07/22 Time: 11:49:11

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW5C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 2.71 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

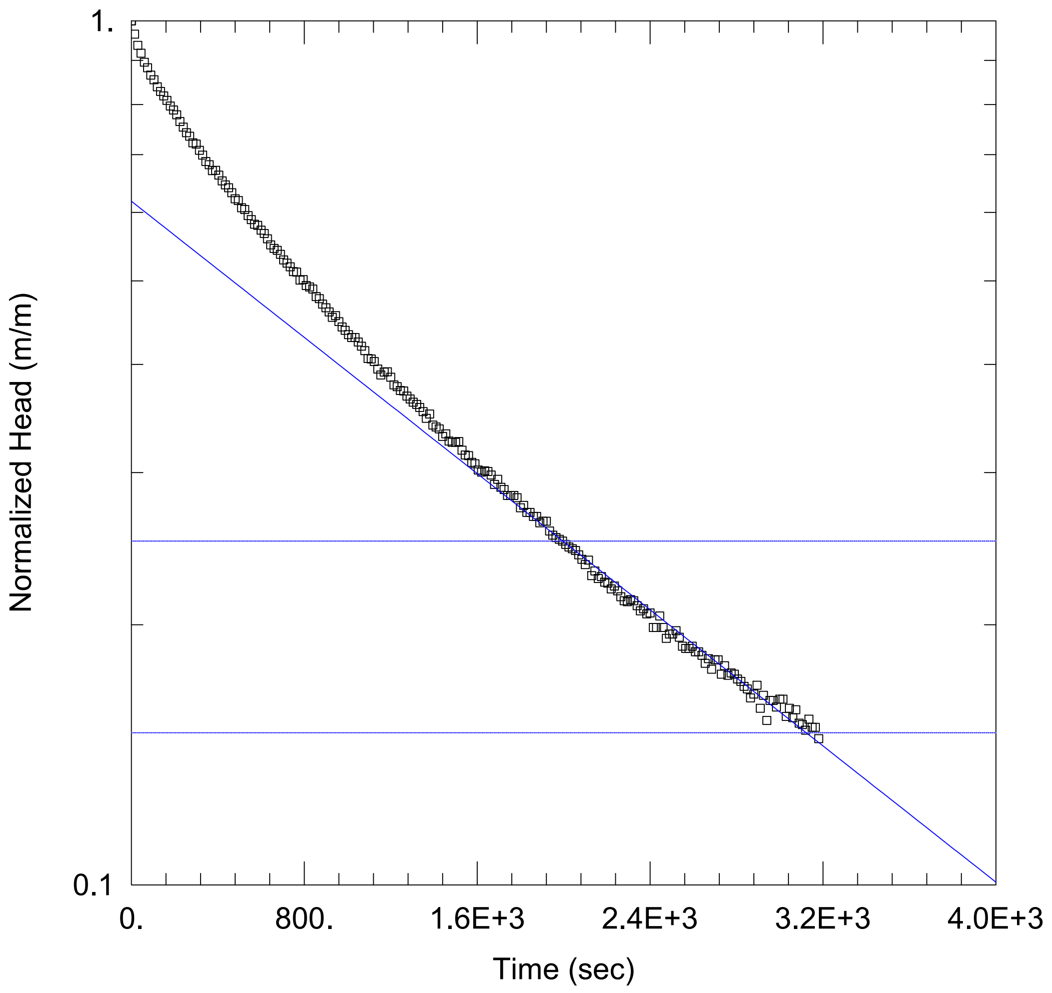
Initial Displacement: 0.1768 m
Total Well Penetration Depth: 3.34 m
Casing Radius: 0.045 m

Static Water Column Height: 2.71 m
Screen Length: 1. m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 1.005E-6 m/sec y0 = 0.1168 m



MW5C - RHT01

Data Set: G:\...\MW5C_RHT1_H.aqt
Date: 12/07/22
Time: 11:50:31

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW5C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 2.71 m
Anisotropy Ratio (Kz/Kr): 1.

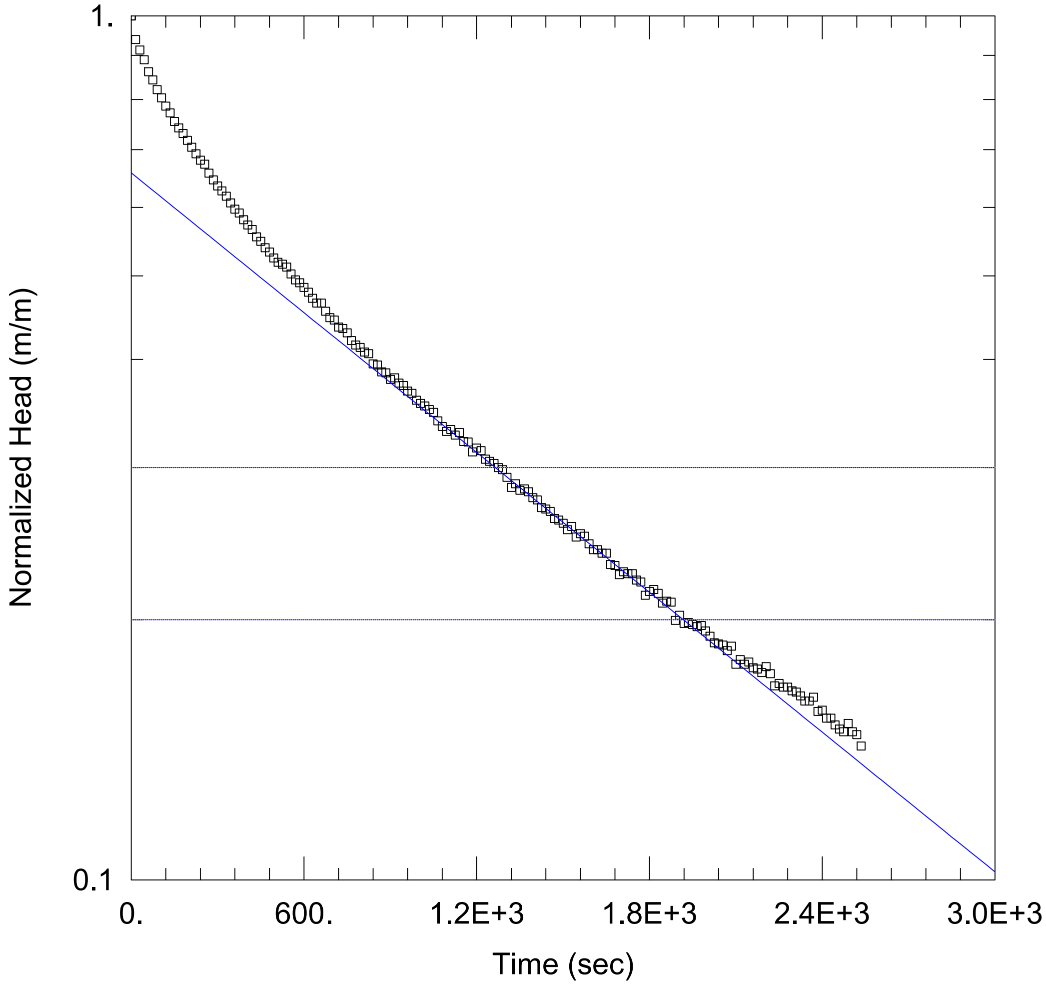
WELL DATA (New Well)

Initial Displacement: 0.1768 m
Static Water Column Height: 2.71 m
Total Well Penetration Depth: 3.34 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.244E-6 m/sec
y0 = 0.1093 m



MW5C - RHT2

Data Set: G:\...\MW5C_RHT2_BR.aqt
Date: 12/07/22
Time: 11:56:30

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW5C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 2.71 m
Anisotropy Ratio (Kz/Kr): 1.

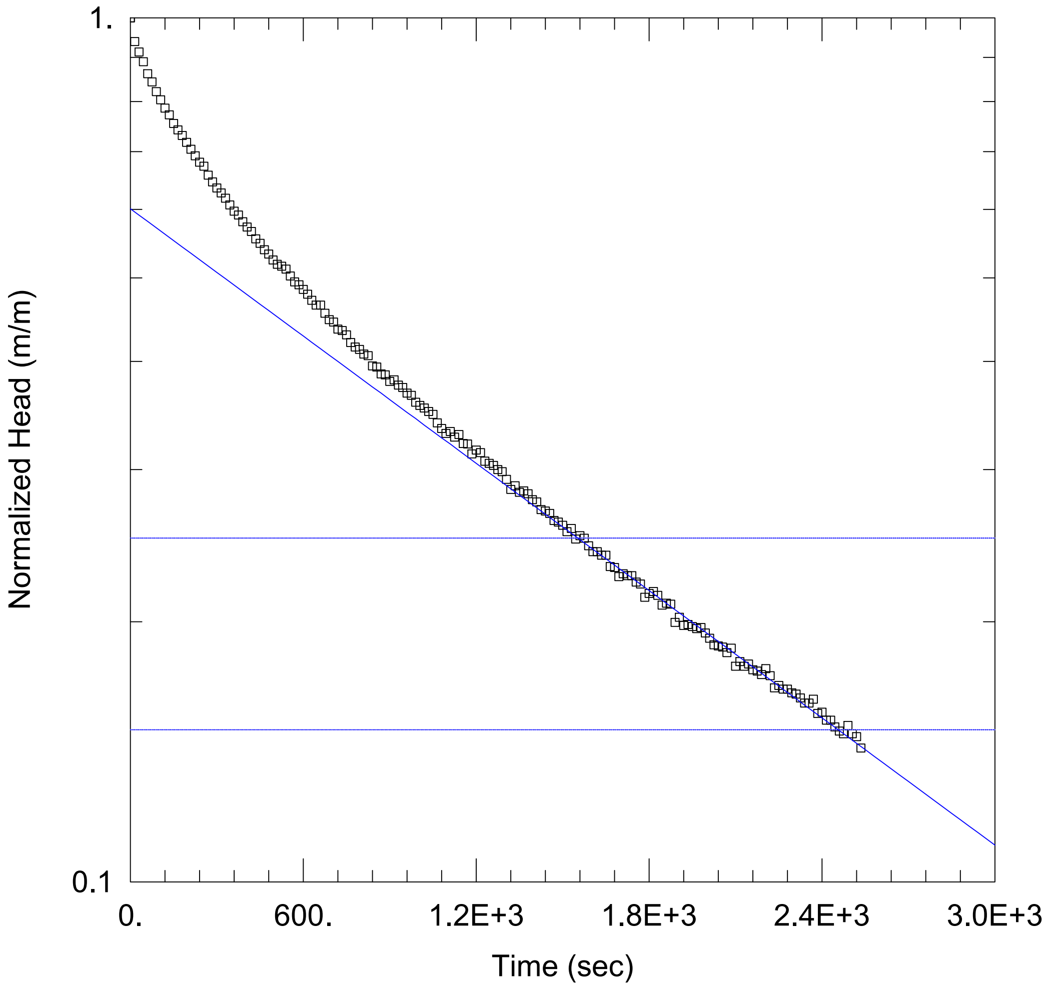
WELL DATA (New Well)

Initial Displacement: 0.1813 m
Static Water Column Height: 2.71 m
Total Well Penetration Depth: 3.34 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.28E-6 m/sec
y0 = 0.1193 m



MW5C - RHT2

Data Set: G:\...\MW5C_RHT2_H.aqt
Date: 12/07/22 Time: 11:57:40

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW5C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 2.71 m
Anisotropy Ratio (Kz/Kr): 1.

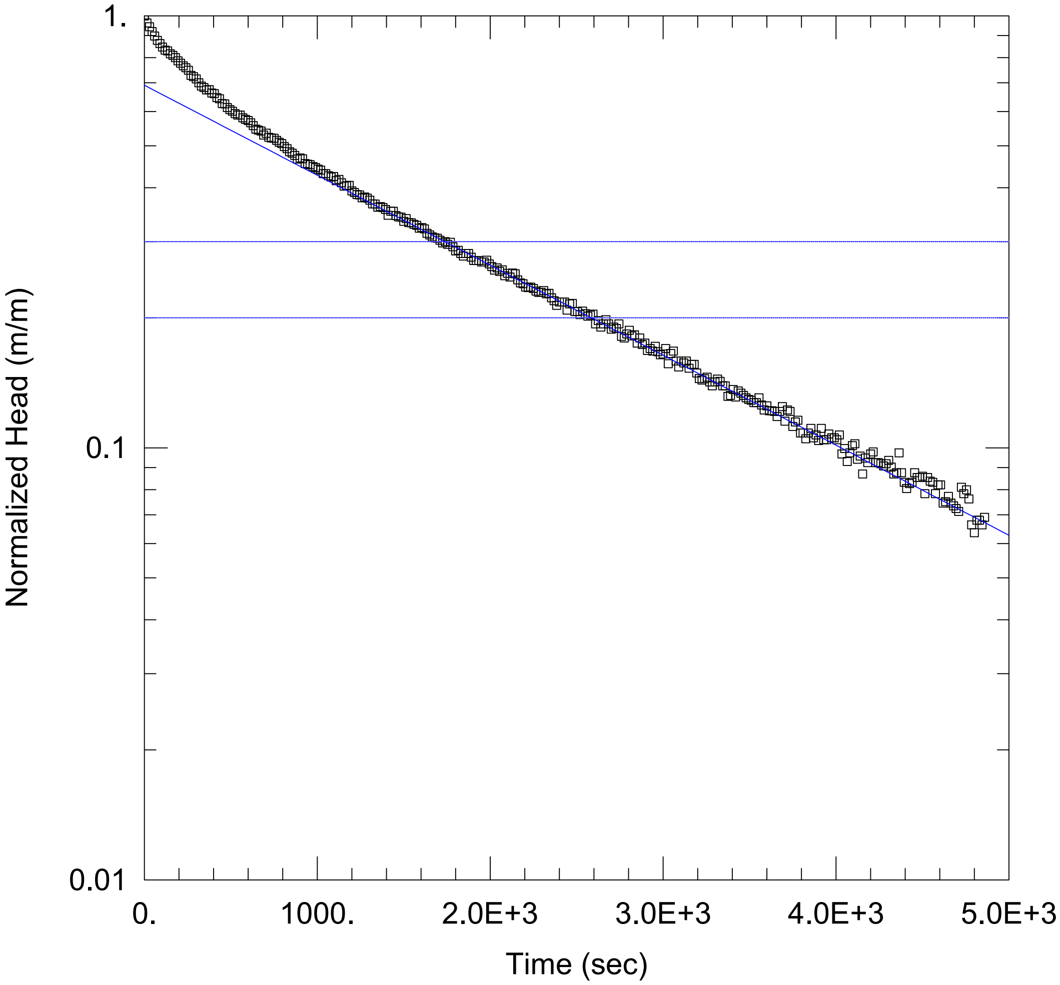
WELL DATA (MW5C)

Initial Displacement: 0.1813 m
Static Water Column Height: 2.71 m
Total Well Penetration Depth: 3.34 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.55E-6 m/sec
y0 = 0.109 m



MW6C - FHT01

Data Set: G:\...\MW6C_FHT1_BR.aqt
Date: 12/07/22 Time: 12:00:02

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW6C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 3.66 m
Anisotropy Ratio (Kz/Kr): 1.

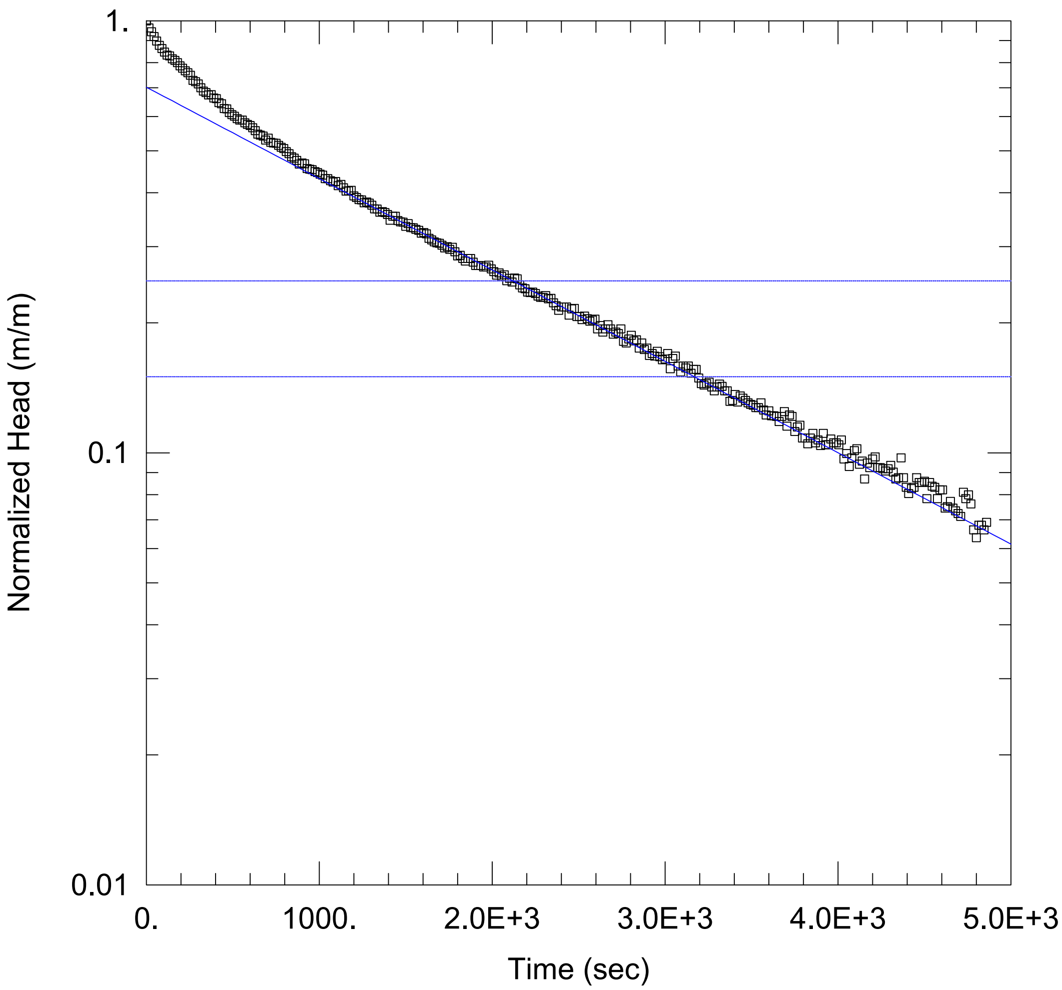
WELL DATA (MW6C)

Initial Displacement: 0.1839 m
Static Water Column Height: 3.66 m
Total Well Penetration Depth: 4.13 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.033E-6 m/sec
y0 = 0.127 m



MW6C - FHT01

Data Set: G:\...\MW6C_FHT1_H.aqt
Date: 12/07/22 Time: 12:01:31

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW6C
Test Date: 14/11/2022

AQUIFER DATA

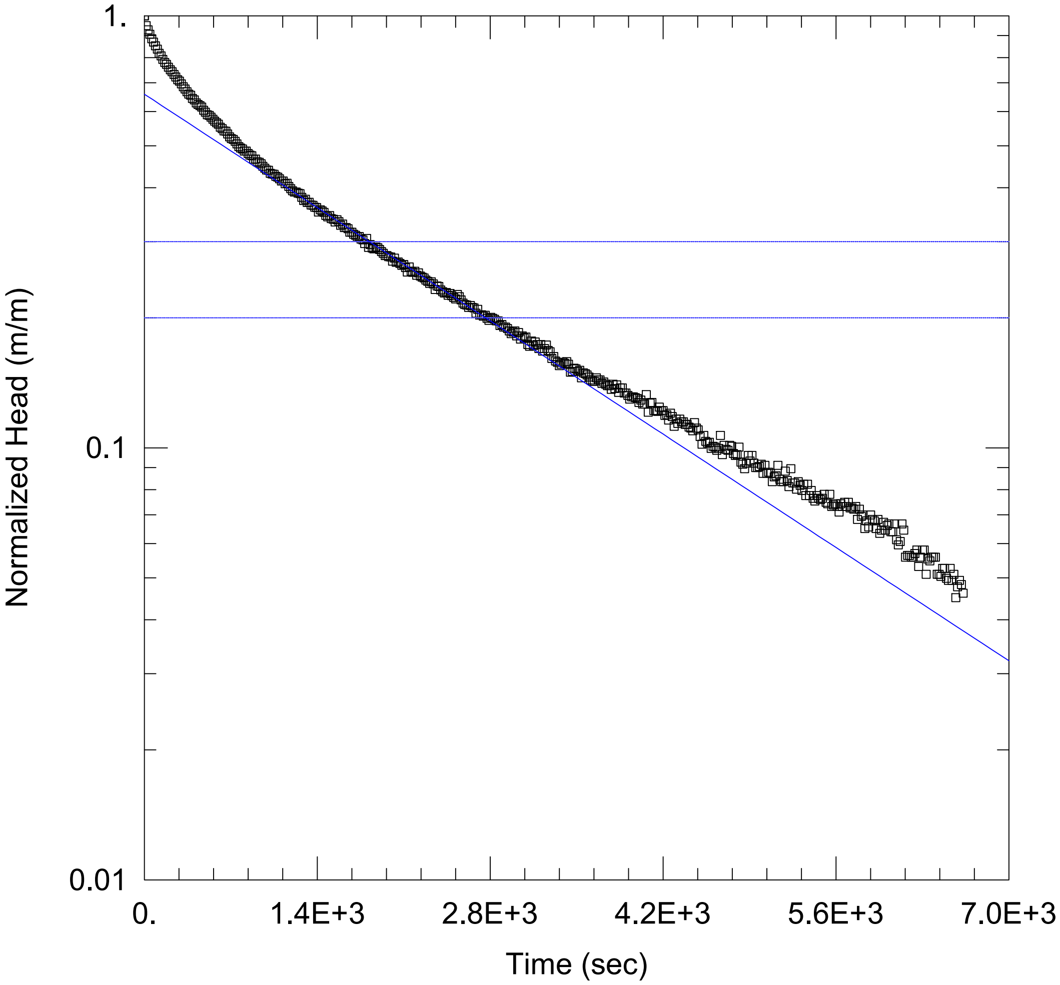
Saturated Thickness: 3.66 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW6C)

Initial Displacement: 0.1839 m
Static Water Column Height: 3.66 m
Total Well Penetration Depth: 4.13 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 1.335E-6 m/sec
y0 = 0.1291 m



MW6C FHT02

Data Set: G:\...\MW6C_FHT2_BR.aqt
Date: 12/07/22 Time: 12:05:46

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW6C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 3.66 m
Anisotropy Ratio (Kz/Kr): 1.

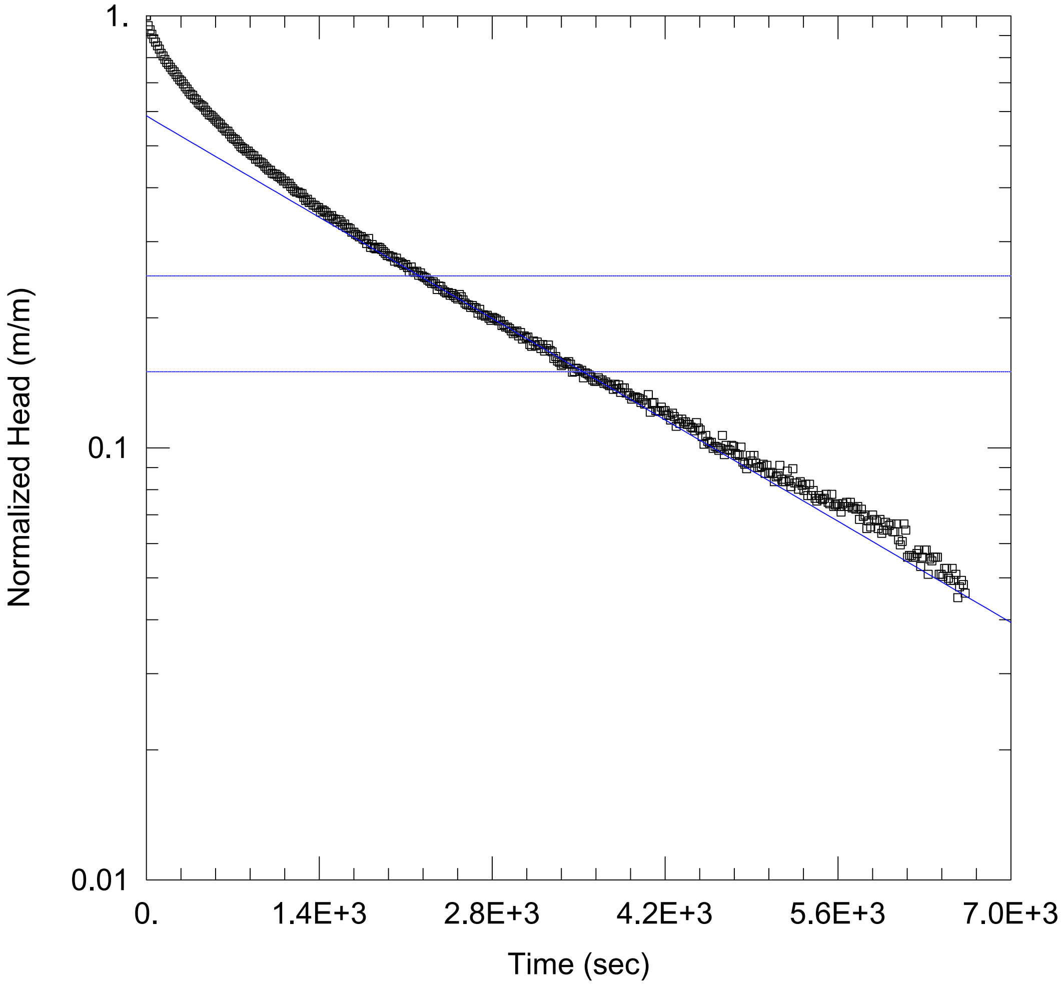
WELL DATA (MW6C)

Initial Displacement: 0.1845 m
Static Water Column Height: 3.66 m
Total Well Penetration Depth: 4.13 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.133 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 9.314E-7 m/sec
y0 = 0.1214 m



MW6C FHT02

Data Set: G:\...\MW6C_FHT2_H.aqt

Date: 12/07/22 Time: 12:06:41

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW6C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 3.66 m Anisotropy Ratio (Kz/Kr): 1.

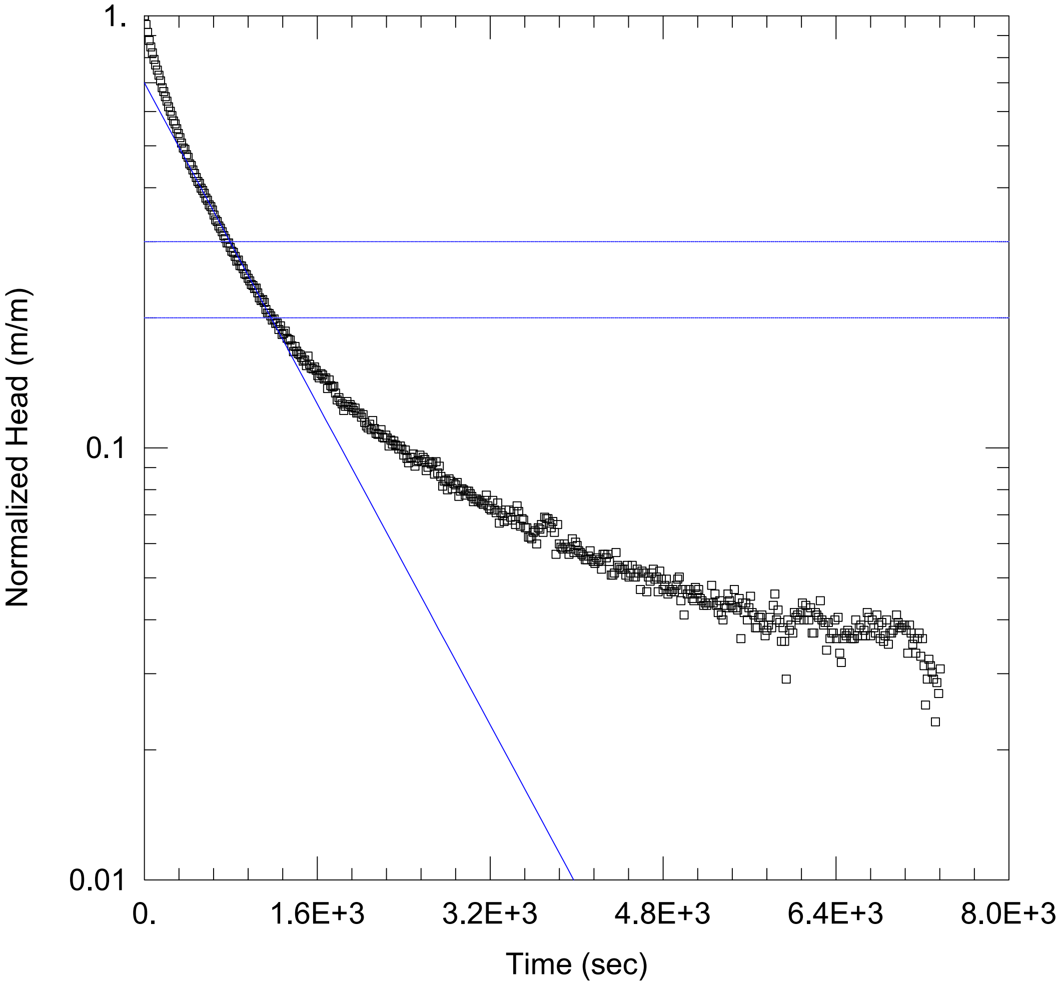
WELL DATA (MW6C)

Initial Displacement: 0.1845 m
Total Well Penetration Depth: 4.13 m
Casing Radius: 0.045 m
Static Water Column Height: 3.66 m
Screen Length: 1. m
Well Radius: 0.133 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 1.06E-6 m/sec y0 = 0.1082 m



MW6C RHT01

Data Set: G:\...\MW6C_RHT1_BR.aqt
Date: 12/07/22 Time: 12:03:53

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW6C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 3.66 m
Anisotropy Ratio (Kz/Kr): 1.

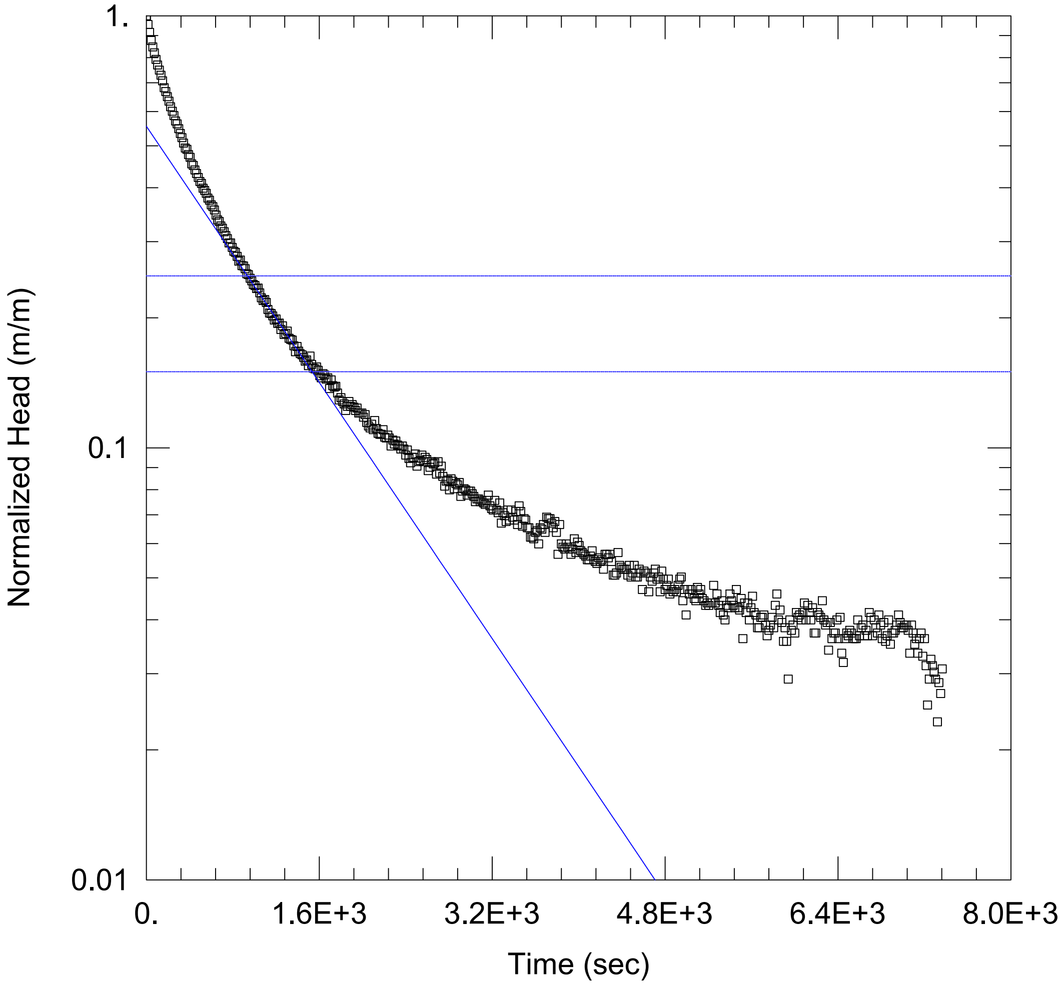
WELL DATA (MW6C)

Initial Displacement: 0.1852 m
Static Water Column Height: 3.66 m
Total Well Penetration Depth: 4.13 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.303E-6 m/sec
y0 = 0.1296 m



MW6C RHT01

Data Set: G:\...\MW6C_RHT1_H.aqt
Date: 12/07/22 Time: 12:04:32

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW6C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 3.66 m
Anisotropy Ratio (Kz/Kr): 1.

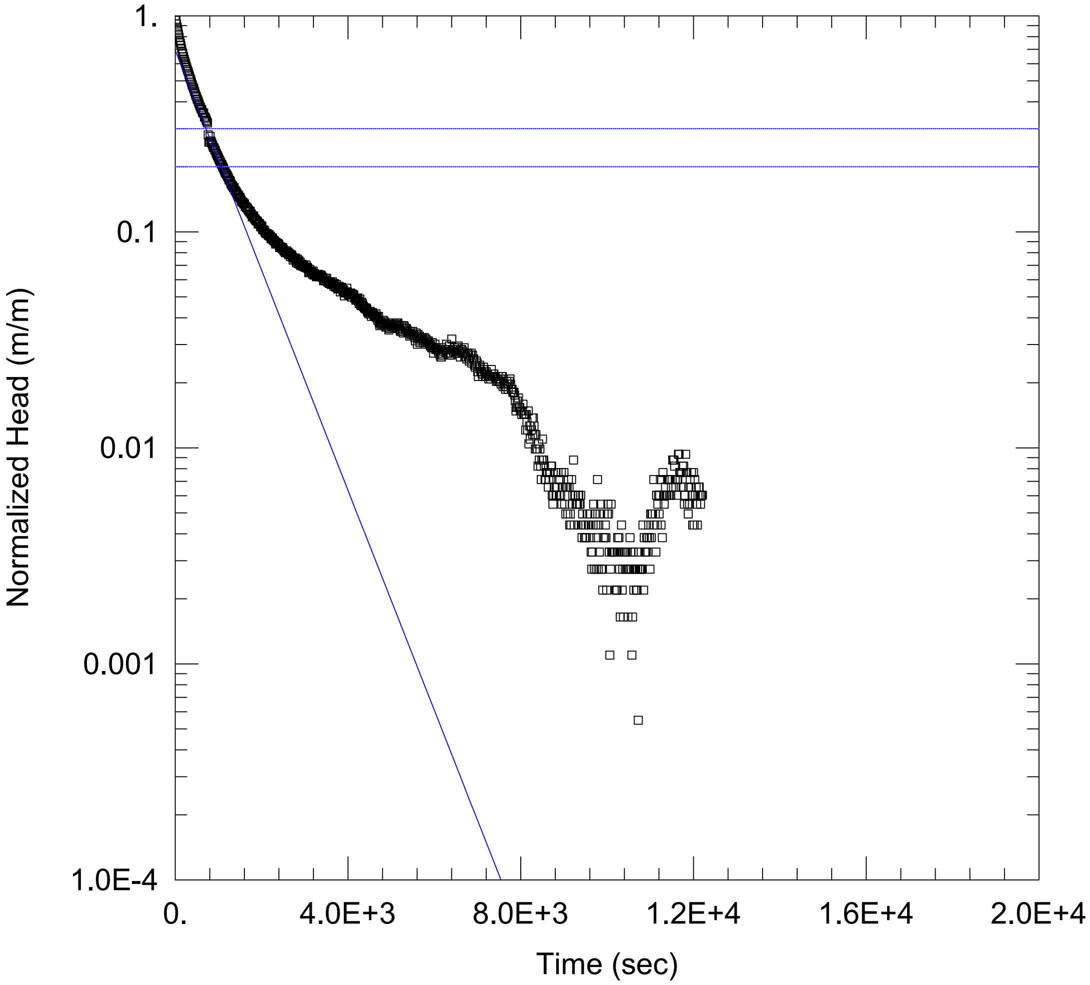
WELL DATA (MW6C)

Initial Displacement: 0.1852 m
Static Water Column Height: 3.66 m
Total Well Penetration Depth: 4.13 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.134 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.339E-6 m/sec
y0 = 0.1028 m



MW6C RHT02

Data Set: G:\...\MW6C_RHT2_BR.aqt
Date: 12/07/22 Time: 12:08:55

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW6C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 3.66 m
Anisotropy Ratio (Kz/Kr): 1.

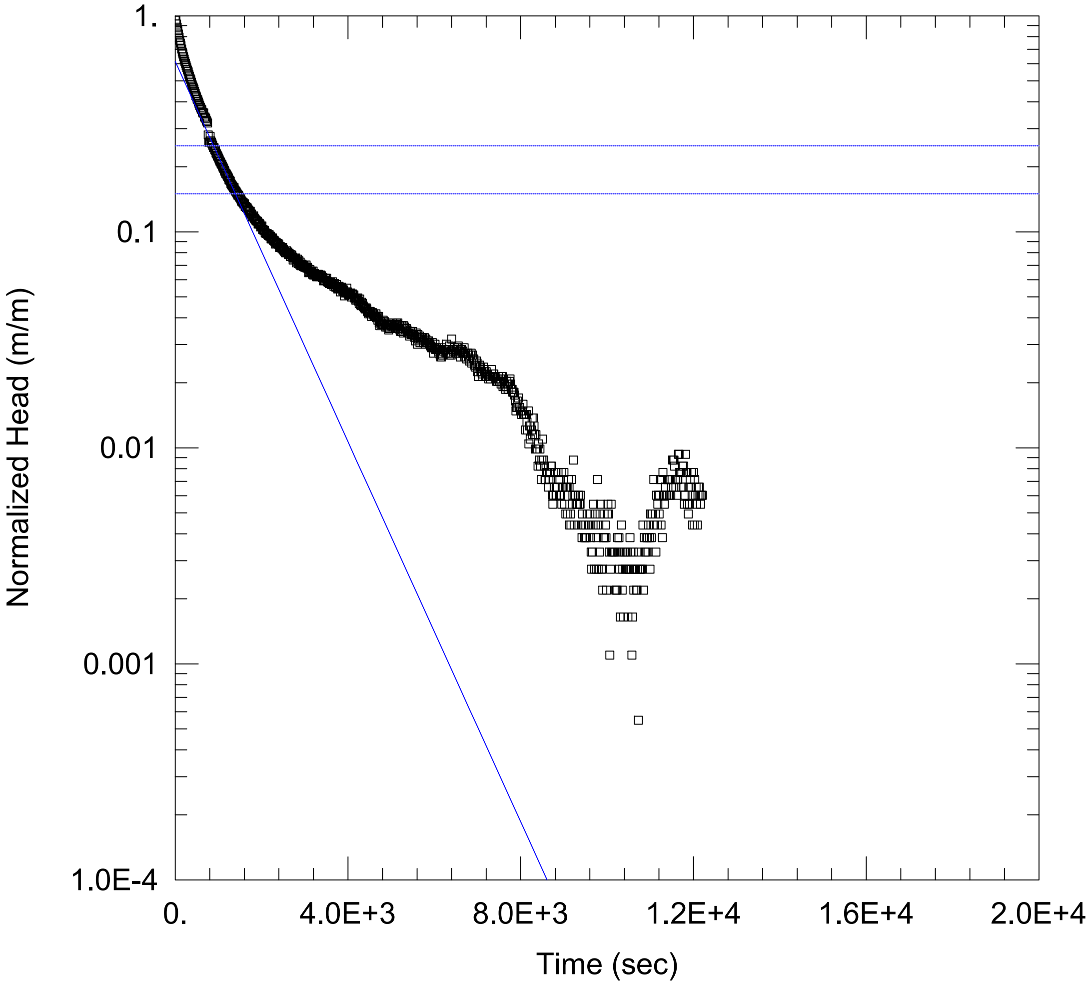
WELL DATA (MW6C)

Initial Displacement: 0.1823 m
Static Water Column Height: 3.66 m
Total Well Penetration Depth: 4.13 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.133 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.532E-6 m/sec
y0 = 0.1261 m



MW6C RHT02

Data Set: G:\...\MW6C_RHT2_H.aqt

Date: 12/07/22 Time: 12:10:11

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW6C
Test Date: 14/11/2022

AQUIFER DATA

Saturated Thickness: 3.66 m Anisotropy Ratio (Kz/Kr): 1.

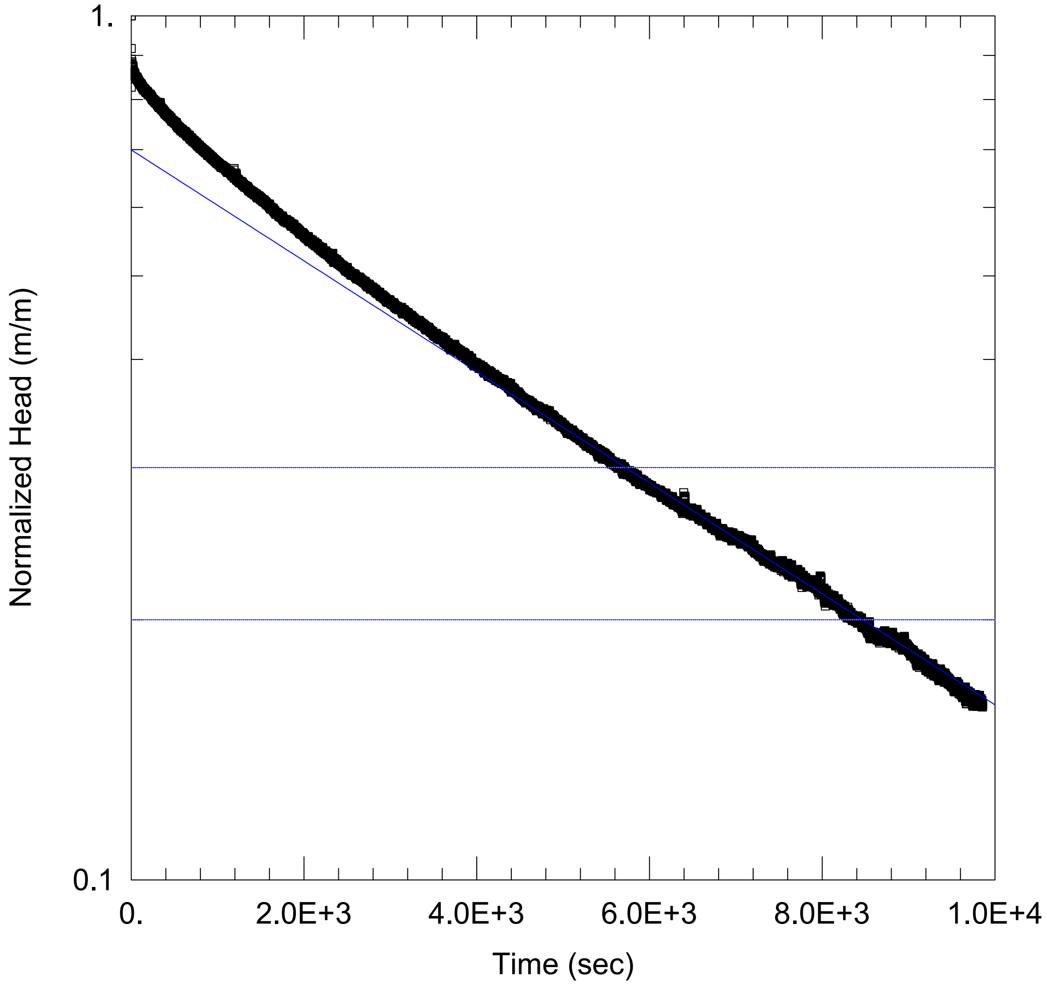
WELL DATA (MW6C)

Initial Displacement: 0.1823 m
Total Well Penetration Depth: 4.13 m
Casing Radius: 0.045 m
Static Water Column Height: 3.66 m
Screen Length: 1. m
Well Radius: 0.133 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 2.785E-6 m/sec y0 = 0.1121 m



MW2C - FHT1

Data Set: G:\...\MW2C-FHT1_BR.aqt
Date: 12/08/22 Time: 11:21:29

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2C
Test Date: 8/9/2022

AQUIFER DATA

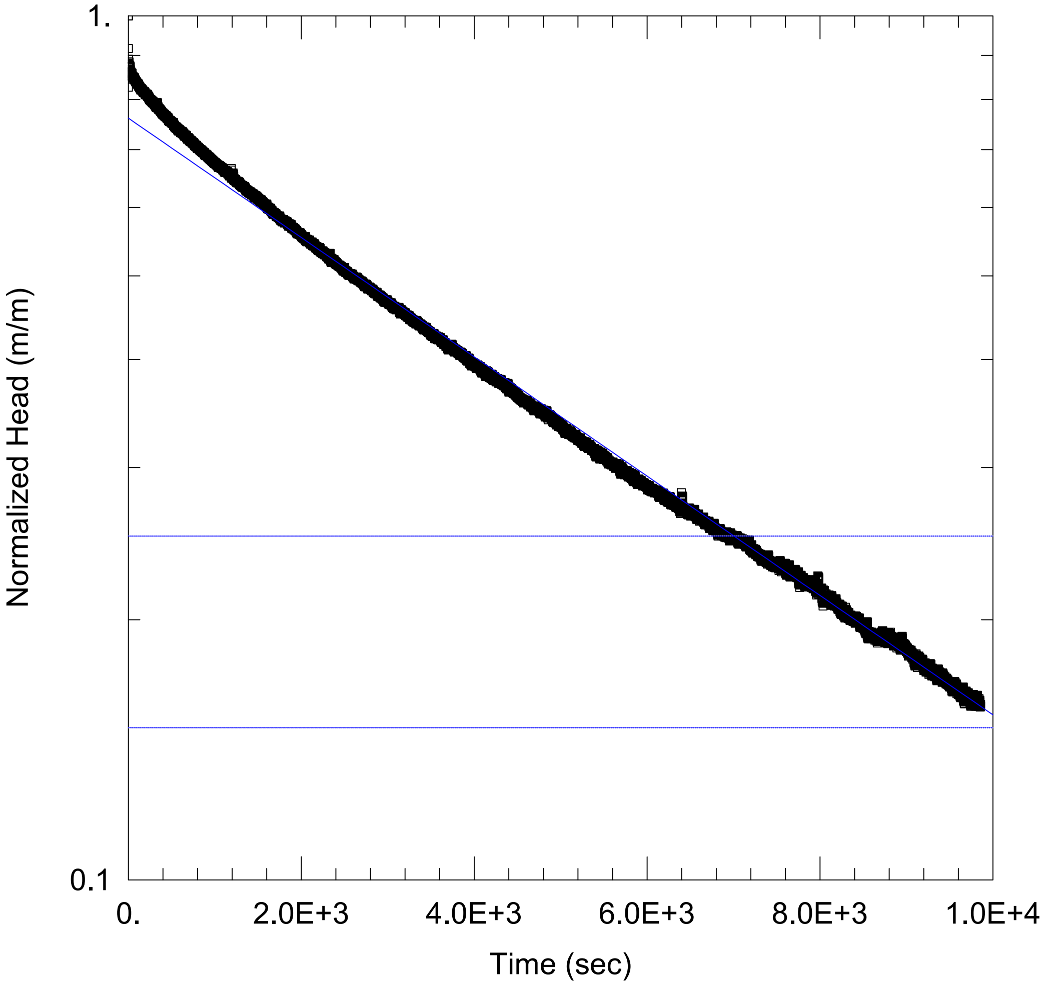
Saturated Thickness: 3.838 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW2C)

Initial Displacement: 0.2776 m
Static Water Column Height: 3.838 m
Total Well Penetration Depth: 3.888 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 3.875E-7 m/sec
y0 = 0.1942 m



MW2C - FHT1

Data Set: G:\...\MW2C-FHT1_H.aqt
Date: 12/08/22 Time: 11:24:29

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2C
Test Date: 8/9/2022

AQUIFER DATA

Saturated Thickness: 3.838 m
Anisotropy Ratio (Kz/Kr): 1.

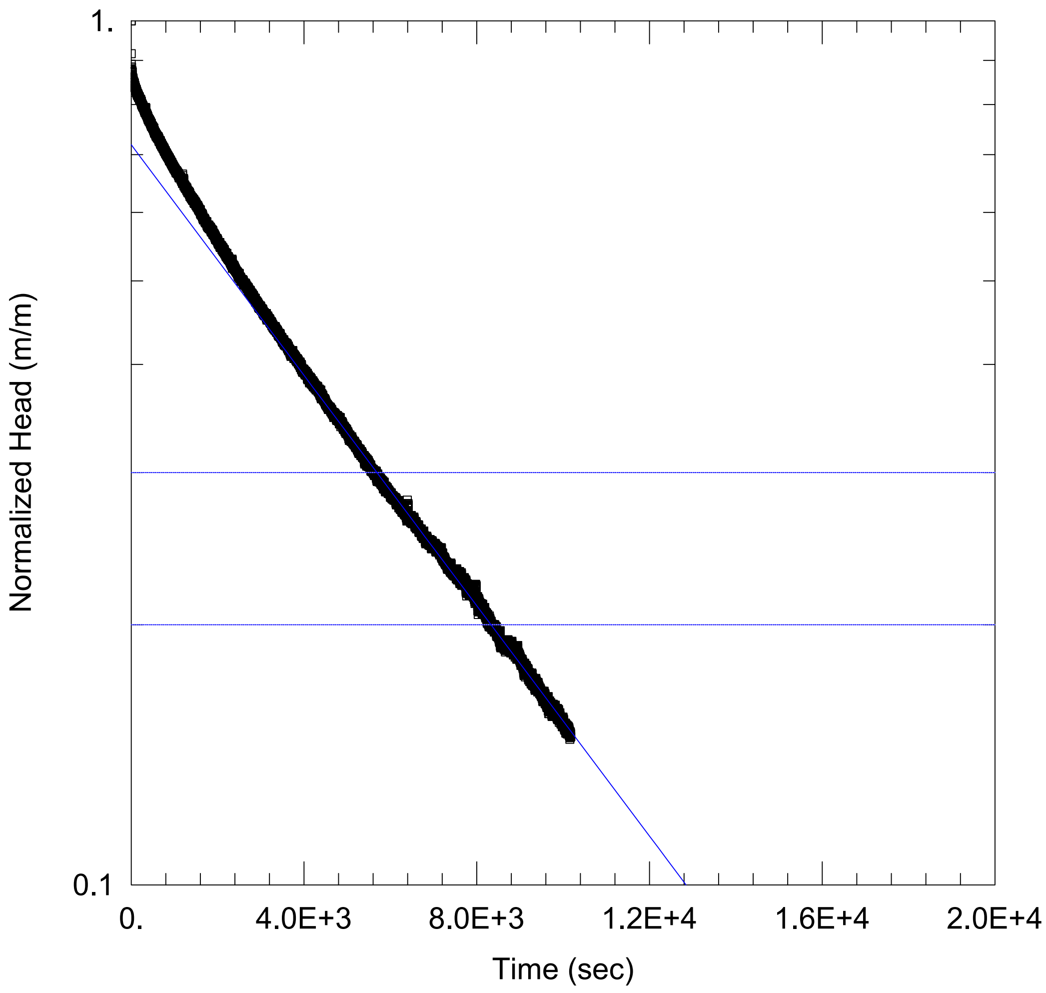
WELL DATA (MW2C)

Initial Displacement: 0.2776 m
Static Water Column Height: 3.838 m
Total Well Penetration Depth: 3.888 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 5.288E-7 m/sec
y0 = 0.2113 m



MW2C - FHT2

Data Set: G:\...\MW2C-FHT2_BR.aqt
Date: 12/08/22
Time: 11:25:56

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2C
Test Date: 8/9/2022

AQUIFER DATA

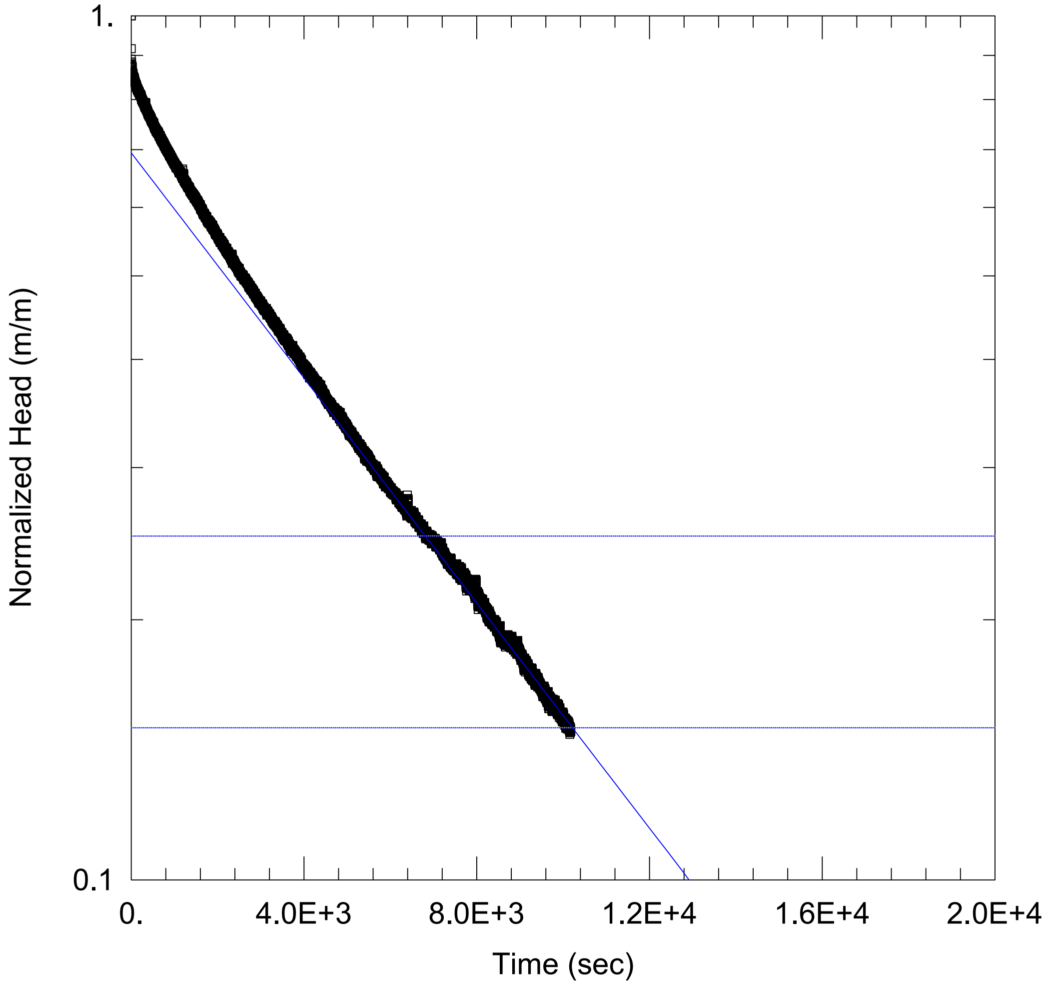
Saturated Thickness: 3.834 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW2C)

Initial Displacement: 0.2769 m
Static Water Column Height: 3.834 m
Total Well Penetration Depth: 3.884 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 4.023E-7 m/sec
y0 = 0.199 m



MW2C - FHT2

Data Set: G:\...\MW2C-FHT2_H.aqt
Date: 12/08/22
Time: 11:23:16

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2C
Test Date: 8/9/2022

AQUIFER DATA

Saturated Thickness: 3.834 m
Anisotropy Ratio (Kz/Kr): 1.

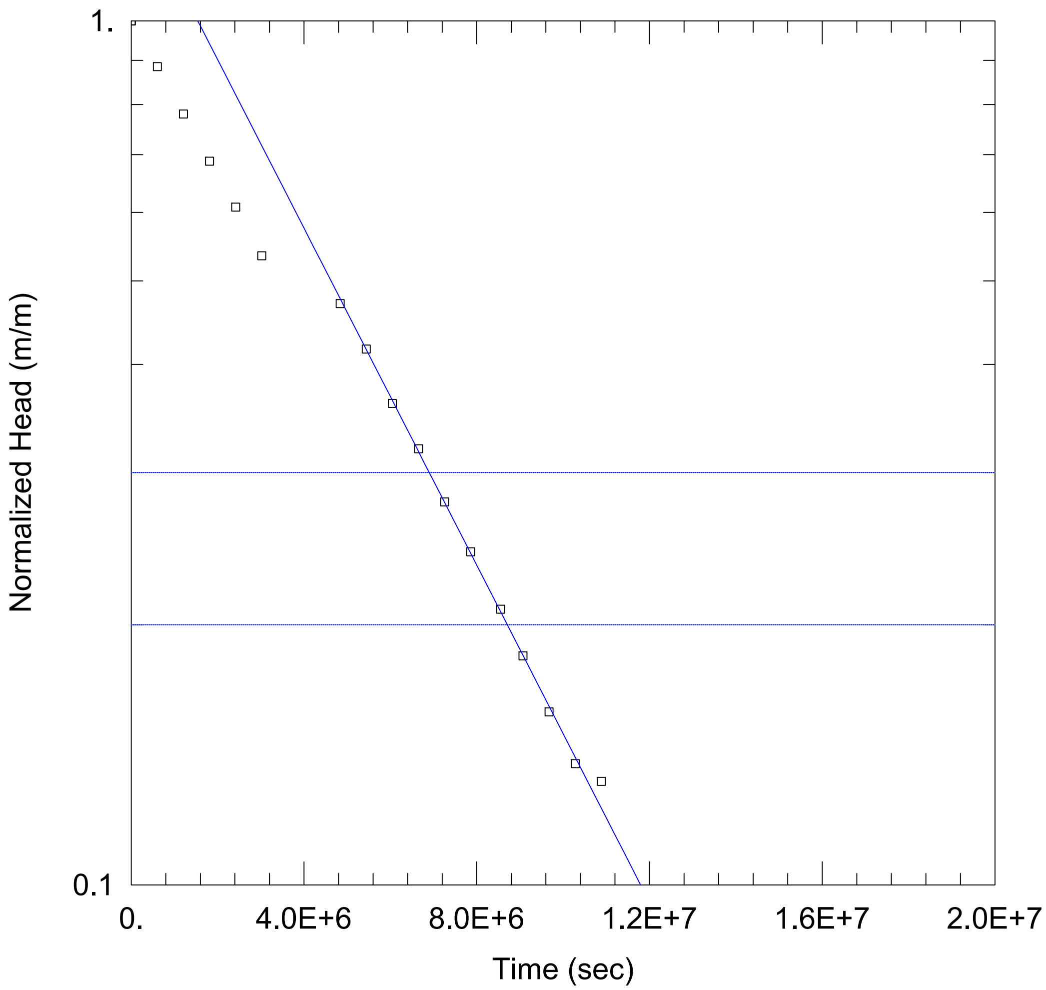
WELL DATA (MW2C)

Initial Displacement: 0.2769 m
Static Water Column Height: 3.834 m
Total Well Penetration Depth: 3.884 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 4.988E-7 m/sec
y0 = 0.1922 m



MW2D - RHT1 - 1997 PURGE

Data Set: G:\...\MW2D-RHT1_BR.aqt
Date: 12/08/22 Time: 11:28:35

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2D
Test Date: 7/08/1997

AQUIFER DATA

Saturated Thickness: 9.982 m
Anisotropy Ratio (Kz/Kr): 1.

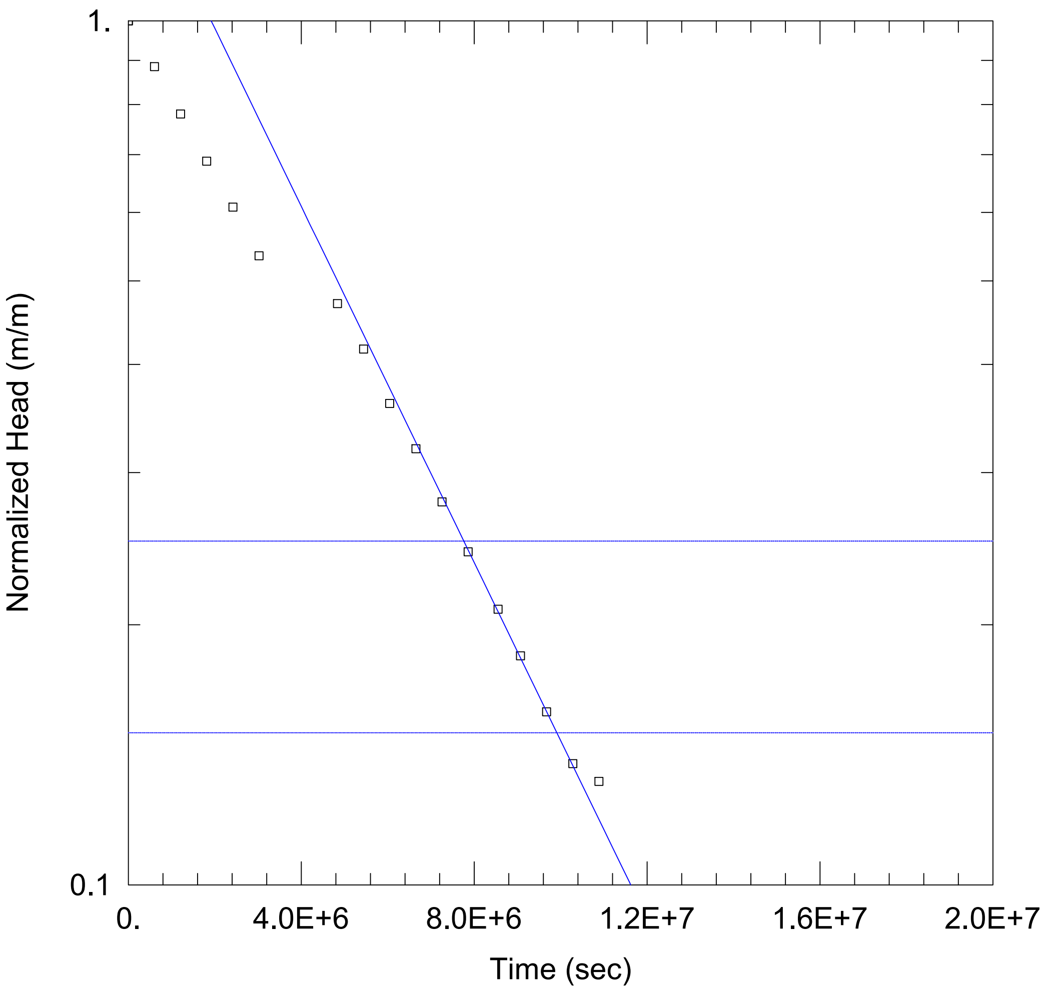
WELL DATA (New Well)

Initial Displacement: 7.82 m
Static Water Column Height: 9.982 m
Total Well Penetration Depth: 10. m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 6.193E-10 m/sec
y0 = 11.05 m



MW2D - RHT1 - 1997 PURGE

Data Set: G:\...\MW2D-RHT1_H.aqt
Date: 12/08/22 Time: 11:29:28

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2D
Test Date: 7/08/1997

AQUIFER DATA

Saturated Thickness: 9.982 m
Anisotropy Ratio (Kz/Kr): 1.

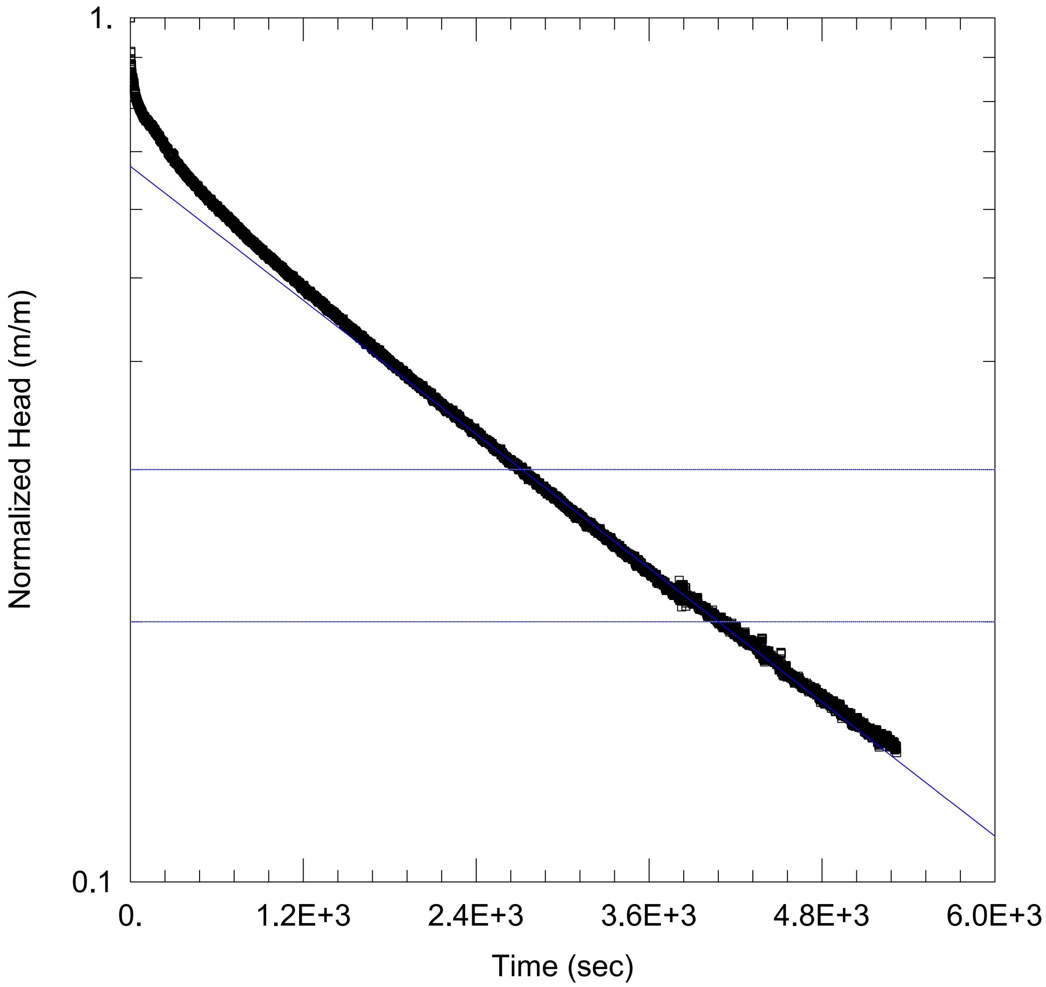
WELL DATA (New Well)

Initial Displacement: 7.82 m
Total Well Penetration Depth: 10. m
Casing Radius: 0.045 m
Static Water Column Height: 9.982 m
Screen Length: 1. m
Well Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 7.203E-10 m/sec
y0 = 12.32 m



MW4C - FHT1

Data Set: G:\...\MW4C FHT1_BR.aqt
Date: 12/08/22 Time: 11:30:13

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW4D
Test Date: 9/09/2022

AQUIFER DATA

Saturated Thickness: 2.699 m
Anisotropy Ratio (Kz/Kr): 1.

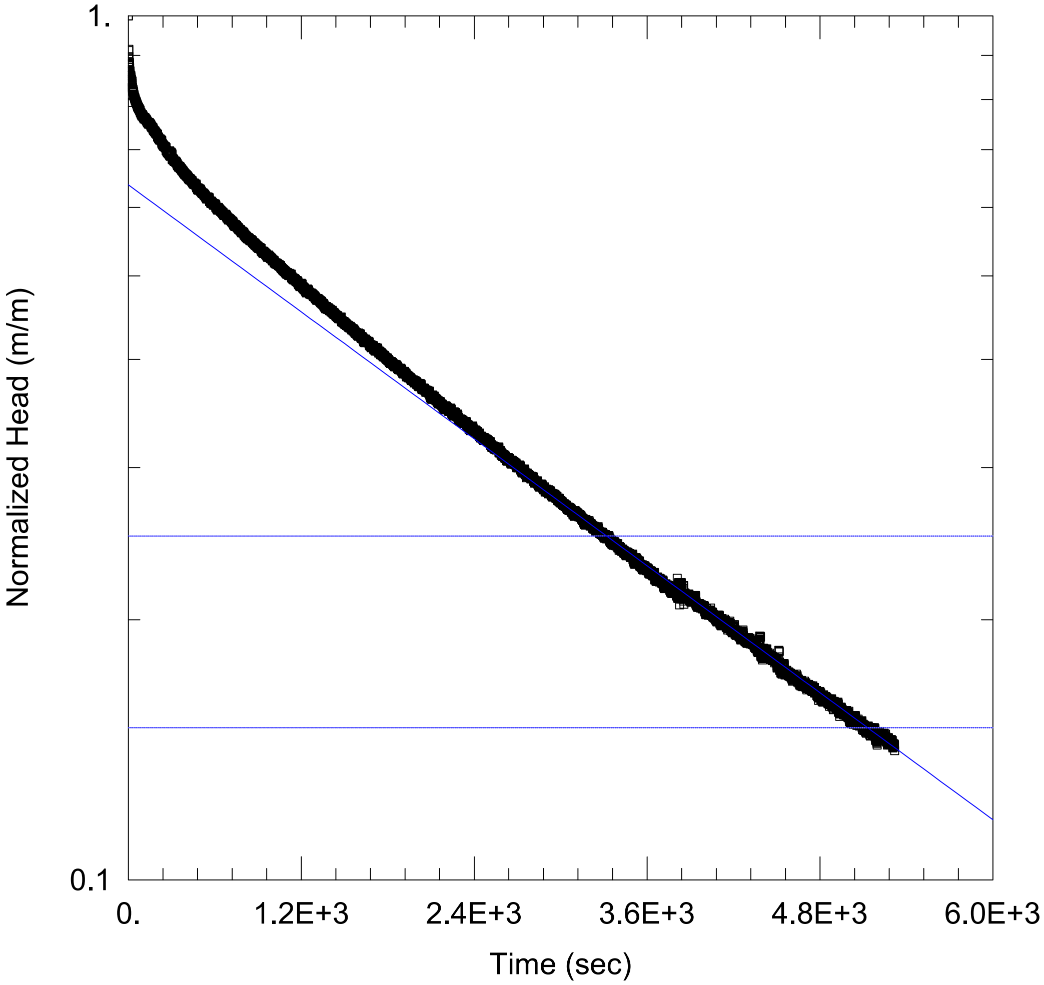
WELL DATA (MW4C)

Initial Displacement: 0.2821 m
Total Well Penetration Depth: 4.717 m
Casing Radius: 0.045 m
Static Water Column Height: 2.699 m
Screen Length: 1. m
Well Radius: 0.1345 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 6.566E-7 m/sec
y0 = 0.1899 m



MW4C - FHT1

Data Set: G:\...\MW4C FHT1_H.aqt
Date: 12/08/22 Time: 11:31:05

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW4D
Test Date: 9/09/2022

AQUIFER DATA

Saturated Thickness: 2.699 m
Anisotropy Ratio (Kz/Kr): 1.

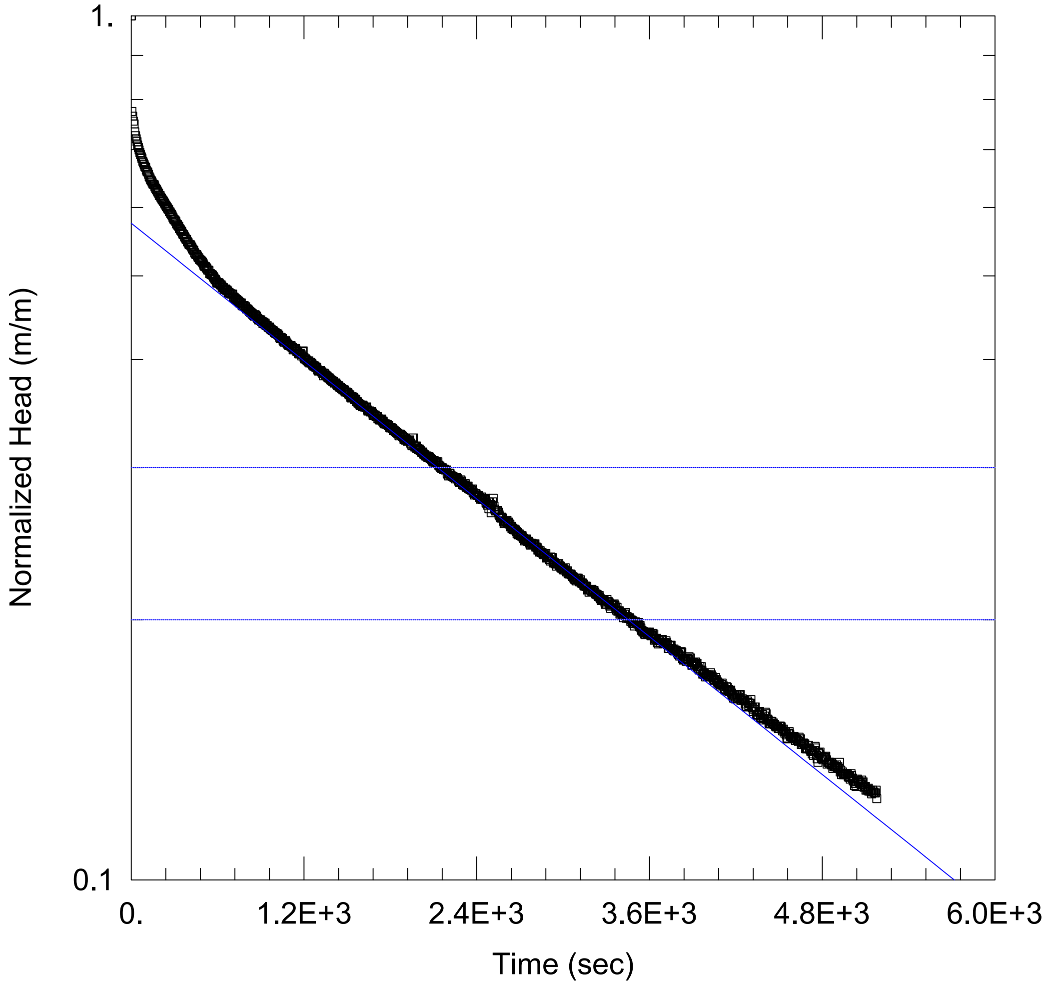
WELL DATA (MW4C)

Initial Displacement: 0.2821 m
Static Water Column Height: 2.699 m
Total Well Penetration Depth: 4.717 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.1345 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 7.718E-7 m/sec
y0 = 0.1797 m



MW4C - FHT2

Data Set: G:\...\MW4C FHT2_BR.aqt
Date: 12/08/22
Time: 11:32:08

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW4D
Test Date: 9/09/2022

AQUIFER DATA

Saturated Thickness: 2.699 m
Anisotropy Ratio (Kz/Kr): 1.

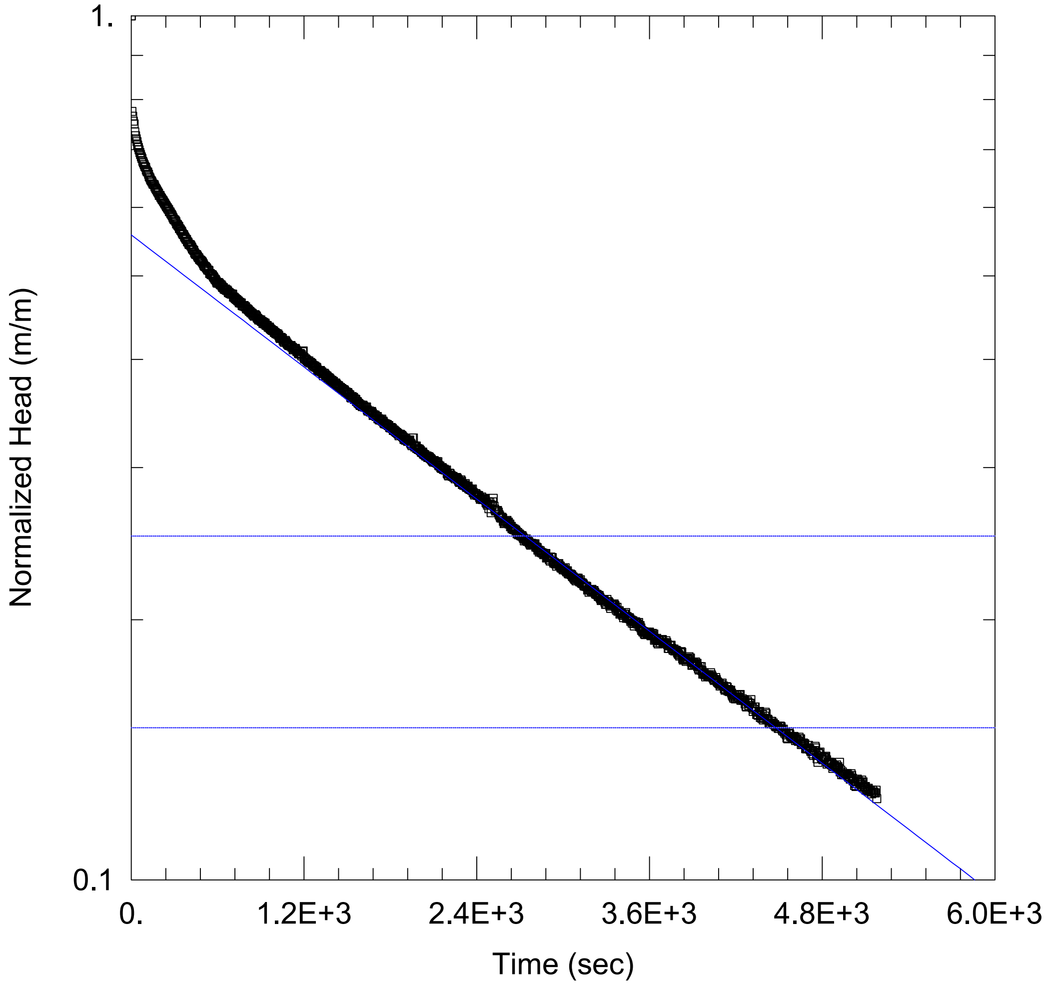
WELL DATA (MW4C)

Initial Displacement: 0.3173 m
Static Water Column Height: 2.699 m
Total Well Penetration Depth: 4.72 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.1345 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 6.755E-7 m/sec
y0 = 0.1825 m



MW4C - FHT2

Data Set: G:\...\MW4C FHT2_H.aqt
Date: 12/08/22
Time: 11:32:49

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW4D
Test Date: 9/09/2022

AQUIFER DATA

Saturated Thickness: 2.699 m
Anisotropy Ratio (Kz/Kr): 1.

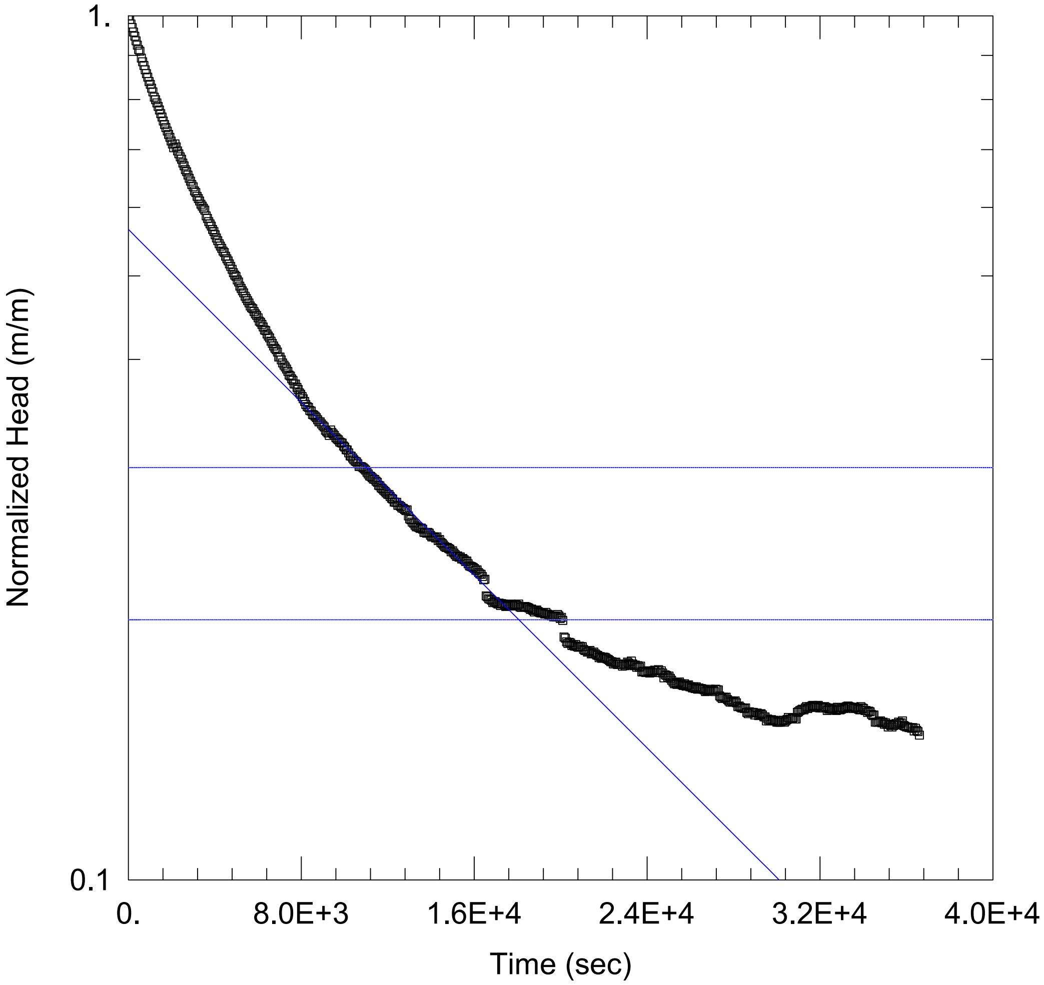
WELL DATA (MW4C)

Initial Displacement: 0.3173 m
Static Water Column Height: 2.699 m
Total Well Penetration Depth: 4.72 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.1345 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 8.03E-7 m/sec
y0 = 0.177 m



MW4D- FHT1

Data Set: G:\...\MW4D-FHT1_BR.aqt
Date: 12/08/22 Time: 11:34:10

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2C
Test Date: 30/07/2022

AQUIFER DATA

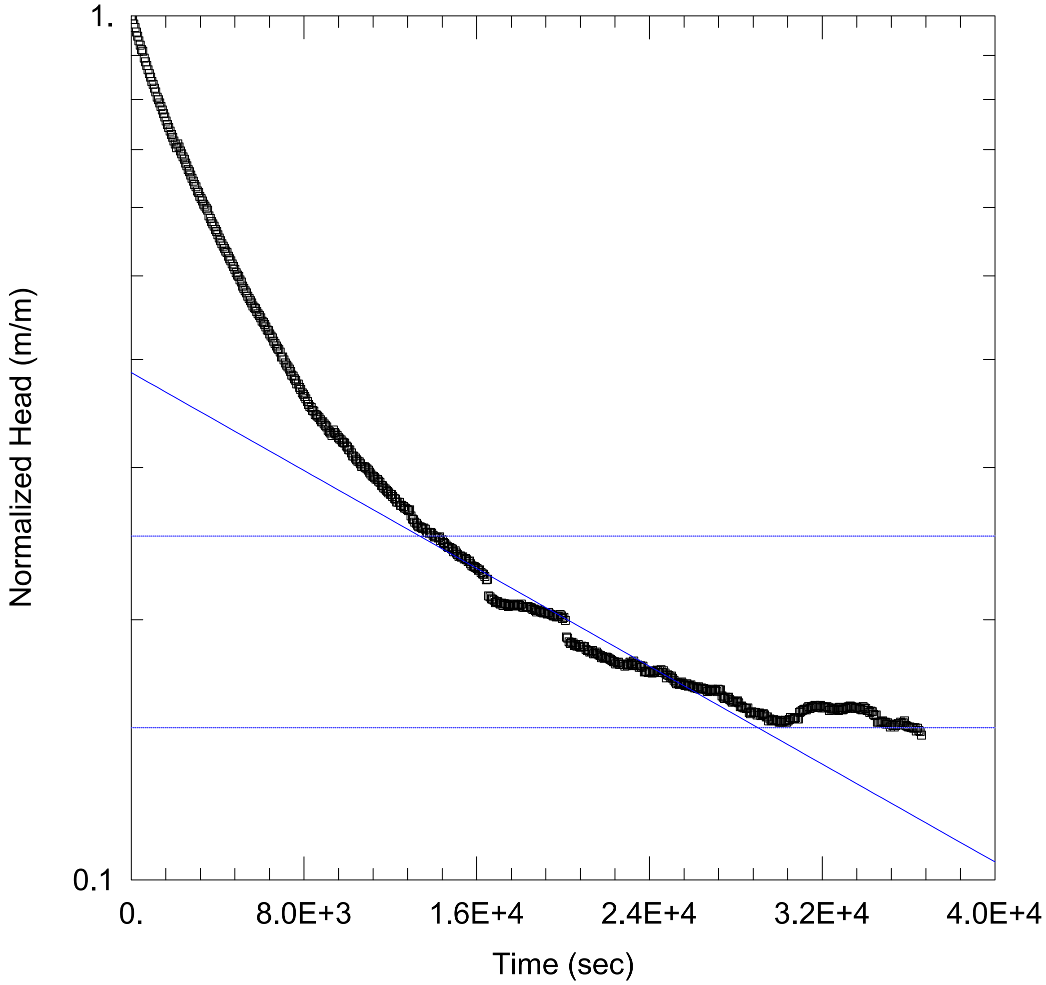
Saturated Thickness: 10.25 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW4D)

Initial Displacement: 0.3712 m
Static Water Column Height: 10.25 m
Total Well Penetration Depth: 10.09 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.1335 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.155E-7 m/sec
y0 = 0.2101 m



MW4D- FHT1

Data Set: G:\...\MW4D-FHT1_H.aqt
Date: 12/08/22 Time: 11:35:18

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2C
Test Date: 30/07/2022

AQUIFER DATA

Saturated Thickness: 10.25 m
Anisotropy Ratio (Kz/Kr): 1.

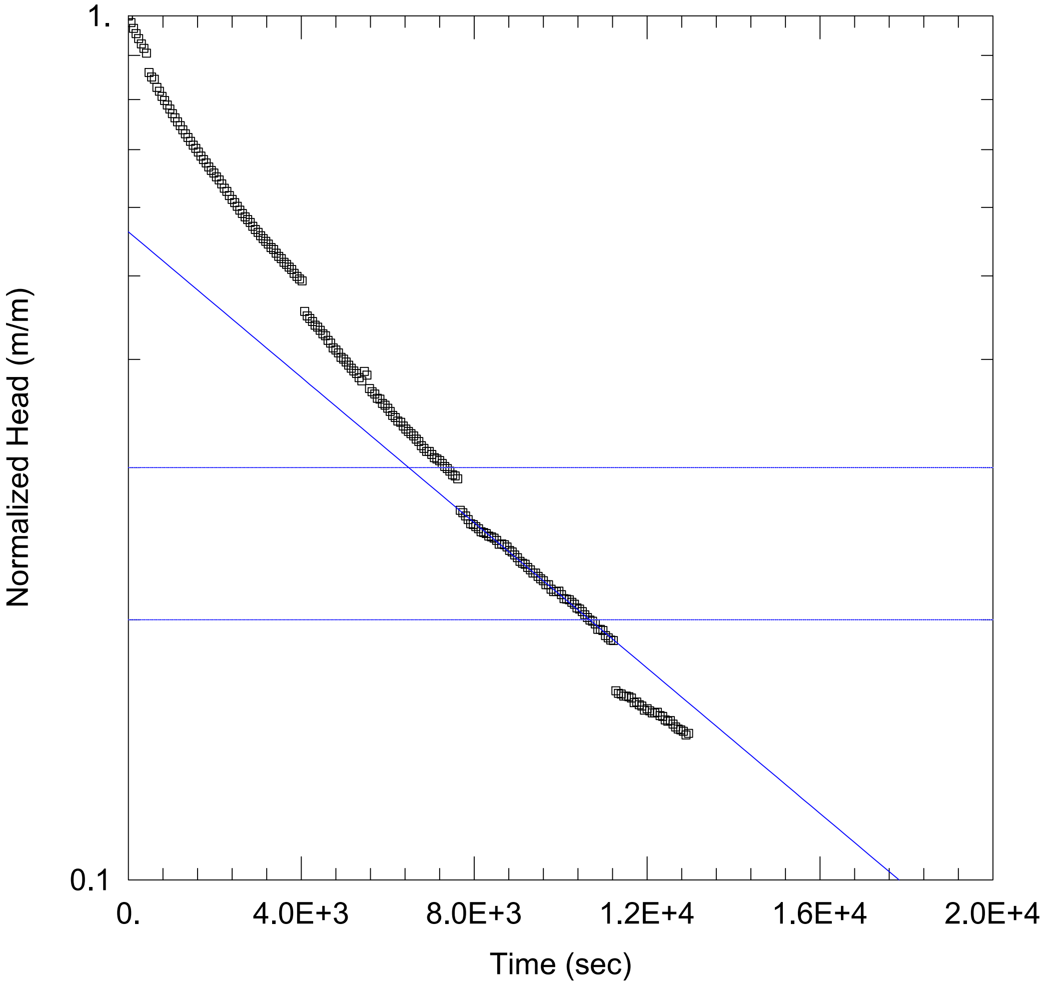
WELL DATA (MW4D)

Initial Displacement: 0.3712 m
Total Well Penetration Depth: 10.09 m
Casing Radius: 0.045 m
Static Water Column Height: 10.25 m
Screen Length: 1. m
Well Radius: 0.1335 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 6.704E-8 m/sec
y0 = 0.1434 m



MW4D- RHT1

Data Set: G:\...\MW4D-RHT1_BR.aqt
Date: 12/08/22 Time: 11:36:06

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2C
Test Date: 30/07/2022

AQUIFER DATA

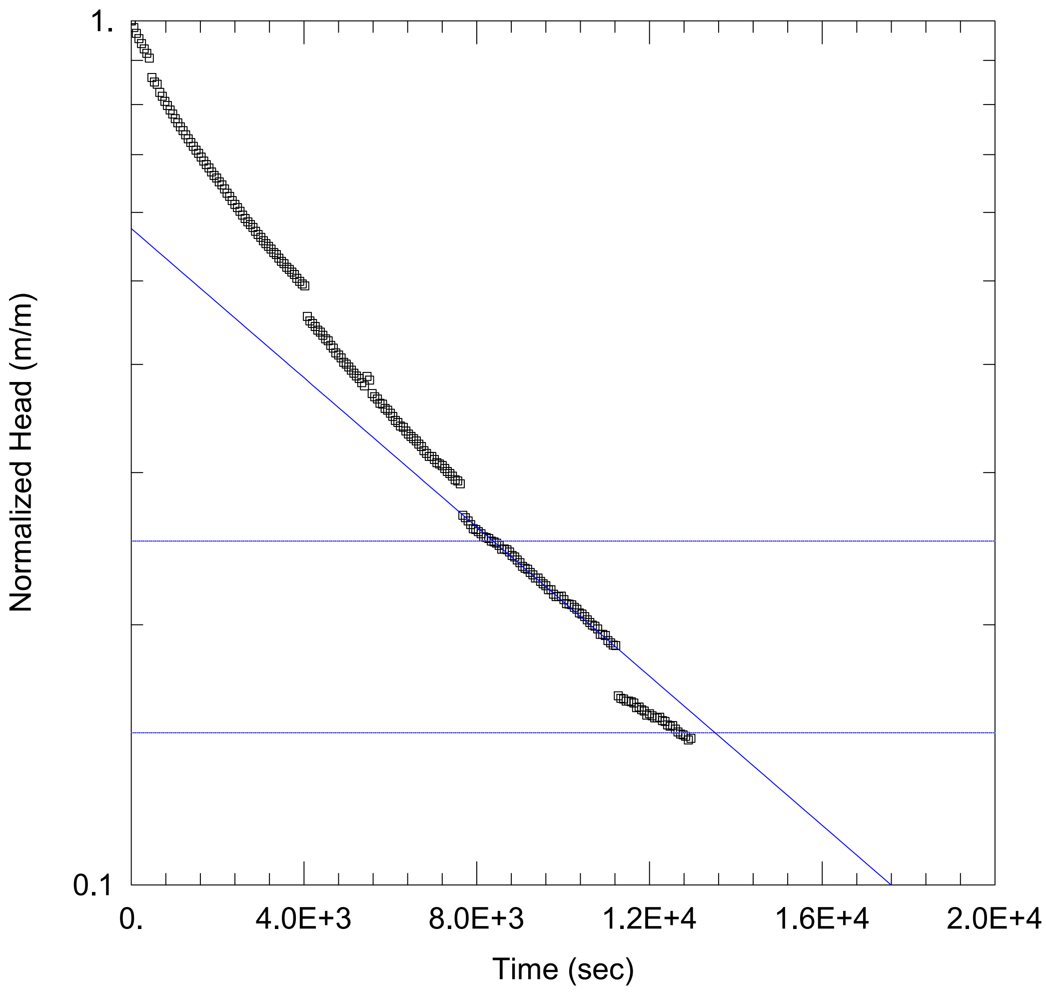
Saturated Thickness: 10.25 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW4D)

Initial Displacement: 0.3487 m
Static Water Column Height: 10.25 m
Total Well Penetration Depth: 1.09 m
Screen Length: 1. m
Casing Radius: 0.045 m
Well Radius: 0.1335 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.08E-7 m/sec
y0 = 0.1961 m



MW4D- RHT1

Data Set: G:\...\MW4D-RHT1_H.aqt
Date: 12/08/22
Time: 11:36:48

PROJECT INFORMATION

Company: GHD
Client: DCC
Project: 12547621
Test Well: MW2C
Test Date: 30/07/2022

AQUIFER DATA

Saturated Thickness: 10.25 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW4D)

Initial Displacement: 0.3487 m
Total Well Penetration Depth: 1.09 m
Casing Radius: 0.045 m
Static Water Column Height: 10.25 m
Screen Length: 1. m
Well Radius: 0.1335 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.044E-7 m/sec
y0 = 0.2005 m

Appendix B

Groundwater levels and plots

B-1 Bore locations and water levels

Table B.1 *Location of bore holes*

Name	X (NZTM[1])	Y (NZTM)	RL (OMD[2])	RL (NZVD[3])	WL below reference point	WL (RL NZVD[3])	WL Date
PS1	1399121	4912577	102.1	1.79	3.6	-1.81	
MW1A	1399031	4912671	104.03	3.72	1.435	2.285	8/07/2022
MW1B	1399028	4912662	103.19	2.89	1.322	1.568	8/07/2022
MH1	1399030	4912661	102.56	2.25	3.391	-1.141	8/07/2022
MW1C	1399031	4912657	103.65	3.34	1.211	2.129	8/07/2022
PS2	1398962	4912722	102.42	2.11	3.265	-1.155	8/07/2022
MW2A	1399000	4912815	103.63	3.32	2.806	0.514	8/07/2022
MW2B	1398995	4912817	102.8	2.49	2.323	0.167	8/07/2022
MH2	1398990	4912820	102.18	1.87	3.13	-1.26	8/07/2022
MW2C	1398986	4912822	102.48	2.17	1.216	0.954	8/07/2022
MW2D	1398980	4912826	102.49	2.18	0.5	1.68	8/07/2022
ST2	1398930	4912847	101	0.69	-	-	-
PS3	1399021	4912915	102.51	2.2	3.02	-0.82	8/07/2022
MW3A	1399054	4913013	102.77	2.46	1.292	1.168	8/07/2022
MW3B	1399049	4913014	102.82	2.51	1.38	1.13	8/07/2022
MH3	1399044	4913015	102.46	2.15	3.142	-0.992	8/07/2022
MW3C	1399036	4913018	102.9	2.59	2.242	0.348	8/07/2022
ST3	1398990	4913033	101	0.69	-	-	-
PS4	1399064	4913137	102.63	2.32	3.21	-0.89	8/07/2022
MW4A	1399160	4913176	103.93	3.62	2.789	0.831	8/07/2022
MW4B	1399158	4913182	102.93	2.62	1.886	0.734	8/07/2022
MW4C	1399156	4913192	102.89	2.58	2.205	0.375	8/07/2022
MW4D	1399162	4913194	104.16	3.85	1.88	1.97	8/07/2022
ST4	1399173	1399173	101	0.69	-	-	-
PS5	1399240	4913216	102.43	2.12	3.196	-1.076	8/07/2022
MW5A	1399334	4913275	103.04	2.73	2.983	-0.253	8/07/2022
MW5B	1399333	4913277	103.04	2.73	2.854	-0.124	8/07/2022
MH5	1399330	4913280	102.45	2.14	3.206	-1.066	8/07/2022
MW5C	1399326	4913286	103.08	2.77	1.772	0.998	8/07/2022
ST 5	1399331	4913307	101	0.69	-	-	-
PS6	1399424	4913304	102.42	2.11	3.874	-1.764	8/07/2022
MW6A	1399508	4913260	102.75	2.44	0.748	1.692	8/07/2022
MW6B	1399513	4913262	102.72	2.41	1.164	1.246	8/07/2022
MH6	1399518	4913264	102.65	2.35	3.125	-0.775	8/07/2022
MW6C	1399525	4913266	102.67	2.36	1.173	1.187	8/07/2022
PS7	1399631	4913185	103.12	2.81	3.913	-1.103	8/07/2022
MW7A	1399652	4913100	103.27	2.96	1.254	1.706	8/07/2022
MW7B	1399657	4913102	103.28	2.97	1.848	1.122	8/07/2022
MH7	1399661	4913104	102.96	2.65	3.528	-0.878	8/07/2022
MW7D	1399670	4913101	103.23	2.92	1.562	1.358	8/07/2022
PS8	1399682	4913035	103.79	3.48	4.056	-0.576	8/07/2022
MW8A	1399617	4912928	105.43	5.12	3.482	1.638	8/07/2022
MW8B	1399622	4912923	105.44	5.13	3.191	1.939	8/07/2022
MH8	1399628	4912920	105.02	4.71	3.912	0.798	8/07/2022

MW8C	1399627	4912915	105.44	5.13	2.296	2.834	8/07/2022
PS9	1399557	4912818	105.97	5.66	5.892	-0.232	8/07/2022
MW9	1399368	4912898	109.74	9.43	-	-	-
MW0C	1399149	4912500	102.55	2.24	1.488	0.752	8/07/2022
2022 Geotechnical Investigation							
BH100	1399159	4913183	-	2.2	0.975	1.225	14/11/2022
BH101	1399045	4913067	-	2.26	1.964	0.296	14/11/2022
BH102	1399010	4912854	-	2.18	1.291	0.889	14/11/2022
BH103	1399103	4912603	-	1.58	1.027	0.553	14/11/2022
BH104	1399552	4912899	-	6.47	7.09	-0.62	14/11/2022
BH105[4]	1399518	4913038	-	6.42	-	-	-
BH106	1399559	4913069	-	6.6	-	-	-
BH107	1399344	4913221	-	6.87	-	-	-
BH108	1399316	4912716	-	12.12	5.272	6.848	14/11/2022
BH109	1399510	4913116	-	7.02	-	-	-
BH110[4]	1399332	4913121	-	7.61	-	-	-
BH111	1399279	4913201	-	6.26	-	-	-
CPT100	1399159	4913183	-	2.19	-	-	-
CPT101	1399044	4913073	-	2.09	-	-	-
CPT102[4]	1399038	4912947	-	1.72	-	-	-
CPT103	1399010	4912854	-	2.2	-	-	-
CPT104	1399020	4912657	-	1.77	-	-	-
CPT105	1399103	4912603	-	1.61	-	-	-
CPT108	1399265	4913233	-	1.66	-	-	-

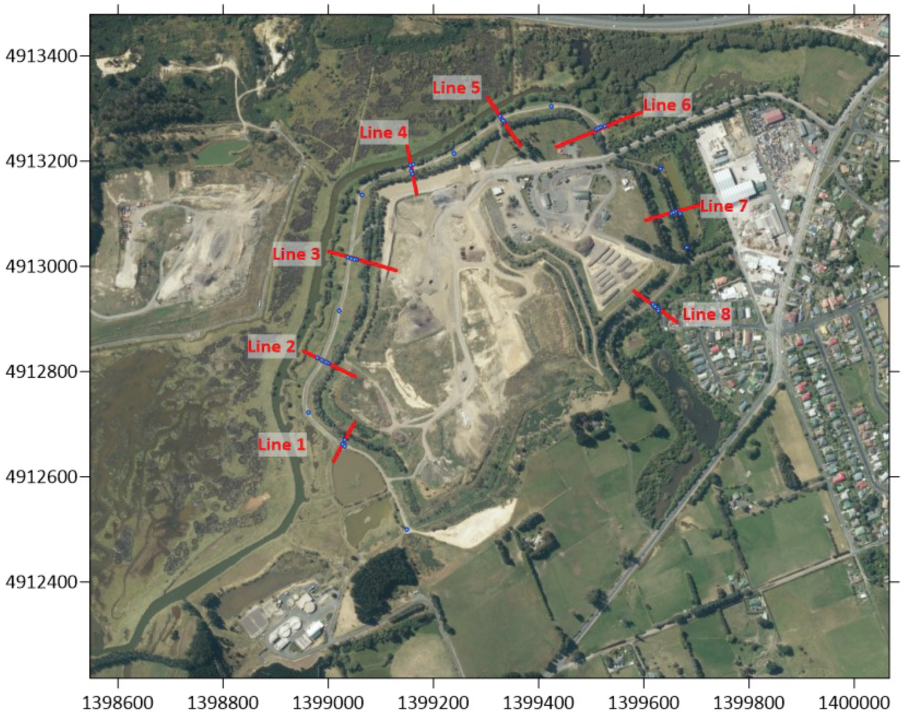
Notes:

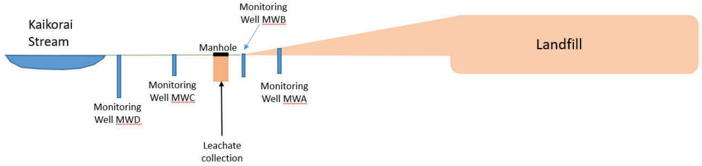
[1] New Zealand Transverse Mercator

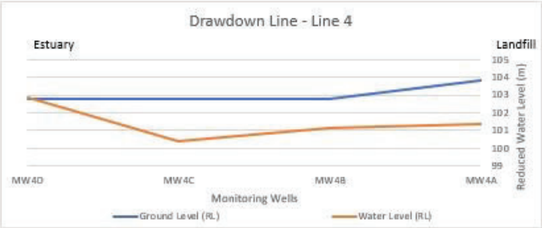
[2] Otago metric datum

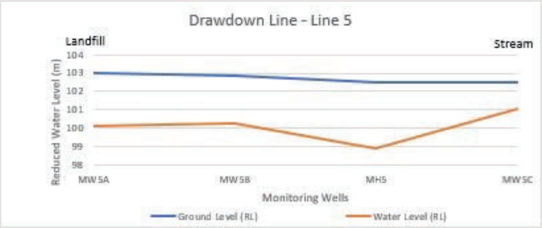
[3] New Zealand Vertical Datum. Locations on monitoring wells lines 1-9 converted from OMD based on correction factor of -(0.388 m + 100 m), from height of mark AG1B **AG1B: W 6 (linz.govt.nz)**

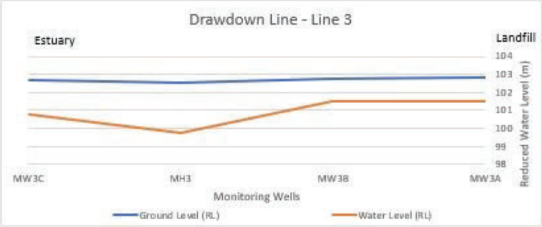
[4] Locations and elevation not surveyed, measured with hand held GPS (approximate only)

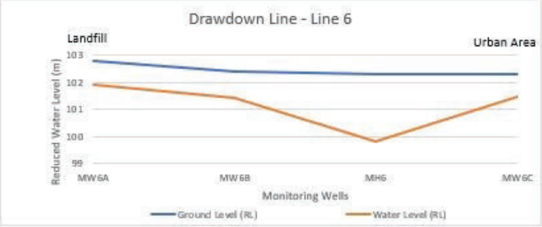


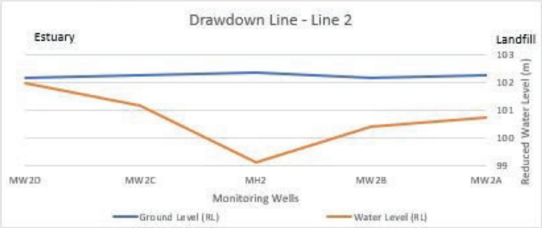


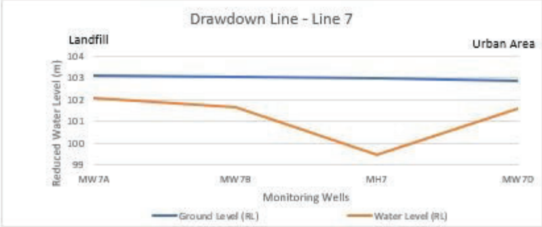


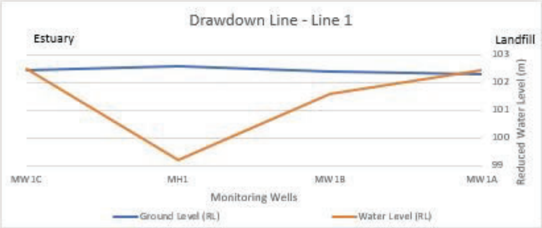


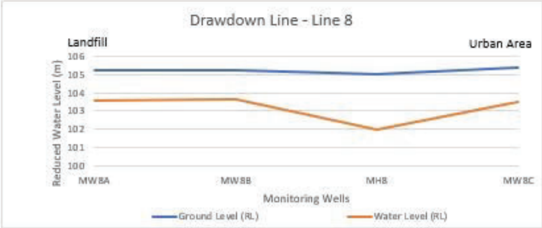












Dunedin City Council

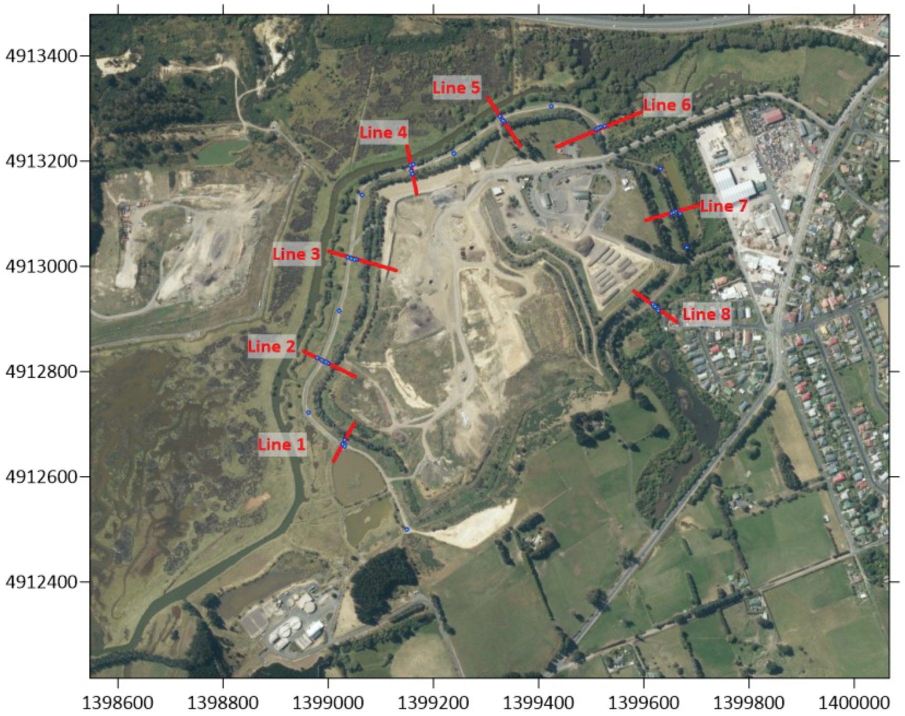
DCC Landfills

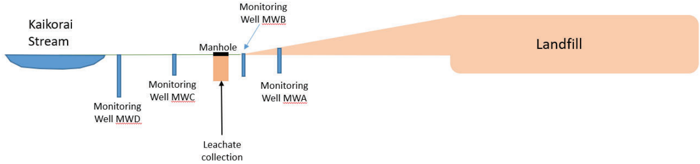
Monthly Transects - Green Island
July 2021

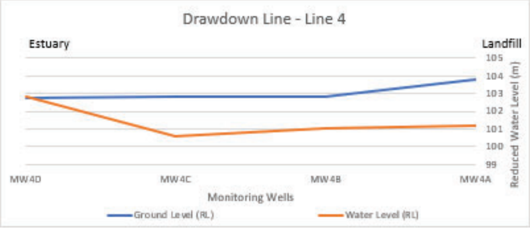
Job Number	12553867
Revision	A
Date	05/09/2022

Figure B-1

Sources: Aerial (LINZ: Aerial Dunedin 0.4m Rural, 2013, NZGD2000) ; Computed using Green_Island_water_levels.xlsb.xlsx



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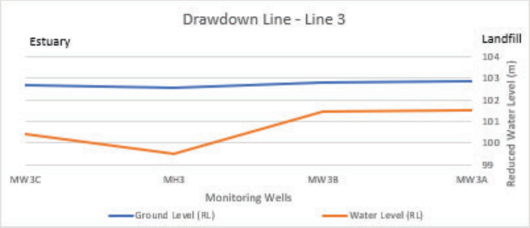
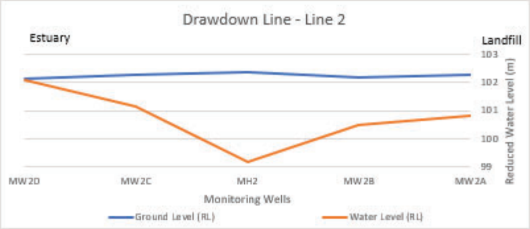

Drawdown Line - Line 3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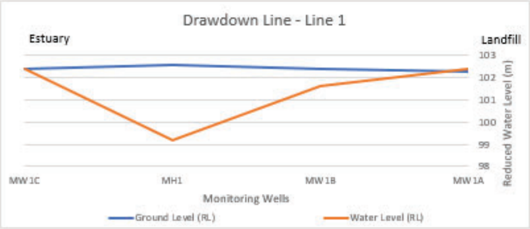
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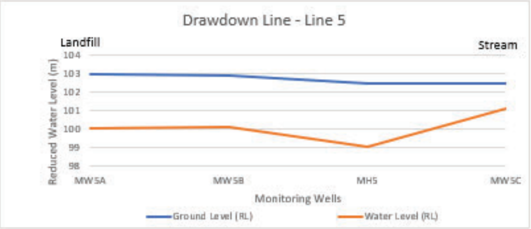
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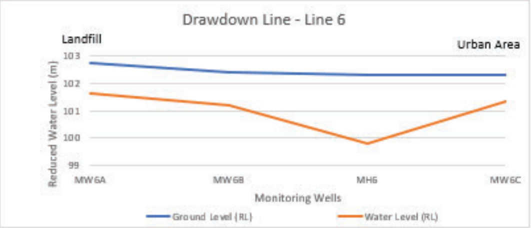
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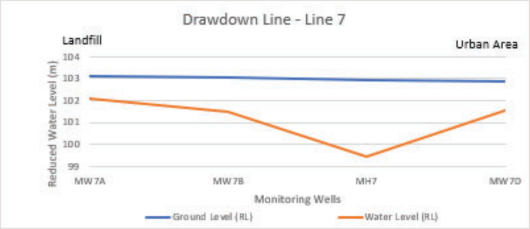
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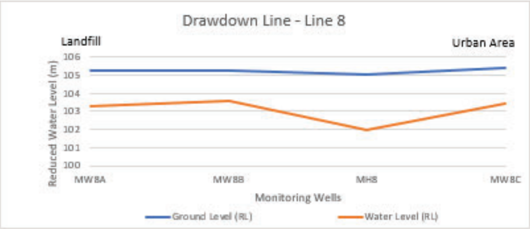
Drawdown Line - Line 8

Sources: Aerial (LINZ: Aerial Dunedin 0.4m Rural, 2013, NZGD2000) ; Computed using Green_Island_water_levels.xlsb.xlsx

Dunedin City Council

DCC Landfills

Monthly Transects - Green Island
October 2021

Job Number	12553867
Revision	A
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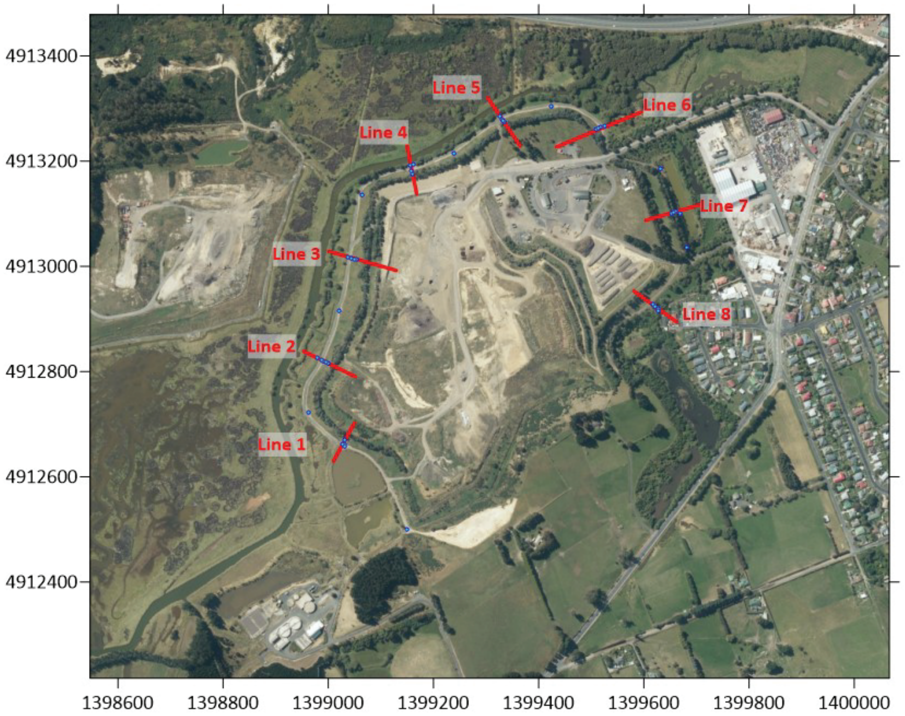
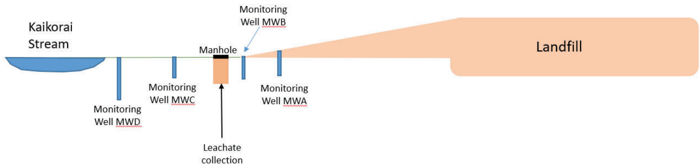
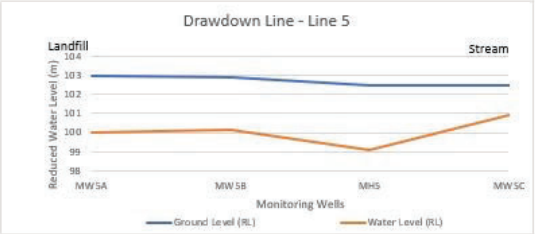
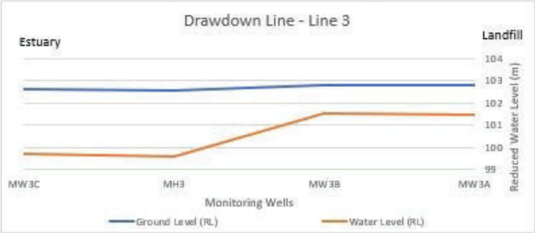
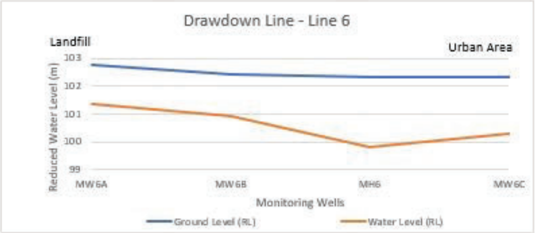
Figure B-2

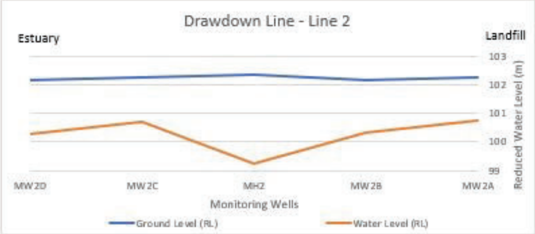


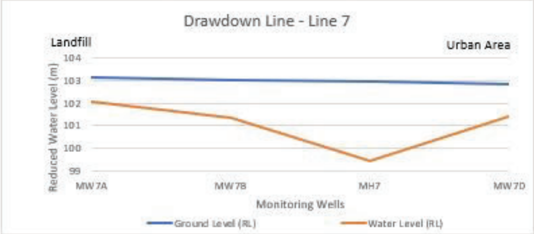


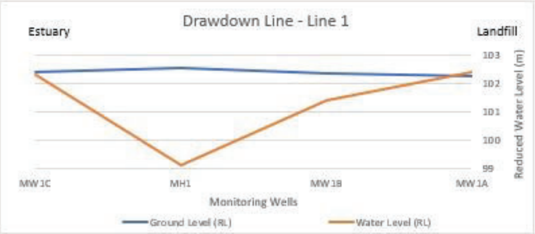


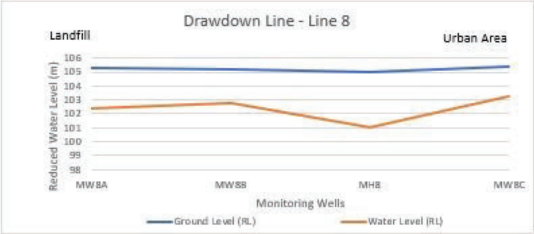












Sources: Aerial (LINZ: Aerial Dunedin 0.4m Rural, 2013, NZGD2000) ; Computed using Green_Island_water_levels.xlsb.xlsx

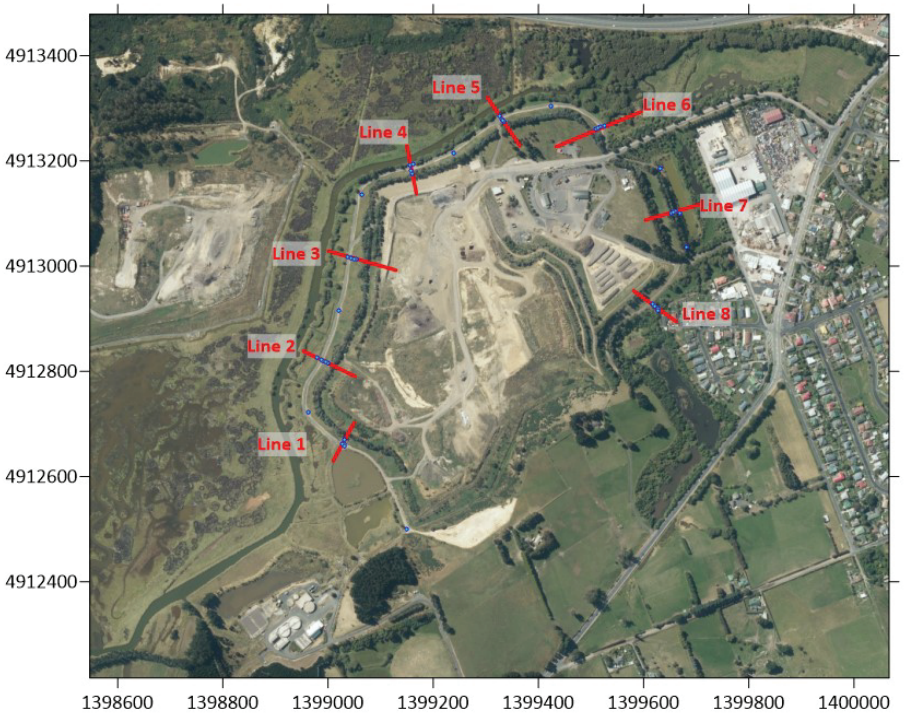
Dunedin City Council

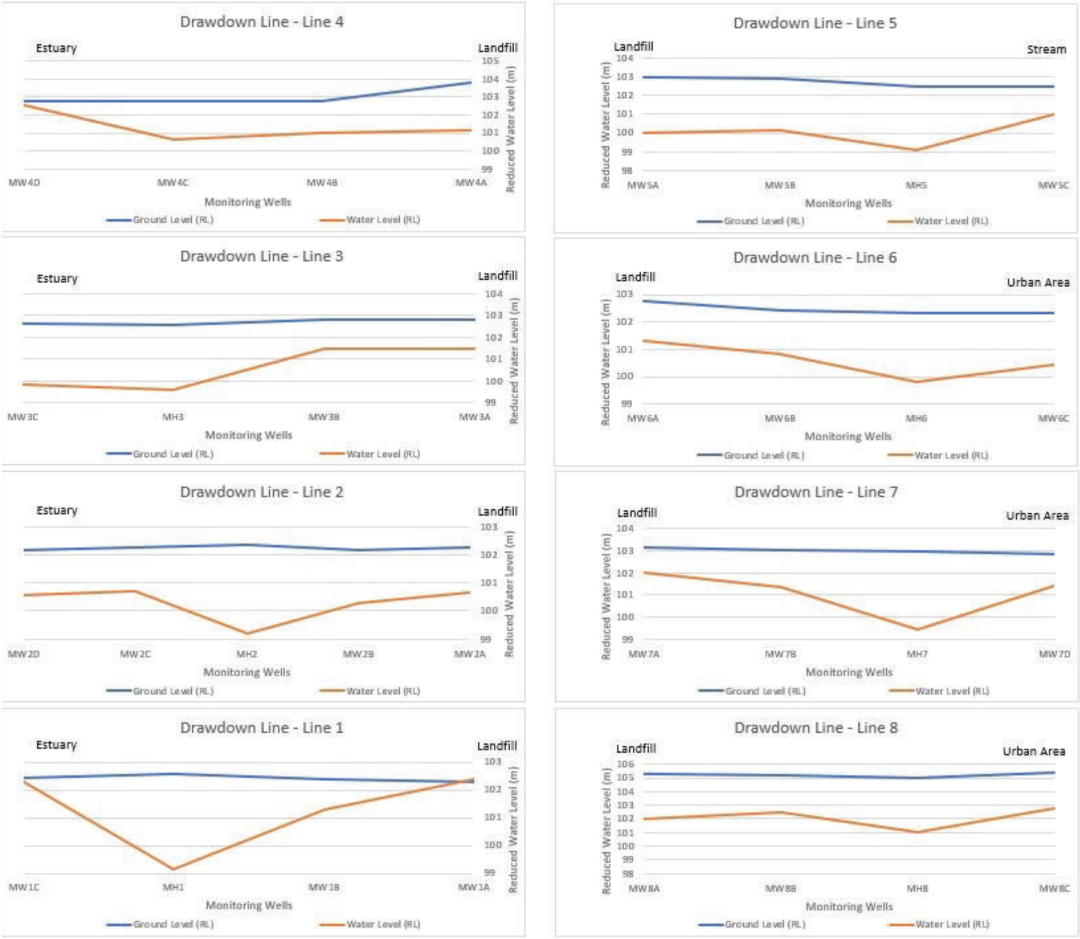
DCC Landfills

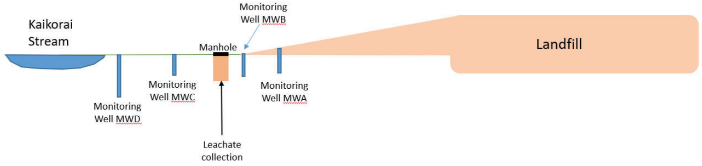
Monthly Transects - Green Island
February 2022

Job Number	12553867
Revision	A
Date	05/09/2022

Figure B-3







Sources: Aerial (LINZ: Aerial Dunedin 0.4m Rural, 2013, NZGD2000) ; Computed using Green_Island_water_levels.xlsb.xlsx

Dunedin City Council

DCC Landfills

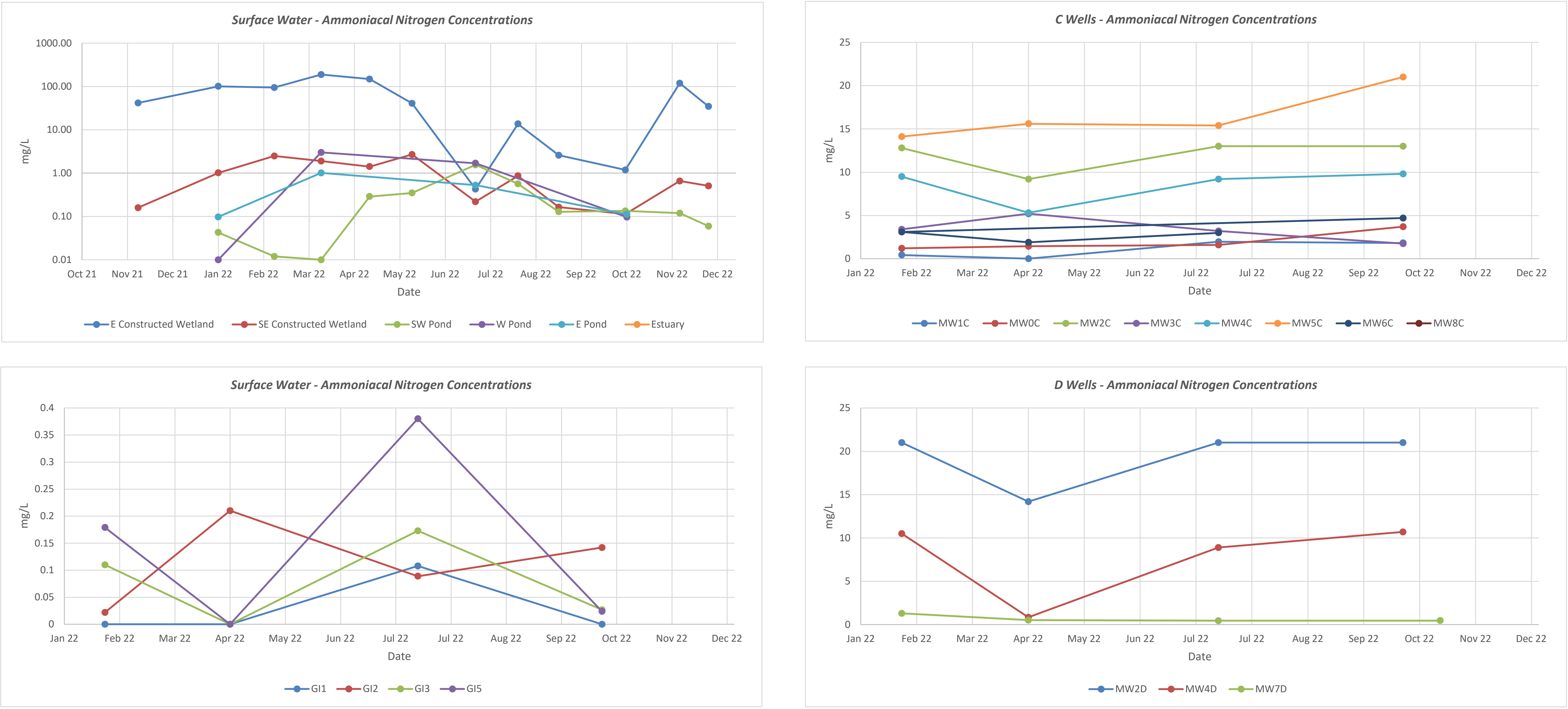
Monthly Transects - Green Island
April 2022

Job Number	12553867
Revision	A
Date	05/09/2022

Figure B-4

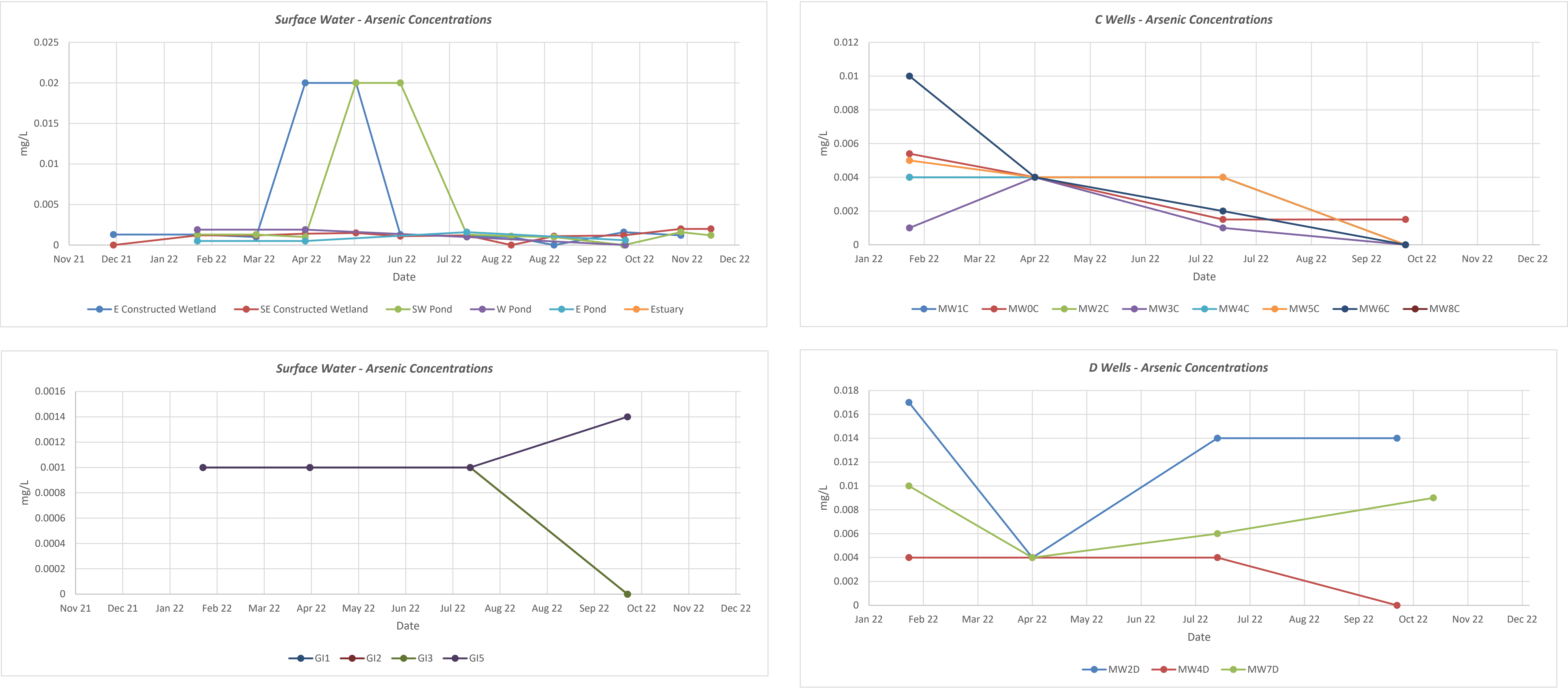
Appendix C

Groundwater quality



Note: Flood event during the July monitoring round - dilution is likely cause of reduced concentrations in surface water sampling locations

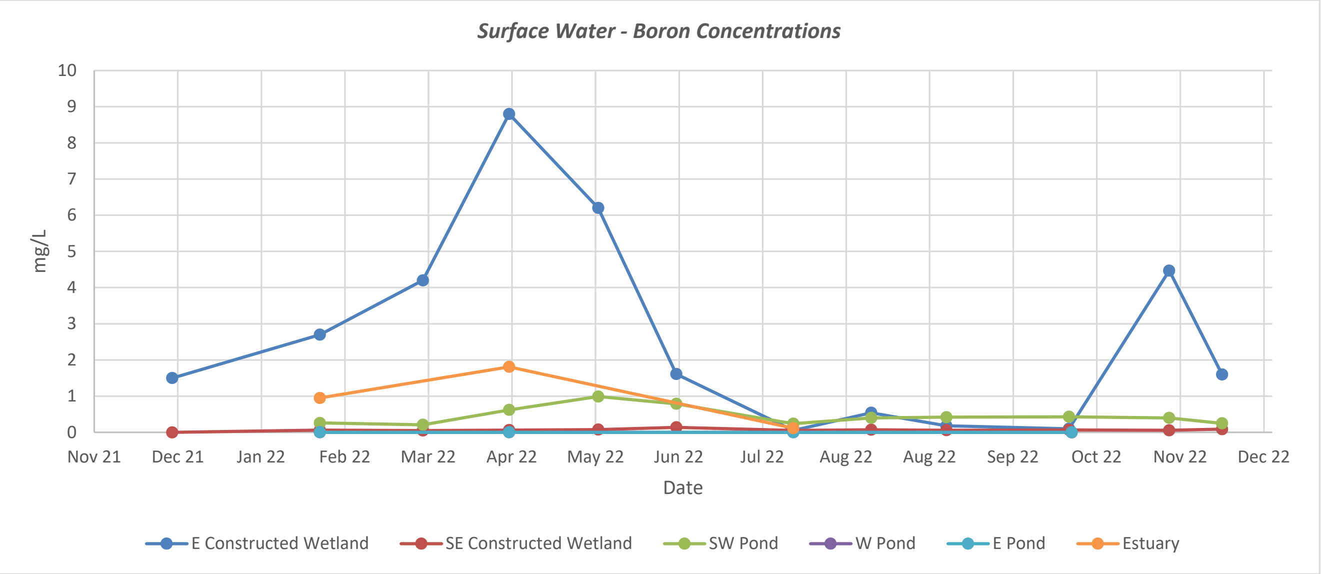
Figure C1-1 Ammonical Nitrogen

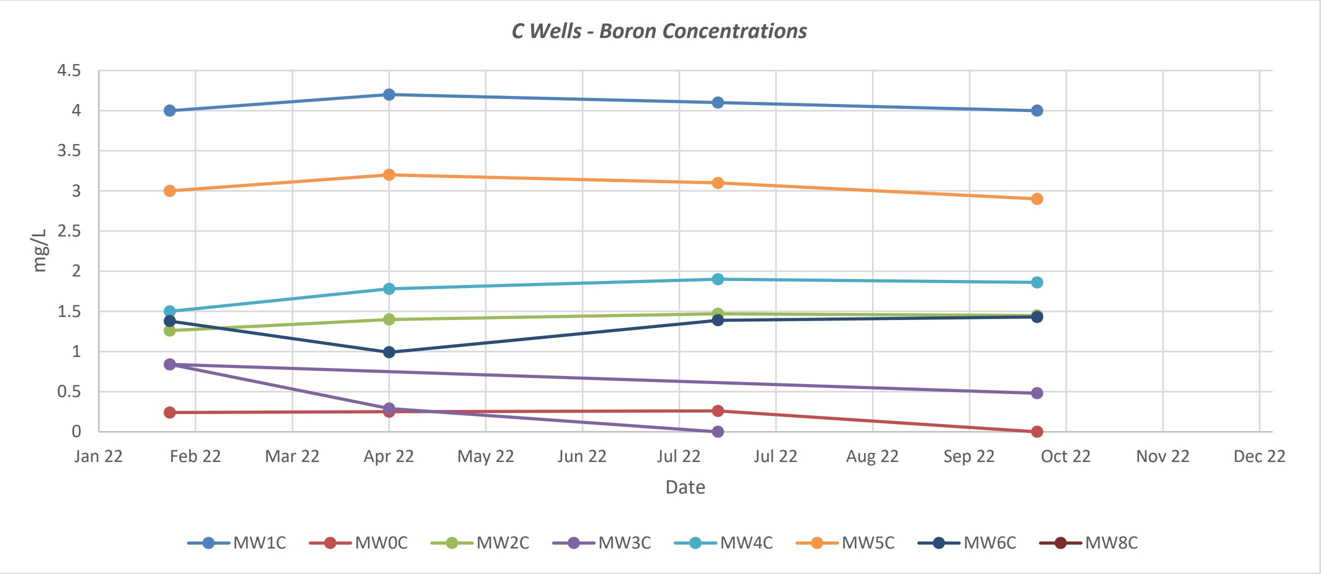


Note: All arsenic concentrations at locations GI1, GI2, GI3 & GI5 were less than the detection limit

Note: Flood event during the July monitoring round - dilution is likely cause of reduced concentrations in surface water sampling locations

Figure C1-2 Arsenic

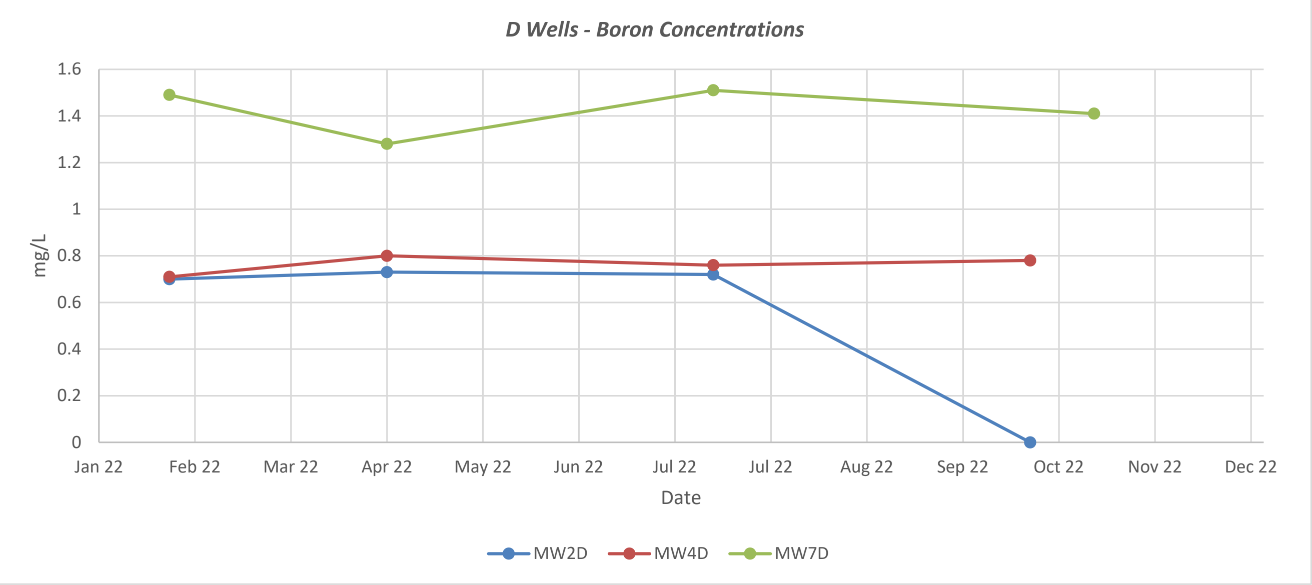


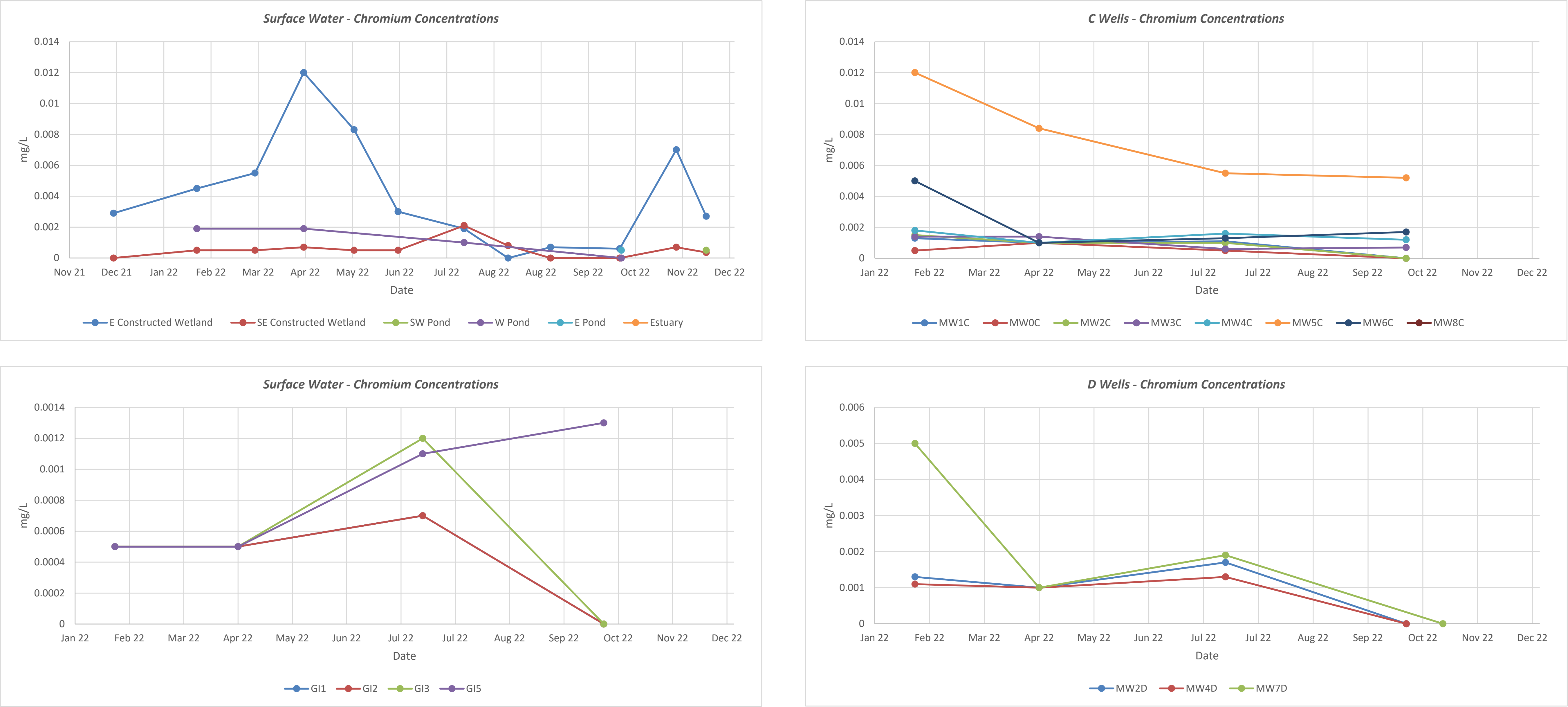


Note: Boron analysis not undertaken in samples GI1, GI2, GI3, GI5

Note: Flood event during the July monitoring round - dilution is likely cause of reduced concentrations in surface water sampling locations

Figure C1-3 Boron





Surface Water - Chromium Concentrations

C Wells - Chromium Concentrations

Surface Water - Chromium Concentrations

D Wells - Chromium Concentrations

Note: Flood event during the July monitoring round - dilution is likely cause of reduced concentrations in surface water sampling locations

Figure C1-4 Chromium

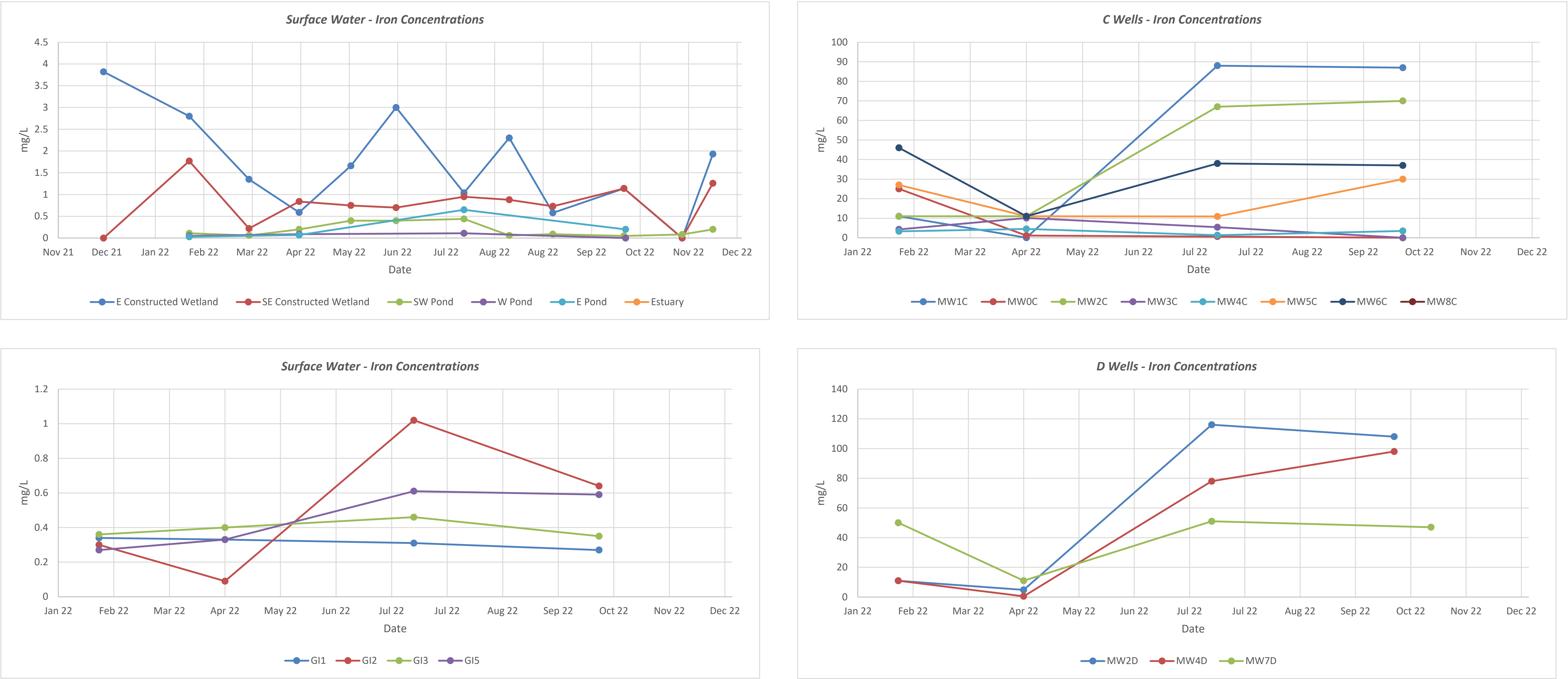


Figure C1-5 Iron

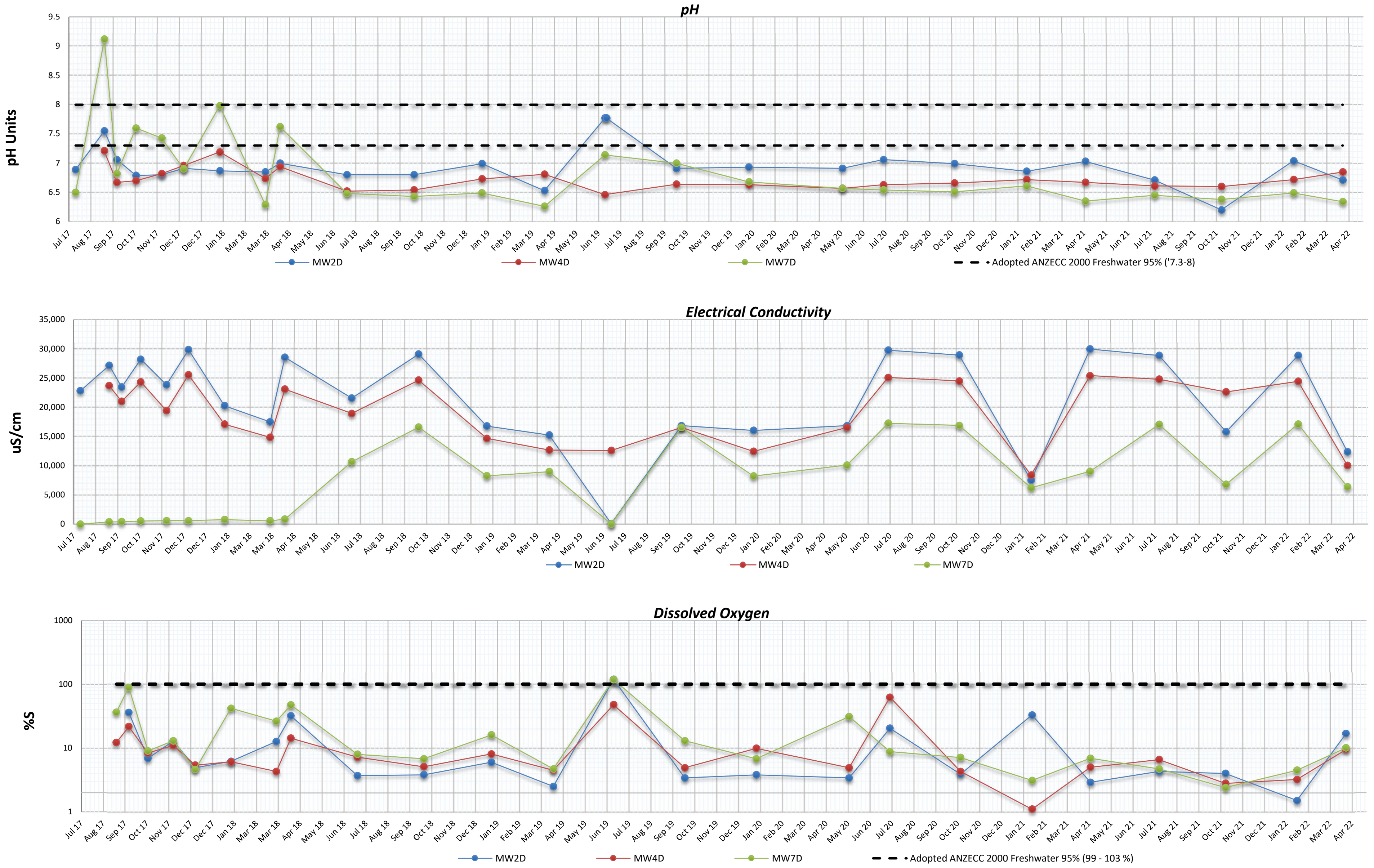


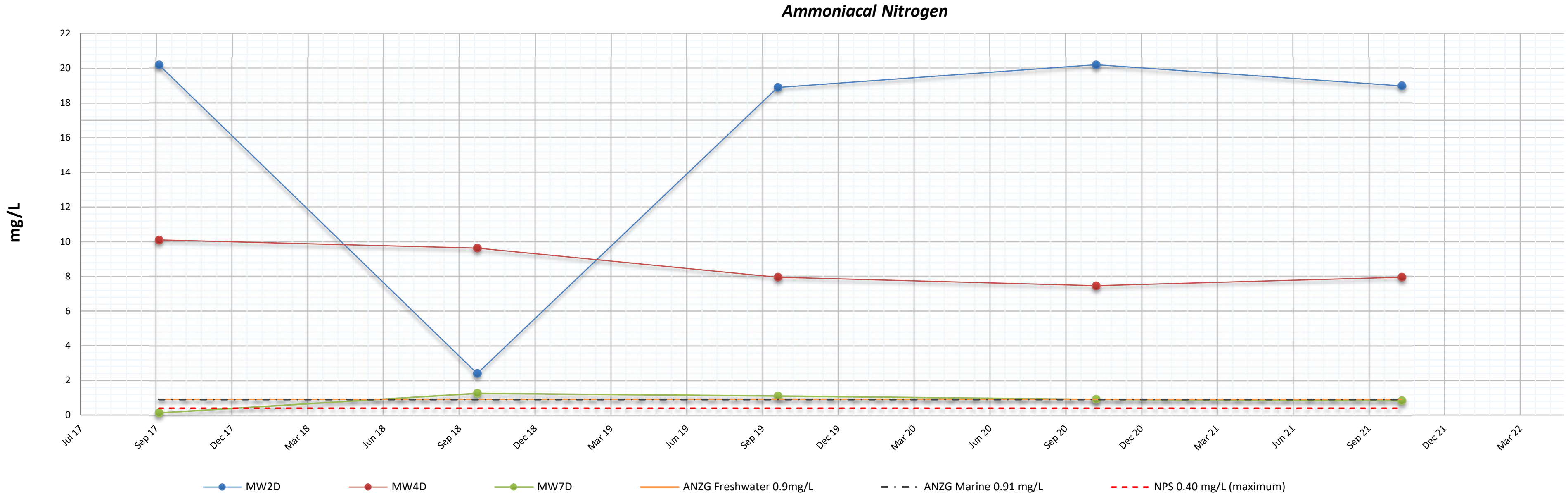
Figure C2-1: Green Island Landfill Deep Wells - Chemistry Data

DCC Landfill _ All Data

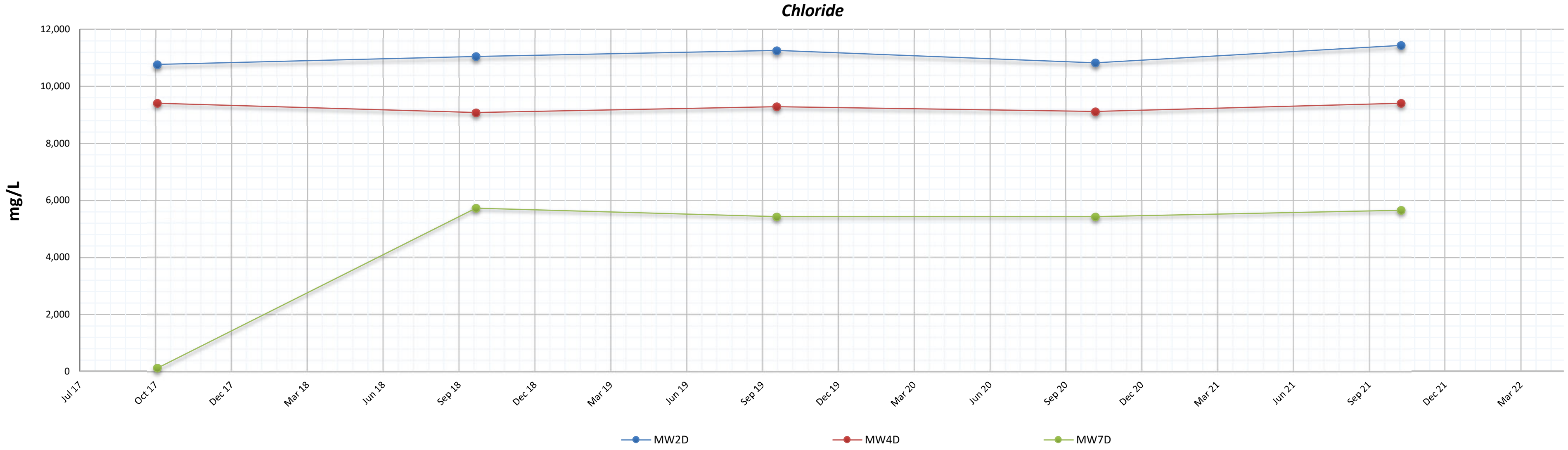
Date:
Aug 21

Drawn: HE
Reviewer: CG

Project Number:
12553867



Ammoniacal Nitrogen



Chloride

Figure C2-2: Green Island Landfill Deep Wells - Chemistry Data

DCC Landfill _ All Data

Date:
Sep 21

Drawn: **CG**
Reviewer: **CG**

Project Number:
12553867

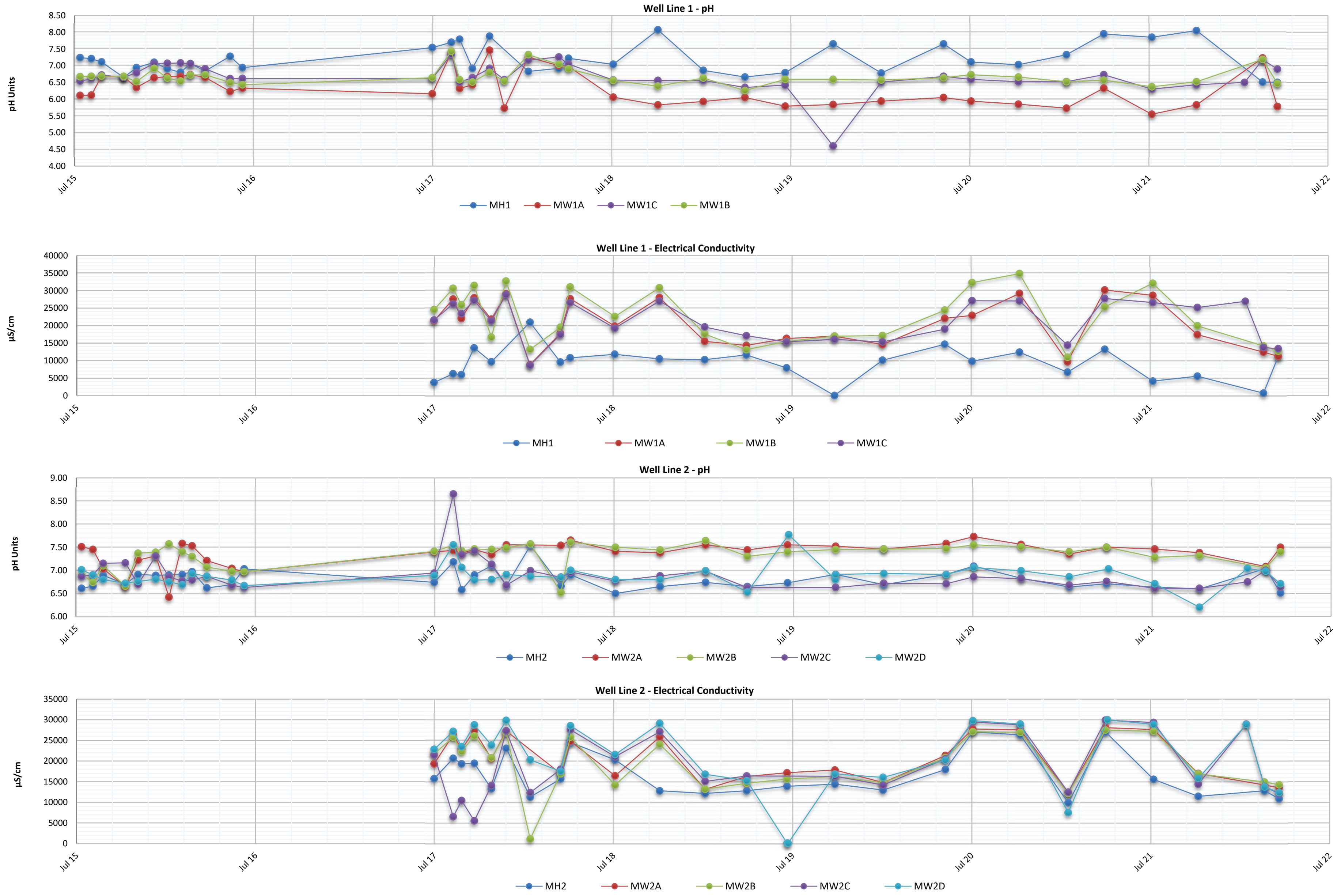


Figure C3-1: Green Island Landfill - Manhole, Shallow Monitoring Wells and Pump Station pH and EC Data

DCC Landfill _ All Data

Date: Aug-22	Page 1
Drawn: HE	Reviewer: CG
Project Number: 12553867	

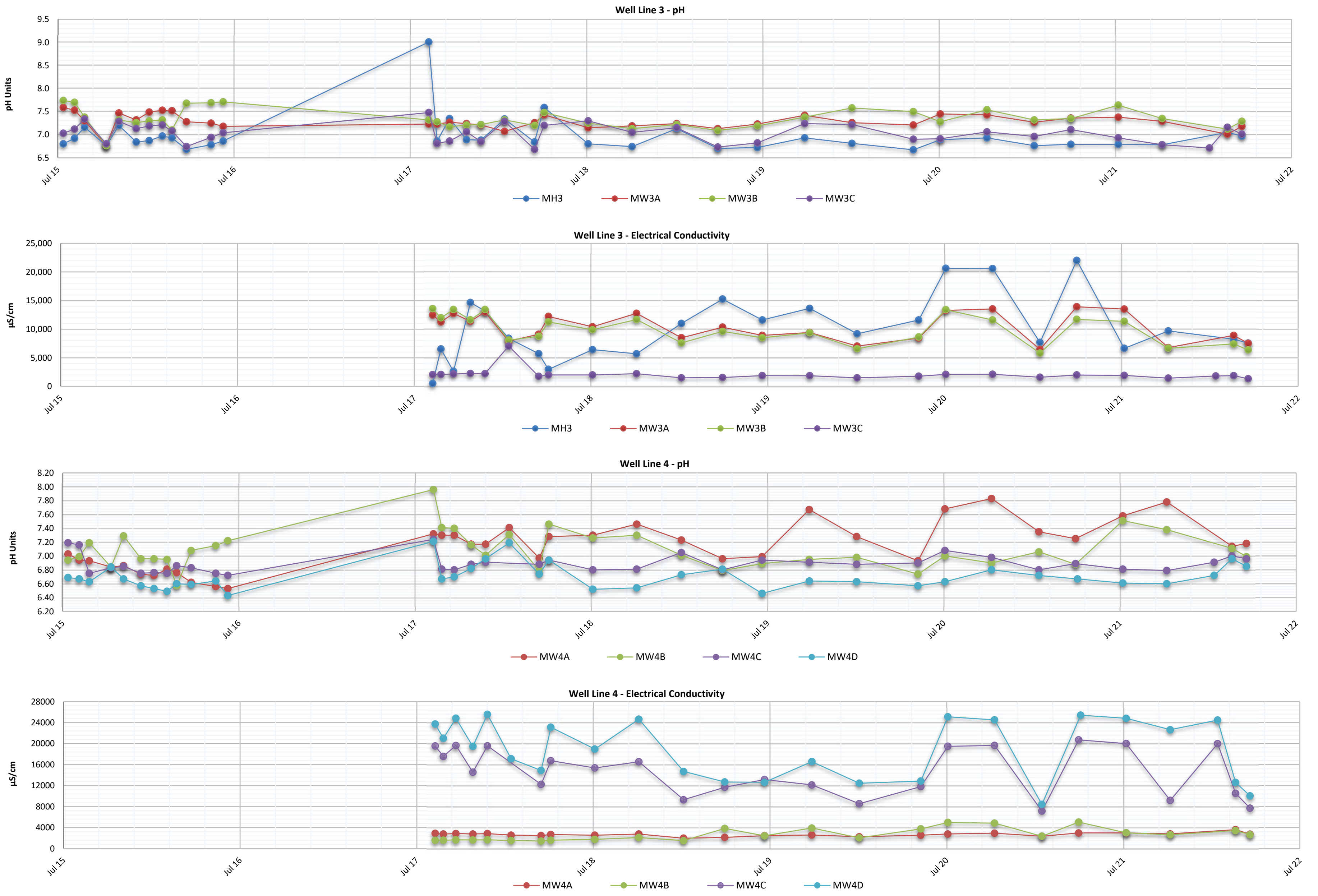


Figure C3-2: Green Island Landfill - Manhole, Shallow Monitoring Wells and Pump Station pH and EC Data

DCC Landfill _ All Data

Date:
Aug-22

Page 2

Drawn:
HE

Reviewer:
CG

Project Number:
12553867

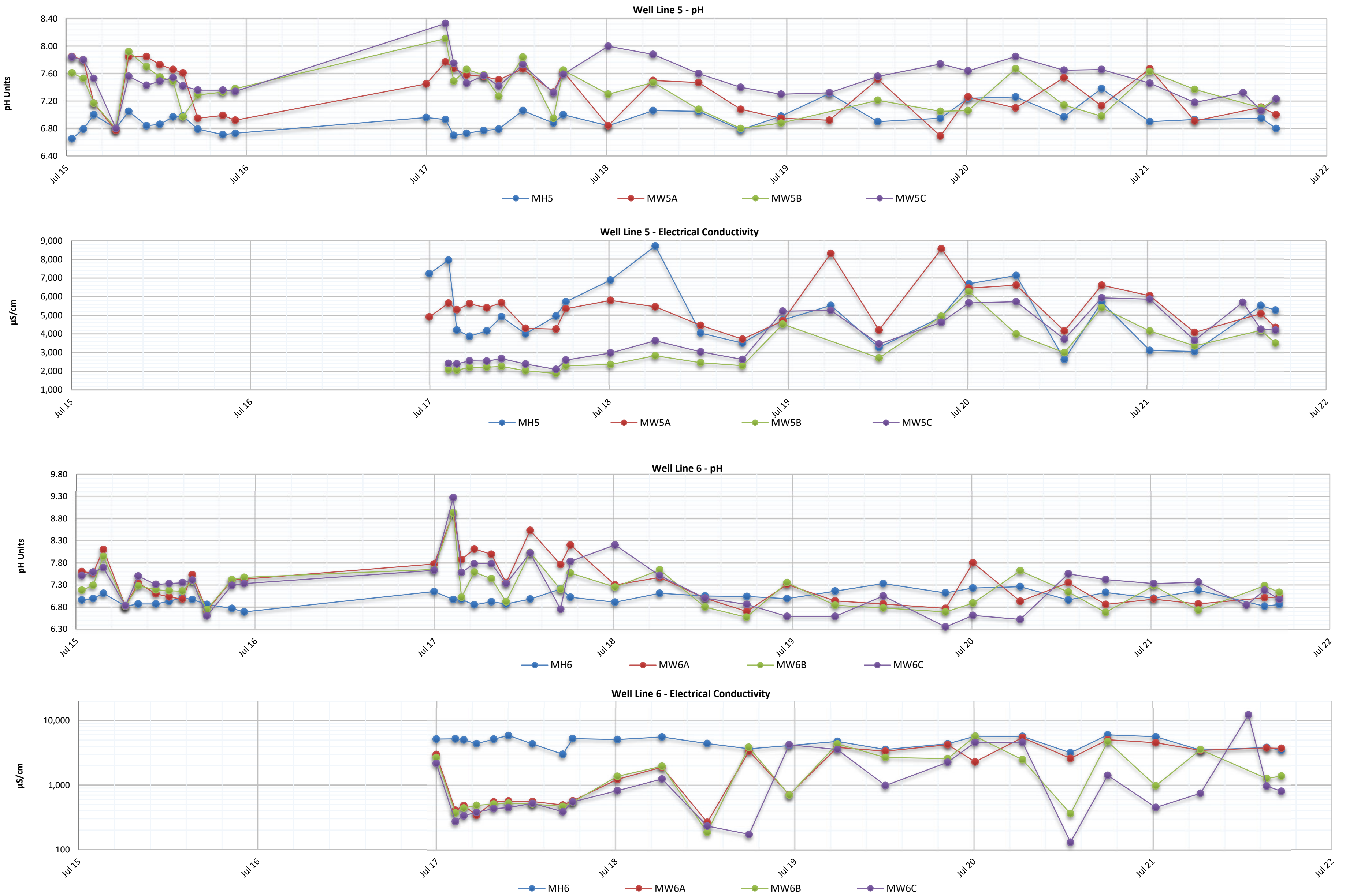
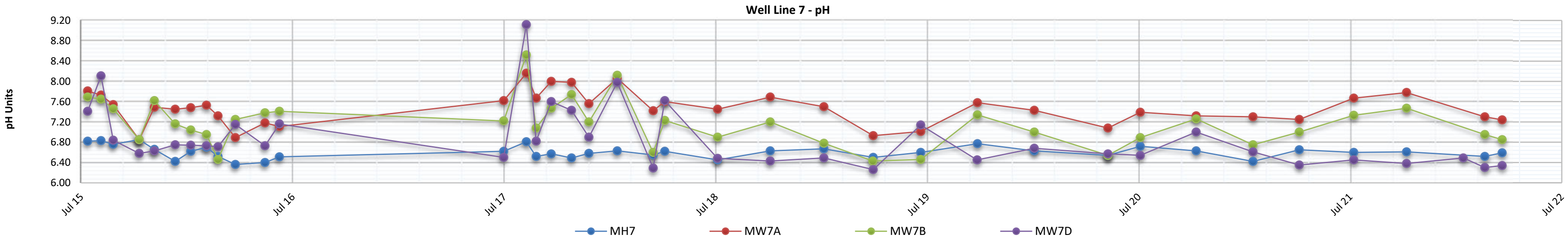
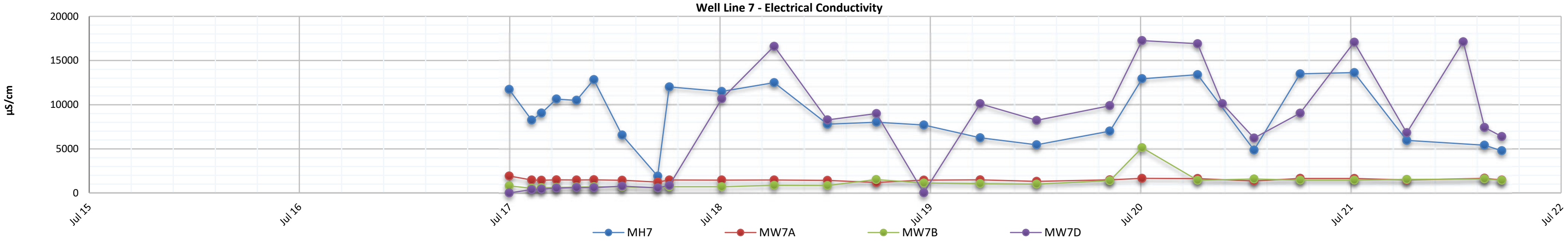


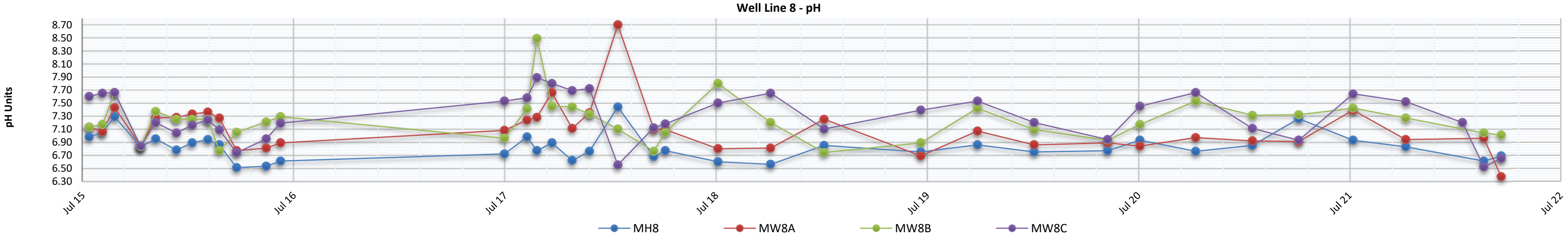
Figure C3-3: Green Island Landfill - Manhole, Shallow Monitoring Wells and Pump Station pH and EC Data

DCC Landfill _ All Data

Date: Aug-22	Page 3
Drawn: HE	Reviewer: CG
Project Number: 12553867	


Well Line 7 - pH


Well Line 7 - Electrical Conductivity


Well Line 8 - pH

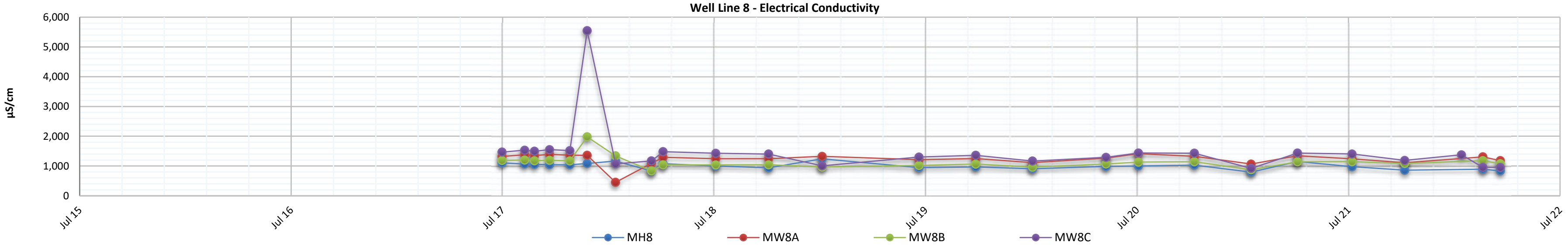
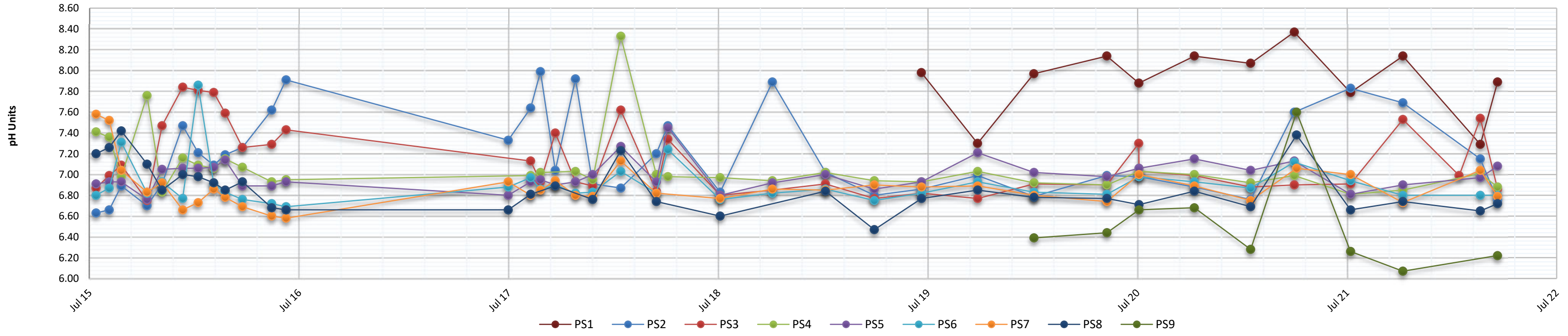
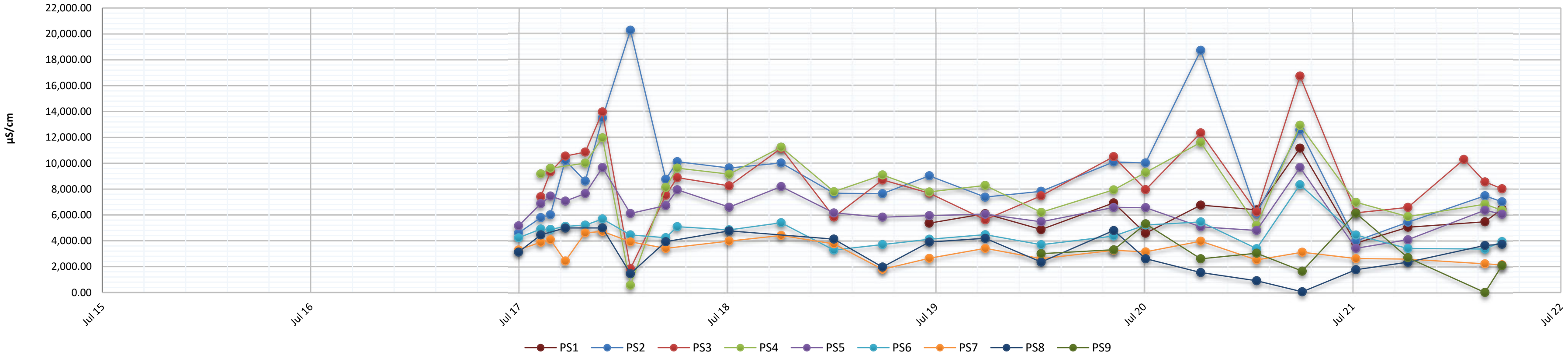

Well Line 8 - Electrical Conductivity

Figure C3-4: Green Island Landfill - Manhole, Shallow Monitoring Wells and Pump Station pH and EC Data

DCC Landfill _ All Data

Date: Aug-22	Page 4
Drawn: HE	Reviewer: CG
Project Number: 12553867	


Pump Stations: pH - PS1 to PS9


Pump Stations: Electrical Conductivity - PS1 to PS9

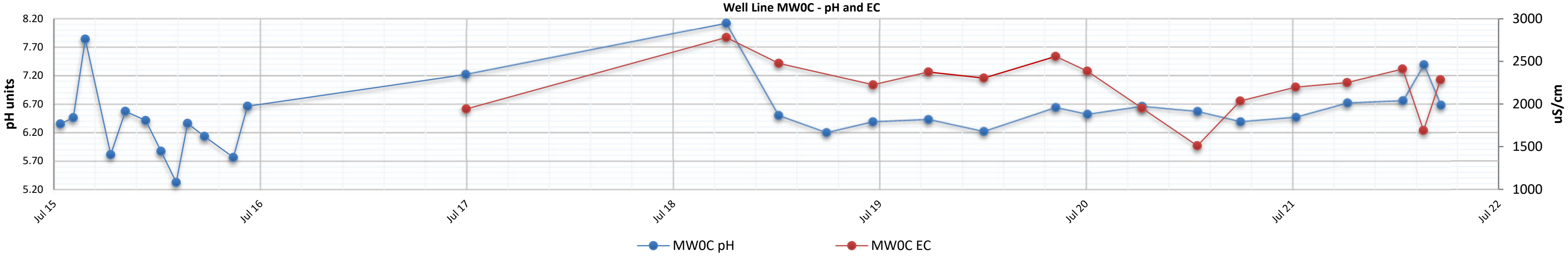

Well Line MW0C - pH and EC

Figure C3-5: Green Island Landfill - Manhole, Shallow Monitoring Wells and Pump Station pH and EC Data

DCC Landfill _ All Data

Date: Aug-22	Page 5
Drawn: HE	Reviewer: CG
Project Number: 12553867	

ANALYTICA LABORATORIES

Analytica Laboratories Limited
Ruakura Research Centre
10 Bisley Road
Hamilton
sales@analytica.co.nz
www.analytica.co.nz

Certificate of Analysis

GHD Ltd
Level 1, Bing Harris Building, 286 Princess Street, Dunedin
Dunedin 9016

Attention: Dusk Main
Phone: 03 479 9481
Email: hayden.erasmus@ghd.com

Lab Reference: 24-19939
Submitted by: Courtney Deavoll
Date Received: 22/06/2024
Testing Initiated: 24/06/2024
Date Completed: 15/07/2024
Order Number: 12613624
Reference: 12613624

Sampling Site: Green Island Landfill

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories (or at the subcontracted laboratories, when applicable). Samples were in acceptable condition unless otherwise noted on this report. Specific testing dates are available on request.

Biochemical Oxygen Demand

		Client Sample ID	BH103
		Date Sampled	21/06/2024
Analyte	Unit	*Reporting Limit*	24-19939-1
Total Biochemical Oxygen Demand	g/m^3	*1*	<1.0

Anion/Cation Suite

		Client Sample ID	BH103
		Date Sampled	21/06/2024
Analyte	Unit	*Reporting Limit*	24-19939-1
pH	pH	*1*	6.8
Electrical Conductivity	µS/cm	*0.2*	37,360.00
Total Alkalinity (CaCO3)	g CaCO$_3$/m^3	*1*	657
Chloride	g/m^3	*0.5*	12,706.76
Sulfate	g/m^3	*0.15*	13.4
Nitrate-N	g/m^3	*0.002*	0.300
Dissolved Reactive Phosphorus (FIA)	g/m^3	*0.002*	<0.002
Ammonia as N	g/m^3	*0.005*	32.7
Sodium	g/m^3	*0.01*	4,740
Potassium	g/m^3	*0.05*	149
Calcium	g/m^3	*0.05*	976
Magnesium	g/m^3	*0.01*	864
Iron	g/m^3	*0.005*	116

Anion/Cation Suite

Client Sample ID			BH103
Date Sampled			21/06/2024
Zinc	g/m^3	*0.001*	0.013
Manganese	g/m^3	*0.0005*	0.854
Sum of Anions*	meq/L	*0.01*	371.78
Sum of Cations*	meq/L	*0.01*	336.38
EC/10*	(mS/m)/10	*0.002*	373.60

Elements in Water (Soluble)

Client Sample ID			BH103
Date Sampled			21/06/2024
Analyte	Unit	*Reporting Limit*	24-19939-1
Boron	g/m^3	*0.01*	0.845
Lead	g/m^3	*0.00005*	0.00042

Carbon in Water

Client Sample ID			BH103
Date Sampled			21/06/2024
Analyte	Unit	*Reporting Limit*	24-19939-1
Total Organic Carbon	g/m^3	*0.5*	22.7

Method Summary

BOD	Dissolved oxygen measured using a dissolved oxygen electrode after a 5 day incubation period. (APHA 5210 B - Online edition).
pH	Samples measured as received using a conventional pH electrode. (APHA 4500 H^+ B. Online edition).
Electrical Conductivity	Samples analysed as received using a conventional conductivity electrode. (APHA 2510 B - Modified - Auto-titrator - Online edition).
Total Alkalinity ($CaCO_3$)	Samples analysed as received by potentiometric titration. (APHA 2320 B Online edition).
Chloride	Analysis by Ion exchange chromatography following sample filtration. (APHA 4110 B - Online edition).
Sulfate	Analysis by Ion exchange chromatography following sample filtration. (APHA 4110B - Online edition).
NO3-N	Calculated from oxidised nitrogen and Nitrite-N, measured colourimetrically by flow injection analysis. (APHA NO_{3-} I. Online edition)
Dissolved Reactive Phosphorus	Samples filtered and measured colourimetrically by flow injection analysis. (APHA 4500-P G - Modified - Online edition)
Ammonia-N	Samples filtered and measured colourimetrically by flow injection analysis. (APHA 4500-NH_3 H - Modified - Online edition).
Soluble Trace Elements	Samples were analysed as received by the laboratory using ICP-MS following a 0.45µm membrane filtration (except when field filtered). In house procedure based on US EPA 200.8.
Sum of Anions	Sum of milliequivalents/Litre of measured Anions.
Sum of Cations	Sum of milliequivalents/Litre of measured Cations.
Total Organic Carbon	Samples analysed as received by combustion analysis at 850°C. Organic carbon is calculated through subtraction of inorganic carbon from total carbon (APHA 5310 B - Online edition)

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Appendix D

Waste history and distribution

Green Island Landfill

Landfilling History and Targeted Contaminated Land Assessment Report

Dunedin City Council

7 March 2023

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1. Introduction

1.1 Background

Existing Otago Regional Council (ORC) resource consents for the operation and management of the Green Island Landfill (the Site), expire in October 2023. It is understood that Dunedin City Council (DCC) is considering options for disposal of waste beyond this date, and eventual closure scenarios for the Landfill.

The Green Island Landfill (the Site) is a municipal landfill facility situated on Taylor Street, to the west of Brighton Road, approximately 10 km southwest of the suburb of Green Island and central Dunedin. A Site Location Plan is provided as Figure 1, overleaf.

GHD Limited (GHD) has been engaged, as part of a wider project to prepare planning documents for application to consent future landfilling and closure, to undertake a review of the history of landfilling at the Site and an assessment of the contamination status of soil recovered during drilling works being undertaken as part of a concurrent GHD geotechnical investigation. The geotechnical investigation was focused on the perimeter of the landfill, with boreholes located mainly around the leachate collection drain / access track area. Further details of borehole locations are provided in Section 4 of this report.

The findings of this report will provide contaminated land status context for both the geotechnical and hydrogeological assessment repots and help inform the design report and consenting process.

1.2 Purpose and Scope of the Environmental Assessment

The purpose of this piece of work is to improve the understanding of the history and extent of landfilling at the Site and assess soil contaminant status in the geotechnical investigation boreholes. This work helps inform the technical reports being prepared as part of the Site's continued operation and closure works and consent application strategy.

The following scope of works was undertaken:

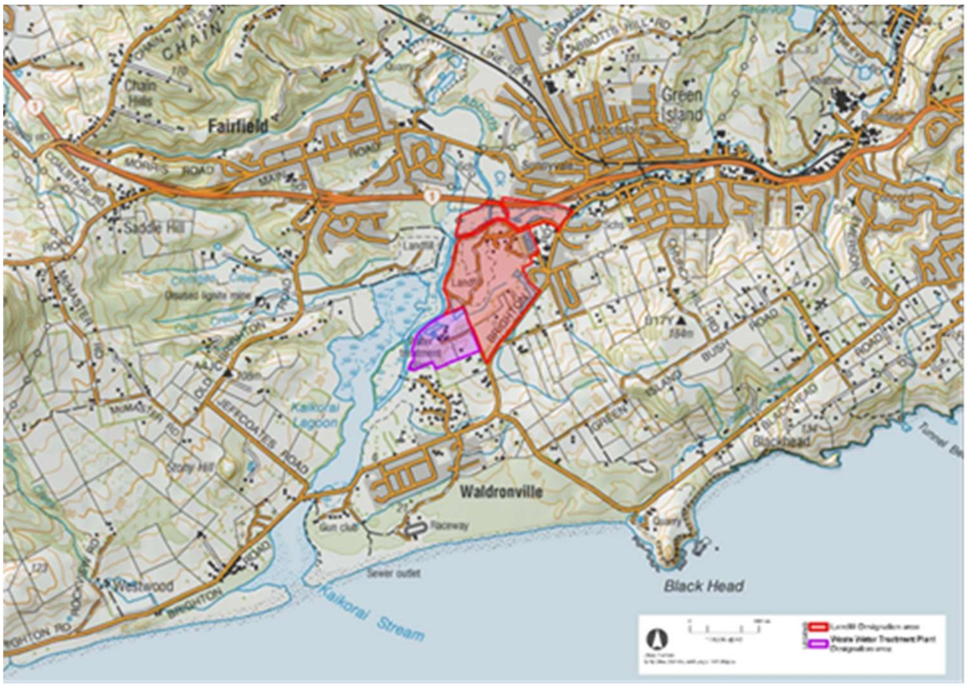
- A review of historical aerial photographs for the Site sourced from Retrolens and DCC.
- A review of historical site investigation reports, Site plans, and compliance reports for the Site.
- Collection of samples from soil cores retrieved during the GHD geotechnical investigation.
- Submission of selected samples to the laboratory for analysis of identified contaminants of concern.
- Comparison of analytical results to adopted guidelines and standards.
- Preparation of a report outlining the history and extent of landfilling at the Site and discussing the findings of the site investigation.

1.3 Assumptions

GHD has made the following assumptions during the preparation of this report:

- Information obtained from third parties and DCC is complete and accurate.
- That the Site will remain in commercial / industrial land use until closure and thereafter will be used for recreational purposes.

Figure 1: Site Location Plan – Green Island Landfill



1.4 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 Dunedin City Council as set out in Section 1 of this report. GHD otherwise disclaims responsibility to any person other than Dunedin City Council and Council officers, consultants, the hearings panel and submitters associated with the resource consent and notice of requirement process for the Green Island Landfill Closure Project arising in connection with this report.

GHD otherwise disclaims responsibility to any person other than Dunedin City Council 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 (refer section(s) 1 through 7 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

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 buildings, services and vegetation. 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.

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.

2. Site Description

2.1 Site setting

The Green Island Landfill (the Site) is a municipal landfill facility situated on Taylor Street, to the west of Brighton Road, approximately 10 km southwest of the suburb of Green Island and central Dunedin. The facility is currently managed and operated by Waste Management Ltd., on behalf of DCC who own the landfill.

The Site is located in a reclaimed wetland area within the Kaikorai Estuary, which is part of the larger Kaikorai Catchment; a 55 km^2 area bounded by the Kaikorai Stream and Abbots Creek and the topography of Chain Hills, to the northwest and north, Kaikorai and Round Hills to the north and northeast and Saddle Hill, to the west.

The Kaikorai Stream historically ran through the Site but was later diverted along the western boundary of the Site to run in a southwest and southerly direction, towards the Kaikorai Lagoon and ultimately the sea. The stream forms the northern and western limits of the landfill before flowing into the Pacific Ocean near Waldronville.

The landfill is approximately 38 hectares in size and is delineated by the legal descriptions in Table 1 below.

Table 1: Legal Descriptions for Green Island Landfill

Legal Descriptions
Pt Secs 44 and 45 Green Island Bush SD
Secs 54-55, 63, 65 Block VII
Section 119 Block VII Dunedin and East Taieri SD

Several activities are currently being undertaken within the boundaries of the landfill including municipal waste disposal, compost production, liquid waste and sludge disposal alongside the operation of a waste transfer station and a recycling centre. A Site layout plan is presented as Figure 2, overleaf.

As can be seen on Figure 2, the working face is currently located towards the centre-south of the landfill, the composting area is located near the eastern boundary and the waste transfer station and recycling station in the north-eastern portion of the landfill. Landfilling is complete over the northern and eastern portion and continues over the remainder of the Landfill.

A network of landfill gas collection wells is installed at the landfill. Additional wells have been installed over time with the development of the landfill. The configuration of the wells changes over time to allow for improved gas collection and collection of gas from areas of new waste. The gas is piped to the Green Island Waste Water Treatment Plant (GIWWTP) for use in the generation of electricity.

A leachate collection trench runs around the perimeter of the northern, western and southern boundaries of the Site. An access track is generally aligned over the top of this trench along much of its length.

Two stormwater sedimentation ponds are located on the landfill, one on the southwestern site boundary (West Pond) and one on the northeast site boundary (East Pond), see Figure 2 overleaf.

2.2 Contaminated land (HAIL) status

The requirements of the Resource Management (National Environmental Standard for Assessing and Managing Contaminants in soil to protect Human Health) Regulations (NESCS, 2011) applies when a selected activity on a piece of land where an activity or industry on the Ministry for the Environment (MfE) hazardous activities and industries list (HAIL) is, has, or is more likely than not to have occurred. Activities such as soil disturbance, subdivision and change in land use are regulated by the NESCS

The Site is known to be part of a landfill and as such is categorised as having HAIL activity G3 (landfill sites) occurring on it.

Figure 2: *Site layout Plan*

3. Landfill History

3.1 Site history

A landfill has been present on the eastern side of the Kaikorai Estuary since 1954. It is understood that waste filling began on the eastern side of the upper Kaikorai Estuary and by the late 1970s, the Site had become the main landfill for Dunedin.

Unregulated and uncontrolled landfilling occurred at the Landfill until the 1980s, when DCC began to manage waste disposal activities through a national planning approach for the area. The landfill was granted resource consents under the RMA in 1994 and a combined leachate interception trench and collection system was constructed at the Site. This comprised nine (9) pump stations interconnected via a gravel-filled trench with an in-built perforated collector drain located around the landfill toe and was retrofitted around the majority of the perimeter of the landfill.

This pump network is set up to maintain a hydraulic gradient towards the trench, minimising the amount of leachate migrating beyond the interceptor trench. The trench is not currently present along the southern boundary of the landfill, between MW0 and PS9, as shown on figure 006116-19-01 Green Island Landfill – Leachate collection and environmental monitoring system, 2004, included in Attachment A. A stormwater interception ditch is located along this boundary which is channelled towards pump station PS1. This gap in the system ws to allow planned placement of waste over this area. In the last few years DCC have decided not to place waste in this area The interception trench allows for the leachate to be collected and discharged to the Green Island WWTP, via a pipeline, located to the southwest of the landfill.

A network of groundwater / leachate monitoring wells was installed in a series of lines crossing perpendicular to the interception trench, to monitor groundwater / leachate levels across the trench to confirm hydraulic containment of the shallow groundwater. This network consists of both shallow and deep monitoring wells and each line is located approximately halfway between each pump station.

A schematic cross section plan of the landfill and the location of the leachate collection drain and monitoring well arrangement is presented in Figure 3 below and in figure 006116-19-01 included in Attachment A.

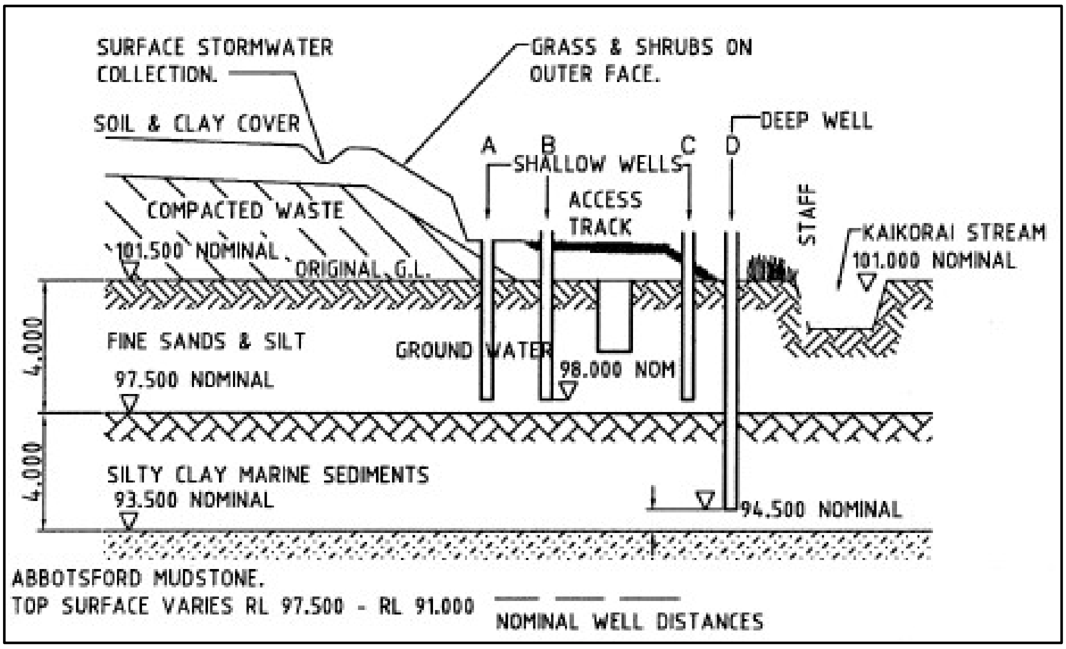


Figure 3: ***Schematic cross section through an example monitoring well line and the leachate collection trench (Source DCC Landfill Annual Survey Plans – July 2004 Sheet No. G11).***

An HDPE liner was historically placed between the leachate interception trench and the Kaikorai Stream to minimise flow from the stream and groundwater migrating eastwards towards the landfill. During this time (HDPE liner placement), a clay bund was also installed around the site boundary to contain both the landfill (deposited waste) and leachate.

3.2 DCC Reports and Plans

A selection of reports provided to GHD by DCC have been reviewed to understand the history of the landfill and its evolution. These are discussed in the following sections.

3.2.1 Beca Steven EIA

In 1992 Beca Steven prepared an Environmental Impact Assessment[1] (EIA) report for the landfill. This report states the following:

Section 4.1.2 The Site

In 1954, an industrial landfill was started on the eastern side of the upper Kaikorai Estuary. At the time, the Kaikorai Stream was still seriously contaminated from industrial dumping, storm water runoff and household waste. There was little thought given to the impact that such an activity might have on the wetland environment in the vicinity, although much of the wetland area was farmed. The same reasons that made the area ideal for industrial development (i.e. close to the city but out of the Otago Harbour catchment), also made it ideal as a refuse site. In the early years of the landfill, as was common practice around the country, little attention was paid to what was dumped or buried on the site.

By the late 1970s Green Island had become the main landfill for all of Dunedin, taking in an average of 58,000 tonnes of refuse annually.

Currently the landfill at Green Island and the adjacent private Maxwell's landfill just across the Kaikorai Stream (started in 1968) cover over 30% of the total estuarine landscape of the valley to a maximum depth of 10 metres. Adjacent to the Green Island Landfill the Kaikorai Stream has been channelled behind bunding for the purposes of the drainage and protection of farmland. One consequence of this has been that the bunded areas form in effect oxidation ponds helping to control and treat leachates.

Section 4.2.2 Existing Features of the Site

The Green Island landfill is situated at the head of the Kaikorai Estuary and is separated by a bund constructed of in situ materials from the Kaikorai Stream. The photograph in Figure 4.2 (see below) shows the position of the site within the locality (Maxwell's landfill is to the left and Green Island DCC landfill to the right).

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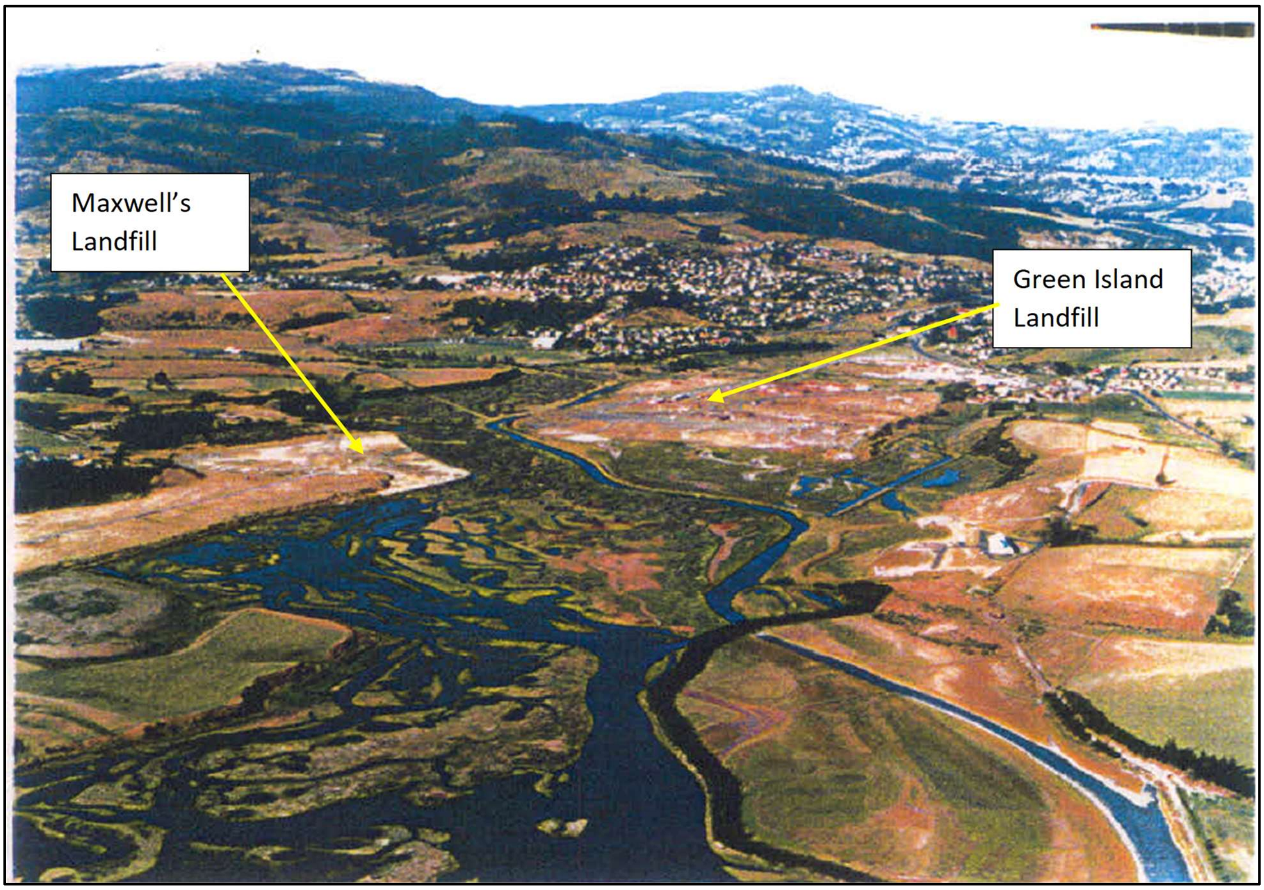
[1] Beca Steven (1992) Environmental Impact Assessment of the Extended Green Island Sanitary Landfill. October 1992.



The site itself is essentially a flat area on top of a raised platform. The flat area presents an untidy appearance due to the presence of windblown rubbish over much of the site and the limited "finishing" of the filled areas which has taken place.

The primary uses of the site are for refuse processing and disposal by land filling.

A prominent use of the site is the stockpiling of car bodies prior to periodic shipment to Auckland for scrap metal recovery.

Section 4.3.4 Refuse Acceptance Policy

Normal domestic and commercial wastes are accepted automatically and whether they contain hazardous or special wastes is left to the disposer to identify, although the landfill operator can inspect any load if there is reason to suspect the material may contain special or hazardous wastes.

Routine special wastes such as dead animals and small volumes of offal are accepted and disposed of by burying at the toe of the landfill.

Section 4.3.6 Surface Water Management

Streams and watercourses approaching the site are diverted around it - one to the south of the landfill which runs outside the southern bund, and one which is channelled down the eastern side of the landfill and discharged to Kaikorai Stream. The watercourse to the east is not well separated from the landfill and contamination of it by leachate occurs over the lower reaches.

Surface water from the area of the completed existing landfill is collected in channels and discharged away from the face. However many of the channels are not well formed or graded, and are affected by landfill settlement. While collecting and preventing some surface water from entering the landfill they are not totally effective. Nevertheless the upper levels of the landfill are relatively dry.

None of the upstream catchments to the south and east are sufficient in size to generate large flows and the opportunity for them to flood the site is virtually non-existent.

To upgrade stormwater control for the existing landfill operation at Green Island, the following mitigating works were recommended in the Existing Green Island Landfill EIA:

- *Constructing and operating two sedimentation ponds within the landfill site*
- *providing a system of surface drains to safely convey stormwater within the site.*
- *providing for the safe conveyance of stormwater around the site without causing erosion of streambanks or the landfill. This is incorporated in the proposed construction of the outer perimeter face.*
- *implementing sound sediment control practices.*
- *conducting a monitoring programme on the discharge from the sedimentation ponds.*

Section 4.3.7 Leachate and Groundwater controls

As described in the Existing Green Island Landfill EIA the recommended method of collecting leachate contaminated groundwater is in a gravel filled trench around the landfill perimeter with a perforated collector drain. Pump stations at about 200m spacing will draw down the groundwater table so that an inward hydraulic gradient is formed. Leachate contaminated groundwater from under the landfills will be intercepted by the trenches which will also draw water from the stream side and the discharge will be piped to the Green Island Wastewater Treatment Plant.

However, because the contamination of groundwater has most likely been confined to the immediate vicinity of the landfill little has travelled beyond the bunded area as evidenced by the water testing carried out to date. No groundwater wells are used in the area. The improved groundwater quality after collection of the leachate, will not be a noticeable benefit in itself, but indirectly will improve the Kaikorai Stream by preventing leachate discharge to it.

Summary

The following is understood:

- Development of the landfill was ad hoc for two to three decades before a proper management plan was put in place.
- Municipal, commercial / industrial, and special and hazardous waste were accepted at the landfill.
- Prior to the installation of the leachate collection trench in 1994, there was very little historical control of leachate collection or discharge and as such leachate was discharging into the Kaikorai Stream.
- Prior to the construction of the sedimentation ponds, stormwater management was historically very limited.
- The stream is contaminated, as is much of the catchment, due to historical commercial and industrial activities upstream of the Site.

3.2.2 Trench installation report

According to the Green Island Landfill Leachate Trench Geological Report[2], the landfill was developed in the upper reaches of Kaikorai Estuary without modern liner and drainage systems beneath the waste and fill to control leachate migration to the underlying sediments and groundwater.

In 1994, a 1,757 m long, gravel filled trench was constructed around most of the perimeter of the landfill to intercept groundwater and leachate flowing from the site. Pumps were installed in the trench to collect leachate / groundwater from the trench and to maintain a hydraulic barrier to manage discharge of leachate to the surrounding environment.

This Report included photographs and stratigraphic logs describing the soil conditions encountered during the trench excavation. An assessment of stratigraphy in this report observed that landfill refuse and/or fill material was the upper most material at 41 of the 76 locations logged and that the maximum thickness of landfill material observed was 2.6 m. The figure with locations of the soil logs was not included in the document, however the locations of the different trench profile logs can be interpreted from their position in relation to individual pump station, manhole and air vent locations.

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[2] Green Island Landfill Leachate Trench Geological Report, Barry J. Douglas Geological Consultants, August 2002

A summary of the locations of where landfill material was encountered, its thickness and composition is provided in Table 2. Please refer to Figure 006116-19-01 in Attachment A for trench profile locations (logs).

Table 2: Landfill material location, thicknesses and composition

Trench profile number	Location	Thickness of landfill (m)	Comments
17	6m north of PS3	0.5	Earthfill intermixed with bricks and shells, black leachate stained refuse
18	33m north of PS3	0.1	Earthfill intermixed with refuse
20	MH3	1.5	Earthfill and mixed refuse
21	29m north of MH3	1.6	Mixed refuse
22	36-42m north of MH3	2	Mixed refuse
23	17-18m south of PS4	0.8	Mixed refuse
25	30.5m north east of PS4	1.4	Mixed refuse
26	38m north east of PS4	1.25	Mixed refuse
27	42m west of AV4	2.1	Mixed refuse
29	0.5 west of AV4	2.6	Mixed refuse
30	AV4	2.6	Mixed refuse
31	4m east of AV4	0.65 (north wall) 2.6 (south wall)	Landfill
32	13m east of AV4	0.5	Brown earthfill intermixed with refuse
34	32m east of AV4		Landfill removed during and after trench construction
42	36m east of PS5	0.4	Intermixed refuse and earthfill
43	49m east of PS5	0.3	Brown earthfill intermixed with refuse
51	MH6	2.0	Landfill
52 (A)	Beneath access road (46m north west of PS7)	~6.0	Mostly earthfill with minor intermixed solid rubble (this material was placed in the 1970's-1990's period)
52 (B)	40m north west of PS7	3.75	Mostly earthfill with minor intermixed solid rubble

53	19m north west of PS7	1.1	Earthfill
55	19m south east of PS7	1.6	Mixed refuse
56	30m south east of PS7	1.6	Mixed refuse
57	49m south east of PS7	0.95	Earthfill and refuse (coke, sawdust, vegetation)
58	50m north of MH7	0.95	earthfill
59	27m north of MH7	1.5	Earthfill and black refuse
60	4-5m north of MH7	1.6	Black refuse
61	MH7	1.2	Black refuse
62	34.7m south of MH7	1.6	Intermixed earthfill and refuse
63	18m north of PS8	1.75	Earthfill and refuse
64	7-8m north of PS8	1.5	Mostly earthfill mixture of sandy and muddy sediments
65	28m south of PS8	2.45	Mostly brown earthfill
66	48m south of PS8	2.4	Mixed refuse
67	60.5m south of PS8	1.9	Landfill
68	MH8a	2.35	Landfill
69	40m west of MH8a	1.95	Intermixed earthfill and refuse
70	64m west of MH8a	2.1	Intermixed earthfill and refuse
71	MH8	1.7	Intermixed earthfill and refuse
72	16m north of PS9	0.95	Earthfill (Landfill)
74	27m north of PS9	1.3	Earthfill (Landfill)
75	37m north of PS9	1.4	Earthfill (Landfill)
76	55m north of PS9 (end of trench)	1.45	Earthfill (Landfill)

Notes:

PS – Pump station

MH – Manhole

AV – Air vent

As can been seen for the above table, refuse material is present on the outside of the leachate collection trench from north of pump station PS3 on the western side of the landfill, to Manhole MH8 on the eastern side of the landfill. The greatest thickness of material was present between Pump station PS4 through to Air vent AV4.

3.2.3 Landfilling contour plan

GHD reviewed a figure depicting the estimated locations of the tip faces at the landfill from 1964 to 2001. This plan has been provided to GHD by DCC and its provenance is unknown, though is likely hand drawn based on aerial photographs review and site history knowledge of previous site managers.

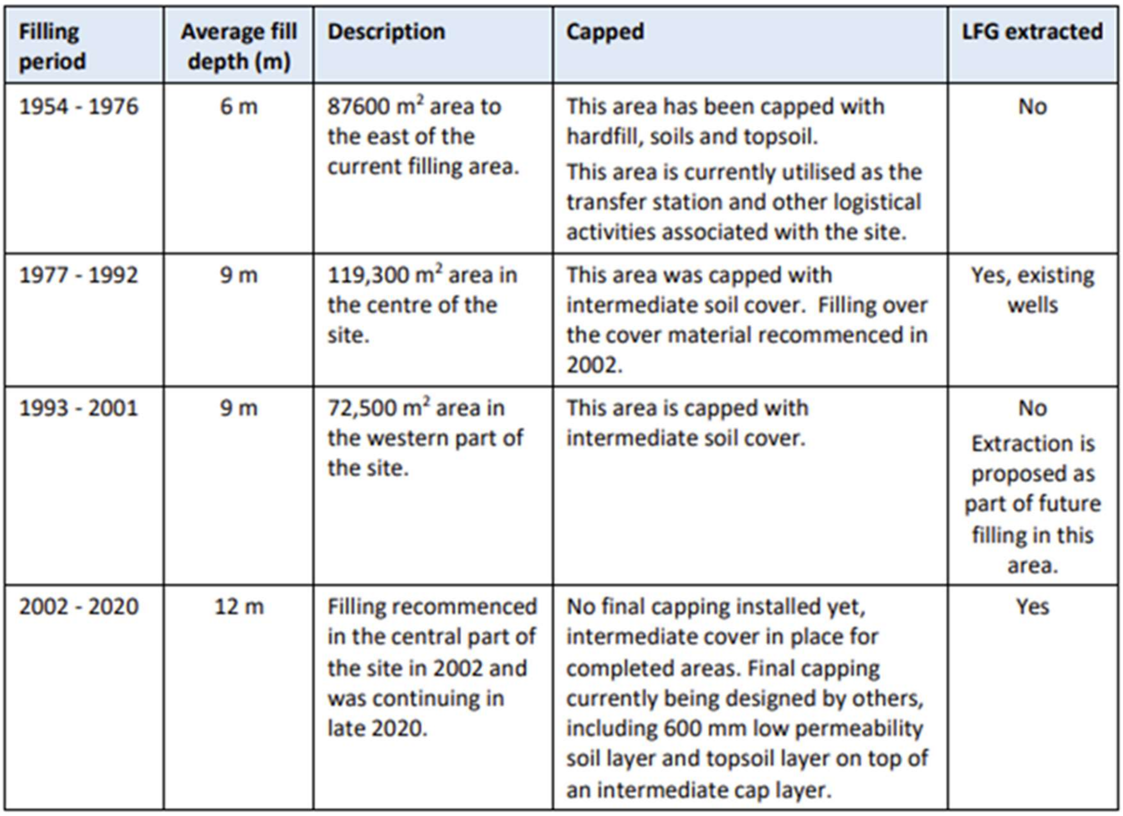
In general, this figure supports other documents and photographs reviewed, in that it shows landfilling operations starting in the southeast portion of the site and advancing to the north and west over time. The historical tip faces appear to be estimates, and the figure does not show landfilling activities outside of the leachate trench. A copy of this figure is included in Attachment A. The historical placement of waste pre installation of the leachate interception trench is discussed further in Section 3.4.

3.2.4 Masterplan 2021

A landfill gas (LFG) masterplan for the landfill was prepared by Tonkin and Taylor in 2021[3].

The report states that in July 2020, there was approximately 4.8M tonnes of waste in the landfill. The history of landfilling at the landfill is summarised in Table 3. The purpose of including this history was to understand the potential generation of landfill gas from historically placed waste. Although the landfill was operational since 1954, tonnage data was first recorded in 1964.

Table 3: Landfilling history (source – Tonkin and Taylor Landfill gas masterplan report (2021))



Filling period	Average fill depth (m)	Description	Capped	LFG extracted
1954 - 1976	6 m	87600 m^2 area to the east of the current filling area.	This area has been capped with hardfill, soils and topsoil. This area is currently utilised as the transfer station and other logistical activities associated with the site.	No
1977 - 1992	9 m	119,300 m^2 area in the centre of the site.	This area was capped with intermediate soil cover. Filling over the cover material recommenced in 2002.	Yes, existing wells
1993 - 2001	9 m	72,500 m^2 area in the western part of the site.	This area is capped with intermediate soil cover.	No Extraction is proposed as part of future filling in this area.
2002 - 2020	12 m	Filling recommenced in the central part of the site in 2002 and was continuing in late 2020.	No final capping installed yet, intermediate cover in place for completed areas. Final capping currently being designed by others, including 600 mm low permeability soil layer and topsoil layer on top of an intermediate cap layer.	Yes

The report states that the landfill has received a mix of municipal waste, commercial and industrial waste, and construction and demolition waste.

This report does not provide a plan showing the extent of the landfilling.

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[3] Tonkin and Taylor (2021)Landfill Gas Masterplan, Green Island Landfill. Job number 1008787.5010.v2. Dated May 2021.

3.3 Historical Aerial Photographs

As part of this report a review of historical aerial photographs from the online repository Retrolens was conducted to assess the landfilling sequencing and historical extent of the landfill.

In general, this review shows that landfilling began at the site before 1958. Landfilling then progressed from the southeast portion of the current property to the north until the eastern portion of the property was covered with fill by 1967. From there, filling advanced northwards and to the west over time. The approximate current landfill footprint was filled by 2000. The 2013 aerial photograph generally shows the Site in its current configuration.

In addition to the aerial photographs obtained from Retrolens, DCC provided GHD with aerial photographs of the Site from 1994 and 1999. These two aerial photographs are of a higher resolution than those obtained from Retrolens. A summary description of the aerial photographs reviewed is provided in the following sections.

3.3.1 1942 Aerial Photograph

No evidence of landfilling is apparent in the 1942 aerial photograph. There is land disturbance evident on the southern boundary, possibly winning material from the hillside for creation of vehicle access to the stream-edge to construct boundary drains.

There appears to be a drain / trench that runs on the inside of the Kaikorai Stream and continues around the boundary of the existing landfill property. There also appears to be another drain or fence which crosses the Site diagonally from northwest to southeast across the wetland.

A raised spur can be noted on the southern site boundary.

(Source – Retrolens)

3.3.2 1947 Aerial Photograph

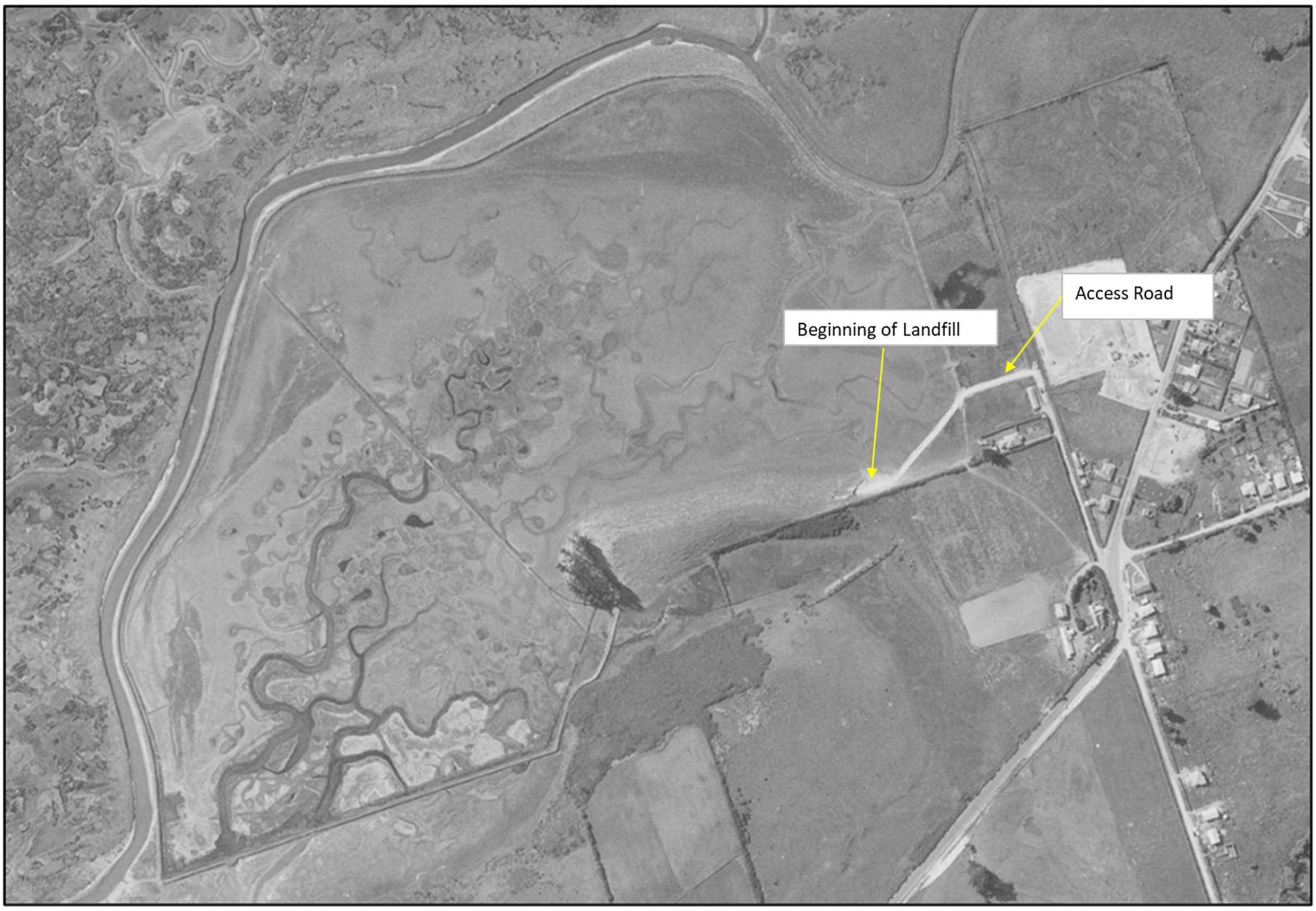
No evidence of landfilling is apparent in the 1947 aerial photograph.

It can be noted that there appears to be a spur of raised ground in the southern portion of the Site with trees at the top. It appears that this portion of the Site increases in height towards the west.

(Source – Retrolens)

3.3.3 1958 Aerial Photograph

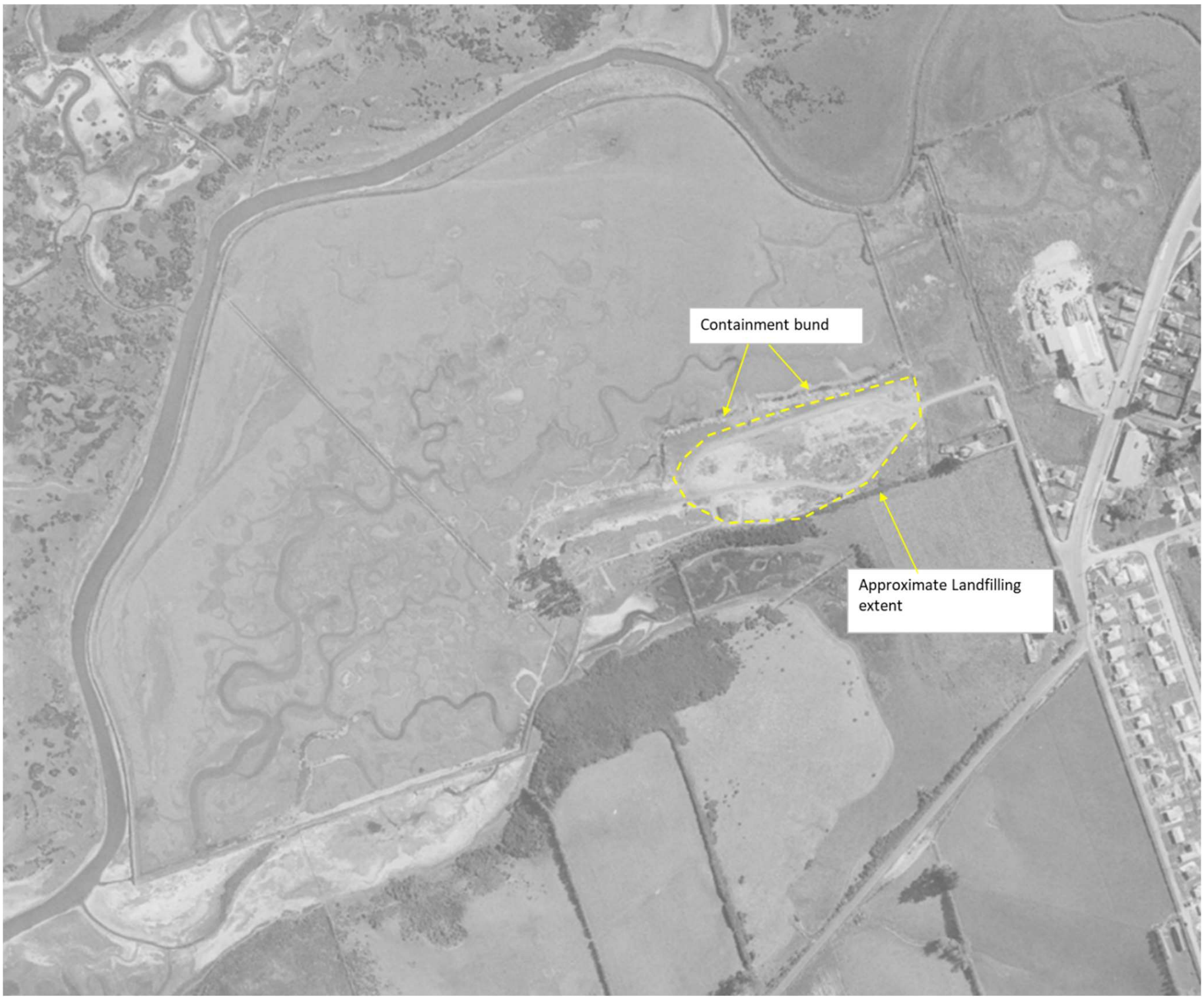
There appears to be an access road into the future landfill at the southeast corner of the current facility. At the end of the access road, it appears that landfilling or initial site development has commenced at the site. It is likely that the area on the southern boundary is being raised / built up to create a road to allow access into the landfill.



(Source – Retrolens)

3.3.4 1962 Aerial Photograph

Landfilling has extended westwards along the southern boundary. A structure, maybe a containment bund, is present on the northern boundary of the landfilling area.



(Source – Retrolens)

3.3.5 1970 Aerial Photograph

Landfilling has continued on the southern boundary of the site and has extended to the north to the edge of the boundary drain. The area of the higher spur of land from the 1940's and 1950's is clearly obvious as a different colour (lighter) along the southern boundary, indicating that this area continues to be used as a source of soil material used during landfilling works.

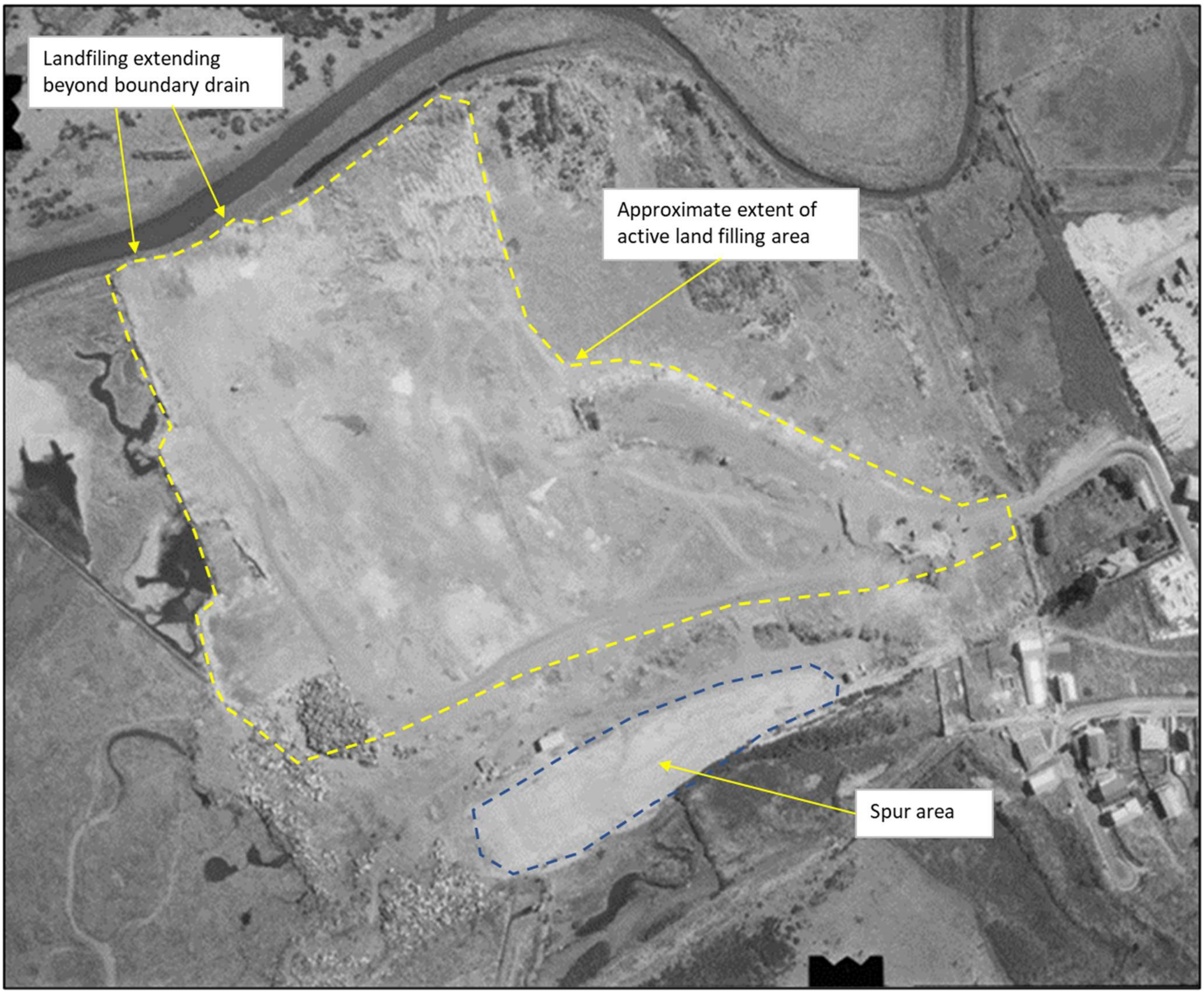
The southeast corner of the landfill (where filling began) has vegetation growing on it, indicating that filling in that area was complete by 1970.

(Source – Retrolens)

3.3.6 1978 Aerial Photograph

Landfilling continues to the north, west and to the northwest. Along a portion of the northern boundary of the landfill , fill has been deposited as far as the inner drain and appearing to infill it. Again, the area of the higher spur of land , visible in the 1940's photographs, appears to have soil disturbance activities being undertaken on it and likely continues to be used as a source area for soil to be used during landfilling activities (cover material etc.).

A portion (southern) of the drain that ran northwest to south east across the Site has been infilled.



(Source – Retrolens)

3.3.7 1985 Aerial Photograph

Filling appears to have progressed north-eastwards across the footprint of the landfill area, with minimal expansion to the west. Waste appears to be have infilled the boundary drain along the central portion of the northern boundary and likely extend beyond it towards the Kaikorai Stream in isolated areas.

Maxwell’s Landfill is present on the opposite side of the Kaikorai Stream.

(Source – Retrolens)

3.3.8 1990 Aerial Photograph

The access road was moved to the northern portion of the Site since 1985. Areas of revegetation are visible on the southeast portion of the site. Fill has expanded to the west especially in the northern half of the landfill. It appears that the boundary drain has been infilled further westwards along the northern boundary with evidence of soil disturbance / landfilling on the northern side of it in one area.

(Source – Retrolens)

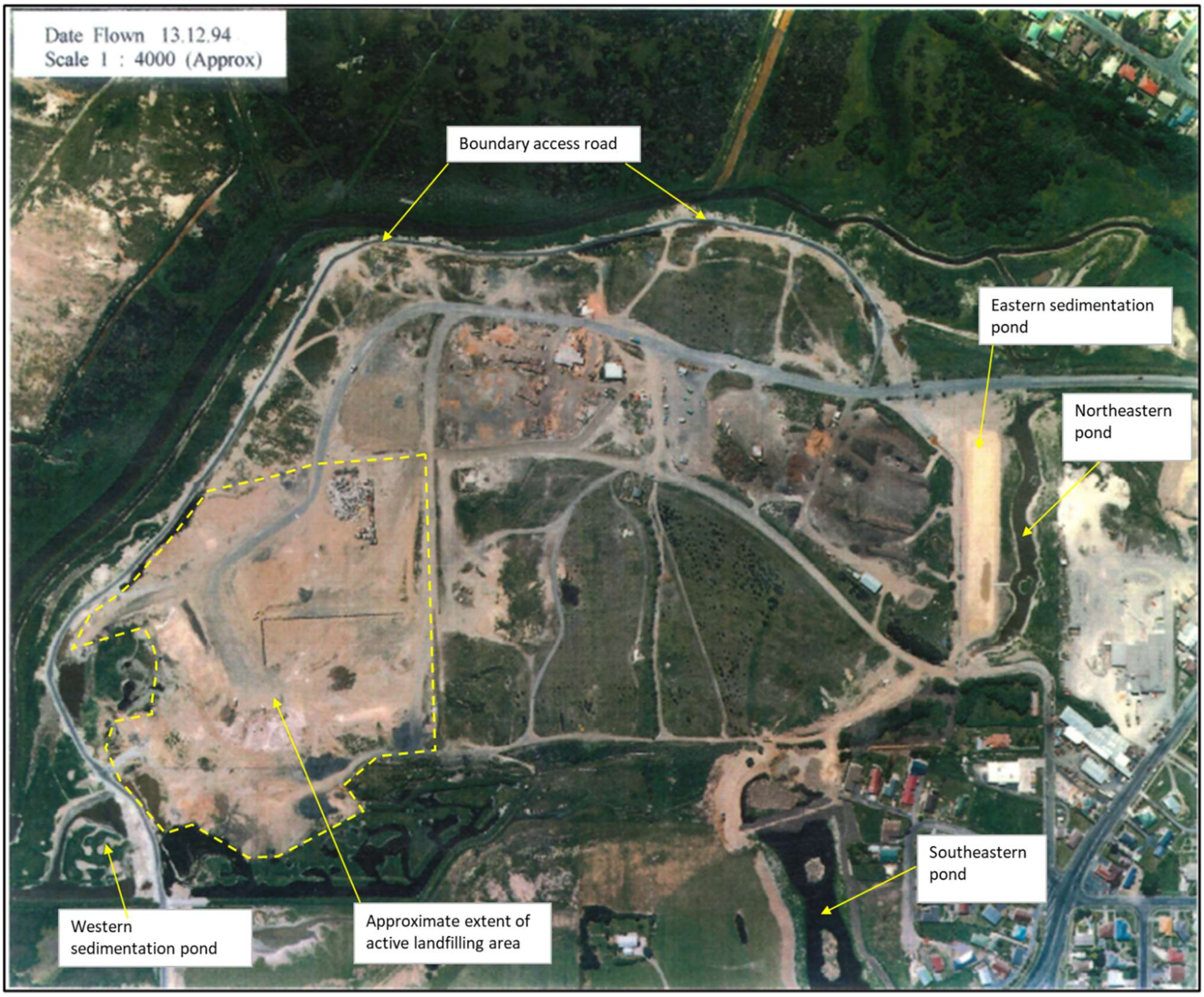
3.3.9 1994 Aerial Photograph

In the 1994 aerial photograph, an access road has been constructed around the northern and western boundary of the Site (along Kaikorai Stream). This access road generally follows the current leachate interceptor trench. Access to the Site is from the east into the northeast corner of the Site, which is the current configuration.

Active filling at the landfill appears to have been concentrated on the western portion of the site and particularly onto the wetlands at the southwest corner. Several support buildings appear to have been built since 1990. Revegetation is ongoing in the southeast quadrant of the site.

It appears that that access track / leachate collection trench has been constructed along the western and northern boundaries. The trench / drain which had run along the southern boundary has been infilled.

It appears that the Eastern and Western sedimentation ponds are under construction and that the north-eastern and south-eastern ponds have been construction.



(Source – DCC)

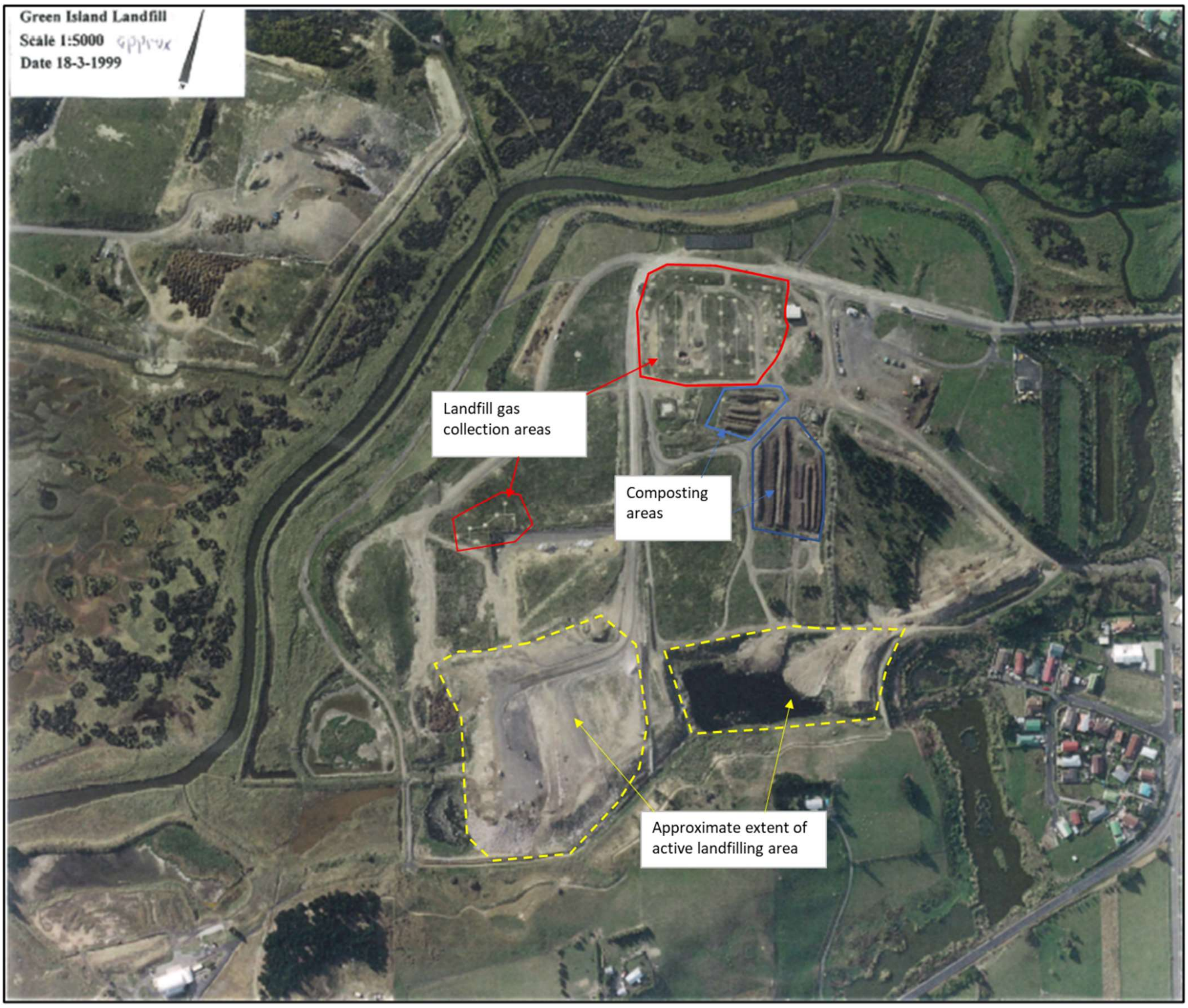
3.3.10 1999 Aerial Photograph

In the 1999 aerial photograph, it appears that the landfill footprint has expanded to include most, if not all, of the current footprint.

The weighbridge has been built in its current location along the main access road to the site.

Active filling is concentrated at the southeast corner and along the central southern boundary of the site. Revegetation is ongoing across much of the site (including the central, eastern and western portions) indicating that active filling is not being undertaken in these areas for some time. Wind-break planting has been established on the northern and western boundary of the landfill.

There appears to be a landfill gas collection network under construction or use in the northern and part of the western portion of the site.



(Source – DCC)

3.3.11 2013 Aerial Photograph

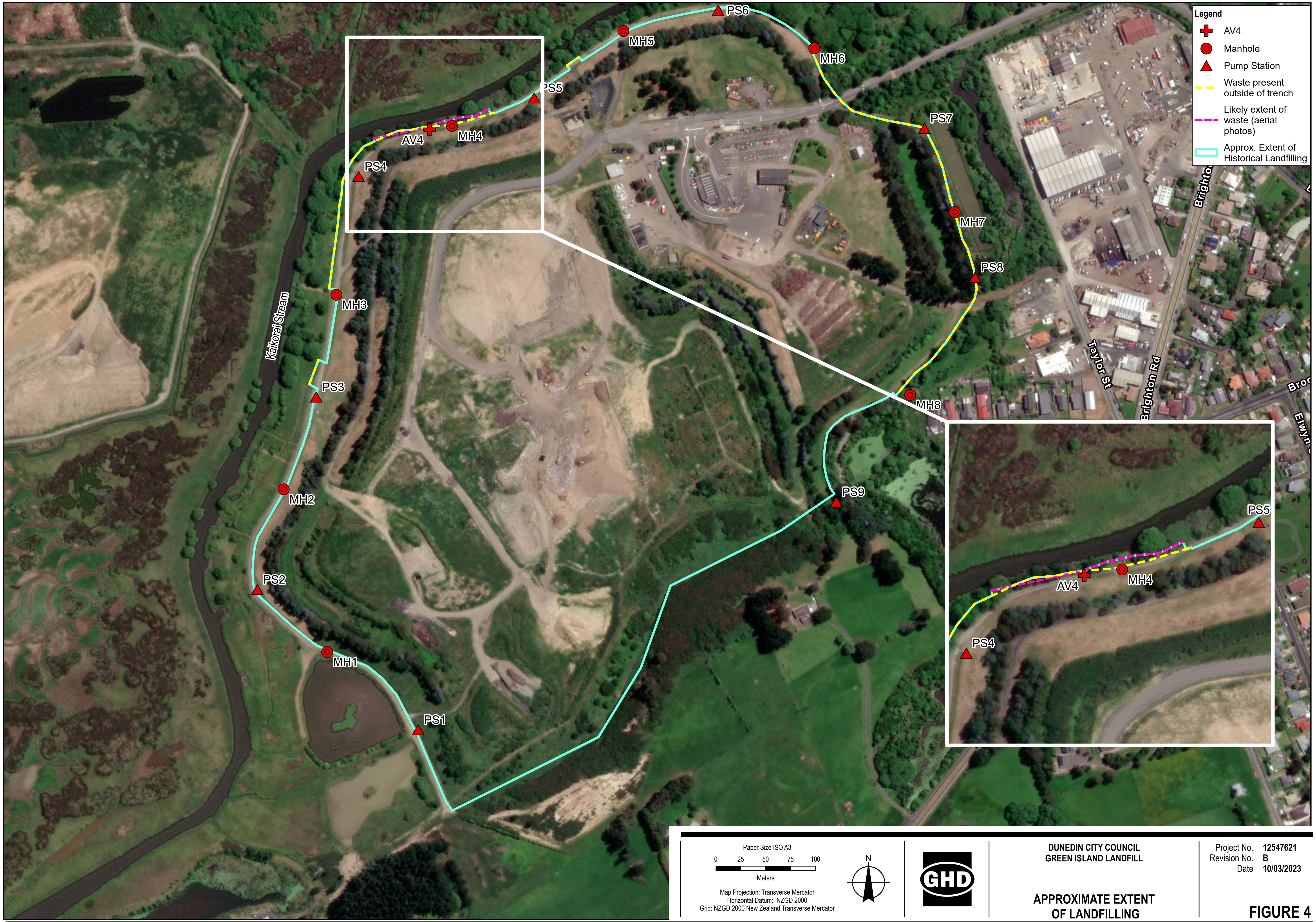
By 2013, the Site is generally in its current configuration. The resource recovery facility / transfer station, wind break planting, the access track (and interceptor trench), and the compost facility are all visible in this aerial photograph. Landfilling appears to be active in the northern portion of the Site. The area of capping completed in 2009 / 2010 is noticeable as vegetated (green) in the southeast corner of the landfill, as is an area of capping underway at that time immediately adjacent to the west.

(Source – Retrolens)

3.4 Landfilling extent

A review of the available historical aerial photographs and leachate collection trench construction report indicates that waste is present on the outside of the leachate collection trench in places, with waste up to 6 m thick on the north eastern boundary in a short section (approximate 20-40 m length). Generally, the thickness of the waste is less than 2.6 m in other areas, and averaging 1.63 m depth over the other 40 locations mapped from the log.

The aerial photographs (1978 and 1982) indicate that landfilling activities likely extended very close to the edge of the Kaikorai Stream banks along the northern boundary with some waste placement also likely to having occurred in these areas. The likely extent of the landfilling is shown on Figure 4, overleaf.



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

DUNEDIN CITY COUNCIL
GREEN ISLAND LANDFILL

APPROXIMATE EXTENT OF LANDFILLING

Project No. **12547621**
Revision No. **B**
Date **10/03/2023**

FIGURE 4

N:\NZ\Christchurch\Projects\51\12547621\GIS\Maps\Deliverables\12547621_GILF_SI_GHD_20221118\12547621_GILF_SI_GHD_20221118.aprx
Print date: 10 Mar 2023 - 11:01

Data source: World Imagery: LINZ
Hybrid Reference Layer: LINZ, Stats NZ, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS. Created by: jholloway

4. Site works

Field work was carried out in compliance with the project specific Job Safety and Environmental Analysis (JSEA) plan. All site investigation staff were inducted to the Site by Waste Management Ltd, the operators of the landfill. Environmental sampling was undertaken between 1 November and 9 November 2022, comprising the following:

- A GHD environmental scientist was on site to assess and sample soil from eight boreholes installed as part of the geotechnical investigation (BH-100 through BH-104, BH-107, BH-108 and BH-111).
- A GHD environmental scientist was on site for the installation of monitoring wells in boreholes BH100, BH-101, and BH-104.
- Soil samples from boreholes BH-102, BH-103, BH-107, BH-108 and BH-111 were collected from core boxes by a GHD environmental scientist. The remainder of the samples were collected during the drilling of BH-100, BH-101 and BH-104.
- Collection of 26 original and 2 duplicate soil samples from the above-mentioned boreholes. Samples were collected from multiple depths in each borehole. The sample depths were chosen based on an assessment of the soil by a GHD environmental scientist.

A site investigation points location plan is presented as Figure 5, overleaf.

As the Site is a known piece of contaminated land, a land use consent was required to drill and install the boreholes. Resource consent RM21.467 (to drill 17 investigation sites on contaminated land for the purpose of geotechnical investigation) was granted by ORC to DCC to undertake these works on 10th October 2021.

Prior to breaking ground, subsurface utilities clearance was undertaken by a specialist contractor (Fulton Hogan), using both a Cable Avoidance Tool (CAT) and Ground Penetrating Radar (GRP) at all borehole locations. A Ground Penetration Permit to Work was issued by an authorised GHD permitter.

Logging of the material encountered during drilling was undertaken by a GHD geotechnical engineer in accordance with NZ Geotechnical Society (2005) field description of soil and rock. Borehole logs are included in Attachment B.

Notes:
1. The borehole ID and ground elevation (m) are shown alongside the borehole symbols.
2. Ground elevations derived from Stantec Topo dated August 2022.

Paper Size ISO A3

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

DUNEDIN CITY COUNCIL
GREEN ISLAND LANDFILL

Project No. **12547621**
Revision No. **A**
Date **17/01/2023**

2022 BOREHOLE LOCATIONS

FIGURE 5

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Print date: 10 Mar 2023 - 09:52

Data source: World Imagery: LINZ
Hybrid Reference Layer: LINZ, Stats NZ, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS. Created by: jholloway

4.1 Soil sampling methodology

The geotechnical investigation was mainly focussed on the peripheries of the landfill to better understand liquefaction potential of the material present in these areas. Consequently, the environmental investigation was limited to the assessment of the material collected during the drilling works in these areas.

Environmental soil samples were collected from a total of eight boreholes at multiple depths at each borehole to target different depths and lithologies to gain an understanding of the material present. GHD collected two duplicate samples for quality control and assurance purposes.

Soil samples were collected in accordance with standard GHD procedures. Samples were placed directly into laboratory supplied containers and then placed in an iced chilly bin and couriered to ALS - Analytica Laboratories under standard GHD Chain of Custody (CoC) procedures. Due to capacity issues at Analytica Laboratories, a portion of the polycyclic aromatic hydrocarbon and semivolatile organic compounds analysis was subcontracted to Eurofins Environmental Testing NZ Limited (Eurofins).

A total of 26 primary soil samples were selected for analysis. Based on the historical land use and observations made during sampling, selected soil samples were analysed for the identified contaminants of concern as follows:

- Heavy metal suite (arsenic, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel and zinc) x26 samples
- Polycyclic Aromatic Hydrocarbons (PAHs) x23 samples
- Semi Volatile Organic Compounds (SVOCs) x13 samples
- Total Petroleum Hydrocarbons (TPH) x1 sample
- Asbestos in soil (presence/absence) x18 samples
- Asbestos in soil (semi-quantitative) x1 sample
- Ammonia – x8 samples
- Two duplicate samples, one of which was analysed for heavy metals and PAHs and the other was analysed for heavy metals only.

4.2 Field Observations

Solid waste and/or fill material was encountered in all eight of the boreholes that were sampled as part of this environmental assessment.

Boreholes BH-100 to BH-104, which were installed on the perimeter of the known landfill area, contained fill and/or solid waste to depths up to 3.95 metres below ground level (m bgl). Boreholes BH-107, BH-108 and BH-111 were installed on the landfill and contained fill to at least 7.5 m bgl, 11.2 m bgl and 4.6 m bgl respectively.

A summary of the borehole locations and the thickness of fill is provided in Table 4 below. Further details can be found on the borehole logs in Attachment B.

Table 4: Borehole locations and fill thicknesses summary

Borehole Number	Depth of borehole (m bgl)	Thickness of Fill / Waste (m)	Location
BH-100	12.95	2.75	Inside / within the trench
BH-101	12.95	1.3	Outside the trench
BH-102	14.95	1.6	Inside the trench (Bund slope)
BH-103	13.15	1.2 – 1.5 (Core loss)	Outside the trench
BH-104	9.95	3.95 – 4.5 (Core loss)	Inside the trench

BH-107	20.0	7.5	Northern portion of landfill (Inside trench)
BH-108	20.85	11.2 – 13.5 (Core loss)	Southern portion of the Landfill
BH-111	19.95	4.6 – 5.5 (Core loss)	Inside the trench – former tyre storage area

A Photo-ionisation detector (PID) was used to screen soil samples for volatile contaminants at all locations, with the exception of borehole BH-100. PID measurements are included in Table 6. It should be noted that some of the PID readings were collected during drilling works while the others were measured during the collection of soil samples from core boxes. For the samples that were collected from the core boxes, the measured PID values are likely lower than what would have been measured if the samples were collected during the drilling works, as the loss of volatiles would likely have occurred over the storage interval.

Table 5: PID measurements

Borehole Name	Date	Depth (m bgl)	PID reading (ppm VOC in headspace)	Measured in field / Core box
BH-101	1 Nov. 2022	0.5	0.0	In field
	1 Nov. 2022	1.5	0.4	
	1 Nov. 2022	2.5	0.1	
	1 Nov. 2022	3.5	0.2	
BH102	1 Nov. 2022	0.6	0.0	Core box
	1 Nov. 2022	1.5	1.9	
	1 Nov. 2022	2.5	0.8	
	1 Nov. 2022	3.5	0.0	
BH-103	1 Nov. 2022	0.2	0.0	Core box
	1 Nov. 2022	1.2	0.1	
	1 Nov. 2022	2.5	0.0	
BH-104	9 Nov. 2022	0.5	0.9	In field
	9 Nov. 2022	1.0	17.4	
	9 Nov. 2022	2.0	1.7	
BH-107	1 Nov. 2022	0.5	0.0	Core box
	1 Nov. 2022	1.5	0.0	
	1 Nov. 2022	2.5	0.0	
BH-108	9 Nov. 2022	0.5	0.9	Core box (core collected earlier that day)
	9 Nov. 2022	1.9	2.0	
	9 Nov. 2022	3.3	27.9	
BH-111	7 Nov. 2022	0.5	1.4	Core box
	7 Nov. 2022	1.5	7.2	
	7 Nov. 2022	2.0	5.0	
	7 Nov. 2022	3.0	3.9	
	7 Nov. 2022	3.2	2.1	

Note: ppm VOC – parts per million Volatile Organic Compound

5. Regulatory Context

5.1 Applicable Soil Contaminant Standards

5.1.1 The National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health

The User's Guide: National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (MfE, 2012) [4] details Soil Contaminant Standards (SCSs) for seven inorganic substances and five organic compounds (or groups of compounds). SCSs are available for these substances and compounds when present in land used for five land use scenarios. The contaminants analysed at this site for which SCSs are available are arsenic, cadmium, chromium, copper, lead, mercury, DDT (Dichlorodiphenyltrichloroethane) and benzo(a)pyrene equivalent (BaP). The NESCS applies to a "piece of land" on which a HAIL activity has occurred or is currently occurring.

The land use category selected for the purposes of this investigation was Commercial / Industrial and is described in the NESCS User Guide as "*Commercial / Industrial site with varying degrees of exposed soil. Exposure of outdoor workers to near-surface soil during routine maintenance and gardening activities with occasional excavation as part of maintaining subsurface utilities. Also, conservatively applicable to outdoor workers on a largely unpaved site*".

Because the landfill area may, at some point in the future, be used for recreational purposes (eg.as a reserve or park), a Recreational land use scenario was also considered. The NESCS User Guide describes Recreational land use as "*Public and private green areas and reserves used for active sports and recreation. This scenario is intended to cover playing fields and suburban reserves where children play frequently. It can also reasonably cover secondary school playing fields but not primary school playing fields.*"

These land-use exposure scenarios have been adopted for screening purposes to include potential receptors including site workers during any future construction works, current and future users of the Site and ongoing maintenance / excavation workers at the site.

The intention of the NESCS is the protection of human health from contaminated land and the appropriate assessment of the risk to human health prior to the undertaking of the regulated activities (e.g. Soil disturbance or land use change).

If the investigation demonstrates that the contaminants tested are at, or below, screening criteria concentrations, the regulations of the NESCS will not apply should any of the regulated activities be undertaken over the Site.

NESCS SCS criteria adopted for the Site are presented in Table 1 through to Table 3 in Attachment C.

5.1.2 Health and Safety at Work (Asbestos) Regulations 2016

The management and/or removal of asbestos in soils is regulated under the Health and Safety at Work (Asbestos) Regulations 2016[5] (Asbestos Regulations). However, the Asbestos Regulations do not provide guidance regarding the definitions of what constitutes an asbestos contaminated site, in particular, with regard to soil. Rather, the Regulations simply states that the Asbestos Regulations apply where a competent person advises that the disturbance and/or removal of soil is likely to lead to airborne contamination at a level that exceeds trace concentrations.

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[4] Ministry for the Environment, 2012. Users Guide: National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health. Wellington: Ministry for the Environment

[5] Health and Safety at Work (Asbestos) Regulations 2016 (15 February 2016) made under sections 24(1) (m), 211, and 218 of the Health and Safety at Work Act 2015

The New Zealand Guidelines for Assessing and Managing Asbestos in Soil (BRANZ Guidelines 2017)

The BRANZ Guidelines 2017[6] provide a methodology to ensure that management of asbestos in soil meets regulatory requirements and an acceptable level of managed risk. This methodology is consistent with the MfE CLMG's for New Zealand and the NESCS for the assessment of asbestos in soil.

If asbestos is detected in soils using a laboratory presence/absence test, the BRANZ Guidelines 2017 then provides an additional guidance for further soil sampling and criteria for the definition of whether the removal of such material is considered licenced asbestos removal (Class A or B), asbestos-related-works or unlicensed works under the Asbestos Regulations.

The adopted asbestos criteria are presented in Table 6 in Attachment C.

5.2 Other applicable Human Health Standards

For contaminants of concern that are not listed as priority contaminants, the NESCS references the Contaminated Land Management Guidelines No. 2: Hierarchy and Application in New Zealand of Environmental Guideline Values (CLMG No.2) to provide guidance.

In the absence of New Zealand risk based human health criteria for certain contaminants of concern, such as nickel and zinc, the Australian National Environment Protection Measure 2013[7] (NEPM) Recreational (C) and Commercial/Industrial (D) guideline values have been adopted for this investigation.

For TPH, naphthalene and pyrene, Tier 1 screening criteria from the MfE Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand[8] have been selected. Tier 1 soil acceptance criteria for Commercial / Industrial land use and Residential land use, All Pathways, Sand 1 - 4 m depth have been adopted. As there are no recreational land use guideline values available, the residential values have been adopted as a conservative screen for this pathway.

The adopted criteria are presented in Tables 1 through to 4 in Attachment C.

5.3 Background Soil Concentrations

Background soil concentrations of heavy metals for the Site were obtained from the Landcare Research (2015) report[9], Tables 13 through Table 15. The area of the landfill is classified as fill and as such does not have background heavy metal concentrations derived. As material has been received at the Site from all over Dunedin, the highest background value from each of the dominant adjacent geological units for each metal was adopted for comparison purposes.

There are currently no published background soil concentrations for PAHs in Dunedin. As such, PAH values established for Christchurch urban soils[10] were adopted for comparative purposes only.

Background concentrations for OCP pesticides were taken from the following two documents:

– Landcare Research (2015). Background soil concentrations of selected trace elements and organic contaminants in New Zealand. Table 21.
– Ministry for the Environment (1998). Ambient concentrations of selected organochlorines in soils. Table F5.1 - mean values.

The adopted criteria are presented in Table 1, Table 2 and Table 3 in Attahment C.

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[6] New Zealand Guidelines for Assessing and Managing Asbestos in Soil - Building Research Association of New Zealand (BRANZ), November 2017

[7] National Environmental Protection Council (NEPC) (2013). National Environmental Protection Measure (Assessment of Site Contamination) as amended in 2013 Schedule B1, Health Investigation Levels (HIL) for soil contaminants.

[8] Ministry for the Environment (1999, revised 2011). Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Module 4- Tier 1 Soil screening Criteria.

[9] Landcare Research (2015). Background soil concentrations of selected trace elements and organic contaminants in New Zealand

[10] Environment Canterbury, 2007, Background concentrations of polycyclic aromatic hydrocarbons in Christchurch urban soils. Report R07/19

5.4 Otago Regional Council Regional Plans

The operative Regional Plan for Otago (Waste) was enacted in April 1997. Section 5 of this Plan details the policies, methods and rules regarding Contaminated Sites. A contaminated site is defined as a site at which hazardous substances occur at concentrations above background levels and where assessment indicates it poses, or is likely to pose, an immediate or long term hazard to human health and/or the environment.

Hazardous substances are defined as follows:

Hazardous substances are substances which impair human, plant or animal health, or which may adversely affect the health or safety of any person or the environment, whether or not they are contained in or form part of any other substance or thing. These include pesticides, petrol, oil, cleaners and paint.

Rule 5.6.1 of the Plan states the following:

Rule 5.6.1 Hazardous wastes at contaminated sites (discretionary activity)

1. The disturbance of land; or
2. The discharge of hazardous waste into water; or
3. The discharge of hazardous waste onto or into land in circumstances that may result in that hazardous waste (or any other hazardous waste emanating as a result of natural processes from that hazardous waste) entering water; or
4. The deposit of any hazardous waste, in, on or under land; or
5. The discharge of hazardous waste into air at or from a contaminated site;

is a discretionary activity.

The operative Regional Plan for Otago (Water for Otago) was enacted in February 1998 and updated in June 2021. Section 7 of the Regional Plan, details policies for the discharge of stormwater and the Rules associated with these policies are contained in Section 12 (water takes, use and management). However, many of the Rules related to the discharge of stormwater within this Section have been repealed.

Rule 12.B.3 (Discharge of hazardous substances, hazardous wastes, specified contaminants, and stormwater, and discharges from industrial or trade premises and consented dams) states that the discharge of stormwater to water, or onto or into land in circumstances where it may enter water, is a restricted discretionary activity. The restrictions include the potential for soil contamination.

Should contaminants be found present in the soil at the Site at concentrations that there is a hazard posed to human health and/or the environment, then a consent may be required under the Regional Council's rules for certain activities to be undertaken. Further discussion is provided in Section 7.3 on consenting requirements.

6. Results

6.1 Soil analytical results

Analytical results compared against the adopted standards and guidelines are presented in Tables 1 through Table 6 in Attachment C. The laboratory reports are included in Attachment D.

In summary:

- Heavy metals
  - Metals including arsenic, cadmium, chromium, lead, nickel and zinc were detected at concentrations above the adopted Dunedin background soil concentrations in 13 of the 28 samples analysed.
  - No heavy metals were reported at concentrations above the adopted background values in samples collected from BH-100 and BH-107.
  - Above background concentrations were limited to the upper 2.5 m of material in boreholes BH-101, BH-102 and BH-103. However, they extended to at least 3.3 bgl in boreholes BH-108 and BH-111.
  - No metals concentrations were detected above the relevant human health screening criteria.
  - Refer to **Table 1** for tabulated analytical metals results.
- PAHs
  - Various PAHs were detected above adopted background soil concentrations in eight samples (not including the field duplicate sample).
  - No PAHs were reported at concentrations above the adopted background values in samples collected from BH-100 and BH-101, BH-102 and BH-103.
  - Above background concentrations of PAHs were distributed through the whole soil profile (surface to 3.3 m bgl).
  - PAH, as BaP toxicity equivalence quotient (TEQ), was greater than the NESCS SCS for Commercial/Industrial and Recreational use in one sample (12547621-BH-104(0.5)) collected at borehole BH-104 in fill material.
  - Refer to **Table 2** for the tabulated PAH results.
- SVOCs
  - Various SVOC were detected above background soil concentrations in five samples, two collected from BH-103 (0.2 and 1.2 m bgl), two collected from BH-107 (1.5 and 2.5 m bgl) and the other from BH-111 (1.5 m bgl).
  - The pesticide 4,4’-DDD was reported present at a low concentration in boreholes BH-103, BH-107 and BH111 in the samples described above. The pesticides 4,4’-DDE and 4,4’-DDT were also reported present in the samples collected and analysed from BH-103.
  - No SVOCs were detected at concentrations above any considered human health or environmental screening criteria.
  - Refer to **Table 3** for a summary of SVOC results. Only those SVOCs which were detected at concentrations above the LOR are presented in the table. The full set of results can be found in the laboratory reports.
- TPH was not detected above any of the considered human health or environmental screening standards. Refer to **Table 4** for tabulated TPH results.
- Ammonia was detected above the laboratory detection limit in four of eight samples. The highest concentrations were found in the samples collected from soils likely to be rich in organic material (on the basis of their lithological description). Refer to **Table 5** for a summary of ammonia results. There are no available guideline criteria available to compare these results against.

- Asbestos
  - Asbestos fines were reported present in one sample collected from BH-107 at a depth of 0.5 m bgl (12547621-BH-107(0.5)), and the sample was further scheduled for semi-quantitative analysis. Asbestos was not detected in the sample examined for semi-quantitative analysis.
  - Asbestos was not detected in any other soil samples collected as part of this investigation.
  - Refer to **Table 6** for a summary of asbestos results.

6.2 Quality Assurance and Quality Control

GHD quality assurance/quality control (QA/QC) procedures to assess data quality were maintained throughout the project.

The QA/QC programme undertaken as part of the assessment by GHD included the following:

- All fieldwork was undertaken by suitably qualified and trained staff. The work managed by a suitably qualified and experienced practitioner (SQEP) and the report was reviewed by a SQEP, as required by the NESCS.
- Collection of two duplicate soil samples for analysis of heavy metals and PAHs.
- Soil samples collected throughout works were dispatched to Analytica Laboratories in Hamilton on the day of collection under standard chain of custody procedures and the analysis was undertaken within the sample holding times.
- Analytica Laboratories is an internationally recognised laboratory endorsed by International Accreditation New Zealand (IANZ) which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC mutual recognition arrangement (ILAC-MRA) this accreditation is internationally recognised. The tests were performed in accordance with the terms of accreditation.

6.2.1 Analytical results

GHD collected two field duplicate samples for quality assurance/quality control (QA/QC) one of which was analysed for both heavy metals and PAHs and the other for heavy metals only.

A quantitative measure of the accuracy of the analytical results received from the laboratory was conducted using calculated relative percentage difference (RPD) values. The RPD values were calculated using the following equation:

$$\text{RPD (\%)} = \frac{\left\langle Co - Cs \right\rangle}{\left\langle \frac{Co + Cs}{2} \right\rangle} \times 100$$

Where *Co* = concentration obtained from the original sample.

Cs = concentration obtained from the duplicate sample.

The usual acceptance criteria for relative percentage difference (RPD) are between 30 and 50% in soils (CLMG, No.5 section 3.9.1 (2011)). However, larger RPDs are allowed for different analytes (up to 100%). A large percentage differential can occur particularly in soils due to the following:

- A small analytical differential between two samples based on the low levels of detection from the primary and duplicate soil sample.
- Soil samples collected from a non-homogenous (heterogeneous) soil profile.

RPD values for the duplicate samples (field) analysed for heavy metals for this assessment ranged from 0% to 61.6%. However, the majority of the RPDs, 17 out of 20, were less than 50%.

RPD values for the duplicate samples (field) analysed for PAHs for this assessment ranged from 127.5% to 187.9%.

The high RPD values for the PAH analysis are likely due to the heterogenous nature of the material at that borehole location (BH-108).

The duplicate quality assurance and quality control (QA/QC) results are provided in Attachment C, Table 7 and the laboratory analytical reports are provided in Attachment D.

The results of the whole QA/QC program are considered to provide an acceptable degree of confidence in the sampling and analytical program.

7. Conclusions

7.1 Landfilling Extent

A review of the available historical aerial photographs and leachate collection trench construction report indicates that waste is present on the outside of the leachate collection trench in places, with waste up to 6 m thick on the north eastern boundary in a short section (approximate 20-40 m length). Generally, the thickness of the waste is less than 2.6 m in other areas, and averaging 1.63 m depth over the other 40 locations mapped from the log.

The aerial photographs (1978 and 1982) indicate that landfilling activities likely extended very close to the edge of the Kaikorai Stream banks along the northern boundary with some waste placement also likely to having occurred in these areas. The trench construction report indicates that waste / landfill material is present on the outside of the trench at the following locations:

- 6m north of PS3 through to 32m east of AV4
- 36m east of PS5 to 49m east of PS5
- MH6 through to 18m north of PS8

Waste is likely to extend either side of these locations. In addition, earthfill is also present from south of PS8 through to the end of the trench (55 m north of PS9).

The likely extent of the landfilling is shown on Figure 4.

7.2 Soil contaminant status

An environmental site investigation was undertaken in conjunction with a geotechnical investigation in October and November 2022. Soil samples were collected from eight of the boreholes drilled during the investigation, six of which were located around the periphery of the landfill and two in the northern portion of the landfill (area of oldest landfilling). These samples were laboratory analysed for the identified contaminants of concern. The material in the boreholes was logged by a geotechnical engineer and observations of soil type and indications of contamination were also made by an environmental scientist.

Municipal solid waste (MSW) and fill material was found present in all the boreholes assessed.

The analytical results indicated that contaminant concentrations at above background values were present through the soil profile from surface to a depth of 3.3 m bgl. One sample, at BH-104(0.5 m bgl), had a reported a BaP equivalent concentration which exceeded the NESCS SCS value for both Commercial / Industrial and Recreational land use.

Asbestos fines were reported present in only one of the 19 samples analysed. Low concentrations of TPH were reported present in the one sample analysed for this contaminant. Elevated concentrations of ammonia were reported in samples collected from borehole horizons described as peat, silty sand, fill / organic silt and fill / wood in sand. These materials are likely to have elevated organic content.

Pesticides (4,4'-DDE, 4,4'-DDD and 4,4'-DDT), at low concentrations, were reported present in five of the thirteen samples analysed for these contaminants.

7.3 Regulatory requirements

7.3.1 NESCS

This investigation has confirmed that HAIL activity G3 (landfill sites) has occurred on the Site and as such the requirements of the NESCS apply to any future redevelopment works (e.g. soil disturbance and land use change).

7.3.2 Regional and Local Council Requirements

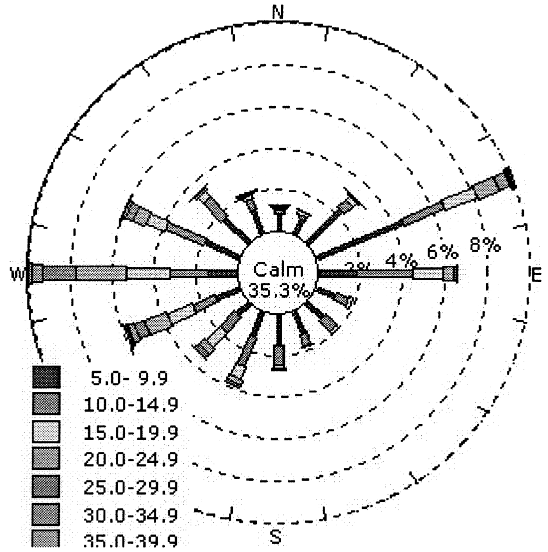
It is understood that a review of Regional and Local Council planning requirements is to be undertaken by Boffa Miskell. As such, further discussion of any requirements has not been undertaken in this report.

Attachments

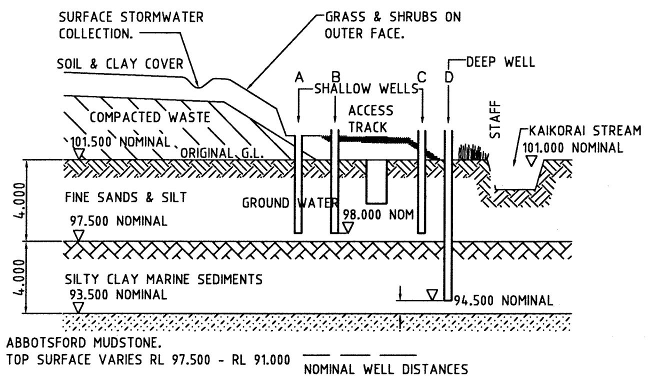
Attachment A
Historical Plans and Figures

DO NOT SCALE - IF IN DOUBT, ASK

ORIGINAL SIZE A1

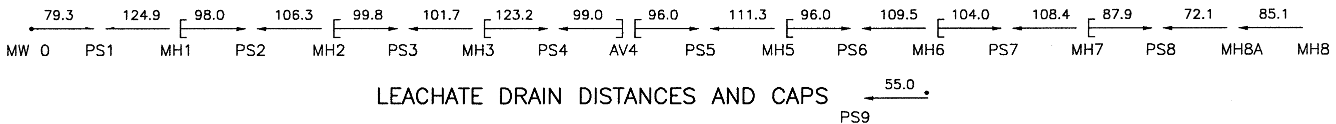


WINDROSE DATA FOR GREEN ISLAND LANDFILL (kM/hr)
FOR PERIOD 01/01/03 TO 31/12/03



TYPICAL CROSS SECTION
LEACHATE TRENCH AND MONITORING WELLS

NTS



LEACHATE DRAIN DISTANCES AND CAPS

LEGEND

FENCE

EXTENT OF LANDFILLED AREA

LANDFILL OPERATION AREA

LANDFILL DESIGNATION D658
DUNEDIN CITY COUNCIL DISTRICT PLAN

SEWER LINE

STORMWATER DITCH

PS	PUMP STATION (TOTAL 9)
MH	MANHOLE (TOTAL 8)
AV	AIR VALVE (TOTAL 6)
MW	MONITORING WELL (SHALLOW 24, DEEP 4)
ST	STAFF (TOTAL 4)
GI	KAIKORAI STREAM SAMPLING POINT (TOTAL 4)

RISING MAIN 125MM HDPE PIPE

LEACHATE COLLECTION TRENCH

NOTE REFER TO CITYCONS DRAWING 5526/234
LEACHATE MONITORING FOR ADDITIONAL DETAIL

Green Island Leachate Collection System - Monitoring Wells

Pump Stations

		Leachate			Pump Level	
Station	Lid Top	Inlet 1	Inlet 2	Pump Inlet	On	Off
PS 1	102.34	98.89	98.90	97.85	99.36	99.16
PS 2	102.42	99.05	99.07	98.36	99.54	99.34
PS 3	102.51	99.01	98.97	98.48	99.45	99.25
PS 4	102.43	98.93	99.02	98.35	99.36	99.16
PS 5	102.43	99.14	99.13	98.30	99.56	99.36
PS 6	102.42	99.18	99.15	98.38	99.61	99.41
PS 7	103.12	98.87	99.04	98.05	99.32	99.12
PS 8	103.79	99.36	99.49	98.43	99.79	99.59
PS 9	105.97	100.17		99.06	100.69	100.49

Manholes

		Leachate	
Station	Lid Top	Inlet 1	Inlet 2
MH 1	102.57	99.09	99.07
MH 2	102.35	98.97	99.02
MH 3	102.57	98.87	98.90
MH 5	102.49	99.09	99.08
MH 6	102.33	98.90	98.88
MH 7	102.96	99.33	99.32
MH 8A	103.60	100.36	100.40
MH 8	105.02	102.00	

Air Valves

Station	Lid Top
AV 1	102.38
AV 2	102.44
AV 3	103.07
AV 4	102.74
AV 5	102.53
AV 6	102.73

Monitoring Wells and Stream Staffs

Station	Distance from Drain	Top	Bottom	Depth	Classification	Ground Level	Landfill Surface
MW 0	-	102.55	97.65	4.9	Shallow	102.44	N/A
MW 1A	10.5	102.44	97.84	4.6	Shallow	102.27	103.0
MW 1B	5.4	102.44	97.84	4.6	Shallow	102.40	N/A
MW 1C	6.2	102.43	97.83	4.6	Shallow	102.22	N/A
MW 2A	10.0	102.37	97.57	4.8	Shallow	102.28	103.6
MW 2B	4.8	102.42	97.62	4.8	Shallow	102.19	102.5
MW 2C	5.1	102.49	97.69	4.8	Shallow	102.26	N/A
MW 2D	11.1	102.51	92.51	10.0	Deep	102.16	N/A
ST 2	47.4	103.0			Staff	101.0	N/A
MW 3A	9.7	103.00	98.48	4.52	Shallow	102.83	103.7
MW 3B	5.1	103.02	98.50	4.52	Shallow	102.78	N/A
MW 3C	4.6	103.05	98.42	4.63	Shallow	102.65	N/A
ST 3	47.0	103.0			Staff	101.1	N/A
MW 4A	9.0	104.00	98.50	5.5	Shallow	103.81	104.3
MW 4B	3.8	103.00	98.30	4.7	Shallow	102.79	103.2
MW 4C	5.4	102.98	98.28	4.7	Shallow	102.79	N/A
MW 4D	5.2	102.99	92.49	10.5	Deep	102.76	N/A
ST 4	9.7	103.0			Staff	101.4	N/A
MW 5A	9.9	103.09	98.57	4.52	Shallow	102.98	N/A
MW 5B	5.3	103.09	98.57	4.52	Shallow	102.89	N/A
MW 5C	5.6	103.07	98.55	4.52	Shallow	102.47	N/A
ST 5	17.2	104.0			Staff	101.15	N/A
MW 6A	10.0	102.82	98.47	4.35	Shallow	102.78	103.2
MW 6B	4.8	102.72	98.37	4.35	Shallow	102.42	N/A
MW 6C	4.9	102.71	98.36	4.35	Shallow	102.31	N/A
MW 7A	9.7	103.27	98.28	4.99	Shallow	103.13	N/A
MW 7B	4.8	103.28	98.29	4.99	Shallow	103.04	N/A
MW 7D	5.3	103.23	96.16	7.07	Deep	102.87	N/A
MW 8A	12.8	105.43	98.33	7.10	Shallow	105.28	N/A
MW 8B	5.7	105.44	98.34	7.10	Shallow	105.23	N/A
MW 8C	4.5	105.44	98.34	7.10	Shallow	105.37	N/A
MW 9	Min 250	109.74	94.24	15.50	Deep	109.48	N/A

NOT FOR CONSTRUCTION

REV	AMENDMENTS	INITIAL	DATE	INITIAL	DATE
		CHECKED		APPROVED	

TAB/DWG : Layout1 / 006116-19-01 G11.dwg
SERVER : DUNEDIN (NZDUN2S01)
XREFS : XBASEPLAN JULY 2004

FIELDBOOK	Name	Date
SURVEYED		
DESIGNED		
DRAWN	M.A.BECHT	09/04
CHECKED		
APPROVED		

MWH

DUNEDIN CITY COUNCIL

DCC LANDFILL
ANNUAL SURVEY PLANS - JULY 2004

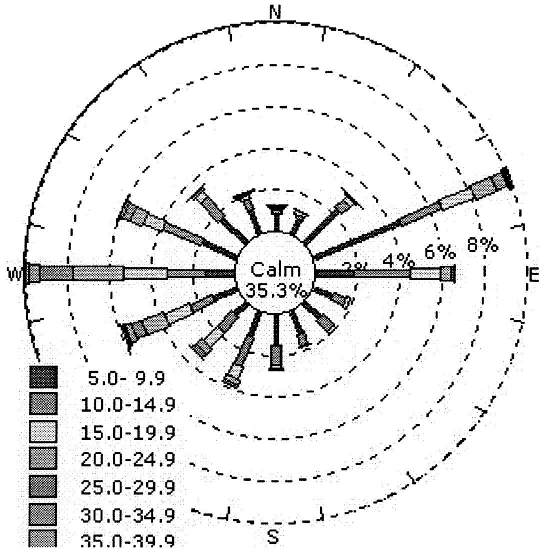
GREEN ISLAND LANDFILL-LEACHATE COLLECTION
& ENVIRONMENTAL MONITORING SYSTEM

Status Stamp: **FINAL**
Date Stamp: **12.10.2004**
SCALES (A1) 1:2500 (A3) 1:5000

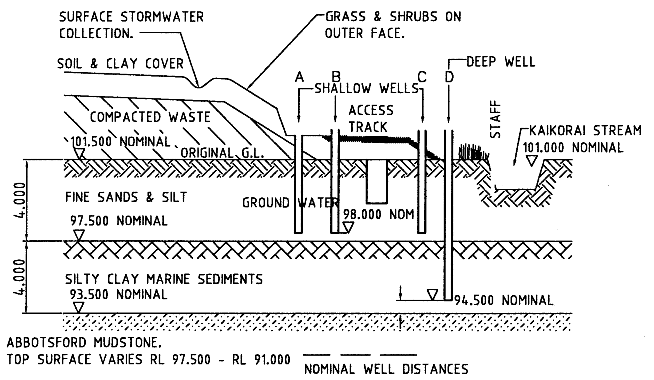
Job No.	Sheet No.	Rev.
006116-19-01	G11	C

P:\B01006116\19\01 July 2004 Update\CAD\006116-19-01 G11.dwg

DO NOT SCALE - IF IN DOUBT, ASK



WINDROSE DATA FOR GREEN ISLAND LANDFILL (kM/hr)
FOR PERIOD 01/01/03 TO 31/12/03



TYPICAL CROSS SECTION
LEACHATE TRENCH AND MONITORING WELLS
NTS

ORIGINAL SIZE A1

Green Island Leachate Collection System - Monitoring Wells

Pump Stations

		Leachate			Pump Level	
Station	Lid Top	Inlet 1	Inlet 2	Pump Inlet	On	Off
PS 1	102.34	98.89	98.90	97.85	99.36	99.16
PS 2	102.42	99.05	99.07	98.36	99.54	99.34
PS 3	102.51	99.01	98.97	98.48	99.45	99.25
PS 4	102.43	98.93	99.02	98.35	99.36	99.16
PS 5	102.43	99.14	99.13	98.30	99.56	99.36
PS 6	102.42	99.18	99.15	98.38	99.61	99.41
PS 7	103.12	98.87	99.04	98.05	99.32	99.12
PS 8	103.79	99.36	99.49	98.43	99.79	99.59
PS 9	105.97	100.17		99.06	100.69	100.49

Manholes

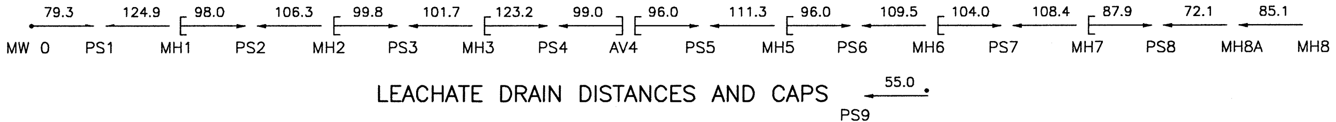
		Leachate	
Station	Lid Top	Inlet 1	Inlet 2
MH 1	102.57	99.09	99.07
MH 2	102.35	98.97	99.02
MH 3	102.57	98.87	98.90
MH 5	102.49	99.09	99.08
MH 6	102.33	98.90	98.88
MH 7	102.96	99.33	99.32
MH 8A	103.60	100.36	100.40
MH 8	105.02	102.00	

Air Valves

Station	Lid Top
AV 1	102.38
AV 2	102.44
AV 3	103.07
AV 4	102.74
AV 5	102.53
AV 6	102.73

Monitoring Wells and Stream Staffs

Station	Distance from Drain	Top	Bottom	Depth	Classification	Ground Level	Landfill Surface
MW 0	-	102.55	97.65	4.9	Shallow	102.44	N/A
MW 1A	10.5	102.44	97.84	4.6	Shallow	102.27	103.0
MW 1B	5.4	102.44	97.84	4.6	Shallow	102.40	N/A
MW 1C	6.2	102.43	97.83	4.6	Shallow	102.22	N/A
MW 2A	10.0	102.37	97.57	4.8	Shallow	102.28	103.6
MW 2B	4.8	102.42	97.62	4.8	Shallow	102.19	102.5
MW 2C	5.1	102.49	97.69	4.8	Shallow	102.26	N/A
MW 2D	11.1	102.51	92.51	10.0	Deep	102.16	N/A
ST 2	47.4	103.0			Staff	101.0	N/A
MW 3A	9.7	103.00	98.48	4.52	Shallow	102.83	103.7
MW 3B	5.1	103.02	98.50	4.52	Shallow	102.78	N/A
MW 3C	4.6	103.05	98.42	4.63	Shallow	102.65	N/A
ST 3	47.0	103.0			Staff	101.1	N/A
MW 4A	9.0	104.00	98.50	5.5	Shallow	103.81	104.3
MW 4B	3.8	103.00	98.30	4.7	Shallow	102.79	103.2
MW 4C	5.4	102.98	98.28	4.7	Shallow	102.79	N/A
MW 4D	5.2	102.99	92.49	10.5	Deep	102.76	N/A
ST 4	9.7	103.0			Staff	101.4	N/A
MW 5A	9.9	103.09	98.57	4.52	Shallow	102.98	N/A
MW 5B	5.3	103.09	98.57	4.52	Shallow	102.89	N/A
MW 5C	5.6	103.07	98.55	4.52	Shallow	102.47	N/A
ST 5	17.2	104.0			Staff	101.15	N/A
MW 6A	10.0	102.82	98.47	4.35	Shallow	102.78	103.2
MW 6B	4.8	102.72	98.37	4.35	Shallow	102.42	N/A
MW 6C	4.9	102.71	98.36	4.35	Shallow	102.31	N/A
MW 7A	9.7	103.27	98.28	4.99	Shallow	103.13	N/A
MW 7B	4.8	103.28	98.29	4.99	Shallow	103.04	N/A
MW 7D	5.3	103.23	96.16	7.07	Deep	102.87	N/A
MW 8A	12.8	105.43	98.33	7.10	Shallow	105.28	N/A
MW 8B	5.7	105.44	98.34	7.10	Shallow	105.23	N/A
MW 8C	4.5	105.44	98.34	7.10	Shallow	105.37	N/A
MW 9	Min 250	109.74	94.24	15.50	Deep	109.48	N/A



LEACHATE DRAIN DISTANCES AND CAPS

LEGEND

─/─/─/─	FENCE
🟩	EXTENT OF LANDFILLED AREA
─ · ─ · ─	LANDFILL OPERATION AREA
▨	LANDFILL DESIGNATION D658 DUNEDIN CITY COUNCIL DISTRICT PLAN
— — —	SEWER LINE
─>─>─	STORMWATER DITCH
PS	PUMP STATION (TOTAL 9)
MH	MANHOLE (TOTAL 8)
AV	AIR VALVE (TOTAL 6)
MW	MONITORING WELL (SHALLOW 24, DEEP 4)
ST	STAFF (TOTAL 4)
GI	KAIKORAI STREAM SAMPLING POINT (TOTAL 4)
▨	RISING MAIN 125MM HDPE PIPE
— —	LEACHATE COLLECTION TRENCH

NOTE REFER TO CITYCONS DRAWING 5526/234
LEACHATE MONITORING FOR ADDITIONAL DETAIL

NOT FOR CONSTRUCTION

REV	AMENDMENTS	INITIAL	DATE	INITIAL	DATE
		CHECKED		APPROVED	

TAB/DWG : Layout1 / 006116-19-01 G11.dwg
SERVER : DUNEDIN (NZDUN2S01)
XREFS : XBASEPLAN JULY 2004

FIELDBOOK	Name	Date
SURVEYED		
DESIGNED		
DRAWN	M.A.BECHT	09/04
CHECKED		
APPROVED		

MWH

DCC
DUNEDIN CITY COUNCIL

DCC LANDFILL
ANNUAL SURVEY PLANS - JULY 2004

GREEN ISLAND LANDFILL-LEACHATE COLLECTION
& ENVIRONMENTAL MONITORING SYSTEM

Status Stamp: FINAL
Date Stamp: 12.10.2004
SCALES (A1) 1:2500 (A3) 1:5000
Job No. 006116-19-01
Sheet No. G11
Rev. C

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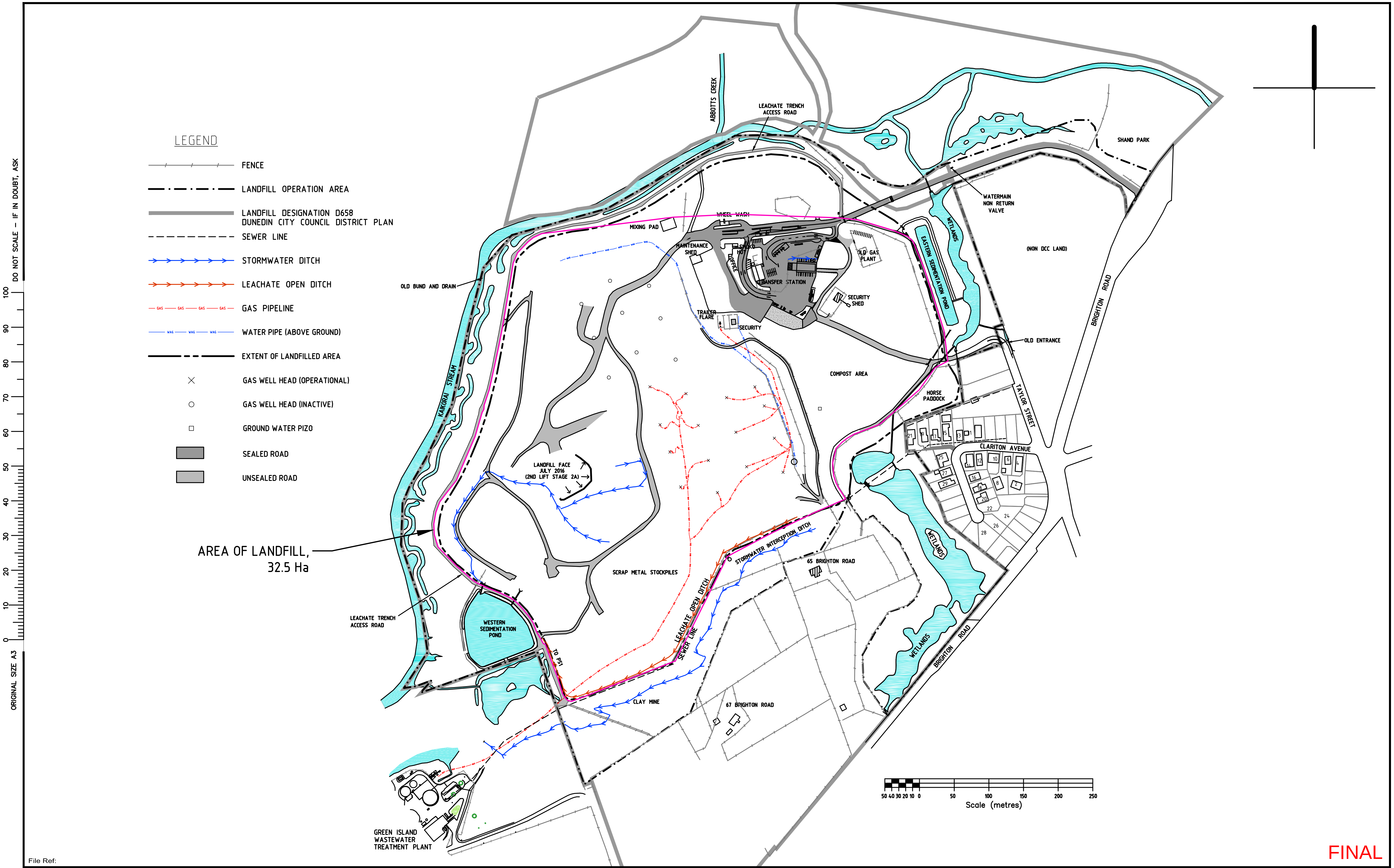


File Ref:

FINAL

Prepared For:

DELTA
THINK.INFRASTRUCTURE

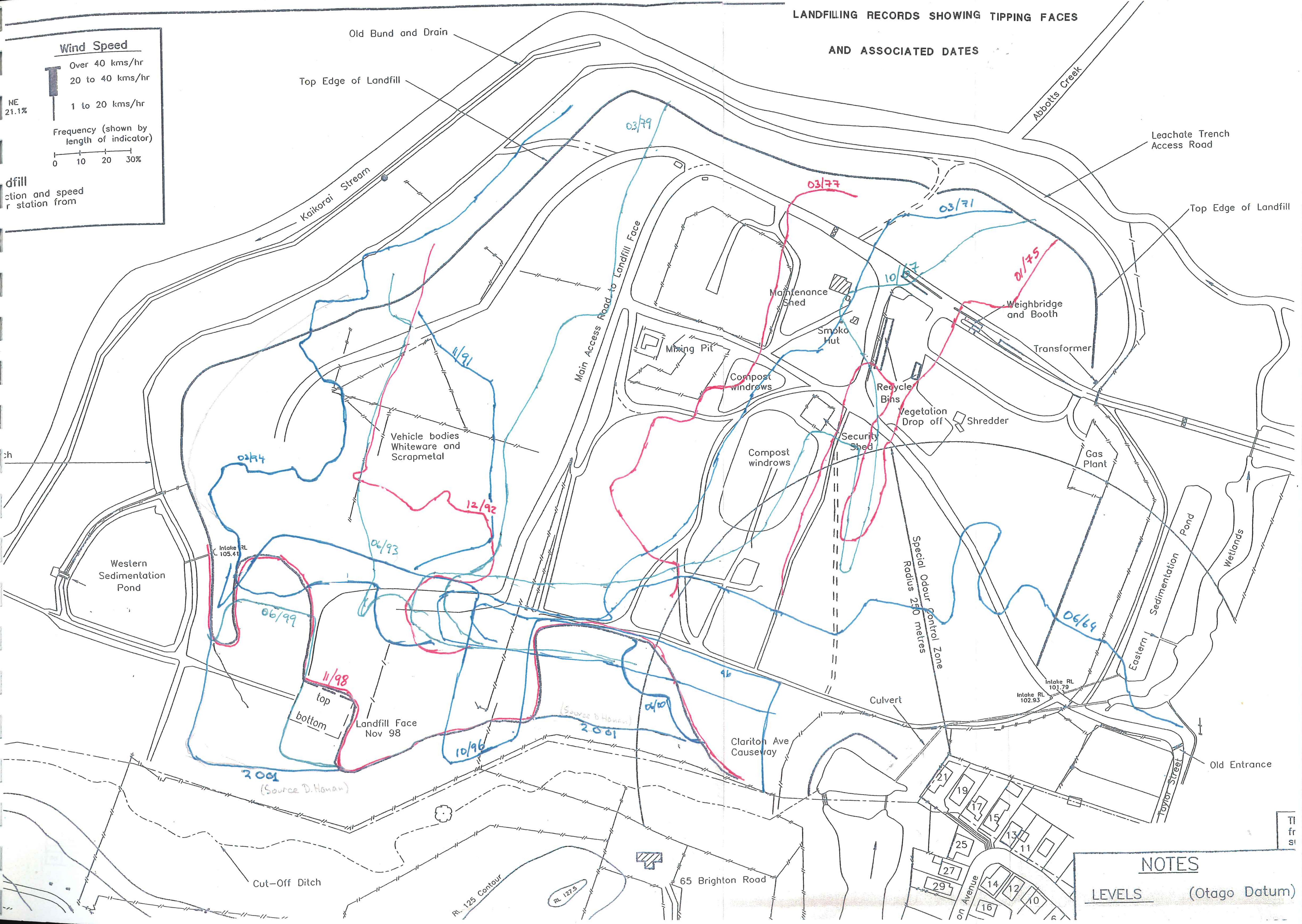
No.	Amendments	Drawn	Date

DCC LANDFILLS
ANNUAL SURVEY PLANS - JULY 2016
GREEN ISLAND LANDFILL
BASE PLAN

Project No.: 16031	Surveyed: DS
Scale: 1:5000	Designed: DH
Date: JULY 2016	Drawn: DS/CC
Sheet: G01	Checked: DH

Survey Services
Surveying Consultants
TL Survey Services Limited
P.O. Box 901 DUNEDIN
Phone (03) 477 1133

LANDFILLING RECORDS SHOWING TIPPING FACES AND ASSOCIATED DATES



Attachment B
Borehole Logs

GLOSSARY OF SYMBOLS

This standard sheet should be read in conjunction with all test hole log sheets and any idealised geological sections prepared for the investigation report.

GENERAL ABBREVIATIONS

Activity type / drilling method

DT	Dual tube
CA	Casing advancement
EXP	Logged exposure
GCOP	GCO probe
HA	Hand Auger
HV	Hydro Vacuum excavation
HQTT	HQ triple tube coring
ICBR	In situ CBR test
IDEN	In situ density test
INST	Instrument
IVAN	In situ vane test
MHA	Machine Hollow auger
MSA	Machine Solid auger
NQTT	NQ triple tube coring
OB	Open barrel
OP	Observation pit/trench
PM	Pressuremeter test hole
PQTT	PQ triple tube coring
RC	Rotary cored
RCG	Rotary drilling in common ground
RO	Rotary open hole
SCP	Static cone penetrometer
SH	Shaft
SNC	Sonic core drilling
SPT	Standard penetration test
TP	Trial pit/trench
TT	Triple tube coring
VC	Vibrocore
W	Wash boring

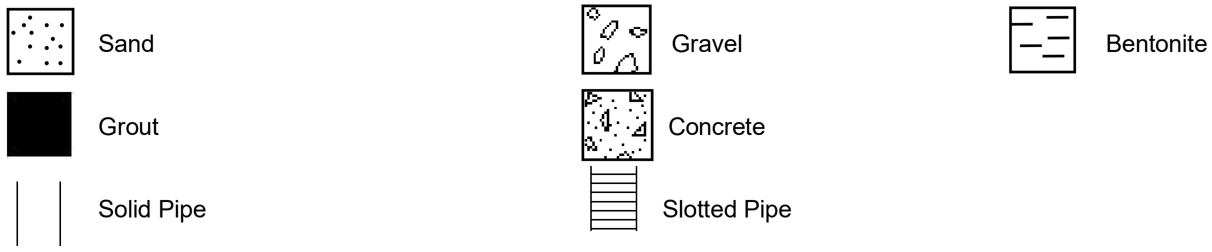
Sampling type

AMAL	Amalgamated sample
B	Bulk disturbed sample
BLK	Block sample
C	Core sample
CBR	CBR mould sample
D	Small disturbed sample
ES	Soil sample for environmental testing
EW	Water sample for environmental testing
G	Gas sample
J	Jar
LB	Large bulk disturbed sample (for earthworks testing)
LDS	Large Disturbed Sample
M	Mazier type sample
P	Piston sample
TW	Thin walled push in sample
U	Undisturbed sample - open drive
U100	U110 Undisturbed Sample
U76	U76 Undisturbed Sample
UT	Thin wall open drive tube sampler
W	Water sample

Other testing

F	Falling Head Permeability Test
N	Total blows - SPT Value
PK	Packer Test
PP	Pocket Penetrometer (suffixed by value in kPa)
PT	Pressuremeter Test
R	Rising Head Permeability Test
SV	Shear Vane Test (suffixed by value in kPa, peak/residual values)
UTP	Unable to penetrate (shear vane testing)
TD	Target depth
HCL	Hydrochloric acid

WELL SYMBOLS

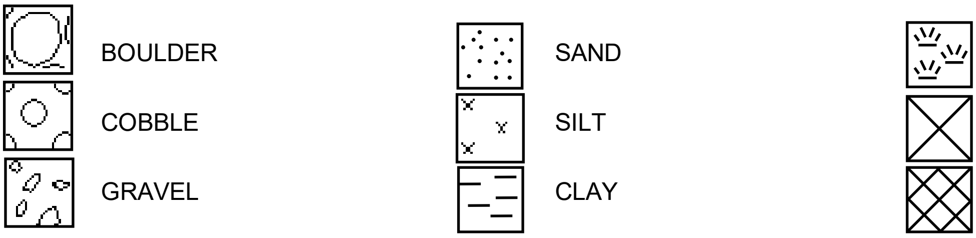


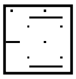
GROUNDWATER SYMBOLS

∇ Groundwater level

SOIL SYMBOLS

Main Components



Note: Composite soil types will be signified by combined symbols, e.g  Sandy CLAY

SOIL DESCRIPTION ABBREVIATIONS

Consistency

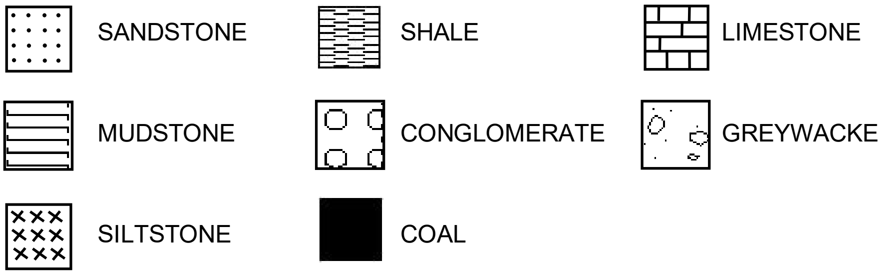
D	Dense
D-VD	Dense to very dense
F	Firm
F-St	Firm to stiff
H	Hard
L	Loose
L-MD	Loose to medium dense
MD	Medium dense
MD-D	Medium dense to dense
S	Soft
S-F	Soft to firm
St	Stiff
St-VSt	Stiff to very stiff
VD	Very dense
VL	Very loose
VL-L	Very loose to loose
VS	Very soft
VS-S	Very soft to soft
VSt	Very stiff
VSt-H	Very Stiff to hard

Moisture Condition

D	Dry
D-M	Dry to moist
M	Moist
M-W	Moist to wet
S	Saturated
W	Wet

ROCK SYMBOLS

Sedimentary



Metamorphic

Igneous

Note: Additional rock symbols may be allocated for a particular project. Interbedded rock will be represented using alternatively the above symbols

ROCK DESCRIPTION ABBREVIATIONS

Rock Strength

EW	Extremely weak
EW - VW	Extremely to very weak
VW	Very weak
VW - W	Very weak to weak
W	Weak
W - MS	Weak to moderately strong
MS	Moderately strong
MS - S	Moderately strong to strong
S	Strong
S – VS	Strong to very strong
VS	Very strong
VS - ES	Very strong to extremely strong
ES	Extremely strong

Weathering

RS	Residual soil
CW-RS	Completely weathered to residual soil
CW	Completely weathered
HW-CW	Highly weathered to completely weathered
HW	Highly weathered
MW-HW	Moderately weathered to highly weathered
MW	Moderated weathering
SW-MW	Slightly weathered to moderately weathered
SW	Slightly Weathered
UW-SW	Unweathered to slightly weathered
UW	Unweathered (fresh)

DEFECT DESCRIPTION ABBREVIATIONS

Fracture Type

BP	Bedding Plane
CB	Cross Bed
Cl	Cleavage
CS	Crushed Seam
CZ	Crush zone
Fl	Foliation
FZ	Fractured Zone (>250 mm)
JS	Joint set
JT	Joint
SF	Sheared Surface
SM	Seam
SS	Sheared Seam
SZ	Sheared Zone (>250 mm)
VN	Vein

Inclination

SB	Sub-horizontal
G	Gently inclined
M	Moderately inclined
S	Steeply inclined
VS	Very steeply inclined
SV	Sub-vertical

Roughness

sl	Slickensided
r	Rough
sm	Smooth

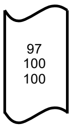
Texture

Pl	Planar
St	Stepped
U	Undulating

Joint Set Counts

X 2	2 joints
X 3	3 joints
X 4	4 joints
X 5	5 joints
X 6	6 joints
X 7	7 joints
X 8	8 joints
X 9	9 joints
> 10	> 10 joints

Core Recovery Parameters



TCR – Total Core Recovery %
SCR – Solid Core Recovery %
RQD – Rock Quality Designation %

Aperture

T	Tight
VN	Very Narrow
N	Narrow
MN	Moderately Narrow
MW	Moderately Wide
W	Wide
VW	Very Wide

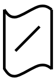
Infilling or Coating

CN	Clean
X	Carbonaceous
CLAY	Clay
KT	Chlorite
CA	Calcite
Fe	Iron Oxide
MI	Micaceous
QZ	Quartz
VE	Veneer

Spacing

EC	Extremely closely spaced
VC	Very closely spaced
C	Closely spaced
MW	Moderately widely spaced
W	Widely spaced
VW	Very widely spaced

Visual Defects



Visual representation of defect angle from horizontal (example shown is 45°)

GHD

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 11/1/2022
Completed: 11/1/2022

Hole No. : BH100

Sheet : 1 of 2
Hole Length : 12.95 m
Scale @ A4 : 1:40
Logged : NP
Processed : NP
Checked : DB

Easting: 1399156
Northing: 4913186
System: NZTM2000
RL: 2.49 m
Datum: NZVD2016
Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
0	FILL: Silty, fine to coarse sand, minor gravel; light brown. Dry, gravel, fine, subangular.	FILL	D	
1	FILL: MSW and wood fragments; dark brown. MSW containing plastics.	FILL		
1.7	CORE LOSS	FILL		
2.5	FILL: Wood fragments in silty, sand matrix; brown to dark brown. Moist.	FILL	M	
2.75	Sandy SILT, some clay, trace rootlets; dark brown. 'Very soft', moist, high plasticity, sand; fine to medium.	UKEM		'VS'
3.25	CORE LOSS	UKEM		
3.5	Sandy SILT, some organic material, minor clay, minor sand, trace rootlets; dark brown. Very soft, moist, low plasticity, sand, fine to medium.	UKEM		
4.1	ORGANIC SILT, some clay, trace shell fragments; dark brown. Firm, moist, high plasticity. Sulphurous smell.	LKEM		F
5.35	Silty CLAY, minor sand, trace organic; greenish grey with black streaking. Stiff, moist, moderate to high plasticity.	LKEM		St
7.8		LKEM		S

RL (m): 2 · 1 · 0 · -1 · -2 · -3 · -4 · -5
Depth (m): 0 · 1 · 2 · 3 · 4 · 5 · 6 · 7 · 8

Sample

Number / Type	Result
	SPT 6/3 2/2 1/1 N = 6
2.75 C- 3.25	SPT 3/3 2/1 1/2 N = 6
	SPT 0/0 0/0 1/1 N = 2
4.10 C- 4.50	SPT 0/0 0/0 0/1 N = 1 **SV@4.5m** **43/17** **kPa**
	SPT 0/0 0/0 0/1 N = 1
6.10 C- 6.50	SPT 0/0 0/0 0/1 N = 1
7.95	SPT 0/0 0/0 0/1 N = 1 **SV@7.5m** **84/17**

Method	TCR RQD SCR (%)
HA	TCR: 100
SNC	TCR: 100
SPT	TCR: 44
SNC	TCR: 0
SPT	TCR: 100
SNC	TCR: 45
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100

Casing · Flush Return (%) 25 50 75 · Weathering · Estimated Strength (MPa) EW VW MS VS ES · Defect Spacing (mm) 20 60 200 600 2000 · Instrumentation Installation · Water level

Water level: 1-11-2022 · 14-11-2022

Notes and Comments:
End of Hole @ 12.95m Shear Vane:
GEO937
MSW - Municipal Solid waste

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
01/11/22	16:15	0.93	12.95
14/11/22	11:06	0.975	11

Project	: GILF Closure Consents	Hole No.	: BH100
Client	: Dunedin City Council	Sheet	: 2 of 2
Site	: Green Island Landfill Dunedin	Hole Length	: 12.95 m
Job Number: 12547621		Scale @ A4	: 1:40
Commenced: 11/1/2022	Completed: 11/1/2022	Logged	: NP
Easting: 1399156	Northing: 4913186	System: NZTM2000	Processed : NP
RL: 2.49 m	Datum: NZVD2016	Method: GPSH	Checked : DB

Depth (m)	Material Description	Geological Unit	Consistency / Relative Density
	Sandy SILT, some clay; greenish grey. Soft, moist, low plasticity, sand, fine. *(continued from layer starting at 7.8m)* 8.50 Becomes some sand, minor clay, colour becomes orangish grey.	LKEM	
10.1	Silty, fine to medium SAND trace organic, dark brown. Very loose, moist, uniformly graded. 10.90 Sand becomes fine to medium	LKEM	VL
11.5	Fine to coarse GRAVEL, minor sand; black. Medium dense, gravel, angular, slightly weathered, weak; sand, coarse.	LKEM	'MD'
11.7	Unweathered to slightly weathered, dark grey to black MUDSTONE, extremely weak. Soil description: Clayey silt, minor sand, dark brown to black. Very stiff, moist, low plasticity, sand, fine.	ABBOTSFORD MUDSTONE	'VSt'
13	End of Hole @ 12.95m		

Sample Number / Type	Result
C- 8.40	kPa
	SPT 0/0 0/2 2/2 N = 6
	SPT 0/0 0/0 0/2 N = 2 **SV@9.5m** **29/17** **kPa**
C- 10.10 – 10.50	SPT 0/0 0/0 0/1 N = 1 **SV@10.5m** **17/6 kPa**
	SPT 9/13 8/4 6/7 N = 25
	SPT 3/5 6/7 10/11 N = 34

Method	TCR RQD SCR (%)
SNC	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100

Weathering: SW

Notes and Comments:

End of Hole @ 12.95m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
01/11/22	16:15	0.93	12.95
14/11/22	11:06	0.975	11

GHD

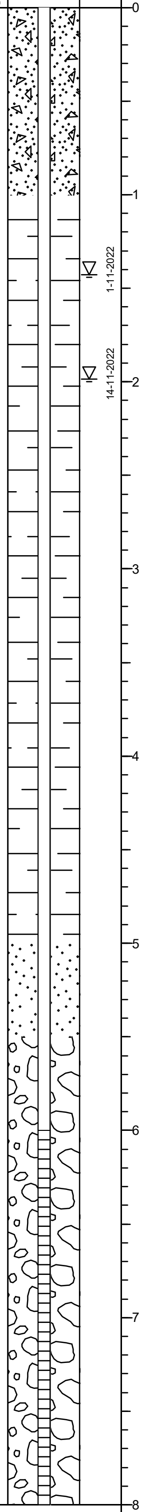
Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 11/1/2022 Completed: 11/1/2022

Hole No. : BH101
Sheet : 1 of 2
Hole Length : 12.95 m
Scale @ A4 : 1:40
Logged : NP
Processed : NP
Checked : DB

Easting: 1399042 Northing: 4913070 System: NZTM2000
RL: 2.21 m Datum: NZVD2016 Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
0	TOPSOIL: Sandy organic silt, minor rootlets; dark brown. Moist, low plasticity.	TOPSOIL	M	
0.4	FILL: Sandy, clayey, silt, some organic material (rootlets) and MSW (15%); orangish brown with grey and black mottling. Moist, sand, fine; MSW contains plastics, low to moderate plasticity.	FILL		
1.3	Fibrous PEAT, minor rootlets; black. Very soft, moist.	UKEM		'VS'
1.5	Sandy ORGANIC SILT, minor clay, trace rootlets; dark brown. Very soft, moist, low plasticity, sand, fine.			
1.95	Silty fine to medium SAND, some clay, trace gravel; dark grey. Very loose, wet, gravel, fine, subrounded. 3.25 - 3.30 Thin fine to coarse SAND lens 3.70 Becomes fine to coarse SAND, minor gravel.		W	VL
3.95	CORE LOSS			
4.5	Clayey ORGANIC SILT; dark brown. Firm, moist, high plasticity. Sulphurous smell.		M	F
6.05	CORE LOSS	LKEM	M	F
6.5	Silty CLAY, trace sand and organic, material and shells; greenish grey with black streaks. Firm, moist, high plasticity, sand, fine.			

Sample Number / Type	Sample Result	Method	TCR RQD SCR (%)
		SNC	TCR: 100
	SPT 0/0 0/0 1/1 N = 2	SPT	TCR: 100
		SNC	TCR: 100
C- 2.50 - 2.90	SPT 0/0 0/0 0/1 N = 1 **SV@2.5m** **9/6 kPa**	SPT	TCR: 100
		SNC	TCR: 100
	SPT 0/0 0/0 1/1 N = 2 **SV@3.5m** **27/9 kPa**	SPT	TCR: 100
		SNC	TCR: 0
	SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
C- 4.95 - 5.40		SNC	TCR: 100
	SPT 0/0 0/0 0/1 N = 1 **SV@5.5m** **29/13** **kPa**	SPT	TCR: 100
		SNC	TCR: 18
C- 6.50 - 6.95	SPT 0/0 0/0 0/1 N = 1 **SV@6.5m** **43/13** **kPa**	SPT	TCR: 100
		SNC	TCR: 100
7.95	SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100



Notes and Comments:
End of Hole @ 12.95m Shear
Vane: GEO937
MSW - Municipal Solid Waste

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
01/11/22	11:30	1.4	12.95
14/11/22	11:15	1.96	

Project	: GILF Closure Consents
Client	: Dunedin City Council
Site	: Green Island Landfill Dunedin
Job Number: 12547621	
Commenced: 11/1/2022	Completed: 11/1/2022
Easting: 1399042	Northing: 4913070
System: NZTM2000	Method: GPSH
RL: 2.21 m	Datum: NZVD2016

Hole No.	: BH101
Sheet	: 2 of 2
Hole Length	: 12.95 m
Scale @ A4	: 1:40
Logged	: NP
Processed	: NP
Checked	: DB

RL (m)	Depth (m)	Graphic	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%) 25 50 75	Weathering	Estimated Strength (MPa) EW VW W MS VS ES	TCR RQD SCR (%)	Defect Spacing (mm) 20 60 200 600 2000	Instrumentation Installation	Water level
-6	8.25		CORE LOSS	LKEM			C- 8.25			SNC				TCR: 55 TCR: 55			
	8.5		Clayey SILT, some sand; orangish grey. Stiff, moist, low to moderate plasticity, sand, fine.			St		SPT 0/0 1/1 2/2 N = 6		SPT				TCR: 100			
-7	9									SNC				TCR: 100			
							9.95	SPT 0/0 0/0 0/2 N = 2 **SV@9.5m** **63/17** **kPa**		SPT				TCR: 100			
-8	10		9.95 Becomes sandy, minor clay				C- 10.30			SNC				TCR: 64			
	10.4		Silty, fine to coarse GRAVEL, some sand, minor clay; grey with orangish brown matrix. Medium dense, moist to wet, gravel, angular to subangular, very weak, completely weathered; sand, fine to coarse.		M-W	MD		SPT 0/5 6/7 7/6 N = 26		SPT				TCR: 100			
-9	11 11.1		Unweathered to slightly weathered, dark grey to black MUDSTONE, extremely weak. Soil description: Clayey silt,minor sand, dark brown to black. 'Very stiff', moist, low plasticity, sand, fine.	ABBOTSFORD MUDSTONE	M	'VSt'				SNC		UW-SW		TCR: 100			
								SPT 2/4 6/7 8/9 N = 30		SPT				TCR: 100			
-10	12									SNC				TCR: 100			
								SPT 3/5 8/8 9/9 N = 34		SPT				TCR: 100			
-11	13		End of Hole @ 12.95m														
-12	14																
-13	15																

Notes and Comments:

End of Hole @ 12.95m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: HD 900 Sonic

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
01/11/22	11:30	1.4	12.95
14/11/22	11:15	1.96	

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 10/31/2022
Completed: 10/31/2022

Hole No. : BH102

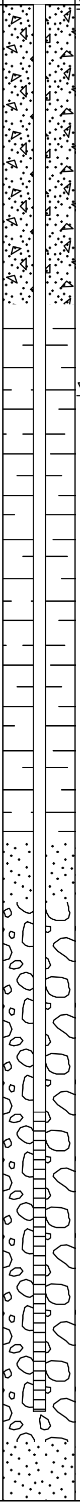
Sheet : 1 of 3
Hole Length : 14.95
Scale @ A4 : 1:25
Logged : NP
Processed : NP
Checked : DB

Easting: 1399006
Northing: 4912860
System: NZTM2000
RL: 1.73 m
Datum: NZVD2016
Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
0	TOPSOIL: organic silt, some sand and grass/rootlets; light brown. Dry, low plasticity.	TS	D	
0.15	FILL: Gravelly, fine sand with MSW (20%), minor silt, trace rootlets; brown with light brown streaking. Dry, gravel, fine to coarse, angular; MSW containing plastics.	FILL		
1	FILL: Fibrous peat with MSW (20%), minor sand and silt; black. Moist, MSW containing plastic; sand, fine.		M	
1.6	Silty CLAY, some sand, minor organics (rootlets, wood fragments), trace shell fragments; greenish grey with orange mottling. 'Very soft', moist, high plasticity. Sand, fine to medium. No dilatant behaviour.	UKEM		'VS'
2.4	Fine to medium SAND, some silt, minor clay, trace shell fragments; light greenish grey. Very loose, wet, well graded.		W	VL
3.95	Clayey ORGANIC SILT, trace shell fragments; dark brown. Firm, wet, high plasticity. Sulphurous smell	LKEM	M	F

Sample Number / Type	Result
	SPT 1/0 1/0 0/1 N = 2
C- 1.95–2.40	
	SPT 0/0 0/0 0/1 N = 1
	SPT 0/0 0/0 0/1 N = 1 **SV@3.5m** **14/6 kPa**
C- 3.95–4.30	
	SPT 0/0 0/0 0/1 N = 1 **SV@4.5m** **26/9 kPa**

Method	TCR RQD SCR (%)
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
SNC	TCR: 100
SPT	TCR: 100
	TCR: 100



Water level: 31-10-2022; 14-11-2022

Notes and Comments:
End of Hole @ 14.95m Shear
Vane: GEO937
MSW - Municipal Solid Waste

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
31/10/22	00:00	0	12.95
14/11/22	11:20	1.29	5.2

Project	: GILF Closure Consents
Client	: Dunedin City Council
Site	: Green Island Landfill Dunedin
Job Number: 12547621	
Commenced: 10/31/2022	Completed: 10/31/2022

Hole No.	: BH102
Sheet	: 2 of 3
Hole Length	: 14.95
Scale @ A4	: 1:25
Logged	: NP
Processed	: NP
Checked	: DB

Easting: 1399006 Northing: 4912860 System: NZTM2000

RL: 1.73 m Datum: NZVD2016 Method: GPSH

RL (m)	Depth (m)	Material Description	Geological Unit	Sample: Number / Type	Sample: Result	Method	TCR RQD SCR (%)
	5	Clayey ORGANIC SILT, trace shell fragments; dark brown. Firm, wet, high plasticity. Sulphurous smell *(continued from layer starting at 4.0m)*	LKEM			SNC	TCR: 100
-4					SPT 0/0 0/0 0/1 N = 1 **SV@5.5m** **27/10** **kPa**	SPT	TCR: 100
	6			C- (5.95–6.50)		SNC	TCR: 100
-5					SPT 0/0 0/0 0/1 N = 1 **SV@6.5m** **29/9 kPa**	SPT	TCR: 100
	7					SNC	TCR: 100
-6	7.6	Silty CLAY, trace sand, trace organics; greenish grey with black streaking. Firm, moist, high plasticity, sand, fine.			SPT 0/0 0/0 0/1 N = 1 **SV@7.5m** **29/13** **kPa**	SPT	TCR: 100
	8			C- (7.95–8.35)		SNC	TCR: 100
-7					SPT 0/0 0/2 1/2 N = 5	SPT	TCR: 100
	9					SNC	TCR: 100
-8					SPT 0/0 2/2 2/2 N = 8	SPT	TCR: 100
	10						TCR: 100

FINAL

Notes and Comments:

End of Hole @ 14.95m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: HD 900 Sonic

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
31/10/22	00:00	0	12.95
14/11/22	11:20	1.29	5.2

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 10/31/2022 Completed: 10/31/2022

Hole No. : BH102

Sheet : 3 of 3
Hole Length : 14.95
Scale @ A4 : 1:25
Logged : NP
Processed : NP
Checked : DB

Easting: 1399006 Northing: 4912860 System: NZTM2000
RL: 1.73 m Datum: NZVD2016 Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density	Weathering
10.00 – 10.65	Silty CLAY, trace sand, trace organics; greenish grey with black streaking. Firm, moist, high plasticity, sand, fine. *(continued from layer starting at 7.6m)*	LKEM			
10.65 – 11.4	SILT, some clay and minor sand and organic material; grey with orange mottling. Very soft, moist, moderate plasticity. Dilatant behaviour, slight sulphurous smell. 11.20 Contains some sand, minor clay. Low plasticity	LKEM			
11.4 – 12.5	Sandy SILT, some clay, minor organic material; dark grey to orange. Firm, wet, high plasticity. Sand, fine to medium. 12.10 Contains minor clay and organic materials; colour becomes grey	LKEM	W	F	
12.5 – 12.95	Gravelly, fine to coarse SAND, some silt; dark brown to black. Loose, moist, gravel, fine, subangular, well graded. 12.65 Contains trace gravel	LKEM			
12.95 – 14.95	Unweathered to slightly weathered, dark grey to black MUDSTONE, extremely weak. Soil description: Clayey silt, minor sand, dark brown to black. 'Very stiff', moist, low plasticity, sand, fine.	ABBOTSFORD MUDSTONE	M	'VSt'	SW

End of Hole @ 14.95m, TD

Sample: C- 11.50 – 11.95

Method	Result	TCR RQD SCR (%)
SNC		TCR: 100
SPT	SPT 0/0 1/1 2/1 N = 5 **SV@10.5m** **29/9 kPa**	TCR: 100
SNC		TCR: 100
SPT	SPT 0/0 1/1 1/2 N = 5	TCR: 100
SNC		TCR: 100
SPT	SPT 0/1 2/2 2/2 N = 8 **SV@12.5m** **10/7 kPa**	TCR: 100
SNC		TCR: 100
SPT	SPT 3/5 5/6 8/9 N = 28	TCR: 100
SNC		TCR: 100
SPT	SPT 4/5 5/7 8/8 N = 28	TCR: 100

Notes and Comments:
End of Hole @ 14.95m
Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
31/10/22	00:00	0	12.95
14/11/22	11:20	1.29	5.2

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 10/25/2022 Completed: 10/25/2022

Hole No. : BH103
Sheet : 1 of 3
Hole Length : 13.15 m
Scale @ A4 : 1:25
Logged : NP
Processed : NP
Checked : DB

Easting: 1399100 Northing: 4912906 System: NZTM2000
RL: 1.46 m Datum: NZVD2016 Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
0	TOPSOIL: Sandy, organic silt; minor organics (rootlets, plant materials, wood fragments) and shells orangish brown. 'Very soft', moist, low plasticity, sand, fine. 0.10 - 0.15 Plant material	TOPSOIL	M	
0.45	FILL: Sandy organic silt, some clay, trace rootlets; greyish brown with black mottling. Moist, sand, fine to medium. 0.45 Sand becomes fine to medium	FILL		
1.2	CORE LOSS			
1.5	Sandy SILT, some clay, trace rootlets; light grey with orange mottling. Firm, moist, low plasticity, sand, fine.	UKEM	M	F
2.45	Clayey SILT, some sand minor shell fragments; grey. Soft, moist, low to moderate plasticity, sand, fine.			S
3.95	CORE LOSS			
4.5	ORGANIC SILT, some sand and clay, trace organics; grey. 'Firm', moist, moderate to high plasticity sulphurous smell.	LKEM		'F'

Depth (m)	Sample Number / Type	Result	Method	TCR RQD SCR (%)
0 – 1.5			SNC	TCR: 100
1.5		SPT 0/0 0/0 0/1 N = 1 **SV@1.5m** **49/17** **kPa**	SPT	TCR: 100
2.10 – 2.50	C-		SNC	TCR: 100
2.50		SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
3		**SV@3m** **21/9 kPa**	SNC	TCR: 100
3.5		SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 67
3.95			SNC	TCR: 0
4.50	C-	SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
				TCR: 36

Water level: 26-10-2022 (0 m); 14-11-2022 (1 m)

Flush Return (%) 25 50 75
Weathering
Estimated Strength (MPa)
Defect Spacing (mm)
Instrumentation Installation

Notes and Comments:
End of Hole @ 13.15m Shear
Vane: GEO937
MSW - Municipal Solid Waste

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic

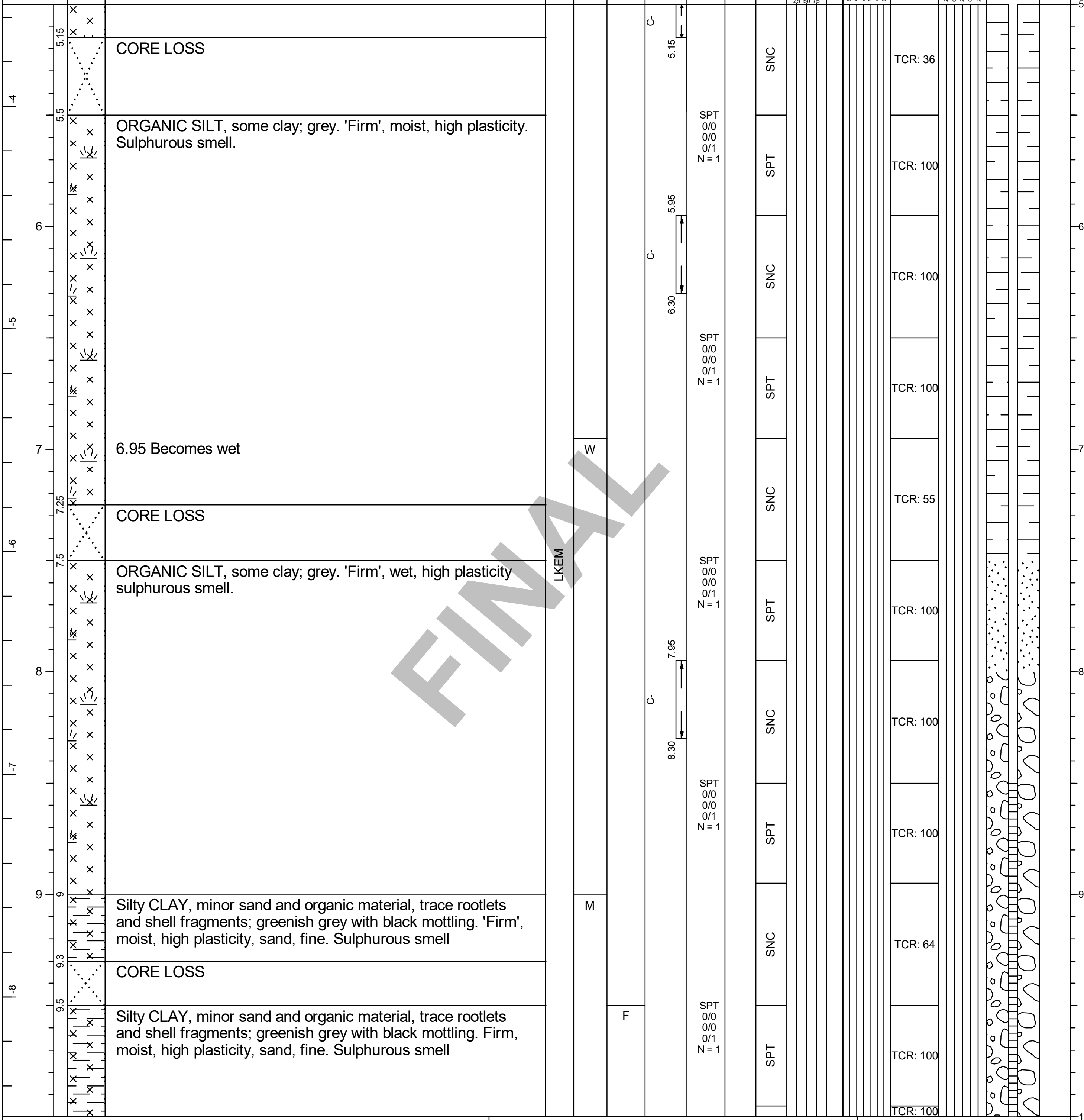
Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
25/10/22	17:00	0	2.15
26/10/22	11:00	0	11
14/11/22	10:27	1.027	10.8

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 10/25/2022
Completed: 10/25/2022

Hole No. : BH103
Sheet : 2 of 3
Hole Length : 13.15 m
Scale @ A4 : 1:25
Logged : NP
Processed : NP
Checked : DB

Easting: 1399100
Northing: 4912906
System: NZTM2000
RL: 1.46 m
Datum: NZVD2016
Method: GPSH



Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
5.15–5.5	CORE LOSS			
5.5–7.25	ORGANIC SILT, some clay; grey. 'Firm', moist, high plasticity. Sulphurous smell.			
6.95	6.95 Becomes wet		W	
7.25–7.5	CORE LOSS			
7.5–9	ORGANIC SILT, some clay; grey. 'Firm', wet, high plasticity sulphurous smell.	LKEM		
9–9.3	Silty CLAY, minor sand and organic material, trace rootlets and shell fragments; greenish grey with black mottling. 'Firm', moist, high plasticity, sand, fine. Sulphurous smell		M	
9.3–9.5	CORE LOSS			
9.5–	Silty CLAY, minor sand and organic material, trace rootlets and shell fragments; greenish grey with black mottling. Firm, moist, high plasticity, sand, fine. Sulphurous smell			F

Sample Number / Type	Result	Method	TCR RQD SCR (%)
C- 5.15		SNC	TCR: 36
	SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
C- 5.95–6.30		SNC	TCR: 100
	SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
		SNC	TCR: 55
	SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
C- 7.95–8.30		SNC	TCR: 100
	SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
		SNC	TCR: 64
	SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
			TCR: 100

Notes and Comments:
End of Hole @ 13.15m
Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
25/10/22	17:00	0	2.15
26/10/22	11:00	0	11
14/11/22	10:27	1.027	10.8

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 10/25/2022
Completed: 10/25/2022

Hole No. : BH103

Sheet : 3 of 3
Hole Length : 13.15 m
Scale @ A4 : 1:25
Logged : NP
Processed : NP
Checked : DB

Easting: 1399100
Northing: 4912906
System: NZTM2000
RL: 1.46 m
Datum: NZVD2016
Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR RQD SCR (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
10.0–10.3	Silty CLAY, minor sand and organic material, trace rootlets and shell fragments; greenish grey with black mottling. Firm, moist, high plasticity, sand, fine. Sulphurous smell *(continued from layer starting at 9.5m)*	LKEM				SV@10m 29/14 kPa		SNC				TCR: 100			
10.3–10.5	CORE LOSS														
10.5–11.0	Silty CLAY, minor sand and organic material, trace rootlets and shell fragments; greenish grey with black mottling. 'Firm', moist, high plasticity, sand, fine. Sulphurous smell			'F'		SPT 0/0 0/0 0/1 N = 1		SPT				TCR: 100			
11.0–11.5					C- 10.95 11.50			SNC				TCR: 100			
11.5–11.95	Sandy ORGANIC SILT, minor organic material (wood fragments); brown. 'Soft', moist,			'S'		SPT 0/0 0/0 0/1 N = 1		SPT				TCR: 100			
11.95–12.75	Unweathered to slightly weathered, dark grey to black MUDSTONE, extremely weak. Soil description: Clayey silt, minor sand, dark brown to black. Hard, moist, high plasticity, sand, fine.	ABBOTSFORD MUDSTONE		H				SNC		SW		TCR: 100			
12.75–13.15						SPT 0/0 2/6 13/12 N = 33		SPT				TCR: 100			
13.15	End of Hole @ 13.15m														

Notes and Comments:
End of Hole @ 13.15m
Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
25/10/22	17:00	0	2.15
26/10/22	11:00	0	11
14/11/22	10:27	1.027	10.8

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 11/9/2022
Completed: 11/9/2022

Hole No. : BH104
Sheet : 1 of 2
Hole Length : 9.95 m
Scale @ A4 : 1:25
Logged : NP
Processed : NP
Checked : DB

Easting: 1399553
Northing: 4912903
System: NZTM2000
RL: 7.41 m
Datum: NZVD2016
Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
0	FILL: Clayey, fine to coarse gravel, some sand and silt; dark grey. Saturated, gravel, angular; sand, fine to coarse.	FILL	S	
0.6	FILL: Silty clay, some silt and sand, trace gravel; orange. Wet, moderate to high plasticity.		W	
1.05	FILL: Fine to coarse sand, some silt, minor gravel; grey. Wet, gravel, fine to medium, angular; well graded.			
1.8	CORE LOSS			
3.5	FILL: MSW (60%), some wood fragments, minor sand and silt; dark grey. Wet, MSW containing metal pieces, soft/hard fragments, glass, paper materials.			
3.95	CORE LOSS			
4.5	Slightly to unweathered, dark grey, MUDSTONE, extremely weak. Soil description: silty clay,minor sand. Very stiff, moist, high plasticity, sand, fine.		M	VSt

Sample Result	Method	Weathering	TCR RQD SCR (%)
	SNC		TCR: 100
SPT 1/0 0/0 0/0 N = 0	SPT		TCR: 67
	SNC		TCR: 100
SPT 2/1 1/0 1/0 N = 2	SPT		TCR: 0
	SNC		TCR: 0
SPT 50 for 30mm bouncing @ 30 mm	SPT		TCR: 100
	SNC		TCR: 0
SPT 4/6 6/6 11/14 N = 37	SPT	UW-SW	TCR: 100
			TCR: 100

Water level: 9-11-2022

Flush Return (%): 25 50 75
Estimated Strength (MPa): EW VW W MS VS ES
Defect Spacing (mm): 20 60 200 600 2000

FINAL

Notes and Comments:
End of Hole @ 9.95m

Shear Vane: GEO937
MSW - Municipal Solid Waste

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
09/11/22	15:15	0.78	3.8
14/11/22	10:56	7.09	9.95

Project	: GILF Closure Consents
Client	: Dunedin City Council
Site	: Green Island Landfill Dunedin
Job Number: 12547621	
Commenced: 11/9/2022	Completed: 11/9/2022

Hole No.	: BH104
Sheet	: 2 of 2
Hole Length	: 9.95 m
Scale @ A4	: 1:25
Logged	: NP
Processed	: NP
Checked	: DB

Easting: 1399553
Northing: 4912903
System: NZTM2000
RL: 7.41 m
Datum: NZVD2016
Method: GPSH

RL (m)	Depth (m)	Material Description	Geological Unit	Sample Result	Method	Weathering	TCR RQD SCR (%)	Water level
2		Slightly to unweathered, dark grey, MUDSTONE, extremely weak. Soil description: silty clay,minor sand. Very stiff, moist, high plasticity, sand, fine. *(continued from layer starting at 4.5m)*	ABBOTSFORD MUDSTONE		SNC	UW-SW	TCR: 100	
	5.5	Unweathered, dark brownish grey with black speckling, SILTSTONE, very weak.		SPT 4/6 7/13 16/14 for 60mm N > 50	SPT		TCR: 100	
1	6				SNC		TCR: 100	
				SPT 3/5 6/10 13/16 N = 46	SPT		TCR: 100	
0	7				SNC		TCR: 100	14-11-2022
				SPT 5/6 8/11 17/14 for 55mm N > 50	SPT	UW	TCR: 100	
-1	8				SNC		TCR: 100	
				SPT 4/7 9/12 14/15 for 60mm N > 50	SPT		TCR: 100	
-2	9				SNC		TCR: 100	
				SPT 4/9 10/12 17/11 for 45mm N > 50	SPT		TCR: 100	

5
6
7
8
9
10

Notes and Comments: End of Hole @ 9.95m

End of Hole @ 9.95m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
09/11/22	15:15	0.78	3.8
14/11/22	10:56	7.09	9.95

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 10/26/2022
Completed: 10/26/2022

Hole No. : BH107

Sheet : 1 of 3
Hole Length : 19.95 m
Scale @ A4 : 1:40
Logged : NP
Processed : NP
Checked : DB

Easting: 1399277
Northing: 4913224
System: NZTM2000
RL: 6.73 m
Datum: NZVD2016
Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
0	FILL: Gravelly silt, some grass and rootlets, dark brown. Moist, low plasticity.	FILL	M	
0.15	FILL: Fine to coarse gravel, minor silt and sand; grey to dark grey. Moist to wet, gravel, angular; sand, fine to coarse.		M-W	
0.45	FILL: Clayey silt, minor organics and MSW (10%); brown with black and orange mottling. Moist, low plasticity.		M	
1	FILL: Gravelly silt, minor soil waste grey to brown. Moist, gravel, medium to coarse, angular.			
1.95	FILL: Silt, some sand, trace gravel; grey with light brown streaking. Moist, sand, fine; gravel, fine, angular; MSW contains glass, organics.		M	
3.1	FILL: Fine to coarse sand, minor gravel; dark bluiesh grey. Wet, gravel, fine to medium, rounded.		W	
3.3	FILL: Sandy, fine to coarse gravel, minor silt; dark grey. Wet, gravel, fine, rounded; sand, fine to coarse.			
3.95	FILL: Clayey silt; some plastic waste; light brown. Wet, high plasticity.			
4.2	FILL: MSW (60%) with gravel, some silt, minor sand; dark brownish grey. Loose, moist to wet, MSW contains soft/hard plastic, metal pieces, wood fragments; gravel, fine to coarse, angular; sand, fine to coarse.		M-W	
6.95	Gravelly SILT with MSW (20%), some organic material; dark blueish grey to grey. Moist; gravel, fine to medium, angular; MSW contains glass and plastic.		M	
7.5	Clayey ORGANIC SILT, minor sand; brown. 'Very soft', wet, high plascitity, sand, fine.	LKEM	W	'VS'

Sample Result	Method	TCR RQD SCR (%)
	SNC	TCR: 100
SPT 0/0 0/0 1/6 N = 7	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 1/1 1/1 N = 4	SPT	TCR: 100
	SNC	TCR: 100
SPT 3/2 3/4 6/2 N = 15	SPT	TCR: 100
	SNC	TCR: 100
SPT 6/3 3/2 2/2 N = 9	SPT	TCR: 100
	SNC	TCR: 100
SPT 5/3 2/1 1/2 N = 6	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 0/2 2/2 N = 6	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 0/1 0/1 N = 2	SPT	TCR: 100

Water level: 26-10-2022

Notes and Comments:
End of Hole @ 19.95m Shear Vane:
GEO937
MSW - Municipal Solid Waste

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
26/10/22	17:00	0	20

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 10/26/2022
Completed: 10/26/2022

Hole No. : BH107

Sheet : 2 of 3
Hole Length : 19.95 m
Scale @ A4 : 1:40
Logged : NP
Processed : NP
Checked : DB

Easting: 1399277
Northing: 4913224
System: NZTM2000
RL: 6.73 m
Datum: NZVD2016
Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density	Weathering
8.15	CORE LOSS				
8.5	Clayey ORGANIC SILT, minor sand; brown. 'Very soft', wet, high plascitity, sand, fine.	LKEM			
10.5	Sandy SILT, trace organics and shell fragments; grey with orange mottling. 'Very soft', moist, low plasticity, sand, fine to medium	LKEM	M	'VS'	
13.95	Clayey ORGANIC SILT, minor sand; brown. 'Very soft', wet, high plascitity, sand, fine.	LKEM	W	'VS'	
14.2	Silty, fine to medium SAND, grey to brownish grey. 'Loose', moist. 14.40 Sand becomes fine to coarse	LKEM	M	L	
14.5	COBBLE, some gravel; black with white flecks. Very dense, moist, cobble, angular; gravel, medium to coarse, angular.	ABBOTSFORD MUDSTONE		VD	
14.75	Moderately weathered SILTSTONE, extremely weak. Soil description: silt, minor sand; greenish grey with orange mottling. Hard, wet, low plasticity, sand, fine.	ABBOTSFORD MUDSTONE	W	'H'	SW

Method	Sample Result	TCR RQD SCR (%)
SNC		TCR: 27 TCR: 27
SPT	SPT 0/0 0/0 0/1 N = 1	TCR: 100
SNC		TCR: 100
SPT	SPT 0/0 1/1 0/1 N = 3	TCR: 78
SNC		TCR: 100
SPT	SPT 0/0 0/0 0/1 N = 1	TCR: 100
SNC		TCR: 100
SPT	SPT 0/0 0/0 0/1 N = 1	TCR: 89
SNC		TCR: 100
SPT	SPT 0/0 0/0 0/1 N = 4	TCR: 73
SNC		TCR: 100
SPT	SPT 0/0 0/0 2/2 N = 4	TCR: 100
SNC		TCR: 100
	SPT 15/50 for 0mm bouncing @ 50 mm	TCR: 100
SNC		TCR: 100
SPT	SPT 5/6 7/12 16/15 N > 50	TCR: 100

Notes and Comments:

End of Hole @ 19.95m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
26/10/22	17:00	0	20

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 10/26/2022
Completed: 10/26/2022

Hole No. : BH107
Sheet : 3 of 3
Hole Length : 19.95 m
Scale @ A4 : 1:40
Logged : NP
Processed : NP
Checked : DB

Easting: 1399277
Northing: 4913224
System: NZTM2000
RL: 6.73 m
Datum: NZVD2016
Method: GPSH

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density	Sample Number / Type	Sample Result	Casing	Method	Flush Return (%)	Weathering	Estimated Strength (MPa)	TCR RQD SCR (%)	Defect Spacing (mm)	Instrumentation Installation	Water level
	16	Moderately weathered SILTSTONE, extremely weak. Soil description: silt, minor sand; greenish grey with orange mottling. Hard, wet, low plasticity, sand, fine. *(continued from layer starting at 14.8m)*	ABBOTSFORD MUDSTONE						SNC		SW		TCR: 100 TCR: 100			
-10							SPT 3/5 6/10 10/12 N = 38									
-11	17						SPT 3/4 8/9 11/12 N = 40									
-12	18						SPT 5/7 11/12 14/12 for 65mm N > 50									
-13	19						SPT 4/5 8/15 16/11 for 55mm N > 50									
	20	End of Hole @ 19.95m, TD														
-14																
-15	21															
-16	22															
-17	23															
	24															

FINAL

Notes and Comments:
End of Hole @ 19.95m
Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
26/10/22	17:00	0	20

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 11/8/2022 Completed: 11/8/2022

Hole No. : BH108
Sheet : 1 of 3
Hole Length : 20.85 m
Scale @ A4 : 1:40
Logged : NP
Processed : NP
Checked : DB

Easting: 1399316 Northing: 4912715 System: NZTM2000
RL: 12.12 m Datum: NZVD2016 Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition
0 – 2.05	FILL: clay, some silt, minor sand, trace gravel, light orangish grey. Moist, moderate to high plasticity, sand, fine to medium; gravel, fine to medium, angular.	FILL	M
2.05 – 3.5	FILL: soil waste, some clay, MSW (10%), trace gravel; dark grey to black. Moist; MSW contains rubber, plastic, glass, metal, paper/cardboard, gravel, fine to medium, angular.		
3.5 – 4.5	CORE LOSS		
4.5 – 5.3	FILL: soil waste, some clay, MSW (10%), trace gravel; dark grey to black. Moist, MSW contains rubber, brick fragments, plastic, glass, metal, paper/cardboard, gravel, fine to medium, angular.		
5.3 – 5.5	CORE LOSS		
5.5 – 6	FILL: MSW (60%) with some soil waste, trace gravel; dark grey to black. Moist, MSW contains rubber, brick fragments, plastic, glass, metal, paper/cardboard; gravel, fine to medium, angular. [FILL]		
6 – 6.5	CORE LOSS		
6.5 – 6.65	FILL: MSW (60%) with some soil waste, trace gravel; dark grey to black. Moist, MSW contains rubber, brick fragments, plastic, glass, metal, paper/cardboard; gravel, fine to medium, angular. [FILL]		
6.65 – 7.5	CORE LOSS		
7.5 – 7.8	FILL: MSW (60%) with some soil waste, trace gravel; dark grey to black. Moist, MSW contains rubber, brick fragments, plastic, glass, metal, paper/cardboard; gravel, fine to medium, angular. [FILL]		
7.8 –			

Sample Result	Method	TCR RQD SCR (%)
	SNC	TCR: 100
SPT 1/3 8/7 4/2 N = 21	SPT	TCR: 100
	SNC	TCR: 100
SPT 2/2 3/7 6/4 N = 20	SPT	TCR: 100
	SNC	TCR: 100
SPT 7/5 4/4 4/3 N = 15	SPT	TCR: 0
	SNC	TCR: 0
SPT 2/4 2/3 1/2 N = 8	SPT	TCR: 100
	SNC	TCR: 64
SPT 2/2 2/3 2/3 N = 9	SPT	TCR: 100
	SNC	TCR: 9
SPT 2/4 3/3 4/4 N = 14	SPT	TCR: 33
	SNC	TCR: 0
SPT 3/5 2/3 3/3 N = 11	SPT	TCR: 67

Water level: 9-11-2022; 14-11-2022

FINAL

Notes and Comments:
End of Hole @ 20.85m Shear Vane:
GEO937
MSW - Municipal Solid Waste

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
09/11/22	09:15	3.82	20.85
14/11/22	11:35	5.27	20.85

Project	: GILF Closure Consents
Client	: Dunedin City Council
Site	: Green Island Landfill Dunedin
Job Number: 12547621	
Commenced: 11/8/2022	Completed: 11/8/2022

Hole No.	: BH108
Sheet	: 2 of 3
Hole Length	: 20.85 m
Scale @ A4	: 1:40
Logged	: NP
Processed	: NP
Checked	: DB

Easting: 1399316
Northing: 4912715
System: NZTM2000
RL: 12.12 m
Datum: NZVD2016
Method: GPSH

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
4		7.50 Gravel becomes fine to coarse CORE LOSS *(continued from layer starting at 7.8m)*			
	8.5	FILL: soil waste, some clay, MSW (10%), trace gravel; dark grey to black. Moist, MSW contains rubber, brick fragments, plastic, glass, metal, paper/cardboard, gravel, fine to medium, angular.			
3	9				
2	9.95 / 10	CORE LOSS			
	10.5	FILL: MSW (60%) with some soil waste, trace gravel; dark grey to black. Moist, MSW contains rubber, brick fragments, plastic, glass, metal, paper/cardboard; gravel, fine to medium, angular. [FILL]	FILL		
1	11				
	11.2	CORE LOSS - pushing tyre			
0	12				
-1	13				
	13.5	Clayey ORGANIC SILT, trace sand; dark brown. 'Very soft', wet, high plasticity.		W	'VS'
-2	13.95 / 14	CORE LOSS			
	14.5	Sandy SILT, some organics, minor clay; dark brown. 'Very soft', wet, high plasticity.	LKEM		
-3	15				
	15.15	CORE LOSS			
	15.5	ORGANIC SILT, minor clay, minor sand; dark brown. 'Very soft', wet, high plasticity.			

Sample Number / Type	Result	Method	TCR RQD SCR (%)
			TCR: 0
		SNC	TCR: 0
	SPT 3/6 7/3 3/4 N = 17	SPT	TCR: 100
		SNC	TCR: 100
	SPT 3/3 4/3 4/3 N = 14	SPT	TCR: 100
		SNC	TCR: 0
	SPT 5/5 7/5 8/6 N = 26	SPT	TCR: 100
		SNC	TCR: 45
	SPT 50 for 10mm bouncing @ 10 mm	SPT	TCR: 0
		SNC	TCR: 0
	SPT 30/20 for 15mm bouncing @ 90 mm	SPT	TCR: 0
		SNC	TCR: 0
C- 13.50 13.95	SPT 9/6 3/2 2/2 N = 9	SPT	TCR: 100
		SNC	TCR: 0
	SPT 0/0 0/0 0/0 N = 0		TCR: 100
		SNC	TCR: 63
C- 15.50	SPT 0/0 0/0 0/0 N = 0	SPT	TCR: 100

Notes and Comments:

End of Hole @ 20.85m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
09/11/22	09:15	3.82	20.85
14/11/22	11:35	5.27	20.85

Project	: GILF Closure Consents
Client	: Dunedin City Council
Site	: Green Island Landfill Dunedin
Job Number: 12547621	
Commenced: 11/8/2022	Completed: 11/8/2022

Hole No.	: BH108
Sheet	: 3 of 3
Hole Length	: 20.85 m
Scale @ A4	: 1:40
Logged	: NP
Processed	: NP
Checked	: DB

Easting: 1399316 Northing: 4912715 System: NZTM2000

RL: 12.12 m Datum: NZVD2016 Method: GPSH

RL (m)	Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density	Weathering
-4	16.2	Moderately weathered, orangish grey MUDSTONE, extremely weak. Soil description: Silty clay, trace sand; orangish grey. 'Very stiff', moist, high plasticity, sand, fine.	LKEM	M	'VSt'	MW
-6	18	Slightly weathered, grey with orange mottling, MUDSTONE, extremely weak. Soil description: Silty clay, minor sand; grey with orange mottling. Hard, moist, moderate to high plasticity, sand, fine. 18.50 Becomes unweathered, colour becomes dark brownish grey. Soil description: CLAY, some silt, minor sand; dark brownish grey. Stiff, moist, moderate to high pasticity, sand, fine.	ABBOTSFORD MUDSTONE	M	'H'	SW
	20.5	Unweathered, dark brownish grey with black glauconitic speckles, SILTSTONE, very weak.		M		UW
		End of Hole @ 20.85m, TD				

Sample Number / Type: 15.95; C- 17.10–17.50

Method	Result	TCR RQD SCR (%)
		TCR: 100
SNC		TCR: 100
SPT	SPT 0/1 2/2 2/2 N = 8	TCR: 100
SNC		TCR: 100
SPT	SPT 3/2 3/3 3/4 N = 13	TCR: 100
SNC		TCR: 100
SPT	SPT 3/3 5/6 7/7 N = 45	TCR: 100
SNC		TCR: 100
SPT	SPT 1/2 3/3 3/3 N = 12	TCR: 100
SNC		TCR: 100
SPT	SPT 3/5 9/13 17/11 for 35mm N > 50	TCR: 100

Notes and Comments:

End of Hole @ 20.85m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical Orientation:

Contractor: Speight Drilling

Equipment: HD 900 Sonic

SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
09/11/22	09:15	3.82	20.85
14/11/22	11:35	5.27	20.85

Project : GILF Closure Consents
Client : Dunedin City Council
Site : Green Island Landfill Dunedin
Job Number: 12547621
Commenced: 11/7/2022
Completed: 11/8/2022

Hole No. : BH111
Sheet : 1 of 3
Hole Length : 19.95 m
Scale @ A4 : 1:40
Logged : NP
Processed : NP
Checked : DB

Easting: 1399277
Northing: 4913200
System: NZTM2000
RL: 3.32 m
Datum: NZVD2016
Method: GPSH

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
0	FILL: Silty, fine to coarse gravel with MSW (20%), minor sand and clay, grey gravel in dark grey matrix. Moist; gravel, subangular; MSW contains soft plastics, cardboard; sand, fine to coarse.	FILL	M	
1.2	CORE LOSS			
1.5	FILL: Soil waste, some organic material and MSW (10%), minor gravel. Moist, gravel, fine to medium, angular; MSW contains, plastic, metal.			
1.95	CORE LOSS			
2.5	FILL: Soil waste, some fibrous peat and MSW (15%), minor silt, dark brown with coloured waste. Moist, MSW contains plastic, metals, wood fragments.			
2.95	FILL: Silt, some clay and sand, minor gravel; dark grey with orange mottling. Moist, low to moderate plasticity; sand, fine; gravel, fine, subangular.			
3.65	CORE LOSS			
4.5	FILL: Medium to coarse gravel with MSW (20%); grey. Gravel, subangular; MSW contains plastic, metal, wood fragments.			
4.64	CORE LOSS			
5.5	CLAY, some silt, minor organic material; trace sand; dark grey with black streaks. 'Soft', moist, high plasticity, sand, fine.	UKEM		'S'
5.7	CORE LOSS			
6.5	Silty CLAY, minor sand and organic material; grey with orange mottling. 'Soft', moist, high plasticity, sand, fine, 6.90 Becomes silty CLAY, colour becomes dark grey with black streaks.			
7.35	Clayey ORGANIC SILT, minor sand, trace rootlets; dark brown. 'Very soft', moist, moderate to high plasticity.	LKEM		'VS'

Sample Result	Method	TCR RQD SCR (%)
	SNC	TCR: 80
SPT 11/6 3/1 2/4 N = 10	SPT	TCR: 100
	SNC	TCR: 0
SPT 5/3 3/3 6/6 N = 18	SPT	TCR: 100
	SNC	TCR: 100
SPT 1/2 1/2 1/1 N = 5	SPT	TCR: 33
	SNC	TCR: 0
SPT 18/32 for 65mm N > 50	SPT	TCR: 22
	SNC	TCR: 0
SPT 6/5 3/1 1/1 N = 5	SPT	TCR: 44
	SNC	TCR: 0
SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100

Water level: 7-11-2022

Notes and Comments:
End of Hole @ 19.95m Shear
Vane: GEO937
MSW - Municipal Solid Waste

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/11/22	17:00	0.78	

Project	: GILF Closure Consents
Client	: Dunedin City Council
Site	: Green Island Landfill Dunedin
Job Number:	12547621
Commenced: 11/7/2022	Completed: 11/8/2022
Easting: 1399277	Northing: 4913200
System: NZTM2000	Method: GPSH
RL: 3.32 m	Datum: NZVD2016

Hole No.	: BH111
Sheet	: 2 of 3
Hole Length	: 19.95 m
Scale @ A4	: 1:40
Logged	: NP
Processed	: NP
Checked	: DB

Depth (m)	Material Description	Geological Unit	Moisture condition	Consistency / Relative Density
	Clayey ORGANIC SILT, minor sand, trace rootlets; dark brown. 'Very soft', moist, moderate to high plasticity. *(continued from layer starting at 7.4m)*	LKEM		
9.05	Clayey SILT, minor sand and organic material; grey with orange mottling. 'Very soft', moist, low to moderate plasticity. 13.00 - 13.50 Becomes, silty CLAY, moderate to high plasticity.	LKEM		'S'
13.95	Silty, fine to medium SAND, some clay; orangish grey. Very loose, moist, well graded.	LKEM		VL
14.6	Moderately weathered, orangish grey MUDSTONE, extremely weak. Soil description: Silty clay, minor sand; orangish grey. 'Very stiff', moist, high plasticity, sand, fine.	ABBOTSFORD MUDSTONE		'VSt'
14.7	Slightly to unweathered, grey to dark grey, MUDSTONE, extremely weak. Soil description: Silt, minor sand; light grey with orange mottling. 'Hard', wet, low plasticity, sand, fine.	ABBOTSFORD MUDSTONE	W	'H'

Result	Method	TCR RQD SCR (%)
		TCR: 100
	SNC	TCR: 100
SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
	SNC	TCR: 100
SPT 0/0 0/0 0/1 N = 1	SPT	TCR: 100
	SNC	TCR: 100
SPT 30/20 N = 50		TCR: 100
	SNC	TCR: 100
SPT 6/6 6/9 10/12 N = 37	SPT	TCR: 100

Weathering: UW-SW

Notes and Comments:

End of Hole @ 19.95m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical

Orientation:

Contractor: Speight Drilling

Equipment: HD 900 Sonic

SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/11/22	17:00	0.78	

Project	: GILF Closure Consents
Client	: Dunedin City Council
Site	: Green Island Landfill Dunedin
Job Number: 12547621	
Commenced: 11/7/2022	Completed: 11/8/2022

Hole No.	: BH111
Sheet	: 3 of 3
Hole Length	: 19.95 m
Scale @ A4	: 1:40
Logged	: NP
Processed	: NP
Checked	: DB

Easting: 1399277
Northing: 4913200
System: NZTM2000
RL: 3.32 m
Datum: NZVD2016
Method: GPSH

Depth (m)	Material Description	Geological Unit	Sample Result	Method	TCR RQD SCR (%)
16	Slightly to unweathered, grey to dark grey, MUDSTONE, extremely weak. Soil description: Silt, minor sand; light grey with orange mottling. 'Hard', wet, low plasticity, sand, fine. *(continued from layer starting at 14.7m)*	ABBOTSFORD MUDSTONE			TCR: 100
				SNC	TCR: 100
			SPT 4/5 7/9 8/12 N = 36	SPT	TCR: 100
17				SNC	TCR: 100
			SPT 5/5 6/8 10/9 N = 33	SPT	TCR: 100
18				SNC	TCR: 100
			SPT 4/5 7/7 10/11 N = 35	SPT	TCR: 100
19				SNC	TCR: 100
			SPT 4/5 7/9 13/15 N = 44	SPT	TCR: 100
20	End of Hole @ 19.95m, TD				

Notes and Comments:

End of Hole @ 19.95m

Shear Vane: GEO937

Refer to explanation sheets for abbreviation and symbols.
Shear Vane values are corrected.

Inclination: Vertical
Orientation:
Contractor: Speight Drilling
Equipment: HD 900 Sonic
SPT ETR: 64%

Ground Water Level

Date	Time	Reading (mbgl)	Hole depth (mbgl)
07/11/22	17:00	0.78	

Attachment C
Analytical Results Tables

Site Name: Green Island Landfill
Table 1: November 2022 Investigation - Analytical Results - Heavy Metals

Client: Dunedin City Council
Project Numebr: 12547621

Lab Reference		22-40179-12	22-40179-13	22-40179-1	22-40179-2	22-40179-3	22-40179-4	22-40179-14	22-40179-15	22-40179-16	22-40179-17	NESCS SCSs for Protection of Human Health based on a Commercial/Industrial land use (mg/kg) [1 & 2]	NESCS SCSs for Protection of Human Health based on a Recreational land use (mg/kg) [1 & 2]	Dunedin Background Soil Concentrations (mg/kg) [3]
Sample Depth	m bgl	1.0	2.7	0.5	1.5	2.5	3.5	0.6	1.5	2.5	3.5			
Borehole		BH-100		BH-101				BH-102						
Sample Name		12547621-BH-100(1.0)	12547621-BH-100(2.7)	12547621-BH-101(0.5)	12547621-BH-101(1.5)	12547621-BH-101(2.5)	12547621-BH-101(3.5)	12547621-BH-102(0.6)	12547621-BH-102(1.5)	12547621-BH-102(2.5)	12547621-BH-102(3.5)			
Soil type		Fill/ sand/ waste	Fill/ wood in sand	Fill/ loam/waste	Peat/sandy silt	Silty sand	Silty sand	Fill/ sand/ waste	Fill/ peat/ waste	Sand	Sand			
Sample Date		01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022			
Heavy Metals														
Arsenic	mg/kg	2.8	7.8	9.7	12	7.1	5.5	4.7	29.7	11	11	**70 [1]**	**80 [1]**	11.77
Boron	mg/kg	1.5	9.2	6.9	27	8.4	11	2.1	32	9.9	9	**>10,000 [1]**	**>10,000 [1]**	-
Cadmium	mg/kg	0.059	0.047	0.3	0.18	0.018	0.029	0.11	0.27	0.012	0.066	**1,300 [1]**	**400 [1]**	0.34
Chromium [4]	mg/kg	21.6	28	29.3	55.2	21.8	18.8	46.2	125	23.7	22.5	**6,300 [1]**	**2,700 [1]**	80.15
Copper	mg/kg	18.5	6.6	14.2	18.2	4.1	4	27.3	34.2	6.5	5.5	**>10,000 [1]**	**>10,000 [1]**	60.85
Lead	mg/kg	14.8	5.01	60.1	50.8	4.9	4.2	44.8	98.5	6.24	4.7	**3,300 [1]**	**880 [1]**	44.34
Mercury	mg/kg	0.055	<0.025	0.079	0.14	<0.025	<0.025	0.12	0.32	<0.025	<0.025	**4,200 [1]**	**1,800 [1]**	-
Nickel	mg/kg	14.1	15.5	36.6	14.8	10.6	9.53	35.9	33.8	11.5	15.1	**6,000 [2]**	**1,200 [2]**	44.96
Zinc	mg/kg	52	47.4	183	119	36.7	29	105	467	49.4	45.9	**400,000 [2]**	**30,000 [2]**	182.8

Lab Reference		22-40179-8	22-40179-9	22-40179-10	22-40179-11	22-41184-5	22-41184-6	22-41184-7	22-40179-5	22-40179-6	22-40179-7	NESCS SCSs for Protection of Human Health based on a Commercial/Industrial land use (mg/kg) [1 & 2]	NESCS SCSs for Protection of Human Health based on a Recreational land use (mg/kg) [1 & 2]	Dunedin Background Soil Concentrations (mg/kg) [3]
Sample Depth	m bgl	0.2	1.2	2.5	3.5	0.5	1.0	2.0	0.5	1.5	2.5			
Borehole		BH-103				BH-104			BH-107					
Sample Name		12547621-BH-103(0.2)	12547621-BH-103(1.2)	12547621-BH-103(2.5)	12547621-BH-103(3.5)	12547621-BH-104(0.5)	12547621-BH-104(1.0)	12547621-BH-104(2.0)	12547621-BH-107(0.5)	12547621-BH-107(1.5)	12547621-BH-107(2.5)			
Soil type		Topsoil/ organic silt	Fill/ organic silt	Clayey silt	Clayey silt	Fill/ clayey gravel	Fill/ silty clay	Fill/ waste material	Clayey silt/ waste	Gravelly silt/ bricks	Silt/ waste			
Sample Date		01/11/2022	01/11/2022	01/11/2022	01/11/2022	09/11/2022	09/11/2022	09/11/2022	01/11/2022	01/11/2022	01/11/2022			
Heavy Metals														
Arsenic	mg/kg	6.8	25.8	8.7	9.4	7.7	4.1	8.9	5	4.8	4.6	**70 [1]**	**80 [1]**	11.77
Beryllium	mg/kg	-	-	-	-	1.79	0.91	0.81	-	-	-	**500 [2]**	**90 [2]**	-
Boron	mg/kg	3.4	20	7.1	9.5	3.4	2.5	11	5.5	14	7.2	**>10,000 [1]**	**>10,000 [1]**	-
Cadmium	mg/kg	0.29	0.28	0.12	0.07	0.15	0.07	0.12	0.052	0.06	0.11	**1,300 [1]**	**400 [1]**	0.34
Chromium [4]	mg/kg	20.1	156	19.8	19.1	46.6	27.3	27.6	18.4	39.2	24.2	**6,300 [1]**	**2,700 [1]**	80.15
Copper	mg/kg	20.3	31.6	6.4	6.7	38.3	18	16.9	8.14	17.7	16.2	**>10,000 [1]**	**>10,000 [1]**	60.85
Lead	mg/kg	77.8	74.3	5.45	6.78	70.7	26.9	16.5	19.7	17.7	32.1	**3,300 [1]**	**880 [1]**	44.34
Mercury	mg/kg	0.1	0.3	0.029	<0.025	0.078	0.033	0.039	0.13	0.091	0.097	**4,200 [1]**	**1,800 [1]**	-
Nickel	mg/kg	19.1	30.7	13.2	12.2	35.8	19.3	18.9	10.2	25.6	9.59	**6,000 [2]**	**1,200 [2]**	44.96
Zinc	mg/kg	120	210	42.7	49.3	115	68.1	68.3	37	67.7	53	**400,000 [2]**	**30,000 [2]**	182.8

Lab Reference		22-41184-1	22-41184-2	22-41184-4*	22-41184-3	22-40820-1	22-40820-2	22-40820-3	22-40820-4**			NESCS SCSs for Protection of Human Health based on a Commercial/Industrial land use (mg/kg) [1 & 2]	NESCS SCSs for Protection of Human Health based on a Recreational land use (mg/kg) [1 & 2]	Dunedin Background Soil Concentrations (mg/kg) [3]
Sample Depth	m bgl	0.5	1.9	1.9	3.3	0.5	1.5	3.2	3.2					
Borehole		BH-108				BH -111								
Sample Name		12547621-BH-108(0.5)	12547621-BH-108(1.9)	12547621-DUP-2	12547621-BH-108(3.3)	12547621-BH-111(0.5)	12547621-BH-111(1.5)	12547621-BH-111(3.2)	12547621-Dup**					
Soil type		Fill/ clay	Fill/ clay	Fill/ clay	Fill/ waste/ clay	Fill/ gravel/ waste	Fill/waste/organics	Fill/ silt	Fill/ silt					
Sample Date		09/11/2022	09/11/2022	09/11/2022	09/11/2022	07/11/2022	07/11/2022	07/11/2022	07/11/2022					
Heavy Metals														
Arsenic	mg/kg	2.4	7.2	7.1	9.1	1.7	8.9	9	9.6			**70 [1]**	**80 [1]**	11.77
Beryllium	mg/kg	0.48	1.42	1.33	3.15	1.2	1.3	1.35	1.75			**500 [2]**	**90 [2]**	-
Boron	mg/kg	1.3	7.6	7.9	40	8.4	20	14	15			**>10,000 [1]**	**>10,000 [1]**	-
Cadmium	mg/kg	0.0056	0.16	0.16	0.42	0.11	2.18	0.18	0.32			**1,300 [1]**	**400 [1]**	0.34
Chromium [4]	mg/kg	11	50.1	49.4	34.7	90.5	34.6	52.7	58.3			**6,300 [1]**	**2,700 [1]**	80.15
Copper	mg/kg	3.3	20.9	20.8	54.2	59.1	40.3	25.2	34.3			**>10,000 [1]**	**>10,000 [1]**	60.85
Lead	mg/kg	11.7	52.9	42.8	316	49.1	179	32.9	62.2			**3,300 [1]**	**880 [1]**	44.34
Mercury	mg/kg	<0.025	0.28	0.27	0.21	<0.025	0.12	0.12	0.21			**4,200 [1]**	**1,800 [1]**	-
Nickel	mg/kg	3.9	38	35.9	31.6	105	32.7	45.4	49			**6,000 [2]**	**1,200 [2]**	44.96
Zinc	mg/kg	20.3	124	121	303	127	403	179	236			**400,000 [2]**	**30,000 [2]**	182.8

Notes:

Values shaded grey exceed the NESCS SCSs for Protection of Human Health (Commercial / Industrial land use)
Values shaded yellow exceed the NESCS SCSs for Protection of Human Health (Recreational land use)
Red Text exceed the adopted Dunedin Background Soil Concentrations (mg/kg)
SCS - Soil contaminant standard

- Data not available or not analysed in this sample

All units are in mg/kg
m bgl - metres below ground level

* Field duplicate of 12547621-BH-108(1.9)
** Field duplicate of 12547621-BH-111(3.2)

References

1. Ministry for the Environment (2011). Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (NESCS).
2. National Environment Protection Council (1999, revised 2013) National Environment Protection (Assessment of Site Contamination) Measure. Table 1A. (NEPM) Health Investigation Levels Commercial / Industrial D.
3. Landcare Research Limited (2006) PBC - Predicted Background Soil Concentrations, New Zealand - fill material (the highest value for each metal from the dominant soil groups surrounding Green Island Landfill) Dunedin , New Zealand
4. NESCS SCS criteria presented are for Chromium (VI)

Site Name: Green Island Landfill
Table 2: PAH Analytical Results November 2022 Site Investigation

Client Name: Dunedin City Council
Project Number: 12547621

Analytica Lab Reference		22-40179-12	22-40179-13	22-40179-1	22-40179-2	22-40179-3	22-40179-4	22-40179-14	22-42925-4	22-42925-5	NESCS SCSs for Commercial / Industrial land use[1] (mg/kg)	NESCS SCSs for Recreational land use[1] (mg/kg)	Guidelines for Hydrocarbon Contamination - Residential Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Guidelines for Hydrocarbon Contamination - Commercial/Industrial Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Background Soil Concentrations, New Zealand [3] (mg/kg)
Eurofins Lab Reference		K22-No0015984	K22-No0015985	K22-Mo0015975	K22-No0015976	K22-No0015977	K22-No0015978	22-40179-14	-	-					
Sample Depth	m bgl	1.0	2.7	0.5	1.5	2.5	3.5	0.6	1.5	2.5					
Test Pit		BH-100		BH-101				BH-102							
Sample Name		12547621-BH-100(1.0)	12547621-BH-100(2.7)	12547621-BH-101(0.5)	12547621-BH-101(1.5)	12547621-BH-101(2.5)	12547621-BH-101(3.5)	12547621-BH-102(0.6)	12547621-BH-102(1.5)	12547621-BH-102(2.5)					
Soil Type		Fill/ sand/ waste	Fill/ wood in sand	Fill/ loam/waste	Peat/sandy silt	Silty sand	Silty sand	Fill/ sand/ waste	Fill/ peat/ waste	Sand					
Sample Date		01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022					
Acenaphthene	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	<0.010	<0.010	-	-	-	-	0.055
Acenaphthylene	mg/kg	0.04	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	<0.010	<0.010	-	-	-	-	0.069
Anthracene	mg/kg	0.04	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	<0.010	<0.010	-	-	-	-	0.113
Benz[a]anthracene	mg/kg	0.17	< 0.03	0.07	0.06	< 0.03	< 0.03	0.1	0.023	<0.020	#	#	-	-	0.47
Benzo[a]pyrene	mg/kg	0.23	< 0.03	0.06	0.05	< 0.03	< 0.03	0.1	0.043	<0.010	#	#	-	-	0.595
Benzo[b]&[j] fluoranthene	mg/kg	0.13	< 0.03	0.04	0.06	< 0.03	< 0.03	0.08	0.054	<0.020	#	#	-	-	0.947
Benzo[g,h,i]perylene	mg/kg	0.08	< 0.03	< 0.03	0.06	< 0.03	< 0.03	0.06	0.028	<0.020	-	-	-	-	0.459
Benzo[k]fluoranthene	mg/kg	0.14	< 0.03	< 0.03	0.06	< 0.03	< 0.03	0.09	0.015	<0.010	#	#	-	-	0.296
Chrysene	mg/kg	0.18	< 0.03	0.09	0.09	< 0.03	< 0.03	0.1	0.038	<0.010	#	#	-	-	0.539
Dibenz(a,h)anthracene	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	<0.010	<0.010	#	#	-	-	0.112
Fluoranthene	mg/kg	0.34	< 0.03	0.11	0.11	< 0.03	< 0.03	0.08	0.055	<0.020	#	#	-	-	1.345
Fluorene	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	<0.010	<0.010	-	-	-	-	0.06
Indeno(1,2,3-cd)pyrene	mg/kg	0.11	< 0.03	< 0.03	0.03	< 0.03	< 0.03	0.06	0.037	<0.010	#	#	-	-	0.385
Naphthalene	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	<0.010	<0.010	-	-	58 (v) / 70 (v)	(190) (4,v) / (230) (4,v)	0.029
Phenanthrene	mg/kg	0.13	< 0.03	0.07	0.05	< 0.03	< 0.03	0.06	0.015	<0.010	-	-	-	-	0.703
Pyrene	mg/kg	0.33	< 0.03	0.13	0.11	< 0.03	< 0.03	0.08	0.06	<0.020	-	-	(1,600) (4,p) / NA (2)	NA (2) / NA (2)	1.362
Benzo[a]pyrene TEQ [4]	mg/kg	0.32	0.08	0.11	0.1	0.08	0.08	0.16	0.07	0.03	35	40	-	-	0.922

Analytica Lab Reference		22-42925-2	22-42925-3	22-41184-5	22-41184-6	22-41184-7	22-40179-5	22-40179-6	22-42925-1	NESCS SCSs for Commercial / Industrial land use[1] (mg/kg)	NESCS SCSs for Recreational land use[1] (mg/kg)	Guidelines for Hydrocarbon Contamination - Residential Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Guidelines for Hydrocarbon Contamination - Commercial/Industrial Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Background Soil Concentrations, New Zealand [3] (mg/kg)
Eurofins Lab Reference		-	-	-	-	-	K22-No0015979	K22-No0015980	-					
Sample Depth	m bgl	0.2	1.2	0.5	1.0	2.0	0.5	1.5	2.5					
Test Pit		BH-103		BH-104			BH-107							
Sample Name		12547621-BH-103(0.2)	12547621-BH-103(1.2)	12547621-BH-104(0.5)	12547621-BH-104(1.0)	12547621-BH-104(2.0)	12547621-BH-107(0.5)	12547621-BH-107(1.5)	12547621-BH-107(2.5)					
Soil Type		Topsoil/ organic silt	Fill/ organic silt	Fill/ clayey gravel	Fill/ silty clay	Fill/ waste material	Clayey silt/ waste	Gravelly silt/ bricks	Silt/ waste					
Sample Date		01/11/2022	01/11/2022	09/11/2022	09/11/2022	09/11/2022	01/11/2022	01/11/2022	01/11/2022					
Acenaphthene	mg/kg	<0.010	<0.010	12	0.01	0.019	< 0.03	0.61	0.033	-	-	-	-	0.055
Acenaphthylene	mg/kg	0.017	0.028	53	0.011	0.027	< 0.03	0.43	0.067	-	-	-	-	0.069
Anthracene	mg/kg	0.02	0.02	93	0.015	0.12	0.07	3.1	0.2	-	-	-	-	0.113
Benz[a]anthracene	mg/kg	0.092	0.14	320	0.039	0.28	0.48	5.4	0.53	#	#	-	-	0.47
Benzo[a]pyrene	mg/kg	0.12	0.23	290	0.058	0.32	0.58	4.5	0.74	#	#	-	-	0.595
Benzo[b]&[j] fluoranthene	mg/kg	0.12	0.27	500	0.058	0.33	0.3	4	0.73	#	#	-	-	0.947
Benzo[g,h,i]perylene	mg/kg	0.064	0.13	170	0.026	0.14	0.25	0.67	0.26	-	-	-	-	0.459
Benzo[k]fluoranthene	mg/kg	0.044	0.091	220	0.028	0.17	0.26	3.2	0.26	#	#	-	-	0.296
Chrysene	mg/kg	0.095	0.2	320	0.059	0.41	0.54	4.4	0.52	#	#	-	-	0.539
Dibenz(a,h)anthracene	mg/kg	0.012	0.023	50	<0.010	0.032	0.07	0.35	0.061	#	#	-	-	0.112
Fluoranthene	mg/kg	0.17	0.31	420	0.076	0.65	0.67	13	1.5	#	#	-	-	1.345
Fluorene	mg/kg	<0.010	<0.010	23	0.015	0.05	< 0.03	1.2	0.083	-	-	-	-	0.06
Indeno(1,2,3-cd)pyrene	mg/kg	0.082	0.17	220	0.029	0.16	0.23	1	0.35	#	#	-	-	0.385
Naphthalene	mg/kg	<0.010	<0.010	2.3	0.083	0.19	< 0.1	0.5	0.053	-	-	58 (v) / 70 (v)	(190) (4,v) / (230) (4,v)	0.029
Phenanthrene	mg/kg	0.057	0.083	220	0.032	0.43	0.1	8.7	0.58	-	-	-	-	0.703
Pyrene	mg/kg	0.17	0.32	380	0.083	0.63	0.81	13	1.4	-	-	(1,600) (4,p) / NA (2)	NA (2) / NA (2)	1.362
Benzo[a]pyrene TEQ [4]	mg/kg	0.17	0.32	470	0.08	0.46	0.79	6.4	1	35	40	-	-	0.922

Lab Reference		22-41184-1	22-41184-2	22-41184-4	22-41184-3	22-40820-1	22-40820-2	22-40820-3	NESCS SCSs for Commercial / Industrial land use[1] (mg/kg)	NESCS SCSs for Recreational land use[1] (mg/kg)	Guidelines for Hydrocarbon Contamination - Residential Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Guidelines for Hydrocarbon Contamination - Commercial/Industrial Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Background Soil Concentrations, New Zealand [3] (mg/kg)
Sample Depth	m bgl	0.5	1.9	1.9	3.3	0.5	1.5	3.2					
Test Pit		BH-108				BH-111							
Sample Name		12547621-BH-108(0.5)	12547621-BH-108(1.9)	12547621-DUP-2*	12547621-BH-108(3.3)	12547621-BH-111(0.5)	12547621-BH-111(1.5)	12547621-BH-111(3.2)					
Soil Type		Fill/ clay	Fill/ clay	Fill/ clay	Fill/ waste/ clay	Fill/ gravel/ waste	Fill/waste/organics	Fill/ silt					
Sample Date		09/11/2022	09/11/2022	09/11/2022	09/11/2022	07/11/2022	07/11/2022	07/11/2022					
Acenaphthene	mg/kg	<0.010	<0.010	0.026	0.033	<0.010	0.038	<0.010	-	-	-	-	0.055
Acenaphthylene	mg/kg	<0.010	0.031	0.14	0.055	<0.010	0.091	0.012	-	-	-	-	0.069
Anthracene	mg/kg	<0.010	0.054	1.5	0.16	<0.010	0.19	0.019	-	-	-	-	0.113
Benz[a]anthracene	mg/kg	<0.020	0.22	4.6	0.73	<0.020	0.41	0.076	#	#	-	-	0.47
Benzo[a]pyrene	mg/kg	<0.010	0.35	2.7	0.75	<0.010	0.66	0.1	#	#	-	-	0.595
Benzo[b]&[j] fluoranthene	mg/kg	<0.020	0.37	4	1.1	<0.020	0.78	0.11	#	#	-	-	0.947
Benzo[g,h,i]perylene	mg/kg	<0.020	0.21	1.2	0.43	<0.020	0.34	0.063	-	-	-	-	0.459
Benzo[k]fluoranthene	mg/kg	<0.010	0.18	1.8	0.55	<0.010	0.29	0.038	#	#	-	-	0.296
Chrysene	mg/kg	<0.010	0.38	3.7	0.92	<0.010	0.42	0.077	#	#	-	-	0.539
Dibenz(a,h)anthracene	mg/kg	<0.010	0.04	0.43	0.12	<0.010	0.086	0.021	#	#	-	-	0.112
Fluoranthene	mg/kg	<0.020	0.42	5.4	1.1	<0.020	0.63	0.18	#	#	-	-	1.345
Fluorene	mg/kg	<0.010	0.017	0.3	0.082	<0.010	0.097	<0.010	-	-	-	-	0.06
Indeno(1,2,3-cd)pyrene	mg/kg	<0.010	0.21	1.5	0.48	<0.010	0.48	0.078	#	#	-	-	0.385
Naphthalene	mg/kg	<0.010	<0.010	0.017	0.077	<0.010	0.28	<0.010	-	-	58 (v) / 70 (v)	(190) (4,v) / (230) (4,v)	0.029
Phenanthrene	mg/kg	<0.010	0.15	4.8	0.58	<0.010	0.66	0.066	-	-	-	-	0.703
Pyrene	mg/kg	<0.020	0.45	4.9	1.2	<0.020	0.52	0.19	-	-	(1,600) (4,p) / NA (2)	NA (2) / NA (2)	1.362
Benzo[a]pyrene TEQ [4]	mg/kg	0.03	0.49	4.4	1.2	0.03	0.96	0.16	35	40	-	-	0.922

Notes:

Values shaded grey exceed the NESCS SCSs for Commercial / Industrial land use
Value shaded yellow exceed the NESCS SCS for Recreational land use
Value shaded peach exceed the MfE Hydrocarbon Guidelines for Residential land use
Value shaded green exceed the MfE Hydrocarbon Guidelines for Commercial / Industrial land use
Red text exceed the ECan Background Concentrations of PAHs in Christchurch Urban Soils guideline values
* - Field duplicate of 12547621-BH-108(1.9)

Values shaded according according to the highest exceedance
All units are in mg/kg
m bgl - metres below ground level
A hyphen (-) indicates criterion not available or sample not anlaysed for this analyte
< - reported at a concentration less than the laboratory limit of reporting (LOR)
# indicates criteria for these compounds are addressed using the Benzo(a)pyrene equivalence calculations provided in the NES SCS (refer to Note 1 & Note 6)
Limiting pathways: (v) = volatilisation, (p) = Produce
(2) = Brackets denote values exceed threshold likely to correspond to formation of residual separate phase hydrocarbons
NA - indicates contaminant not limiting as estimated health-based criterion is significantly higher than that likely to be encountered on site.

References

1. Ministry for the Environment (2011). Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (NESCS). Soil Contaminant Standards (SCS
2. Ministry for the Environment (2011) Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Module 4 - Tier 1 Soil screening criteria. Table 4.10. Residential land use and Table 4.11 Commercial / Industrial land use.
3. Environment Canterbury (2007). Background Concentrations of polycyclic aromatic hydrocarbons in Christchurch urban soils. Report No. R07/19. Table 9.
4. Benzo(a)pyrene equivalent concentration calculated as the sum of the carcinogenic PAHs in accordance with the methodology published in the NESCS.

Site Name: Green Island Landfill
Table 3: Semi volatile organic compounds (SVOC) Analytical Results
November 2022 SIte Investigation

Client Name: Dunedin City Council
Project Number: 12547621

Analytica Lab Reference		22-40179-12	22-40179-13	22-40179-1	22-40179-2	22-40179-14	22-40179-15	22-40179-16	NESCS SCSs[1] for Commercial/Industrial land use (mg/kg)	NESCS SCSs [1] for Recreational land use (mg/kg)	Guidelines for Hydrocarbon Contamination - Residential Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Guidelines for Hydrocarbon Contamination - Commercial/Industrial Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Background Soil Concentrations, New Zealand [4,5,6] (mg/kg)
Eurofins Lab reference		K22-No0015984	K22-No0015985	K22-No0015975	K22-No0015976	K22-No0015986	K22-No0015987	K22-No0015988					
Sample Depth	m bgl	1.0	2.7	0.5	1.5	0.6	1.5	2.5					
Borehole		**BH-100**		**BH-101**		**BH-102**							
Sample Name		12547621-BH-100(1.0)	12547621-BH-100(2.7)	12547621-BH-101(0.5)	12547621-BH-101(1.5)	12547621-BH-102(0.6)	12547621-BH-102 1.2	12547621-BH-102 2.5					
Soil Type		Fill/ sand/ waste	Fill/ wood in sand	Fill/ loam/waste	Peat/sandy silt	Fill/ sand/ waste							
Sample Date		01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	0.1/11/2022	1/11/2022					
Semi volatile organic compounds (SVOCs)													
4.4'-DDD	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	-	-	-	-	0.00471
4.4'-DDE	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	-	-			0.0229
4.4'-DDT	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	**1,000**	**400**			0.0236
Acenaphthylene	mg/kg	0.04	< 0.03	< 0.03	< 0.03	< 0.03	<0.03	<0.03	-	-	-	-	0.069
Anthracene	mg/kg	0.04	< 0.03	< 0.03	< 0.03	< 0.03	<0.03	<0.03	-	-	-	-	0.113
Benz(a)anthracene	mg/kg	0.17	< 0.03	0.07	0.06	0.1	0.19	<0.03	-	-	-	-	0.47
Benzo(a)pyrene	mg/kg	0.23	< 0.03	0.06	0.05	0.1	0.30	<0.03	-	-	-	-	0.595
Benzo(a)pyrene TEQ (lower bound)*[3]	mg/kg	0.29	< 0.03	0.07	0.07	0.13	0.46	<0.03	**35**	**40**	-	-	0.922
Benzo(a)pyrene TEQ (medium bound)*[3]	mg/kg	0.31	0.04	0.09	0.09	0.15	0.46	<0.03	**35**	**40**	-	-	0.922
Benzo(a)pyrene TEQ (upper bound)*[3]	mg/kg	0.32	0.08	0.11	0.1	0.16	0.46	0.08	**35**	**40**	-	-	0.922
Benzo(b&j)fluoranthene	mg/kg	0.13	< 0.03	0.04	0.06	0.08	0.27	<0.03	-	-	-	-	0.947
Benzo(g.h.i)perylene	mg/kg	0.08	< 0.03	< 0.03	0.06	0.06	0.25	<0.03	-	-	-	-	0.459
Benzo(k)fluoranthene	mg/kg	0.14	< 0.03	< 0.03	0.06	0.09	0.26	<0.03	-	-	-	-	0.296
Chrysene	mg/kg	0.18	< 0.03	0.09	0.09	0.1	0.27	<0.03	-	-	-	-	0.539
Dibenz(a.h)anthracene	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.06	<0.03	-	-	-	-	0.112
Fluoranthene	mg/kg	0.34	< 0.03	0.11	0.11	0.08	0.30	<0.03	-	-	-	-	1.345
Indeno(1.2.3-cd)pyrene	mg/kg	0.11	< 0.03	< 0.03	0.03	0.06	0.18	<0.03	-	-	-	-	0.385
Naphthalene	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	<0.1	<0.1	-	-	58 (v) / 70 (v)	(190) (4,v) / (230) (4,v)	0.029
Phenanthrene	mg/kg	0.13	< 0.03	0.07	0.05	0.06	0.13	<0.03	-	-	-	-	0.703
Pyrene	mg/kg	0.33	< 0.03	0.13	0.11	0.08	0.35	<0.03	-	-	(1,600) (4,p) / NA (2)	NA (2) / NA (2)	1.362

Analytica Lab Reference		22-40179-8	22-40179-9	22-40179-6	22-40179-7	22-40820-2	22-40820-3	NESCS SCSs[1] for Commercial/Industrial land use (mg/kg)	NESCS SCSs [1] for Recreational land use (mg/kg)	Guidelines for Hydrocarbon Contamination - Residential Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Guidelines for Hydrocarbon Contamination - Commercial/Industrial Use - All Pathways - Sand (<1m / 1-4m) (mg/kg) [2]	Background Soil Concentrations, New Zealand [4,5,6] (mg/kg)
Eurofins Lab reference		K22-No0015982	K22-No0015983	K22-No0015980	K22-No0015981	-	-					
Sample Depth	m bgl	0.2	1.2	1.5	2.5	1.5	3.2					
Borehole		**BH-103**		**BH-107**		**BH-111**						
Sample Name		12547621-BH-103 0.2	12547621-BH-103 1.2	12547621-BH-107(1.5)	12547621-BH-107 2.5	12547621-BH-111(1.5)	12547621-BH-111(3.2)					
Soil Type				Gravelly silt/ bricks		Fill/waste/organics	Fill/ silt					
Sample Date		0.1/11/2022	1/11/2022	01/11/2022	1/11/2022	07/11/2022	07/11/2022					
Semi volatile organic compounds (SVOCs)												
4.4'-DDD	mg/kg	0.04	0.04	0.01	0.01	0.38	<0.30	-	-	-	-	0.00471
4.4'-DDE	mg/kg	0.04	<0.01	< 0.01	<0.01	<0.30	<0.30	-	-			0.0229
4.4'-DDT	mg/kg	0.13	0.06	< 0.01	<0.01	<0.50	<0.50	**1,000**	**400**			0.0236
Acenaphthene	mg/kg	<0.03	<0.03	0.61	<0.03	<0.10	<0.10	-	-	-	-	0.055
Acenaphthylene	mg/kg	< 0.03	< 0.03	0.43	<0.03	0.14	<0.10	-	-	-	-	0.069
Anthracene	mg/kg	<0.03	<0.03	3.1	0.12	0.18	<0.10	-	-	-	-	0.113
Benz(a)anthracene	mg/kg	0.08	0.12	5.4	0.22	0.35	<0.10	-	-	-	-	0.47
Benzo(a)pyrene	mg/kg	0.09	0.20	4.5	0.28	0.62	0.24	-	-	-	-	0.595
Benzo(a)pyrene TEQ (lower bound)*[3]	mg/kg	0.12	0.25	6.4	0.36	1.0	0.30	**35**	**40**	-	-	0.922
Benzo(a)pyrene TEQ (medium bound)*[3]	mg/kg	0.13	0.27	6.4	0.37	-	-	**35**	**40**	-	-	0.922
Benzo(a)pyrene TEQ (upper bound)*[3]	mg/kg	0.15	0.28	6.4	0.39	1.0	0.40	**35**	**40**	-	-	0.922
Benzo(b&j)fluoranthene	mg/kg	0.05	0.12	4.0	0.22	0.74	0.26	-	-	-	-	0.947
Benzo(g.h.i)perylene	mg/kg	0.08	0.12	0.67	0.13	0.36	0.15	-	-	-	-	0.459
Benzo(k)fluoranthene	mg/kg	0.06	0.14	3.2	0.15	0.31	0.13	-	-	-	-	0.296
Bis(2-ethylhexyl)phthalate	mg/kg	<0.5	<0.5	< 0.5	<0.5	0.50	<0.50	-	-	-	-	-
Chrysene	mg/kg	0.12	0.22	4.4	0.24	0.36	0.13	-	-	-	-	0.539
Dibenz(a.h)anthracene	mg/kg	<0.03	<0.03	0.35	<0.03	0.17	<0.10	-	-	-	-	0.112
Dibenzofuran	mg/kg	<0.5	<0.5	0.5	<0.5	<0.30	<0.030	-	-	-	-	-
Fluoranthene	mg/kg	0.14	0.30	13	0.51	0.96	0.33	-	-	-	-	1.345
Fluorene	mg/kg	<0.03	<0.03	1.2	0.05	0.13	<0.10	-	-	-	-	0.06
Indeno(1.2.3-cd)pyrene	mg/kg	0.05	0.10	1.0	0.12	0.48	0.19	-	-	-	-	0.385
Naphthalene	mg/kg	<0.1	<0.1	0.5	<0.1	0.12	<0.10	-	-	58 (v) / 70 (v)	(190) (4,v) / (230) (4,v)	0.029
Phenanthrene	mg/kg	0.04	0.12	8.7	0.31	0.58	0.14	-	-	-	-	0.703
Pyrene	mg/kg	0.13	0.34	13	0.53	0.87	0.3	-	-	(1,600) (4,p) / NA (2)	NA (2) / NA (2)	1.362

Notes:

Values shaded grey exceed the NESCS SCSs for Protection of Human Health (Commercial / Industrial land use)
Values shaded yellow exceed the NESCS SCSs for Protection of Human Health (Recreational land use)
Value shaded peach exceed the MfE Hydrocarbon Guidelines for Residential land use
Value shaded green exceed the MfE Hydrocarbon Guidelines for Commercial / Industrial land use
Red text indicates values exceeds the adopted background concentration value

mg/kg - miligrams per kilogram
m bgl - metres below ground level
A hyphen (-) indicates criterion not available for this analyte
< - reported at a concentration less than the laboratory limit of reporting (LOR)

References:

1. Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (NESCS). Soil contaminant standards (SCS) for Commercial / Industrial Land use
2. Ministry for the Environment (2011) Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Module 4 - Tier 1 Soil screening criteria. Table 4.10. Residential land use and Table 4.11 Commercial / Industrial land use.
3. Benzo(a)pyrene equivalent concentration calculated as the sum of the carcinogenic PAHs in accordance with the methodology published in the NESCS.
3. US EPA Superfund EGV (June, 2013)
4. Ministry for the Environment (1998). Ambient concentrations of selected organochlorines in soils. Table F3 - mean values.
5. Environment Canterbury (2007). Background Concentrations of polycyclic aromatic hydrocarbons in Christchurch urban soils. Report No. R07/19. Table 9.
6. Landcare Research Limited (2015) Background soil concentrations of selected trace elements and organic contaminants in New Zealand . Table 21. Christchurch Soils.

Green Island Landfill
Soil Analytical Results November 2022
Table 4: Total Petroleum Hydrocarbons (TPH)

Sample ID		22-40820-2	**Guidelines for Hydrocarbon Contamination -Commercial / Industrial - All Pathways - Sand (1-4m) (mg/kg)[1]**	**Guidelines for Hydrocarbon Contamination - Residential - All Pathways - Sand (1-4m) (mg/kg)[1]**
Sample Depth	m bgl	1.5		
Borehole		**BH-111**		
Sample Name		12547621-BH-111(1.5)		
Soil Type		Fill/waste/organics		
Sample Date		07/11/2022		
Total Petroleum Hydrocarbons (TPH)				
C7-C9	mg/kg	<10	**120** (m)	**120** (m)
C10-C14	mg/kg	40	**(1,900)** (2,x)	**(560)** (2,x)
C15-C36	mg/kg	681	**NA**	**NA**
C7-C36 (Total)	mg/kg	721	-	-

Notes:

All units are in mg/kg

m bgl - metres below ground level

A hyphen (-) indicates criterion not available

< - reported at a concentration less than the laboratory limit of reporting (LOR)

Limiting pathways: (m) = Maintenance/Excavation , (2) = Brackets denote values exceed threshold likely to correspond to formation of residual separate phasehydrocarbons, (x) = PAH surrogate

NA - indicates estimated criterion exceeds 20,000 mg/kg. At 20,000 mg/kg residual separate phase is expected to have formed in soil matrix. Some aesthetic impact may be noted.

References

1. Ministry for the Environment (2011) Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Module 4 - Tier 1 Soil screening criteria. Table 4.14. Commercial / Industrial land use.

Green Island Landfill
Soil Analytical Results November 2022
Table 5: Ammonia in Soil

Lab Reference		22-40179	22-40179	22-40179	22-40179	22-40179	22-40179	22-40179	22-40179
Sample Depth	m bgl	1.0	2.7	0.5	1.5	2.5	1.2	3.5	0.5
Borehole		**BH-100**		**BH-101**			**BH-103**		**BH-107**
Soil type		Fill/ sand/ waste	Fill/ wood in sand	Fill/ loam/waste	Peat/sandy silt	Silty sand	Fill/ organic silt	Clayey silt	Clayey silt/ waste
Sample Name		12547621-BH-100	12547621-BH-100(2.7)	12547621-BH-101(0.5)	12547621-BH-101(1.5)	12547621-BH-101(2.5)	12547621-BH-103	12547621-BH-103	12547621-BH-107(0.5)
Sample Date		01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Ammonia									
Ammonia	mg/kg	<5.00	5.27	<5.00	43.6	7.24	17.4	<5.00	<5.00

Notes:
All units are in mg/kg
m bgl - metres below ground level

Green Island Landfill
Soil Analytical Results November 2022
Table 6: Asbestos in Soil

Laboratory ID		22-40290-10	22-40290-11	22-40290-1	22-40290-12	22-40290-13	22-40290-8	22-40968-5	BRANZ [1] - Guideline Values Commercial / Industrial % w/w
Borehole		**BH-100**		**BH-101**	**BH-102**		**BH-103**	**BH-104**	
GHD Sample Reference		12547621-BH-100(1.0)	12547621-BH-100(2.7)	12547621-BH-101(0.5)	12547621-BH-102(0.6)	12547621-BH-102(1.5)	12547621-BH-103(0.2)	12547621-BH-104 (0.5)	
Sample Date		01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022	09/11/2022	
Depth (m bgl)		1.0	2.7	0.5	0.6	1.5	0.2	0.5	
SoilType		Fill/ sand/ waste	Fill/ wood in sand	Fill/ loam/waste	Fill/ sand/ waste	Fill/ peat/ waste	Topsoil/ organic silt	Fill/ clayey gravel	
Asbestos weight (g)	>10mm fraction	-	-	-	-	-	-	-	-
	2-10mm fraction	-	-	-	-	-	-	-	-
	<2mm fraction	-	-	-	-	-	-	-	-
W/W asbestos %	ACM	Absent	Absent	Absent	Absent	Absent	Absent	Absent	**0.05**
	AF/FA	Absent	Absent	Absent	Absent	Absent	Absent	Absent	**0.001**

Laboratory ID		22-40968-6	22-40968-7	22-40290-5	22-40968-1*	22-40290-6	22-40290-7	-	BRANZ [1] - Guideline Values Commercial / Industrial % w/w
		BH-104		**BH-107**					
GHD Sample Reference		12547621-BH-104 (1.0)	12547621-BH-104 (2.0)	12547621-BH-107(0.5)	12547621-BH-107 (0.5)	12547621-BH-107(1.5)	12547621-BH-107(2.5)	-	
Sample Date		09/11/2022	09/11/2022	01/11/2022	09/11/2022	01/11/2022	01/11/2022	-	
Depth (m bgl)		1.0	2.0	0.5	0.5	1.5	2.5	-	
Soil Type		Fill/ silty clay	Fill/ waste material	Clayey silt/ waste	Clayey silt/ waste	Gravelly silt/ bricks	Silt/ waste	-	
Asbestos weight (g)	>10mm fraction	-	-	-	None detected	-	-	-	-
	2-10mm fraction	-	-	-	None detected	-	-	-	-
	<2mm fraction	-	-	-	None detected	-	-	-	-
W/W asbestos %	ACM	Absent	Absent	Absent	Absent	Absent	Absent	-	**0.05**
	AF/FA	Absent	Absent	Present	Absent	Absent	Absent	-	**0.001**

Laboratory ID		22-40968-2	22-40968-3	22-40968-4	22-40546-1	22-40546-2	22-40546-3	-	BRANZ [1] - Guideline Values Commercial / Industrial % w/w
		BH-108			**BH-111**				
GHD Sample Reference		12547621-BH-108 (0.5)	12547621-BH-108 (1.9)	12547621-BH-108 (3.3)	12547621 - BH - 111 (0.5)	12547621 - BH - 111 (1.5)	12547621 - BH - 111 (3.2)	-	
Sample Date		09/11/2022	09/11/2022	09/11/2022	07/11/2022	07/11/2022	07/11/2022	-	
Depth (m bgl)		0.5	1.9	3.3	0.5	1.5	3.2	-	
Soil Type		Fill/ clay	Fill/ clay	Fill/ waste/ clay	Fill/ gravel/ waste	Fill/waste/organics	Fill/ silt	-	
Asbestos weight (g)	>10mm fraction	-	-	-	-	-	-	-	-
	2-10mm fraction	-	-	-	-	-	-	-	-
	<2mm fraction	-	-	-	-	-	-	-	-
W/W asbestos %	ACM	Absent	Absent	Absent	Absent	Absent	Absent	-	**0.05**
	AF/FA	Absent	Absent	Absent	Absent	Absent	Absent	-	**0.001**

Notes:

Peach shading indicates that asbestos was found present but at concentrations less than the guideline value

Blue shading indicates asbestos present at concentrations above the adopted BRANZ guideline values

* This sample was a retest of the sample collected at the same location and depth on 1 November 2022

Reference:

1. BRANZ (2017) New Zealand Guidelines for Assessing and Managing Asbestos in Soil. Table 5 - Commercial / Industrial guideline values

Table 7
Soil Analytical Results - QA/QC Analysis

Dunedin City Council
Green Island Landfill
Soil Sampling Results
12547621

QA/QC TYPE		**FIELD DUPLICATE**		
Sample Name		**12547621-BH-108(1.9)**	**12547621-DUP-2**	**RPD**
Sample Date		9/11/2022		
Soil type		Fill / Clay	Fill / Clay	
Laboratory Number		22-41184-2	22-41184-4	
Depth (mbgl)		1.9		
Heavy Metals				
Arsenic	mg/kg	7.2	7.1	-1.4
Beryllium	mg/kg	1.42	1.33	-6.5
Boron	mg/kg	7.6	7.9	3.9
Cadmium	mg/kg	0.16	0.16	0.0
Chromium	mg/kg	50.1	49.4	-1.4
Copper	mg/kg	20.9	20.8	-0.5
Lead	mg/kg	52.9	42.8	-21.1
Mercury	mg/kg	0.28	0.27	-3.6
Nickel	mg/kg	38	35.9	-5.7
Zinc	mg/kg	124	121	-2.4

QA/QC TYPE		**FIELD DUPLICATE**		
Sample Name		**12547621-BH-111(3.2)**	**12547621-DUP**	**RPD**
Sample Date		7/11/2022		
Soil type		Fill / Silt	Fill / Silt	
Laboratory Number		22-40820-3	22-40820-04	
Depth (mbgl)		3.2		
Heavy Metals				
Arsenic	mg/kg	9	9.6	6.5
Beryllium	mg/kg	1.35	1.75	25.8
Boron	mg/kg	14	15	6.9
Cadmium	mg/kg	0.18	0.32	56.0
Chromium	mg/kg	52.7	58.3	10.1
Copper	mg/kg	25.2	34.3	30.6
Lead	mg/kg	32.9	62.2	61.6
Mercury	mg/kg	0.12	0.21	54.5
Nickel	mg/kg	45.4	49	7.6
Zinc	mg/kg	179	236	27.5

QA/QC TYPE		**FIELD DUPLICATE**		
Sample Name		**12547621-BH-108(1.9)**	**12547621-DUP-2**	**RPD**
Sample Date		9/11/2022		
Laboratory Number		22-41184-2	22-41184-4	
Depth (mbgl)		1.9		
Acenaphthene	mg/kg	<0.010	0.026	-
Acenaphthylene	mg/kg	0.031	0.14	127.5
Anthracene	mg/kg	0.054	1.5	186.1
Benz[a]anthracene	mg/kg	0.22	4.6	181.7
Benzo[a]pyrene	mg/kg	0.35	2.7	154.1
Benzo[b]&[j] fluoranthene	mg/kg	0.37	4	166.1
Benzo[g,h,i]perylene	mg/kg	0.21	1.2	140.4
Benzo[k]fluoranthene	mg/kg	0.18	1.8	163.6
Chrysene	mg/kg	0.38	3.7	162.7
Dibenz(a,h)anthracene	mg/kg	0.04	0.43	166.0
Fluoranthene	mg/kg	0.42	5.4	171.1
Fluorene	mg/kg	0.017	0.3	178.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.21	1.5	150.9
Naphthalene	mg/kg	<0.010	0.017	-
Phenanthrene	mg/kg	0.15	4.8	187.9
Pyrene	mg/kg	0.45	4.9	166.4
Benzo[a]pyrene TEQ [3]	mg/kg	0.49	4.4	159.9

Attachment D
Laboratory Reports

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Certificate of Analysis

GHD Ltd
Level 1, Bing Harris Building, 286 Princess Street, Dunedin
Dunedin 9016

Attention: Cecilia Gately
Phone: 021 973 994
Email: danny.fitzgerald@ghd.com

Lab Reference: 22-40179
Submitted by: Danny Fitzgerald
Date Received: 04/11/2022
Testing Initiated: 4/11/2022
Date Completed: 22/11/2022
Order Number:
Reference: 12547621

Sampling Site: Green Island Landfill

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories. Samples were in acceptable condition unless otherwise noted on this report.
Specific testing dates are available on request.

9 Heavy Metals in Soil

Client Sample ID			12547621-BH-101 0.5	12547621-BH-101 1.5	12547621-BH-101 2.5	12547621-BH-101 3.5	12547621-BH-107 0.5
Date Sampled			01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-1	22-40179-2	22-40179-3	22-40179-4	22-40179-5
Arsenic	mg/kg dry wt	*0.125*	9.7	12	7.1	5.5	5.0
Boron	mg/kg dry wt	*1.25*	6.9	27	8.4	11	5.5
Cadmium	mg/kg dry wt	*0.005*	0.30	0.18	0.018	0.029	0.052
Chromium	mg/kg dry wt	*0.125*	29.3	55.2	21.8	18.8	18.4
Copper	mg/kg dry wt	*0.075*	14.2	18.2	4.1	4.0	8.14
Lead	mg/kg dry wt	*0.25*	60.1	50.8	4.9	4.2	19.7
Mercury	mg/kg dry wt	*0.025*	0.079	0.14	<0.025	<0.025	0.13
Nickel	mg/kg dry wt	*0.05*	36.6	14.8	10.6	9.53	10.2
Zinc	mg/kg dry wt	*0.05*	183	119	36.7	29.0	37.0

9 Heavy Metals in Soil

Client Sample ID			12547621-BH-107 1.5	12547621-BH-107 2.5	12547621-BH-103 0.2	12547621-BH-103 1.2	12547621-BH-103 2.5
Date Sampled			01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-6	22-40179-7	22-40179-8	22-40179-9	22-40179-10
Arsenic	mg/kg dry wt	*0.125*	4.8	4.6	6.8	25.8	8.7
Boron	mg/kg dry wt	*1.25*	14	7.2	3.4	20	7.1
Cadmium	mg/kg dry wt	*0.005*	0.060	0.11	0.29	0.28	0.12
Chromium	mg/kg dry wt	*0.125*	39.2	24.2	20.1	156	19.8
Copper	mg/kg dry wt	*0.075*	17.7	16.2	20.3	31.6	6.4

9 Heavy Metals in Soil

		Client Sample ID	12547621-BH-107 1.5	12547621-BH-107 2.5	12547621-BH-103 0.2	12547621-BH-103 1.2	12547621-BH-103 2.5
		Date Sampled	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Lead	mg/kg dry wt	*0.25*	17.7	32.1	77.8	74.3	5.45
Mercury	mg/kg dry wt	*0.025*	0.091	0.097	0.10	0.30	0.029
Nickel	mg/kg dry wt	*0.05*	25.6	9.59	19.1	30.7	13.2
Zinc	mg/kg dry wt	*0.05*	67.7	53.0	120	210	42.7

9 Heavy Metals in Soil

		Client Sample ID	12547621-BH-103 3.5	12547621-BH-100 1.0	12547621-BH-100 2.7	12547621-BH-102 0.6	12547621-BH-102 1.5
		Date Sampled	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-11	22-40179-12	22-40179-13	22-40179-14	22-40179-15
Arsenic	mg/kg dry wt	*0.125*	9.4	2.8	7.8	4.7	29.7
Boron	mg/kg dry wt	*1.25*	9.5	1.5	9.2	2.1	32
Cadmium	mg/kg dry wt	*0.005*	0.070	0.059	0.047	0.11	0.27
Chromium	mg/kg dry wt	*0.125*	19.1	21.6	28.0	46.2	125
Copper	mg/kg dry wt	*0.075*	6.7	18.5	6.6	27.3	34.2
Lead	mg/kg dry wt	*0.25*	6.78	14.8	5.01	44.8	98.5
Mercury	mg/kg dry wt	*0.025*	<0.025	0.055	<0.025	0.12	0.32
Nickel	mg/kg dry wt	*0.05*	12.2	14.1	15.5	35.9	33.8
Zinc	mg/kg dry wt	*0.05*	49.3	52.0	47.4	105	467

9 Heavy Metals in Soil

		Client Sample ID	12547621-BH-102 2.5	12547621-BH-102 3.5
		Date Sampled	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-16	22-40179-17
Arsenic	mg/kg dry wt	*0.125*	11	11
Boron	mg/kg dry wt	*1.25*	9.9	9.0
Cadmium	mg/kg dry wt	*0.005*	0.012	0.066
Chromium	mg/kg dry wt	*0.125*	23.7	22.5
Copper	mg/kg dry wt	*0.075*	6.5	5.5
Lead	mg/kg dry wt	*0.25*	6.24	4.7
Mercury	mg/kg dry wt	*0.025*	<0.025	<0.025
Nickel	mg/kg dry wt	*0.05*	11.5	15.1
Zinc	mg/kg dry wt	*0.05*	49.4	45.9

Soil Aggregate Properties and Nutrients

		Client Sample ID	12547621-BH-101 0.5	12547621-BH-101 1.5	12547621-BH-101 2.5	12547621-BH-107 0.5	12547621-BH-103 1.2
		Date Sampled	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-1	22-40179-2	22-40179-3	22-40179-5	22-40179-9
Ammonia-N*	mg/kg dry wt	*5*	<5.00	43.6	7.24	<5.00	17.4

Soil Aggregate Properties and Nutrients

		Client Sample ID	12547621-BH-103 3.5	12547621-BH-100 1.0	12547621-BH-100 2.7
		Date Sampled	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-11	22-40179-12	22-40179-13
Ammonia-N*	mg/kg dry wt	*5*	<5.00	<5.00	5.27

Custom Job

		Client Sample ID	12547621-BH-101 0.5	12547621-BH-101 1.5	12547621-BH-101 2.5	12547621-BH-101 3.5	12547621-BH-107 0.5
		Date Sampled	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-1	22-40179-2	22-40179-3	22-40179-4	22-40179-5
Custom Job			Complete	Complete	Complete	Complete	Complete

Custom Job

		Client Sample ID	12547621-BH-107 1.5	12547621-BH-107 2.5	12547621-BH-103 0.2	12547621-BH-103 1.2	12547621-BH-100 1.0
		Date Sampled	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-6	22-40179-7	22-40179-8	22-40179-9	22-40179-12
Custom Job			Complete	Complete	Complete	Complete	Complete

Custom Job

		Client Sample ID	12547621-BH-100 2.7	12547621-BH-102 0.6	12547621-BH-102 1.5	12547621-BH-102 2.5
		Date Sampled	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-40179-13	22-40179-14	22-40179-15	22-40179-16
Custom Job			Complete	Complete	Complete	Complete

Method Summary

Elements in Soil	Samples dried and passed through a 2 mm sieve followed by acid digestion and analysis by ICP-MS. In accordance with in-house procedure based on US EPA method 200.8.
Ammonia-N in Soil	1:5 water extraction (NEPM, Schedule B3, Laboratory Analysis of Potentially Contaminated Soil, 2011) followed by colour-metric analysis (APHA 4500 NH_3 - F Online edition - modified - Discrete Analyser).

Jarred Wilson, DipSci
Trace Elements Team Leader

Sandra Mathews, B.Eng.
Technologist

Adam Ang
Team Leader

Sharelle Frank, B.Sc. (Tech)
Technologist

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Certificate of Analysis

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Dunedin 9016
Attention: Cecilia Gately
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Email: danny.fitzgerald@ghd.com

Lab Reference: 22-40290
Submitted by: Danny Fitzgerald
Date Received: 04/11/2022
Testing Initiated: 7/11/2022
Date Completed: 8/11/2022
Order Number:
Reference: 12547621

Sampling Site: Green Island Landfill
Description of Work: PA - 12547621

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories. Samples were in acceptable condition unless otherwise noted on this report.
Specific testing dates are available on request.

Asbestos in Soil (Qualitative)

Sample Details

Laboratory ID	Client Sample ID	Sample Location	Sample Description	Date Sampled	Date Analysed
22-40290-1	12547621-BH-101 0.5		Soil	01/11/2022	07/11/2022
22-40290-5	12547621-BH-107 0.5		Soil	01/11/2022	07/11/2022
22-40290-6	12547621-BH-107 1.5		Soil	01/11/2022	07/11/2022
22-40290-7	12547621-BH-107 2.5		Soil	01/11/2022	08/11/2022
22-40290-8	12547621-BH-103 0.2		Soil	01/11/2022	08/11/2022
22-40290-10	12547621-BH-100 1.0		Soil	01/11/2022	08/11/2022
22-40290-11	12547621-BH-100 2.7		Soil	01/11/2022	08/11/2022
22-40290-12	12547621-BH-102 0.6		Soil	01/11/2022	08/11/2022
22-40290-13	12547621-BH-102 1.5		Soil	01/11/2022	08/11/2022

Information in the above table supplied by the client: Client Sample ID, Sample Location, Date Sampled.

Laboratory ID	Client Sample ID	Fibre Types	Trace Asbestos (Presence / Absence)	Asbestos (Presence / Absence)
	Units			
22-40290-1	12547621-BH-101 0.5	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40290-5	12547621-BH-107 0.5	Chrysotile (White Asbestos) Organic Fibres	Absent	Present
22-40290-6	12547621-BH-107 1.5	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40290-7	12547621-BH-107 2.5	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40290-8	12547621-BH-103 0.2	Asbestos NOT Detected. Organic Fibres	Absent	Absent

Laboratory ID	Client Sample ID	Fibre Types	Trace Asbestos (Presence / Absence)	Asbestos (Presence / Absence)
Units				
22-40290-10	12547621-BH-100 1.0	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40290-11	12547621-BH-100 2.7	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40290-12	12547621-BH-102 0.6	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40290-13	12547621-BH-102 1.5	Asbestos NOT Detected. Organic Fibres	Absent	Absent

Information in the above table supplied by the client: Client Sample ID.

Asbestos in Soil (Qualitative) Approver:

Av. Eeden

Aleesha van Eeden, M.Sc.
Technician

Method Summary

Asbestos Fibres in Soil (Qualitative)

Sample analysis was performed using polarised light microscopy with dispersion staining in accordance with AS4964-2004 Method for the qualitative identification of asbestos in bulk samples.

Note 1: The reporting limit for this analysis is 0.1g/kg (0.01%) by application of polarised light microscopy, dispersion staining and trace analysis techniques.

Note 2: Trace asbestos is indicative that freely liberated respirable fibres are present and dust control measures should be implemented or increased on site. This is not the sole indicator for the friable nature of the asbestos present.

Note 3: If mineral fibres of unknown type are detected, by PLM and dispersion staining, these may or may not be asbestos fibres. To confirm the identity of this fibre, another independent analytical technique such as XRD analysis is advised.

Note 4: The laboratory does not take responsibility for the sampling procedure or accuracy of sample location description.

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Certificate of Analysis

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Level 1, Bing Harris Building, 286 Princess Street, Dunedin
Dunedin 9016
Attention: Cecilia Gately
Phone: 021973994
Email: danny.fitzgerald@ghd.com

Lab Reference: 22-40546
Submitted by: Danny FitzGerald
Date Received: 07/11/2022
Testing Initiated: 7/11/2022
Date Completed: 9/11/2022
Order Number: N/A
Reference: 12547621

Sampling Site: Green Island LF
Description of Work: Soil - Green Island LF

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories. Samples were in acceptable condition unless otherwise noted on this report.
Specific testing dates are available on request.

AMENDED REPORT. This report replaces in full a previous version 22-40546[R00] sent on 09/11/2022. Changes have been made to the Client Sample ID's as per request of the client.

Asbestos in Soil (Qualitative)

Sample Details

Laboratory ID	Client Sample ID	Sample Location	Sample Description	Date Sampled	Date Analysed
22-40546-1	12547621 - BH - 111 (0.5)	N/A	Soil	07/11/2022	09/11/2022
22-40546-2	12547621 - BH - 111 (1.5)	N/A	Soil	07/11/2022	09/11/2022
22-40546-3	12547621 - BH - 111 (3.2)	N/A	Soil	07/11/2022	09/11/2022

Information in the above table supplied by the client: Client Sample ID, Sample Location, Date Sampled.

Laboratory ID	Client Sample ID	Fibre Types	Trace Asbestos (Presence / Absence)	Asbestos (Presence / Absence)
	Units			
22-40546-1	12547621 - BH - 111 (0.5)	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40546-2	12547621 - BH - 111 (1.5)	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40546-3	12547621 - BH - 111 (3.2)	Asbestos NOT Detected. Organic Fibres	Absent	Absent

Information in the above table supplied by the client: Client Sample ID.

Asbestos in Soil (Qualitative) Approver:

Av. Eeden

Aleesha van Eeden, M.Sc.
Technician

Method Summary

Asbestos Fibres in Soil (Qualitative)

Sample analysis was performed using polarised light microscopy with dispersion staining in accordance with AS4964-2004 Method for the qualitative identification of asbestos in bulk samples.

Note 1: The reporting limit for this analysis is 0.1g/kg (0.01%) by application of polarised light microscopy, dispersion staining and trace analysis techniques.

Note 2: Trace asbestos is indicative that freely liberated respirable fibres are present and dust control measures should be implemented or increased on site. This is not the sole indicator for the friable nature of the asbestos present.

Note 3: If mineral fibres of unknown type are detected, by PLM and dispersion staining, these may or may not be asbestos fibres. To confirm the identity of this fibre, another independent analytical technique such as XRD analysis is advised.

Note 4: The laboratory does not take responsibility for the sampling procedure or accuracy of sample location description.

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Certificate of Analysis

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Attention: Cecilia Gately
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Email: danny.fitzgerald@ghd.com

Lab Reference: 22-40820
Submitted by: Danny FitzGerald
Date Received: 09/11/2022
Testing Initiated: 9/11/2022
Date Completed: 24/11/2022
Order Number:
Reference: 12547621

Sampling Site:

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories. Samples were in acceptable condition unless otherwise noted on this report.
Specific testing dates are available on request.

Heavy Metals in Soil

		Client Sample ID	12547621-BH-111(0.5) 0.5	12547621-BH-111(1.5) 1.5	12547621-BH-111(3.2) 3.2	12547621-Dup
		Date Sampled	07/11/2022	07/11/2022	07/11/2022	07/11/2022
Analyte	Unit	*Reporting Limit*	22-40820-1	22-40820-2	22-40820-3	22-40820-4
Arsenic	mg/kg dry wt	*0.125*	1.7	8.9	9.0	9.6
Beryllium	mg/kg dry wt	*0.013*	1.2	1.3	1.35	1.75
Boron	mg/kg dry wt	*1.25*	8.4	20	14	15
Cadmium	mg/kg dry wt	*0.005*	0.11	2.18	0.18	0.32
Chromium	mg/kg dry wt	*0.125*	90.5	34.6	52.7	58.3
Copper	mg/kg dry wt	*0.075*	59.1	40.3	25.2	34.3
Lead	mg/kg dry wt	*0.25*	49.1	179	32.9	62.2
Mercury	mg/kg dry wt	*0.025*	<0.025	0.12	0.12	0.21
Nickel	mg/kg dry wt	*0.05*	105	32.7	45.4	49.0
Zinc	mg/kg dry wt	*0.05*	127	403	179	236

Polycyclic Aromatic Hydrocarbons - Soil

		Client Sample ID	12547621-BH-111(0.5) 0.5	12547621-BH-111(1.5) 1.5	12547621-BH-111(3.2) 3.2
		Date Sampled	07/11/2022	07/11/2022	07/11/2022
Analyte	Unit	*Reporting Limit*	22-40820-1	22-40820-2	22-40820-3
1-Methylnaphthalene	mg/kg dry wt	*0.01*	<0.010	0.093	<0.010
2-Methylnaphthalene	mg/kg dry wt	*0.01*	<0.010	0.12	<0.010
Acenaphthene	mg/kg dry wt	*0.01*	<0.010	0.038	<0.010
Acenaphthylene	mg/kg dry wt	*0.01*	<0.010	0.091	0.012

Polycyclic Aromatic Hydrocarbons - Soil

Client Sample ID			12547621- BH-111(0.5) 0.5	12547621- BH-111(1.5) 1.5	12547621- BH-111(3.2) 3.2
Date Sampled			07/11/2022	07/11/2022	07/11/2022
Anthracene	mg/kg dry wt	*0.01*	<0.010	0.19	0.019
Benz[a]anthracene	mg/kg dry wt	*0.02*	<0.020	0.41	0.076
Benzo[a]pyrene	mg/kg dry wt	*0.01*	<0.010	0.66	0.10
Benzo[b]&[j] fluoranthene	mg/kg dry wt	*0.02*	<0.020	0.78	0.11
Benzo[g,h,i]perylene	mg/kg dry wt	*0.02*	<0.020	0.34	0.063
Benzo[k]fluoranthene	mg/kg dry wt	*0.01*	<0.010	0.29	0.038
Chrysene	mg/kg dry wt	*0.01*	<0.010	0.42	0.077
Dibenz(a,h)anthracene	mg/kg dry wt	*0.01*	<0.010	0.086	0.021
Fluoranthene	mg/kg dry wt	*0.02*	<0.020	0.63	0.18
Fluorene	mg/kg dry wt	*0.01*	<0.010	0.097	<0.010
Indeno(1,2,3-cd)pyrene	mg/kg dry wt	*0.01*	<0.010	0.48	0.078
Naphthalene	mg/kg dry wt	*0.01*	<0.010	0.28	<0.010
Phenanthrene	mg/kg dry wt	*0.01*	<0.010	0.66	0.066
Pyrene	mg/kg dry wt	*0.02*	<0.020	0.52	0.19
Benzo[a]pyrene TEQ (LOR)	mg/kg dry wt	*0.03*	0.030	0.96	0.16
Benzo[a]pyrene TEQ (Zero)	mg/kg dry wt	*0.01*	<0.010	0.96	0.16
Anthracene-d10 (Surrogate)	%	*1*	99	94	100

Total Petroleum Hydrocarbons - Soil

Client Sample ID			12547621- BH-111(1.5) 1.5
Date Sampled			07/11/2022
Analyte	Unit	*Reporting Limit*	22-40820-2
C7-C9	mg/kg dry wt	*10*	<10
C10-C14	mg/kg dry wt	*15*	40
C15-C36	mg/kg dry wt	*25*	681
C7-C36 (Total)	mg/kg dry wt	*50*	721

Moisture Content

Client Sample ID			12547621- BH-111(0.5) 0.5	12547621- BH-111(1.5) 1.5	12547621- BH-111(3.2) 3.2
Date Sampled			07/11/2022	07/11/2022	07/11/2022
Analyte	Unit	*Reporting Limit*	22-40820-1	22-40820-2	22-40820-3
Moisture Content	%	*1*	14	49	24

Semivolatile Organic Compounds - Soil

Client Sample ID			12547621- BH-111(1.5) 1.5	12547621- BH-111(3.2) 3.2
Date Sampled			07/11/2022	07/11/2022
Analyte	Unit	*Reporting Limit*	22-40820-2	22-40820-3
Phenol	mg/kg dry wt	*0.3*	<0.30	<0.30
2-Chlorophenol	mg/kg dry wt	*0.3*	<0.30	<0.30
2-Methylphenol	mg/kg dry wt	*0.3*	<0.30	<0.30
2-Nitrophenol	mg/kg dry wt	*1.0*	<1.0	<1.0

Semivolatile Organic Compounds - Soil

		Client Sample ID	12547621- BH-111(1.5) 1.5	12547621- BH-111(3.2) 3.2
		Date Sampled	07/11/2022	07/11/2022
2,4-Dimethylphenol	mg/kg dry wt	*0.3*	<0.30	<0.30
2,4-Dichlorophenol	mg/kg dry wt	*0.3*	<0.30	<0.30
2,6-Dichlorophenol	mg/kg dry wt	*0.3*	<0.30	<0.30
4-Chloro-3-methylphenol	mg/kg dry wt	*0.3*	<0.30	<0.30
2,4,5-Trichlorophenol	mg/kg dry wt	*5*	<5.0	<5.0
2,4,6-Trichlorophenol	mg/kg dry wt	*5*	<5.0	<5.0
2,3,4,6-Tetrachlorophenol	mg/kg dry wt	*5*	<5.0	<5.0
4-Methylphenol	mg/kg dry wt	*0.3*	<0.30	<0.30
Naphthalene	mg/kg dry wt	*0.1*	0.12	<0.10
2-Methylnaphthalene	mg/kg dry wt	*0.1*	0.11	<0.10
2-Chloronaphthalene	mg/kg dry wt	*0.3*	<0.30	<0.30
Acenaphthene	mg/kg dry wt	*0.1*	<0.10	<0.10
Acenaphthylene	mg/kg dry wt	*0.1*	0.14	<0.10
Fluorene	mg/kg dry wt	*0.1*	0.13	<0.10
Phenanthrene	mg/kg dry wt	*0.1*	0.58	0.14
Anthracene	mg/kg dry wt	*0.1*	0.18	<0.10
2-Phenylphenol	mg/kg dry wt	*0.5*	<0.50	<0.50
Fluoranthene	mg/kg dry wt	*0.1*	0.96	0.33
Benzo[a]anthracene	mg/kg dry wt	*0.1*	0.35	<0.10
Chrysene	mg/kg dry wt	*0.1*	0.36	0.13
Bis(2-ethylhexyl) adipate	mg/kg dry wt	*0.5*	<0.50	<0.50
Benzo[b and j]fluoranthene	mg/kg dry wt	*0.1*	0.74	0.26
Benzo[k]fluoranthene	mg/kg dry wt	*0.1*	0.31	0.13
Benzo[a]pyrene	mg/kg dry wt	*0.1*	0.62	0.24
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	*0.1*	0.48	0.19
Dibenzo[a,h]anthracene	mg/kg dry wt	*0.1*	0.17	<0.10
Benzo[g,h,i]perylene	mg/kg dry wt	*0.1*	0.36	0.15
Pyrene	mg/kg dry wt	*0.2*	0.87	0.30
Benzo[a]pyrene TEQ (LOR)	mg/kg dry wt	*0.2*	1.0	0.40
Benzo[a]pyrene TEQ (Zero)	mg/kg dry wt	*0.1*	1.0	0.30
4,4'-DDD	mg/kg dry wt	*0.3*	0.38	<0.30
4,4'-DDE	mg/kg dry wt	*0.3*	<0.30	<0.30
4,4'-DDT	mg/kg dry wt	*0.5*	<0.50	<0.50
alpha-BHC	mg/kg dry wt	*0.3*	<0.30	<0.30
beta-BHC	mg/kg dry wt	*0.3*	<0.30	<0.30
gamma-BHC (Lindane)	mg/kg dry wt	*0.3*	<0.30	<0.30
delta-BHC	mg/kg dry wt	*0.3*	<0.30	<0.30
Aldrin	mg/kg dry wt	*0.3*	<0.30	<0.30
cis-Chlordane	mg/kg dry wt	*0.3*	<0.30	<0.30
trans-Chlordane	mg/kg dry wt	*0.3*	<0.30	<0.30
Dieldrin	mg/kg dry wt	*0.5*	<0.50	<0.50
Endosulfan I	mg/kg dry wt	*0.3*	<0.30	<0.30
Endosulfan II	mg/kg dry wt	*0.5*	<0.50	<0.50
Endosulfan sulfate	mg/kg dry wt	*0.5*	<0.50	<0.50
Endrin	mg/kg dry wt	*0.5*	<0.50	<0.50
Endrin aldehyde	mg/kg dry wt	*0.5*	<0.50	<0.50
Endrin ketone	mg/kg dry wt	*0.5*	<0.50	<0.50
Hexachlorobenzene	mg/kg dry wt	*0.3*	<0.30	<0.30
Heptachlor	mg/kg dry wt	*0.3*	<0.30	<0.30

Semivolatile Organic Compounds - Soil

Client Sample ID			12547621-BH-111(1.5) 1.5	12547621-BH-111(3.2) 3.2
Date Sampled			07/11/2022	07/11/2022
Heptachlor epoxide	mg/kg dry wt	*0.3*	<0.30	<0.30
Methoxychlor	mg/kg dry wt	*0.5*	<0.50	<0.50
Bis(2-ethylhexyl) phthalate	mg/kg dry wt	*0.5*	0.50	<0.50
Butyl benzyl phthalate	mg/kg dry wt	*0.5*	<0.50	<0.50
Di-n-butyl phthalate	mg/kg dry wt	*1*	<1.0	<1.0
Di-n-octyl phthalate	mg/kg dry wt	*0.5*	<0.50	<0.50
Diethyl phthalate	mg/kg dry wt	*0.3*	<0.30	<0.30
Dimethyl phthalate	mg/kg dry wt	*0.3*	<0.30	<0.30
N-Nitrosodiphenylamine	mg/kg dry wt	*0.3*	<0.30	<0.30
N-Nitrosodi-n-propylamine	mg/kg dry wt	*0.3*	<0.30	<0.30
2,4-Dinitrotoluene	mg/kg dry wt	*0.3*	<0.30	<0.30
2,6-Dinitrotoluene	mg/kg dry wt	*0.3*	<0.30	<0.30
Azobenzene	mg/kg dry wt	*0.5*	<0.50	<0.50
Isophorone	mg/kg dry wt	*0.5*	<0.50	<0.50
Nitrobenzene	mg/kg dry wt	*0.3*	<0.30	<0.30
4-Bromophenyl phenyl ether	mg/kg dry wt	*0.3*	<0.30	<0.30
4-Chlorophenyl phenyl ether	mg/kg dry wt	*0.3*	<0.30	<0.30
Bis(2-Chloroethyl) ether	mg/kg dry wt	*0.3*	<0.30	<0.30
Bis(2-Chloro-1-methylethyl) ether	mg/kg dry wt	*0.3*	<0.30	<0.30
Bis(2-Chloroethoxy) methane	mg/kg dry wt	*0.3*	<0.30	<0.30
1,2-Dichlorobenzene	mg/kg dry wt	*0.3*	<0.30	<0.30
1,3-Dichlorobenzene	mg/kg dry wt	*0.3*	<0.30	<0.30
1,4-Dichlorobenzene	mg/kg dry wt	*0.3*	<0.30	<0.30
Hexachlorobutadiene	mg/kg dry wt	*0.3*	<0.30	<0.30
Hexachlorocylopentadiene	mg/kg dry wt	*0.3*	<0.30	<0.30
Hexachloroethane	mg/kg dry wt	*0.3*	<0.30	<0.30
4-Chloroaniline	mg/kg dry wt	*1.0*	<1.0	<1.0
2-Nitroaniline	mg/kg dry wt	*0.3*	<0.30	<0.30
3-Nitroaniline	mg/kg dry wt	*0.5*	<0.50	<0.50
Aniline	mg/kg dry wt	*1.0*	<1.0	<1.0
3,3'-Dichlorobenzidine	mg/kg dry wt	*0.5*	<0.50	<0.50
Dibenzofuran	mg/kg dry wt	*0.3*	<0.30	<0.30
Methyl methanesulfonate	mg/kg dry wt	*1.0*	<1.0	<1.0
Ethyl methanesulfonate	mg/kg dry wt	*1*	<1.0	<1.0
Benzyl alcohol	mg/kg dry wt	*1*	<1.0	<1.0
Phenol-d5 (Surrogate)	%	*1*	89	90
2-Fluorophenol (Surrogate)	%	*1*	91	93
2-Fluorobiphenyl (Surrogate)	%	*1*	98	100
2,4,6-Tribromophenol (Surrogate)	%	*1*	98	120
p-Terphenyl-d14 (Surrogate)	%	*1*	96	93
Nitrobenzene-d5 (Surrogate)	%	*1*	98	98

Method Summary

Elements in Soil	Samples dried and passed through a 2 mm sieve followed by acid digestion and analysis by ICP-MS. In accordance with in-house procedure based on US EPA method 200.8.
PAH in Soil	Solvent extraction, silica cleanup, followed by GC-MS analysis. **Benzo[a]pyrene TEQ (LOR)**: The most conservative TEQ estimate, where a result is reported as less than the limit of reporting (LOR) the LOR value is used to calculate the TEQ for that PAH. **Benzo[a]pyrene TEQ (Zero)**: The least conservative TEQ estimate, PAHs reported as less than the limit of reporting (LOR) are not included in the TEQ calculation. Benzo[a]pyrene toxic equivalence (TEQ) is calculated according to *'Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health'*. Ministry for the Environment. 2011. (In accordance with in-house procedure).
TPH in Soil	Solvent extraction, silica cleanup, followed by GC-FID analysis. (C7-C36). (In accordance with in-house procedure based on US EPA 8015).
Moisture	Moisture content is determined gravimetrically by drying at 103 °C.
SVOC in Soil	Solvent extraction, followed by GC-MS analysis.(In-house based on US EPA 8270).

Thara Samarasinghe, B.Sc.
Technician

Astra Southwood
Lab Technician

Prianshv

Prianshu Chawla, B.Tech
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Certificate of Analysis

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Lab Reference:	22-40968
Submitted by:	Danny Fitzgerald
Date Received:	09/11/2022
Testing Initiated:	9/11/2022
Date Completed:	14/11/2022
Order Number:	N/A
Reference:	12547621

Sampling Site: Green Island LF
Description of Work: Soils - Green Island LF

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories. Samples were in acceptable condition unless otherwise noted on this report.
Specific testing dates are available on request.

Asbestos in Soil (Semi-Quantitative)

Sample Details

Laboratory ID	Client Sample ID	Sample Location	Sample Description	Date Sampled	Date Analysed
22-40968-1	12547621-BH-107 (0.5)	N/A	Soil	09/11/2022	14/11/2022

Information in the above table supplied by the client: Client Sample ID, Sample Location, Date Sampled

Analysis Results (Summary)

Laboratory ID	Client Sample ID	Asbestos	Sample Weight as Received	Moisture Content	Trace Asbestos (Presence / Absence)	Asbestos (Presence / Absence)
	Units		g	%		
22-40968-1	12547621-BH-107 (0.5)	Asbestos NOT Detected. Organic Fibres	1,152.0	18.2	Absent	Absent

Information in the above table supplied by the client: Client Sample ID

Analysis Results (Size Fraction Breakdown)

Laboratory ID	Client Sample ID	Fraction Size	Fraction Weight*	AF/FA Weight*	ACM Weight*	ACM Content*	Asbestos Matrix	Asbestos Weight*	W/W% Asbestos*
Units *Reporting Limit*			g 0	g 0	g 0	%		g 0	
22-40968-1	12547621-BH-107 (0.5)	>10mm	215.00	0.0000	0.0000	0	No Asbestos Detected	0.0000	<0.001 (ACM) <0.001 (AF/FA)
		2-10mm	425.50	0.0000	-	-	No Asbestos Detected	0.0000	
		<2mm	302.00	0.0000	-	-	No Asbestos Detected	0.0000	

Information in the above table supplied by the client: Client Sample ID

Asbestos in Soil (Semi-Quantitative) Approver:

Emily Wang, M.Sc.
Laboratory Technician

Method Summary

Asbestos Fibres in Soil (Semi-Quantitative)

Sample analysis was performed using polarised light microscopy with dispersion staining in accordance with AS4964-2004 Method for the qualitative identification of asbestos in soil samples.

Note 1: The reporting limit for this analysis is 0.1g/kg (0.01%) by application of polarised light microscopy, dispersion staining and trace analysis techniques.

Note 2: Trace asbestos is indicative that freely liberated respirable fibres are present and dust control measures should be implemented or increased on site. This is not the sole indicator for the friable nature of the asbestos present.

Note 3: If mineral fibres of unknown type are detected, by PLM and dispersion staining, these may or may not be asbestos fibres. To confirm the identity of this fibre, another independent analytical technique such as XRD analysis is advised.

Note 4: The laboratory does not take responsibility for the sampling procedure or accuracy of sample location description.

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Certificate of Analysis

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Lab Reference: 22-40968
Submitted by: Danny Fitzgerald
Date Received: 09/11/2022
Testing Initiated: 9/11/2022
Date Completed: 14/11/2022
Order Number: N/A
Reference: 12547621

Sampling Site: Green Island LF
Description of Work: Soils - Green Island LF

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories. Samples were in acceptable condition unless otherwise noted on this report.
Specific testing dates are available on request.

Asbestos in Soil (Qualitative)

Sample Details

Laboratory ID	Client Sample ID	Sample Location	Sample Description	Date Sampled	Date Analysed
22-40968-2	12547621-BH-108 (0.5)	N/A	Soil	09/11/2022	14/11/2022
22-40968-3	12547621-BH-108 (1.9)	N/A	Soil	09/11/2022	14/11/2022
22-40968-4	12547621-BH-108 (3.3)	N/A	Soil	09/11/2022	14/11/2022
22-40968-5	12547621-BH-104 (0.5)	N/A	Soil	09/11/2022	14/11/2022
22-40968-6	12547621-BH-104 (1.0)	N/A	Soil	09/11/2022	14/11/2022
22-40968-7	12547621-BH-104 (2.0)	N/A	Soil	09/11/2022	14/11/2022

Information in the above table supplied by the client: Client Sample ID, Sample Location, Date Sampled.

Laboratory ID	Client Sample ID	Fibre Types	Trace Asbestos (Presence / Absence)	Asbestos (Presence / Absence)
	Units			
22-40968-2	12547621-BH-108 (0.5)	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40968-3	12547621-BH-108 (1.9)	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40968-4	12547621-BH-108 (3.3)	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40968-5	12547621-BH-104 (0.5)	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40968-6	12547621-BH-104 (1.0)	Asbestos NOT Detected. Organic Fibres	Absent	Absent
22-40968-7	12547621-BH-104 (2.0)	Asbestos NOT Detected. Organic Fibres	Absent	Absent

Information in the above table supplied by the client: Client Sample ID.

Asbestos in Soil (Qualitative) Approver:

Emily Wang, M.Sc.
Laboratory Technician

Method Summary

Asbestos Fibres in Soil (Qualitative)	Sample analysis was performed using polarised light microscopy with dispersion staining in accordance with AS4964-2004 Method for the qualitative identification of asbestos in bulk samples. Note 1: The reporting limit for this analysis is 0.1g/kg (0.01%) by application of polarised light microscopy, dispersion staining and trace analysis techniques. Note 2: Trace asbestos is indicative that freely liberated respirable fibres are present and dust control measures should be implemented or increased on site. This is not the sole indicator for the friable nature of the asbestos present. Note 3: If mineral fibres of unknown type are detected, by PLM and dispersion staining, these may or may not be asbestos fibres. To confirm the identity of this fibre, another independent analytical technique such as XRD analysis is advised. Note 4: The laboratory does not take responsibility for the sampling procedure or accuracy of sample location description.

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Certificate of Analysis

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Attention: Cecilia Gately
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Lab Reference: 22-41184
Submitted by: Danny FitzGerald
Date Received: 10/11/2022
Testing Initiated: 11/11/2022
Date Completed: 16/11/2022
Order Number:
Reference: 12547621

Sampling Site: Green Island LF

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories. Samples were in acceptable condition unless otherwise noted on this report.
Specific testing dates are available on request.

Heavy Metals in Soil

		Client Sample ID	12547621 - BH - 108 0.5	12547621 - BH - 108 1.9	12547621 - BH - 108 3.3	12547621 - DUP-2	12547621 - BH - 104 0.5
		Date Sampled	09/11/2022	09/11/2022	09/11/2022	09/11/2022	09/11/2022
Analyte	Unit	*Reporting Limit*	22-41184-1	22-41184-2	22-41184-3	22-41184-4	22-41184-5
Arsenic	mg/kg dry wt	*0.125*	2.4	7.2	9.1	7.1	7.7
Beryllium	mg/kg dry wt	*0.013*	0.48	1.42	3.15	1.33	1.79
Boron	mg/kg dry wt	*1.25*	1.3	7.6	40	7.9	3.4
Cadmium	mg/kg dry wt	*0.005*	0.0056	0.16	0.42	0.16	0.15
Chromium	mg/kg dry wt	*0.125*	11	50.1	34.7	49.4	46.6
Copper	mg/kg dry wt	*0.075*	3.3	20.9	54.2	20.8	38.3
Lead	mg/kg dry wt	*0.25*	11.7	52.9	316	42.8	70.7
Mercury	mg/kg dry wt	*0.025*	<0.025	0.28	0.21	0.27	0.078
Nickel	mg/kg dry wt	*0.05*	3.9	38.0	31.6	35.9	35.8
Zinc	mg/kg dry wt	*0.05*	20.3	124	303	121	115

Heavy Metals in Soil

		Client Sample ID	12547621 - BH - 104 1.0	12547621 - BH - 104 2.0
		Date Sampled	09/11/2022	09/11/2022
Analyte	Unit	*Reporting Limit*	22-41184-6	22-41184-7
Arsenic	mg/kg dry wt	*0.125*	4.1	8.9
Beryllium	mg/kg dry wt	*0.013*	0.91	0.81
Boron	mg/kg dry wt	*1.25*	2.5	11
Cadmium	mg/kg dry wt	*0.005*	0.070	0.12

Heavy Metals in Soil

Client Sample ID			12547621 - BH - 104 1.0	12547621 - BH - 104 2.0
Date Sampled			09/11/2022	09/11/2022
Chromium	mg/kg dry wt	*0.125*	27.3	27.6
Copper	mg/kg dry wt	*0.075*	18.0	16.9
Lead	mg/kg dry wt	*0.25*	26.9	16.5
Mercury	mg/kg dry wt	*0.025*	0.033	0.039
Nickel	mg/kg dry wt	*0.05*	19.3	18.9
Zinc	mg/kg dry wt	*0.05*	68.1	68.3

Polycyclic Aromatic Hydrocarbons - Soil

Client Sample ID			12547621 - BH - 108 0.5	12547621 - BH - 108 1.9	12547621 - BH - 108 3.3	12547621 - DUP-2	12547621 - BH - 104 0.5
Date Sampled			09/11/2022	09/11/2022	09/11/2022	09/11/2022	09/11/2022
Analyte	Unit	*Reporting Limit*	22-41184-1	22-41184-2	22-41184-3	22-41184-4	22-41184-5
1-Methylnaphthalene	mg/kg dry wt	*0.01*	<0.010	<0.010	0.046	<0.010	2.1
2-Methylnaphthalene	mg/kg dry wt	*0.01*	<0.010	<0.010	0.051	0.011	1.7
Acenaphthene	mg/kg dry wt	*0.01*	<0.010	<0.010	0.033	0.026	12
Acenaphthylene	mg/kg dry wt	*0.01*	<0.010	0.031	0.055	0.14	53
Anthracene	mg/kg dry wt	*0.01*	<0.010	0.054	0.16	1.5	93
Benz[a]anthracene	mg/kg dry wt	*0.02*	<0.020	0.22	0.73	4.6	320
Benzo[a]pyrene	mg/kg dry wt	*0.01*	<0.010	0.35	0.75	2.7	290
Benzo[b]&[j] fluoranthene	mg/kg dry wt	*0.02*	<0.020	0.37	1.1	4.0	500
Benzo[g,h,i]perylene	mg/kg dry wt	*0.02*	<0.020	0.21	0.43	1.2	170
Benzo[k]fluoranthene	mg/kg dry wt	*0.01*	<0.010	0.18	0.55	1.8	220
Chrysene	mg/kg dry wt	*0.01*	<0.010	0.38	0.92	3.7	320
Dibenz(a,h)anthracene	mg/kg dry wt	*0.01*	<0.010	0.040	0.12	0.43	50
Fluoranthene	mg/kg dry wt	*0.02*	<0.020	0.42	1.1	5.4	420
Fluorene	mg/kg dry wt	*0.01*	<0.010	0.017	0.082	0.30	23
Indeno(1,2,3-cd)pyrene	mg/kg dry wt	*0.01*	<0.010	0.21	0.48	1.5	220
Naphthalene	mg/kg dry wt	*0.01*	<0.010	<0.010	0.077	0.017	2.3
Phenanthrene	mg/kg dry wt	*0.01*	<0.010	0.15	0.58	4.8	220
Pyrene	mg/kg dry wt	*0.02*	<0.020	0.45	1.2	4.9	380
Benzo[a]pyrene TEQ (LOR)	mg/kg dry wt	*0.03*	0.030	0.49	1.2	4.4	470
Benzo[a]pyrene TEQ (Zero)	mg/kg dry wt	*0.01*	<0.010	0.49	1.2	4.4	470
Anthracene-d10 (Surrogate)	%	*1*	95	99	110	120	110

Polycyclic Aromatic Hydrocarbons - Soil

Client Sample ID			12547621 - BH - 104 1.0	12547621 - BH - 104 2.0
Date Sampled			09/11/2022	09/11/2022
Analyte	Unit	*Reporting Limit*	22-41184-6	22-41184-7
1-Methylnaphthalene	mg/kg dry wt	*0.01*	0.014	0.012
2-Methylnaphthalene	mg/kg dry wt	*0.01*	0.021	0.015
Acenaphthene	mg/kg dry wt	*0.01*	0.010	0.019
Acenaphthylene	mg/kg dry wt	*0.01*	0.011	0.027
Anthracene	mg/kg dry wt	*0.01*	0.015	0.12
Benz[a]anthracene	mg/kg dry wt	*0.02*	0.039	0.28
Benzo[a]pyrene	mg/kg dry wt	*0.01*	0.058	0.32

Polycyclic Aromatic Hydrocarbons - Soil

Client Sample ID			12547621 - BH - 104 1.0	12547621 - BH - 104 2.0
Date Sampled			09/11/2022	09/11/2022
Benzo[b]&[j] fluoranthene	mg/kg dry wt	*0.02*	0.058	0.33
Benzo[g,h,i]perylene	mg/kg dry wt	*0.02*	0.026	0.14
Benzo[k]fluoranthene	mg/kg dry wt	*0.01*	0.028	0.17
Chrysene	mg/kg dry wt	*0.01*	0.059	0.41
Dibenz(a,h)anthracene	mg/kg dry wt	*0.01*	<0.010	0.032
Fluoranthene	mg/kg dry wt	*0.02*	0.076	0.65
Fluorene	mg/kg dry wt	*0.01*	0.015	0.050
Indeno(1,2,3-cd)pyrene	mg/kg dry wt	*0.01*	0.029	0.16
Naphthalene	mg/kg dry wt	*0.01*	0.083	0.19
Phenanthrene	mg/kg dry wt	*0.01*	0.032	0.43
Pyrene	mg/kg dry wt	*0.02*	0.083	0.63
Benzo[a]pyrene TEQ (LOR)	mg/kg dry wt	*0.03*	0.080	0.46
Benzo[a]pyrene TEQ (Zero)	mg/kg dry wt	*0.01*	0.070	0.46
Anthracene-d10 (Surrogate)	%	*1*	100	110

Moisture Content

Client Sample ID			12547621 - BH - 108 0.5	12547621 - BH - 108 1.9	12547621 - BH - 108 3.3	12547621 - DUP-2	12547621 - BH - 104 0.5
Date Sampled			09/11/2022	09/11/2022	09/11/2022	09/11/2022	09/11/2022
Analyte	Unit	*Reporting Limit*	22-41184-1	22-41184-2	22-41184-3	22-41184-4	22-41184-5
Moisture Content	%	*1*	19	23	15	24	19

Moisture Content

Client Sample ID			12547621 - BH - 104 1.0	12547621 - BH - 104 2.0
Date Sampled			09/11/2022	09/11/2022
Analyte	Unit	*Reporting Limit*	22-41184-6	22-41184-7
Moisture Content	%	*1*	19	26

Method Summary

Elements in Soil	Samples dried and passed through a 2 mm sieve followed by acid digestion and analysis by ICP-MS. In accordance with in-house procedure based on US EPA method 200.8.
PAH in Soil	Solvent extraction, silica cleanup, followed by GC-MS analysis. **Benzo[a]pyrene TEQ (LOR)**: The most conservative TEQ estimate, where a result is reported as less than the limit of reporting (LOR) the LOR value is used to calculate the TEQ for that PAH. **Benzo[a]pyrene TEQ (Zero)**: The least conservative TEQ estimate, PAHs reported as less than the limit of reporting (LOR) are not included in the TEQ calculation. Benzo[a]pyrene toxic equivalence (TEQ) is calculated according to *'Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health'*. Ministry for the Environment. 2011. (In accordance with in-house procedure).
Moisture	Moisture content is determined gravimetrically by drying at 103 °C.

Jarred Wilson, DipSci
Trace Elements Team Leader

Astra Southwood
Lab Technician

Prianshu Chawla, B.Tech
Technologist

Brent Boynes
Lab Technician

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Certificate of Analysis

GHD Ltd
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Dunedin 9016

Attention: Cecilia Gately
Phone: 021 973 994
Email: danny.fitzgerald@ghd.com

Sampling Site: Green Island Landfill

Lab Reference: 22-42925
Submitted by: Danny Fitzgerald
Date Received: 24/11/2022
Testing Initiated: 24/11/2022
Date Completed: 29/11/2022
Order Number:
Reference: 12547621

Report Comments

Samples were collected by yourselves (or your agent) and analysed as received at Analytica Laboratories. Samples were in acceptable condition unless otherwise noted on this report.
Specific testing dates are available on request.

Polycyclic Aromatic Hydrocarbons - Soil

		Client Sample ID	12547621-BH-107 2.5	12547621-BH-103 0.2	12547621-BH-103 1.2	12547621-BH-102 1.5	12547621-BH-102 2.5
		Date Sampled	01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-42925-1	22-42925-2	22-42925-3	22-42925-4	22-42925-5
1-Methylnaphthalene	mg/kg dry wt	*0.01*	0.028	<0.010	<0.010	<0.010	<0.010
2-Methylnaphthalene	mg/kg dry wt	*0.01*	0.027	<0.010	<0.010	<0.010	<0.010
Acenaphthene	mg/kg dry wt	*0.01*	0.033	<0.010	<0.010	<0.010	<0.010
Acenaphthylene	mg/kg dry wt	*0.01*	0.067	0.017	0.028	<0.010	<0.010
Anthracene	mg/kg dry wt	*0.01*	0.20	0.020	0.020	<0.010	<0.010
Benz[a]anthracene	mg/kg dry wt	*0.02*	0.53	0.092	0.14	0.023	<0.020
Benzo[a]pyrene	mg/kg dry wt	*0.01*	0.74	0.12	0.23	0.043	<0.010
Benzo[b]&[j] fluoranthene	mg/kg dry wt	*0.02*	0.73	0.12	0.27	0.054	<0.020
Benzo[g,h,i]perylene	mg/kg dry wt	*0.02*	0.26	0.064	0.13	0.028	<0.020
Benzo[k]fluoranthene	mg/kg dry wt	*0.01*	0.26	0.044	0.091	0.015	<0.010
Chrysene	mg/kg dry wt	*0.01*	0.52	0.095	0.20	0.038	<0.010
Dibenz(a,h)anthracene	mg/kg dry wt	*0.01*	0.061	0.012	0.023	<0.010	<0.010
Fluoranthene	mg/kg dry wt	*0.02*	1.5	0.17	0.31	0.055	<0.020
Fluorene	mg/kg dry wt	*0.01*	0.083	<0.010	<0.010	<0.010	<0.010
Indeno(1,2,3-cd)pyrene	mg/kg dry wt	*0.01*	0.35	0.082	0.17	0.037	<0.010
Naphthalene	mg/kg dry wt	*0.01*	0.053	<0.010	<0.010	<0.010	<0.010
Phenanthrene	mg/kg dry wt	*0.01*	0.58	0.057	0.083	0.015	<0.010
Pyrene	mg/kg dry wt	*0.02*	1.4	0.17	0.32	0.060	<0.020
Benzo[a]pyrene TEQ (LOR)	mg/kg dry wt	*0.03*	1.0	0.17	0.32	0.070	0.030
Benzo[a]pyrene TEQ (Zero)	mg/kg dry wt	*0.01*	1.0	0.17	0.32	0.060	<0.010

Polycyclic Aromatic Hydrocarbons - Soil

Client Sample ID			12547621-BH-107 2.5	12547621-BH-103 0.2	12547621-BH-103 1.2	12547621-BH-102 1.5	12547621-BH-102 2.5
Date Sampled			01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Anthracene-d10 (Surrogate)	%	*1*	100	110	110	110	100

Moisture Content

Client Sample ID			12547621-BH-107 2.5	12547621-BH-103 0.2	12547621-BH-103 1.2	12547621-BH-102 1.5	12547621-BH-102 2.5
Date Sampled			01/11/2022	01/11/2022	01/11/2022	01/11/2022	01/11/2022
Analyte	Unit	*Reporting Limit*	22-42925-1	22-42925-2	22-42925-3	22-42925-4	22-42925-5
Moisture Content	%	*1*	21	23	53	48	27

Method Summary

PAH in Soil	Solvent extraction, silica cleanup, followed by GC-MS analysis. **Benzo[a]pyrene TEQ (LOR)**: The most conservative TEQ estimate, where a result is reported as less than the limit of reporting (LOR) the LOR value is used to calculate the TEQ for that PAH. **Benzo[a]pyrene TEQ (Zero)**: The least conservative TEQ estimate, PAHs reported as less than the limit of reporting (LOR) are not included in the TEQ calculation. Benzo[a]pyrene toxic equivalence (TEQ) is calculated according to *'Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health'*. Ministry for the Environment. 2011. (In accordance with in-house procedure).
Moisture	Moisture content is determined gravimetrically by drying at 103 °C.

Prianshu Chawla, B.Tech
Technologist

Brent Boynes
Lab Technician

Environment Testing

Certificate of Analysis

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

Analytica Laboratories LTD
10 Bisley Road
Hamilton
New Zealand 3214

Attention:	**Customer Service**
Report	**938712-S**
Project name	
Project ID	22-40179
Received Date	Nov 08, 2022

Client Sample ID			**22-40179-1**	**22-40179-2**	**22-40179-3**	**22-40179-4**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015975**	**K22-No0015976**	**K22-No0015977**	**K22-No0015978**
Date Sampled			**Nov 02, 2022**	**Nov 02, 2022**	**Nov 02, 2022**	**Nov 02, 2022**
Test/Reference	LOR	Unit				
Polycyclic Aromatic Hydrocarbons (NZ MfE)						
Acenaphthene	0.03	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03
Acenaphthylene	0.03	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03
Anthracene	0.03	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03
Benz(a)anthracene	0.03	mg/kg	0.07	0.06	< 0.03	< 0.03
Benzo(a)pyrene	0.03	mg/kg	0.06	0.05	< 0.03	< 0.03
Benzo(a)pyrene TEQ (lower bound)*	0.03	mg/kg	0.07	0.07	< 0.03	< 0.03
Benzo(a)pyrene TEQ (medium bound)*	0.03	mg/kg	0.09	0.09	0.04	0.04
Benzo(a)pyrene TEQ (upper bound)*	0.03	mg/kg	0.11	0.10	0.08	0.08
Benzo(b&j)fluoranthene^{N07}	0.03	mg/kg	0.04	0.06	< 0.03	< 0.03
Benzo(g.h.i)perylene	0.03	mg/kg	< 0.03	0.06	< 0.03	< 0.03
Benzo(k)fluoranthene	0.03	mg/kg	< 0.03	0.06	< 0.03	< 0.03
Chrysene	0.03	mg/kg	0.09	0.09	< 0.03	< 0.03
Dibenz(a.h)anthracene	0.03	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03
Fluoranthene	0.03	mg/kg	0.11	0.11	< 0.03	< 0.03
Fluorene	0.03	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03
Indeno(1.2.3-cd)pyrene	0.03	mg/kg	< 0.03	0.03	< 0.03	< 0.03
Naphthalene	0.1	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1
Phenanthrene	0.03	mg/kg	0.07	0.05	< 0.03	< 0.03
Pyrene	0.03	mg/kg	0.13	0.11	< 0.03	< 0.03
p-Terphenyl-d14 (surr.)	1	%	83	79	73	77
2-Fluorobiphenyl (surr.)	1	%	76	68	62	61
Semivolatile Organics						
1-Chloronaphthalene	0.5	mg/kg	< 0.5	< 0.5	-	-
1-Naphthylamine	0.5	mg/kg	< 0.5	< 0.5	-	-
1.2-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
1.2.3-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
1.2.3.4-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
1.2.3.5-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
1.2.4-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
1.2.4.5-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
1.3-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
1.3.5-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
1.4-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
2-Chloronaphthalene	0.5	mg/kg	< 0.5	< 0.5	-	-
2-Chlorophenol	0.5	mg/kg	< 0.5	< 0.5	-	-

Client Sample ID			22-40179-1	22-40179-2	22-40179-3	22-40179-4
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015975**	**K22-No0015976**	**K22-No0015977**	**K22-No0015978**
Date Sampled			Nov 02, 2022	Nov 02, 2022	Nov 02, 2022	Nov 02, 2022
Test/Reference	LOR	Unit				
Semivolatile Organics						
2-Fluorobiphenyl (surr.)	1	%	76	68	-	-
2-Methyl-4.6-dinitrophenol	5	mg/kg	< 5	< 5	-	-
2-Methylnaphthalene	0.5	mg/kg	< 0.5	< 0.5	-	-
2-Methylphenol (o-Cresol)	0.2	mg/kg	< 0.2	< 0.2	-	-
2-Naphthylamine	0.5	mg/kg	< 0.5	< 0.5	-	-
2-Nitroaniline	0.5	mg/kg	< 0.5	< 0.5	-	-
2-Nitrophenol	1	mg/kg	< 1	< 1	-	-
2-Picoline	0.5	mg/kg	< 0.5	< 0.5	-	-
2.3.4.6-Tetrachlorophenol	5	mg/kg	< 5	< 5	-	-
2.4-Dichlorophenol	0.5	mg/kg	< 0.5	< 0.5	-	-
2.4-Dimethylphenol	0.5	mg/kg	< 0.5	< 0.5	-	-
2.4-Dinitrophenol	5	mg/kg	< 5	< 5	-	-
2.4-Dinitrotoluene	0.5	mg/kg	< 0.5	< 0.5	-	-
2.4.5-Trichlorophenol	1	mg/kg	< 1	< 1	-	-
2.4.6-Tribromophenol (surr.)	1	%	92	85	-	-
2.4.6-Trichlorophenol	1	mg/kg	< 1	< 1	-	-
2.6-Dichlorophenol	0.5	mg/kg	< 0.5	< 0.5	-	-
2.6-Dinitrotoluene	0.5	mg/kg	< 0.5	< 0.5	-	-
3&4-Methylphenol (m&p-Cresol)	0.4	mg/kg	< 0.4	< 0.4	-	-
3-Methylcholanthrene	0.5	mg/kg	< 0.5	< 0.5	-	-
3.3'-Dichlorobenzidine	0.5	mg/kg	< 0.5	< 0.5	-	-
4-Aminobiphenyl	0.5	mg/kg	< 0.5	< 0.5	-	-
4-Bromophenyl phenyl ether	0.5	mg/kg	< 0.5	< 0.5	-	-
4-Chloro-3-methylphenol	1	mg/kg	< 1	< 1	-	-
4-Chlorophenyl phenyl ether	0.5	mg/kg	< 0.5	< 0.5	-	-
4-Nitrophenol	5	mg/kg	< 5	< 5	-	-
4.4'-DDD	0.01	mg/kg	< 0.01	< 0.01	-	-
4.4'-DDE	0.01	mg/kg	< 0.01	< 0.01	-	-
4.4'-DDT	0.01	mg/kg	< 0.01	< 0.01	-	-
7.12-Dimethylbenz(a)anthracene	0.5	mg/kg	< 0.5	< 0.5	-	-
a-HCH	0.01	mg/kg	< 0.01	< 0.01	-	-
Acenaphthene	0.03	mg/kg	< 0.03	< 0.03	-	-
Acenaphthylene	0.03	mg/kg	< 0.03	< 0.03	-	-
Acetophenone	0.5	mg/kg	< 0.5	< 0.5	-	-
Aldrin	0.01	mg/kg	< 0.01	< 0.01	-	-
Aniline	0.5	mg/kg	< 0.5	< 0.5	-	-
Anthracene	0.03	mg/kg	< 0.03	< 0.03	-	-
b-HCH	0.01	mg/kg	< 0.01	< 0.01	-	-
Benz(a)anthracene	0.03	mg/kg	0.07	0.06	-	-
Benzo(a)pyrene	0.03	mg/kg	0.06	0.05	-	-
Benzo(a)pyrene TEQ (lower bound)*	0.03	mg/kg	0.07	0.07	-	-
Benzo(a)pyrene TEQ (medium bound)*	0.03	mg/kg	0.09	0.09	-	-
Benzo(a)pyrene TEQ (upper bound)*	0.03	mg/kg	0.11	0.10	-	-
Benzo(b&j)fluoranthene^{N07}	0.03	mg/kg	0.04	0.06	-	-
Benzo(g.h.i)perylene	0.03	mg/kg	< 0.03	0.06	-	-
Benzo(k)fluoranthene	0.03	mg/kg	< 0.03	0.06	-	-
Benzyl chloride	0.5	mg/kg	< 0.5	< 0.5	-	-
Bis(2-chloroethoxy)methane	0.5	mg/kg	< 0.5	< 0.5	-	-
Bis(2-chloroisopropyl)ether	0.5	mg/kg	< 0.5	< 0.5	-	-

Client Sample ID			22-40179-1	22-40179-2	22-40179-3	22-40179-4
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015975**	**K22-No0015976**	**K22-No0015977**	**K22-No0015978**
Date Sampled			Nov 02, 2022	Nov 02, 2022	Nov 02, 2022	Nov 02, 2022
Test/Reference	LOR	Unit				
Semivolatile Organics						
Bis(2-ethylhexyl)phthalate	0.5	mg/kg	< 0.5	< 0.5	-	-
Butyl benzyl phthalate	0.5	mg/kg	< 0.5	< 0.5	-	-
Chrysene	0.03	mg/kg	0.09	0.09	-	-
d-HCH	0.01	mg/kg	< 0.01	< 0.01	-	-
Di-n-butyl phthalate	0.5	mg/kg	< 0.5	< 0.5	-	-
Di-n-octyl phthalate	0.5	mg/kg	< 0.5	< 0.5	-	-
Dibenz(a.h)anthracene	0.03	mg/kg	< 0.03	< 0.03	-	-
Dibenz(a.j)acridine	0.5	mg/kg	< 0.5	< 0.5	-	-
Dibenzofuran	0.5	mg/kg	< 0.5	< 0.5	-	-
Dieldrin	0.01	mg/kg	< 0.01	< 0.01	-	-
Diethyl phthalate	0.5	mg/kg	< 0.5	< 0.5	-	-
Dimethyl phthalate	0.5	mg/kg	< 0.5	< 0.5	-	-
Dimethylaminoazobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
Diphenylamine	0.5	mg/kg	< 0.5	< 0.5	-	-
Endosulfan I	0.01	mg/kg	< 0.01	< 0.01	-	-
Endosulfan II	0.01	mg/kg	< 0.01	< 0.01	-	-
Endosulfan sulphate	0.01	mg/kg	< 0.01	< 0.01	-	-
Endrin	0.01	mg/kg	< 0.01	< 0.01	-	-
Endrin aldehyde	0.01	mg/kg	< 0.01	< 0.01	-	-
Endrin ketone	0.01	mg/kg	< 0.01	< 0.01	-	-
Fluoranthene	0.03	mg/kg	0.11	0.11	-	-
Fluorene	0.03	mg/kg	< 0.03	< 0.03	-	-
g-HCH (Lindane)	0.01	mg/kg	< 0.01	< 0.01	-	-
Heptachlor	0.01	mg/kg	< 0.01	< 0.01	-	-
Heptachlor epoxide	0.01	mg/kg	< 0.01	< 0.01	-	-
Hexachlorobenzene	0.01	mg/kg	< 0.01	< 0.01	-	-
Hexachlorobutadiene	0.5	mg/kg	< 0.5	< 0.5	-	-
Hexachlorocyclopentadiene	0.5	mg/kg	< 0.5	< 0.5	-	-
Hexachloroethane	0.5	mg/kg	< 0.5	< 0.5	-	-
Indeno(1.2.3-cd)pyrene	0.03	mg/kg	< 0.03	0.03	-	-
Methoxychlor	0.01	mg/kg	< 0.01	< 0.01	-	-
N-Nitrosodibutylamine	0.5	mg/kg	< 0.5	< 0.5	-	-
N-Nitrosodipropylamine	0.5	mg/kg	< 0.5	< 0.5	-	-
N-Nitrosopiperidine	0.5	mg/kg	< 0.5	< 0.5	-	-
Naphthalene	0.1	mg/kg	< 0.1	< 0.1	-	-
Nitrobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
Nitrobenzene-d5 (surr.)	1	%	89	81	-	-
Pentachlorobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
Pentachloronitrobenzene	0.5	mg/kg	< 0.5	< 0.5	-	-
Pentachlorophenol	1	mg/kg	< 1	< 1	-	-
Phenanthrene	0.03	mg/kg	0.07	0.05	-	-
Phenol	0.5	mg/kg	< 0.5	< 0.5	-	-
Phenol-d6 (surr.)	1	%	70	69	-	-
Pronamide	0.5	mg/kg	< 0.5	< 0.5	-	-
Pyrene	0.03	mg/kg	0.13	0.11	-	-
Trifluralin	0.5	mg/kg	< 0.5	< 0.5	-	-
% Moisture	1	%	30	35	24	29

Client Sample ID			22-40179-5	22-40179-6	22-40179-7	22-40179-8
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015979**	**K22-No0015980**	**K22-No0015981**	**K22-No0015982**
Date Sampled			Nov 02, 2022	Nov 02, 2022	Nov 02, 2022	Nov 02, 2022
Test/Reference	LOR	Unit				
Polycyclic Aromatic Hydrocarbons (NZ MfE)						
Acenaphthene	0.03	mg/kg	< 0.03	0.61	-	-
Acenaphthylene	0.03	mg/kg	< 0.03	0.43	-	-
Anthracene	0.03	mg/kg	0.07	3.1	-	-
Benz(a)anthracene	0.03	mg/kg	0.48	5.4	-	-
Benzo(a)pyrene	0.03	mg/kg	0.58	4.5	-	-
Benzo(a)pyrene TEQ (lower bound)*	0.03	mg/kg	0.79	6.4	-	-
Benzo(a)pyrene TEQ (medium bound)*	0.03	mg/kg	0.79	6.4	-	-
Benzo(a)pyrene TEQ (upper bound)*	0.03	mg/kg	0.79	6.4	-	-
Benzo(b&j)fluoranthene[N07]	0.03	mg/kg	0.30	4.0	-	-
Benzo(g.h.i)perylene	0.03	mg/kg	0.25	0.67	-	-
Benzo(k)fluoranthene	0.03	mg/kg	0.26	3.2	-	-
Chrysene	0.03	mg/kg	0.54	4.4	-	-
Dibenz(a.h)anthracene	0.03	mg/kg	0.07	0.35	-	-
Fluoranthene	0.03	mg/kg	0.67	13	-	-
Fluorene	0.03	mg/kg	< 0.03	1.2	-	-
Indeno(1.2.3-cd)pyrene	0.03	mg/kg	0.23	1.0	-	-
Naphthalene	0.1	mg/kg	< 0.1	0.5	-	-
Phenanthrene	0.03	mg/kg	0.10	8.7	-	-
Pyrene	0.03	mg/kg	0.81	13	-	-
p-Terphenyl-d14 (surr.)	1	%	74	79	-	-
2-Fluorobiphenyl (surr.)	1	%	65	71	-	-
Semivolatile Organics						
1-Chloronaphthalene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1-Naphthylamine	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.2-Dichlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.2.3-Trichlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.2.3.4-Tetrachlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.2.3.5-Tetrachlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.2.4-Trichlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.2.4.5-Tetrachlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.3-Dichlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.3.5-Trichlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
1.4-Dichlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2-Chloronaphthalene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2-Chlorophenol	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2-Fluorobiphenyl (surr.)	1	%	-	71	INT	56
2-Methyl-4.6-dinitrophenol	5	mg/kg	-	< 5	< 5	< 5
2-Methylnaphthalene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2-Methylphenol (o-Cresol)	0.2	mg/kg	-	< 0.2	< 0.2	< 0.2
2-Naphthylamine	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2-Nitroaniline	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2-Nitrophenol	1	mg/kg	-	< 1	< 1	< 1
2-Picoline	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2.3.4.6-Tetrachlorophenol	5	mg/kg	-	< 5	< 5	< 5
2.4-Dichlorophenol	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2.4-Dimethylphenol	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2.4-Dinitrophenol	5	mg/kg	-	< 5	< 5	< 5
2.4-Dinitrotoluene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2.4.5-Trichlorophenol	1	mg/kg	-	< 1	< 1	< 1

Client Sample ID			22-40179-5	22-40179-6	22-40179-7	22-40179-8
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015979**	**K22-No0015980**	**K22-No0015981**	**K22-No0015982**
Date Sampled			Nov 02, 2022	Nov 02, 2022	Nov 02, 2022	Nov 02, 2022
Test/Reference	LOR	Unit				
Semivolatile Organics						
2.4.6-Tribromophenol (surr.)	1	%	-	93	71	53
2.4.6-Trichlorophenol	1	mg/kg	-	< 1	< 1	< 1
2.6-Dichlorophenol	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
2.6-Dinitrotoluene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
3&4-Methylphenol (m&p-Cresol)	0.4	mg/kg	-	< 0.4	< 0.4	< 0.4
3-Methylcholanthrene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
3.3'-Dichlorobenzidine	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
4-Aminobiphenyl	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
4-Bromophenyl phenyl ether	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
4-Chloro-3-methylphenol	1	mg/kg	-	< 1	< 1	< 1
4-Chlorophenyl phenyl ether	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
4-Nitrophenol	5	mg/kg	-	< 5	< 5	< 5
4.4'-DDD	0.01	mg/kg	-	0.01	0.01	0.04
4.4'-DDE	0.01	mg/kg	-	< 0.01	< 0.01	0.04
4.4'-DDT	0.01	mg/kg	-	< 0.01	< 0.01	0.13
7.12-Dimethylbenz(a)anthracene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
a-HCH	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Acenaphthene	0.03	mg/kg	-	0.61	< 0.03	< 0.03
Acenaphthylene	0.03	mg/kg	-	0.43	< 0.03	< 0.03
Acetophenone	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Aldrin	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Aniline	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Anthracene	0.03	mg/kg	-	3.1	0.12	< 0.03
b-HCH	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Benz(a)anthracene	0.03	mg/kg	-	5.4	0.22	0.08
Benzo(a)pyrene	0.03	mg/kg	-	4.5	0.28	0.09
Benzo(a)pyrene TEQ (lower bound)*	0.03	mg/kg	-	6.4	0.36	0.12
Benzo(a)pyrene TEQ (medium bound)*	0.03	mg/kg	-	6.4	0.37	0.13
Benzo(a)pyrene TEQ (upper bound)*	0.03	mg/kg	-	6.4	0.39	0.15
Benzo(b&j)fluoranthene^{N07}	0.03	mg/kg	-	4.0	0.22	0.05
Benzo(g.h.i)perylene	0.03	mg/kg	-	0.67	0.13	0.08
Benzo(k)fluoranthene	0.03	mg/kg	-	3.2	0.15	0.06
Benzyl chloride	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Bis(2-chloroethoxy)methane	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Bis(2-chloroisopropyl)ether	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Bis(2-ethylhexyl)phthalate	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Butyl benzyl phthalate	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Chrysene	0.03	mg/kg	-	4.4	0.24	0.12
d-HCH	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Di-n-butyl phthalate	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Di-n-octyl phthalate	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Dibenz(a.h)anthracene	0.03	mg/kg	-	0.35	< 0.03	< 0.03
Dibenz(a.j)acridine	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Dibenzofuran	0.5	mg/kg	-	0.5	< 0.5	< 0.5
Dieldrin	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Diethyl phthalate	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Dimethyl phthalate	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Dimethylaminoazobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Diphenylamine	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5

Client Sample ID			22-40179-5	22-40179-6	22-40179-7	22-40179-8
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015979**	**K22-No0015980**	**K22-No0015981**	**K22-No0015982**
Date Sampled			Nov 02, 2022	Nov 02, 2022	Nov 02, 2022	Nov 02, 2022
Test/Reference	LOR	Unit				
Semivolatile Organics						
Endosulfan I	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Endosulfan II	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Endosulfan sulphate	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Endrin	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Endrin aldehyde	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Endrin ketone	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Fluoranthene	0.03	mg/kg	-	13	0.51	0.14
Fluorene	0.03	mg/kg	-	1.2	0.05	< 0.03
g-HCH (Lindane)	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Heptachlor	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Heptachlor epoxide	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Hexachlorobenzene	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
Hexachlorobutadiene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Hexachlorocyclopentadiene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Hexachloroethane	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Indeno(1.2.3-cd)pyrene	0.03	mg/kg	-	1.0	0.12	0.05
Methoxychlor	0.01	mg/kg	-	< 0.01	< 0.01	< 0.01
N-Nitrosodibutylamine	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
N-Nitrosodipropylamine	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
N-Nitrosopiperidine	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Naphthalene	0.1	mg/kg	-	0.5	< 0.1	< 0.1
Nitrobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Nitrobenzene-d5 (surr.)	1	%	-	62	INT	61
Pentachlorobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Pentachloronitrobenzene	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Pentachlorophenol	1	mg/kg	-	< 1	< 1	< 1
Phenanthrene	0.03	mg/kg	-	8.7	0.31	0.04
Phenol	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Phenol-d6 (surr.)	1	%	-	57	51	57
Pronamide	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
Pyrene	0.03	mg/kg	-	13	0.53	0.13
Trifluralin	0.5	mg/kg	-	< 0.5	< 0.5	< 0.5
% Moisture	1	%	31	8.9	22	22

Client Sample ID			22-40179-9	22-40179-12	22-40179-13	22-40179-14
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015983**	**K22-No0015984**	**K22-No0015985**	**K22-No0015986**
Date Sampled			Nov 02, 2022	Nov 02, 2022	Nov 02, 2022	Nov 02, 2022
Test/Reference	LOR	Unit				
Polycyclic Aromatic Hydrocarbons (NZ MfE)						
Acenaphthene	0.03	mg/kg	-	< 0.03	< 0.03	< 0.03
Acenaphthylene	0.03	mg/kg	-	0.04	< 0.03	< 0.03
Anthracene	0.03	mg/kg	-	0.04	< 0.03	< 0.03
Benz(a)anthracene	0.03	mg/kg	-	0.17	< 0.03	0.10
Benzo(a)pyrene	0.03	mg/kg	-	0.23	< 0.03	0.10
Benzo(a)pyrene TEQ (lower bound)*	0.03	mg/kg	-	0.29	< 0.03	0.13

Client Sample ID			22-40179-9	22-40179-12	22-40179-13	22-40179-14
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015983**	**K22-No0015984**	**K22-No0015985**	**K22-No0015986**
Date Sampled			Nov 02, 2022	Nov 02, 2022	Nov 02, 2022	Nov 02, 2022
Test/Reference	LOR	Unit				
Polycyclic Aromatic Hydrocarbons (NZ MfE)						
Benzo(a)pyrene TEQ (medium bound)*	0.03	mg/kg	-	0.31	0.04	0.15
Benzo(a)pyrene TEQ (upper bound)*	0.03	mg/kg	-	0.32	0.08	0.16
Benzo(b&j)fluoranthene[N07]	0.03	mg/kg	-	0.13	< 0.03	0.08
Benzo(g.h.i)perylene	0.03	mg/kg	-	0.08	< 0.03	0.06
Benzo(k)fluoranthene	0.03	mg/kg	-	0.14	< 0.03	0.09
Chrysene	0.03	mg/kg	-	0.18	< 0.03	0.10
Dibenz(a.h)anthracene	0.03	mg/kg	-	< 0.03	< 0.03	< 0.03
Fluoranthene	0.03	mg/kg	-	0.34	< 0.03	0.08
Fluorene	0.03	mg/kg	-	< 0.03	< 0.03	< 0.03
Indeno(1.2.3-cd)pyrene	0.03	mg/kg	-	0.11	< 0.03	0.06
Naphthalene	0.1	mg/kg	-	< 0.1	< 0.1	< 0.1
Phenanthrene	0.03	mg/kg	-	0.13	< 0.03	0.06
Pyrene	0.03	mg/kg	-	0.33	< 0.03	0.08
p-Terphenyl-d14 (surr.)	1	%	-	81	94	101
2-Fluorobiphenyl (surr.)	1	%	-	68	62	70
Semivolatile Organics						
1-Chloronaphthalene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1-Naphthylamine	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.2-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.2.3-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.2.3.4-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.2.3.5-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.2.4-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.2.4.5-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.3-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.3.5-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
1.4-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2-Chloronaphthalene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2-Chlorophenol	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2-Fluorobiphenyl (surr.)	1	%	67	68	62	70
2-Methyl-4.6-dinitrophenol	5	mg/kg	< 5	< 5	< 5	< 5
2-Methylnaphthalene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2-Methylphenol (o-Cresol)	0.2	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
2-Naphthylamine	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2-Nitroaniline	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2-Nitrophenol	1	mg/kg	< 1	< 1	< 1	< 1
2-Picoline	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2.3.4.6-Tetrachlorophenol	5	mg/kg	< 5	< 5	< 5	< 5
2.4-Dichlorophenol	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2.4-Dimethylphenol	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2.4-Dinitrophenol	5	mg/kg	< 5	< 5	< 5	< 5
2.4-Dinitrotoluene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2.4.5-Trichlorophenol	1	mg/kg	< 1	< 1	< 1	< 1
2.4.6-Tribromophenol (surr.)	1	%	92	69	58	INT
2.4.6-Trichlorophenol	1	mg/kg	< 1	< 1	< 1	< 1
2.6-Dichlorophenol	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
2.6-Dinitrotoluene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
3&4-Methylphenol (m&p-Cresol)	0.4	mg/kg	< 0.4	< 0.4	< 0.4	< 0.4
3-Methylcholanthrene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5

Client Sample ID **Sample Matrix** **Eurofins Sample No.** **Date Sampled** Test/Reference	LOR	Unit	22-40179-9 **Soil** **K22-No0015983** Nov 02, 2022	22-40179-12 **Soil** **K22-No0015984** Nov 02, 2022	22-40179-13 **Soil** **K22-No0015985** Nov 02, 2022	22-40179-14 **Soil** **K22-No0015986** Nov 02, 2022
Semivolatile Organics						
3.3'-Dichlorobenzidine	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
4-Aminobiphenyl	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
4-Bromophenyl phenyl ether	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
4-Chloro-3-methylphenol	1	mg/kg	< 1	< 1	< 1	< 1
4-Chlorophenyl phenyl ether	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
4-Nitrophenol	5	mg/kg	< 5	< 5	< 5	< 5
4.4'-DDD	0.01	mg/kg	0.04	< 0.01	< 0.01	< 0.01
4.4'-DDE	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
4.4'-DDT	0.01	mg/kg	0.06	< 0.01	< 0.01	< 0.01
7.12-Dimethylbenz(a)anthracene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
a-HCH	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Acenaphthene	0.03	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03
Acenaphthylene	0.03	mg/kg	< 0.03	0.04	< 0.03	< 0.03
Acetophenone	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Aldrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Aniline	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Anthracene	0.03	mg/kg	< 0.03	0.04	< 0.03	< 0.03
b-HCH	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Benz(a)anthracene	0.03	mg/kg	0.12	0.17	< 0.03	0.10
Benzo(a)pyrene	0.03	mg/kg	0.20	0.23	< 0.03	0.10
Benzo(a)pyrene TEQ (lower bound)*	0.03	mg/kg	0.25	0.29	< 0.03	0.13
Benzo(a)pyrene TEQ (medium bound)*	0.03	mg/kg	0.27	0.31	0.04	0.15
Benzo(a)pyrene TEQ (upper bound)*	0.03	mg/kg	0.28	0.32	0.08	0.16
Benzo(b&j)fluoranthene^{N07}	0.03	mg/kg	0.12	0.13	< 0.03	0.08
Benzo(g.h.i)perylene	0.03	mg/kg	0.12	0.08	< 0.03	0.06
Benzo(k)fluoranthene	0.03	mg/kg	0.14	0.14	< 0.03	0.09
Benzyl chloride	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Bis(2-chloroethoxy)methane	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Bis(2-chloroisopropyl)ether	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Bis(2-ethylhexyl)phthalate	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Butyl benzyl phthalate	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Chrysene	0.03	mg/kg	0.22	0.18	< 0.03	0.10
d-HCH	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Di-n-butyl phthalate	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Di-n-octyl phthalate	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Dibenz(a.h)anthracene	0.03	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03
Dibenz(a.j)acridine	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Dibenzofuran	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Dieldrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Diethyl phthalate	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Dimethyl phthalate	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Dimethylaminoazobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Diphenylamine	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Endosulfan I	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endosulfan II	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endosulfan sulphate	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endrin aldehyde	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endrin ketone	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01

Client Sample ID			22-40179-9	22-40179-12	22-40179-13	22-40179-14
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015983**	**K22-No0015984**	**K22-No0015985**	**K22-No0015986**
Date Sampled			**Nov 02, 2022**	**Nov 02, 2022**	**Nov 02, 2022**	**Nov 02, 2022**
Test/Reference	LOR	Unit				
Semivolatile Organics						
Fluoranthene	0.03	mg/kg	0.30	0.34	< 0.03	0.08
Fluorene	0.03	mg/kg	< 0.03	< 0.03	< 0.03	< 0.03
g-HCH (Lindane)	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Heptachlor	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Heptachlor epoxide	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Hexachlorobenzene	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Hexachlorobutadiene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Hexachlorocyclopentadiene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Hexachloroethane	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Indeno(1.2.3-cd)pyrene	0.03	mg/kg	0.10	0.11	< 0.03	0.06
Methoxychlor	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
N-Nitrosodibutylamine	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
N-Nitrosodipropylamine	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
N-Nitrosopiperidine	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Naphthalene	0.1	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1
Nitrobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Nitrobenzene-d5 (surr.)	1	%	72	61	56	60
Pentachlorobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Pentachloronitrobenzene	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Pentachlorophenol	1	mg/kg	< 1	< 1	< 1	< 1
Phenanthrene	0.03	mg/kg	0.12	0.13	< 0.03	0.06
Phenol	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Phenol-d6 (surr.)	1	%	65	57	71	70
Pronamide	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
Pyrene	0.03	mg/kg	0.34	0.33	< 0.03	0.08
Trifluralin	0.5	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5
% Moisture	1	%	50	17	32	15

Client Sample ID			22-40179-15	22-40179-16
Sample Matrix			**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015987**	**K22-No0015988**
Date Sampled			**Nov 02, 2022**	**Nov 02, 2022**
Test/Reference	LOR	Unit		
Semivolatile Organics				
1-Chloronaphthalene	0.5	mg/kg	< 0.5	< 0.5
1-Naphthylamine	0.5	mg/kg	< 0.5	< 0.5
1.2-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5
1.2.3-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5
1.2.3.4-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5
1.2.3.5-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5
1.2.4-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5
1.2.4.5-Tetrachlorobenzene	0.5	mg/kg	< 0.5	< 0.5
1.3-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5
1.3.5-Trichlorobenzene	0.5	mg/kg	< 0.5	< 0.5
1.4-Dichlorobenzene	0.5	mg/kg	< 0.5	< 0.5
2-Chloronaphthalene	0.5	mg/kg	< 0.5	< 0.5

Client Sample ID			22-40179-15	22-40179-16
Sample Matrix			**Soil**	**Soil**
Eurofins Sample No.			**K22-No0015987**	**K22-No0015988**
Date Sampled			Nov 02, 2022	Nov 02, 2022
Test/Reference	LOR	Unit		
Semivolatile Organics				
2-Chlorophenol	0.5	mg/kg	< 0.5	< 0.5
2-Fluorobiphenyl (surr.)	1	%	75	65
2-Methyl-4.6-dinitrophenol	5	mg/kg	< 5	< 5
2-Methylnaphthalene	0.5	mg/kg	< 0.5	< 0.5
2-Methylphenol (o-Cresol)	0.2	mg/kg	< 0.2	< 0.2
2-Naphthylamine	0.5	mg/kg	< 0.5	< 0.5
2-Nitroaniline	0.5	mg/kg	< 0.5	< 0.5
2-Nitrophenol	1	mg/kg	< 1	< 1
2-Picoline	0.5	mg/kg	< 0.5	< 0.5
2.3.4.6-Tetrachlorophenol	5	mg/kg	< 5	< 5
2.4-Dichlorophenol	0.5	mg/kg	< 0.5	< 0.5
2.4-Dimethylphenol	0.5	mg/kg	< 0.5	< 0.5
2.4-Dinitrophenol	5	mg/kg	< 5	< 5
2.4-Dinitrotoluene	0.5	mg/kg	< 0.5	< 0.5
2.4.5-Trichlorophenol	1	mg/kg	< 1	< 1
2.4.6-Tribromophenol (surr.)	1	%	92	64
2.4.6-Trichlorophenol	1	mg/kg	< 1	< 1
2.6-Dichlorophenol	0.5	mg/kg	< 0.5	< 0.5
2.6-Dinitrotoluene	0.5	mg/kg	< 0.5	< 0.5
3&4-Methylphenol (m&p-Cresol)	0.4	mg/kg	< 0.4	< 0.4
3-Methylcholanthrene	0.5	mg/kg	< 0.5	< 0.5
3.3'-Dichlorobenzidine	0.5	mg/kg	< 0.5	< 0.5
4-Aminobiphenyl	0.5	mg/kg	< 0.5	< 0.5
4-Bromophenyl phenyl ether	0.5	mg/kg	< 0.5	< 0.5
4-Chloro-3-methylphenol	1	mg/kg	< 1	< 1
4-Chlorophenyl phenyl ether	0.5	mg/kg	< 0.5	< 0.5
4-Nitrophenol	5	mg/kg	< 5	< 5
4.4'-DDD	0.01	mg/kg	< 0.01	< 0.01
4.4'-DDE	0.01	mg/kg	< 0.01	< 0.01
4.4'-DDT	0.01	mg/kg	< 0.01	< 0.01
7.12-Dimethylbenz(a)anthracene	0.5	mg/kg	< 0.5	< 0.5
a-HCH	0.01	mg/kg	< 0.01	< 0.01
Acenaphthene	0.03	mg/kg	< 0.03	< 0.03
Acenaphthylene	0.03	mg/kg	< 0.03	< 0.03
Acetophenone	0.5	mg/kg	< 0.5	< 0.5
Aldrin	0.01	mg/kg	< 0.01	< 0.01
Aniline	0.5	mg/kg	< 0.5	< 0.5
Anthracene	0.03	mg/kg	< 0.03	< 0.03
b-HCH	0.01	mg/kg	< 0.01	< 0.01
Benz(a)anthracene	0.03	mg/kg	0.19	< 0.03
Benzo(a)pyrene	0.03	mg/kg	0.30	< 0.03
Benzo(a)pyrene TEQ (lower bound)*	0.03	mg/kg	0.46	< 0.03
Benzo(a)pyrene TEQ (medium bound)*	0.03	mg/kg	0.46	0.04
Benzo(a)pyrene TEQ (upper bound)*	0.03	mg/kg	0.46	0.08
Benzo(b&j)fluoranthene^{N07}	0.03	mg/kg	0.27	< 0.03
Benzo(g.h.i)perylene	0.03	mg/kg	0.25	< 0.03
Benzo(k)fluoranthene	0.03	mg/kg	0.26	< 0.03
Benzyl chloride	0.5	mg/kg	< 0.5	< 0.5
Bis(2-chloroethoxy)methane	0.5	mg/kg	< 0.5	< 0.5

Client Sample ID **Sample Matrix** **Eurofins Sample No.** **Date Sampled** Test/Reference	LOR	Unit	**22-40179-15** **Soil** **K22-No0015987** **Nov 02, 2022**	**22-40179-16** **Soil** **K22-No0015988** **Nov 02, 2022**
Semivolatile Organics				
Bis(2-chloroisopropyl)ether	0.5	mg/kg	< 0.5	< 0.5
Bis(2-ethylhexyl)phthalate	0.5	mg/kg	< 0.5	< 0.5
Butyl benzyl phthalate	0.5	mg/kg	< 0.5	< 0.5
Chrysene	0.03	mg/kg	0.27	< 0.03
d-HCH	0.01	mg/kg	< 0.01	< 0.01
Di-n-butyl phthalate	0.5	mg/kg	< 0.5	< 0.5
Di-n-octyl phthalate	0.5	mg/kg	< 0.5	< 0.5
Dibenz(a.h)anthracene	0.03	mg/kg	0.06	< 0.03
Dibenz(a.j)acridine	0.5	mg/kg	< 0.5	< 0.5
Dibenzofuran	0.5	mg/kg	< 0.5	< 0.5
Dieldrin	0.01	mg/kg	< 0.01	< 0.01
Diethyl phthalate	0.5	mg/kg	< 0.5	< 0.5
Dimethyl phthalate	0.5	mg/kg	< 0.5	< 0.5
Dimethylaminoazobenzene	0.5	mg/kg	< 0.5	< 0.5
Diphenylamine	0.5	mg/kg	< 0.5	< 0.5
Endosulfan I	0.01	mg/kg	< 0.01	< 0.01
Endosulfan II	0.01	mg/kg	< 0.01	< 0.01
Endosulfan sulphate	0.01	mg/kg	< 0.01	< 0.01
Endrin	0.01	mg/kg	< 0.01	< 0.01
Endrin aldehyde	0.01	mg/kg	< 0.01	< 0.01
Endrin ketone	0.01	mg/kg	< 0.01	< 0.01
Fluoranthene	0.03	mg/kg	0.30	< 0.03
Fluorene	0.03	mg/kg	< 0.03	< 0.03
g-HCH (Lindane)	0.01	mg/kg	< 0.01	< 0.01
Heptachlor	0.01	mg/kg	< 0.01	< 0.01
Heptachlor epoxide	0.01	mg/kg	< 0.01	< 0.01
Hexachlorobenzene	0.01	mg/kg	< 0.01	< 0.01
Hexachlorobutadiene	0.5	mg/kg	< 0.5	< 0.5
Hexachlorocyclopentadiene	0.5	mg/kg	< 0.5	< 0.5
Hexachloroethane	0.5	mg/kg	< 0.5	< 0.5
Indeno(1.2.3-cd)pyrene	0.03	mg/kg	0.18	< 0.03
Methoxychlor	0.01	mg/kg	< 0.01	< 0.01
N-Nitrosodibutylamine	0.5	mg/kg	< 0.5	< 0.5
N-Nitrosodipropylamine	0.5	mg/kg	< 0.5	< 0.5
N-Nitrosopiperidine	0.5	mg/kg	< 0.5	< 0.5
Naphthalene	0.1	mg/kg	< 0.1	< 0.1
Nitrobenzene	0.5	mg/kg	< 0.5	< 0.5
Nitrobenzene-d5 (surr.)	1	%	63	63
Pentachlorobenzene	0.5	mg/kg	< 0.5	< 0.5
Pentachloronitrobenzene	0.5	mg/kg	< 0.5	< 0.5
Pentachlorophenol	1	mg/kg	< 1	< 1
Phenanthrene	0.03	mg/kg	0.13	< 0.03
Phenol	0.5	mg/kg	< 0.5	< 0.5
Phenol-d6 (surr.)	1	%	73	INT
Pronamide	0.5	mg/kg	< 0.5	< 0.5
Pyrene	0.03	mg/kg	0.35	< 0.03
Trifluralin	0.5	mg/kg	< 0.5	< 0.5
% Moisture	1	%	48	27

Sample History

Where samples are submitted/analysed over several days, the last date of extraction is reported.

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
Polycyclic Aromatic Hydrocarbons (NZ MfE) - Method: LTM-ORG-2130 PAH and Phenols in Soil and Water by GC MSMS	Auckland	Nov 08, 2022	14 Days
Semivolatile Organics - Method: LTM-ORG-2190 SVOC in Water & Soil by GC-MS	Auckland	Nov 08, 2022	14 Days
% Moisture - Method: LTM-GEN-7080 Moisture Content in Soil by Gravimetry	Auckland	Nov 08, 2022	14 Days

Company Name:	Analytica Laboratories LTD	**Order No.:**	22-40179	**Received:**	Nov 8, 2022 12:19 PM
Address:	10 Bisley Road Hamilton New Zealand 3214	**Report #:**	938712	**Due:**	Nov 15, 2022
		Phone:	(07) 9744740	**Priority:**	5 Day
		Fax:		**Contact Name:**	Customer Service
Project Name:					
Project ID:	22-40179				

Eurofins Analytical Services Manager : Karishma Patel

Sample Detail						Moisture Set	Polycyclic Aromatic Hydrocarbons (NZ MfE)	Semivolatile Organics
Auckland Laboratory - IANZ# 1327						X	X	X
Christchurch Laboratory - IANZ# 1290								
External Laboratory								
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**			
1	22-40179-1	Nov 02, 2022		Soil	K22-No0015975	X	X	X
2	22-40179-2	Nov 02, 2022		Soil	K22-No0015976	X	X	X
3	22-40179-3	Nov 02, 2022		Soil	K22-No0015977	X	X	
4	22-40179-4	Nov 02, 2022		Soil	K22-No0015978	X	X	
5	22-40179-5	Nov 02, 2022		Soil	K22-No0015979	X	X	
6	22-40179-6	Nov 02, 2022		Soil	K22-No0015980	X	X	X
7	22-40179-7	Nov 02, 2022		Soil	K22-No0015981	X		X
8	22-40179-8	Nov 02, 2022		Soil	K22-No0015982	X		X
9	22-40179-9	Nov 02, 2022		Soil	K22-No0015983	X		X
10	22-40179-12	Nov 02, 2022		Soil	K22-No0015984	X	X	X
11	22-40179-13	Nov 02, 2022		Soil	K22-No0015985	X	X	X
12	22-40179-14	Nov 02, 2022		Soil	K22-No0015986	X	X	X

Company Name: Analytica Laboratories LTD
Address: 10 Bisley Road
Hamilton
New Zealand 3214

Project Name:
Project ID: 22-40179

Order No.: 22-40179
Report #: 938712
Phone: (07) 9744740
Fax:

Received: Nov 8, 2022 12:19 PM
Due: Nov 15, 2022
Priority: 5 Day
Contact Name: Customer Service

Eurofins Analytical Services Manager : Karishma Patel

Sample Detail						Moisture Set	Polycyclic Aromatic Hydrocarbons (NZ MfE)	Semivolatile Organics
Auckland Laboratory - IANZ# 1327						X	X	X
Christchurch Laboratory - IANZ# 1290								
External Laboratory								
13	22-40179-15	Nov 02, 2022		Soil	K22-No0015987	X		X
14	22-40179-16	Nov 02, 2022		Soil	K22-No0015988	X		X
Test Counts						14	9	11

Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples follows guidelines delineated in the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended May 2013 and are included in this QC report where applicable. Additional QC data may be available on request.
2. All soil/sediment/solid results are reported on a dry basis, unless otherwise stated.
3. All biota/food results are reported on a wet weight basis on the edible portion, unless otherwise stated.
4. Actual LORs are matrix dependant. Quoted LORs may be raised where sample extracts are diluted due to interferences.
5. Results are uncorrected for matrix spikes or surrogate recoveries except for PFAS compounds.
6. SVOC analysis on waters are performed on homogenised, unfiltered samples, unless noted otherwise.
7. Samples were analysed on an 'as received' basis.
8. Information identified on this report with blue colour, indicates data provided by customer that may have an impact on the results.
9. This report replaces any interim results previously issued.

Holding Times

Please refer to 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours prior to sample receipt deadlines as stated on the SRA.

If the Laboratory did not receive the information in the required timeframe, and regardless of any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the date of sampling, therefore compliance to these may be outside the laboratory's control.

For VOCs containing vinyl chloride, styrene and 2-chloroethyl vinyl ether the holding time is 7 days however for all other VOCs such as BTEX or C6-10 TRH then the holding time is 14 days.

Units

mg/kg: milligrams per kilogram	**mg/L:** milligrams per litre	**µg/L:** micrograms per litre
ppm: parts per million	**ppb:** parts per billion	**%:** Percentage
org/100 mL: Organisms per 100 millilitres	**NTU:** Nephelometric Turbidity Units	**MPN/100 mL:** Most Probable Number of organisms per 100 millilitres

Terms

APHA	American Public Health Association
COC	Chain of Custody
CP	Client Parent - QC was performed on samples pertaining to this report
CRM	Certified Reference Material (ISO17034) - reported as percent recovery.
Dry	Where a moisture has been determined on a solid sample the result is expressed on a dry basis.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
LOR	Limit of Reporting.
LCS	Laboratory Control Sample - reported as percent recovery.
Method Blank	In the case of solid samples these are performed on laboratory certified clean sands and in the case of water samples these are performed on de-ionised water.
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC is representative of the sequence or batch that client samples were analysed within.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
SRA	Sample Receipt Advice
Surr - Surrogate	The addition of a like compound to the analyte target and reported as percentage recovery.
TBTO	Tributyltin oxide (*bis*-tributyltin oxide) - individual tributyltin compounds cannot be identified separately in the environment however free tributyltin was measured and its values were converted stoichiometrically into tributyltin oxide for comparison with regulatory limits.
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	Toxic Equivalency Quotient or Total Equivalence
QSM	US Department of Defense Quality Systems Manual Version 5.4
US EPA	United States Environmental Protection Agency
WA DWER	Sum of PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFBS, PFHxS, PFOS, 6:2 FTSA, 8:2 FTSA

QC - Acceptance Criteria

The acceptance criteria should be used as a guide only and may be different when site specific Sampling Analysis and Quality Plan (SAQP) have been implemented

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is 30% however the following acceptance guidelines are equally applicable:

Results <10 times the LOR: No Limit

Results between 10-20 times the LOR: RPD must lie between 0-50%

Results >20 times the LOR : RPD must lie between 0-30%

NOTE: pH duplicates are reported as a range not as RPD

Surrogate Recoveries: Recoveries must lie between 20-130% for Speciated Phenols & 50-150% for PFAS

PFAS field samples that contain surrogate recoveries in excess of the QC limit designated in QSM 5.4 where no positive PFAS results have been reported have been reviewed and no data was affected.

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QC Data General Comments

1. Where a result is reported as a less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch, but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown is not data from your samples.
3. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling. Therefore, laboratory analysis is unlikely to be completed within holding time.Analysis will begin as soon as possible after sample receipt.
4. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of recovery the term "INT" appears against that analyte.
5. For Matrix Spikes and LCS results a dash "-" in the report means that the specific analyte was not added to the QC sample.
6. Duplicate RPDs are calculated from raw analytical data thus it is possible to have two sets of data.

Quality Control Results

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Method Blank							
Polycyclic Aromatic Hydrocarbons (NZ MfE)							
Acenaphthene	mg/kg	< 0.03			0.03	Pass	
Acenaphthylene	mg/kg	< 0.03			0.03	Pass	
Anthracene	mg/kg	< 0.03			0.03	Pass	
Benz(a)anthracene	mg/kg	< 0.03			0.03	Pass	
Benzo(a)pyrene	mg/kg	< 0.03			0.03	Pass	
Benzo(b&j)fluoranthene	mg/kg	< 0.03			0.03	Pass	
Benzo(g.h.i)perylene	mg/kg	< 0.03			0.03	Pass	
Benzo(k)fluoranthene	mg/kg	< 0.03			0.03	Pass	
Chrysene	mg/kg	< 0.03			0.03	Pass	
Dibenz(a.h)anthracene	mg/kg	< 0.03			0.03	Pass	
Fluoranthene	mg/kg	< 0.03			0.03	Pass	
Fluorene	mg/kg	< 0.03			0.03	Pass	
Indeno(1.2.3-cd)pyrene	mg/kg	< 0.03			0.03	Pass	
Naphthalene	mg/kg	< 0.1			0.1	Pass	
Phenanthrene	mg/kg	< 0.03			0.03	Pass	
Pyrene	mg/kg	< 0.03			0.03	Pass	
Method Blank							
Semivolatile Organics							
1-Chloronaphthalene	mg/kg	< 0.5			0.5	Pass	
1-Naphthylamine	mg/kg	< 0.5			0.5	Pass	
1.2-Dichlorobenzene	mg/kg	< 0.5			0.5	Pass	
1.2.3-Trichlorobenzene	mg/kg	< 0.5			0.5	Pass	
1.2.3.4-Tetrachlorobenzene	mg/kg	< 0.5			0.5	Pass	
1.2.3.5-Tetrachlorobenzene	mg/kg	< 0.5			0.5	Pass	
1.2.4-Trichlorobenzene	mg/kg	< 0.5			0.5	Pass	
1.2.4.5-Tetrachlorobenzene	mg/kg	< 0.5			0.5	Pass	
1.3-Dichlorobenzene	mg/kg	< 0.5			0.5	Pass	
1.3.5-Trichlorobenzene	mg/kg	< 0.5			0.5	Pass	
1.4-Dichlorobenzene	mg/kg	< 0.5			0.5	Pass	
2-Chloronaphthalene	mg/kg	< 0.5			0.5	Pass	
2-Chlorophenol	mg/kg	< 0.5			0.5	Pass	
2-Methyl-4.6-dinitrophenol	mg/kg	< 5			5	Pass	
2-Methylnaphthalene	mg/kg	< 0.5			0.5	Pass	
2-Methylphenol (o-Cresol)	mg/kg	< 0.2			0.2	Pass	
2-Naphthylamine	mg/kg	< 0.5			0.5	Pass	
2-Nitroaniline	mg/kg	< 0.5			0.5	Pass	
2-Nitrophenol	mg/kg	< 1			1	Pass	
2-Picoline	mg/kg	< 0.5			0.5	Pass	
2.3.4.6-Tetrachlorophenol	mg/kg	< 5			5	Pass	
2.4-Dichlorophenol	mg/kg	< 0.5			0.5	Pass	
2.4-Dimethylphenol	mg/kg	< 0.5			0.5	Pass	
2.4-Dinitrophenol	mg/kg	< 5			5	Pass	
2.4-Dinitrotoluene	mg/kg	< 0.5			0.5	Pass	
2.4.5-Trichlorophenol	mg/kg	< 1			1	Pass	
2.4.6-Trichlorophenol	mg/kg	< 1			1	Pass	
2.6-Dichlorophenol	mg/kg	< 0.5			0.5	Pass	
2.6-Dinitrotoluene	mg/kg	< 0.5			0.5	Pass	
3&4-Methylphenol (m&p-Cresol)	mg/kg	< 0.4			0.4	Pass	
3-Methylcholanthrene	mg/kg	< 0.5			0.5	Pass	
3.3'-Dichlorobenzidine	mg/kg	< 0.5			0.5	Pass	

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
4-Aminobiphenyl	mg/kg	< 0.5			0.5	Pass	
4-Bromophenyl phenyl ether	mg/kg	< 0.5			0.5	Pass	
4-Chloro-3-methylphenol	mg/kg	< 1			1	Pass	
4-Chlorophenyl phenyl ether	mg/kg	< 0.5			0.5	Pass	
4-Nitrophenol	mg/kg	< 5			5	Pass	
4.4'-DDD	mg/kg	< 0.01			0.01	Pass	
4.4'-DDE	mg/kg	< 0.01			0.01	Pass	
4.4'-DDT	mg/kg	< 0.01			0.01	Pass	
7.12-Dimethylbenz(a)anthracene	mg/kg	< 0.5			0.5	Pass	
a-HCH	mg/kg	< 0.01			0.01	Pass	
Acetophenone	mg/kg	< 0.5			0.5	Pass	
Aldrin	mg/kg	< 0.01			0.01	Pass	
Aniline	mg/kg	< 0.5			0.5	Pass	
b-HCH	mg/kg	< 0.01			0.01	Pass	
Benzyl chloride	mg/kg	< 0.5			0.5	Pass	
Bis(2-chloroethoxy)methane	mg/kg	< 0.5			0.5	Pass	
Bis(2-chloroisopropyl)ether	mg/kg	< 0.5			0.5	Pass	
Bis(2-ethylhexyl)phthalate	mg/kg	< 0.5			0.5	Pass	
Butyl benzyl phthalate	mg/kg	< 0.5			0.5	Pass	
d-HCH	mg/kg	< 0.01			0.01	Pass	
Di-n-butyl phthalate	mg/kg	< 0.5			0.5	Pass	
Di-n-octyl phthalate	mg/kg	< 0.5			0.5	Pass	
Dibenz(a.j)acridine	mg/kg	< 0.5			0.5	Pass	
Dibenzofuran	mg/kg	< 0.5			0.5	Pass	
Dieldrin	mg/kg	< 0.01			0.01	Pass	
Diethyl phthalate	mg/kg	< 0.5			0.5	Pass	
Dimethyl phthalate	mg/kg	< 0.5			0.5	Pass	
Dimethylaminoazobenzene	mg/kg	< 0.5			0.5	Pass	
Diphenylamine	mg/kg	< 0.5			0.5	Pass	
Endosulfan I	mg/kg	< 0.01			0.01	Pass	
Endosulfan II	mg/kg	< 0.01			0.01	Pass	
Endosulfan sulphate	mg/kg	< 0.01			0.01	Pass	
Endrin	mg/kg	< 0.01			0.01	Pass	
Endrin aldehyde	mg/kg	0.01			0.01	Pass	
Endrin ketone	mg/kg	< 0.01			0.01	Pass	
g-HCH (Lindane)	mg/kg	< 0.01			0.01	Pass	
Heptachlor	mg/kg	< 0.01			0.01	Pass	
Heptachlor epoxide	mg/kg	< 0.01			0.01	Pass	
Hexachlorobenzene	mg/kg	< 0.01			0.01	Pass	
Hexachlorobutadiene	mg/kg	< 0.5			0.5	Pass	
Hexachlorocyclopentadiene	mg/kg	< 0.5			0.5	Pass	
Hexachloroethane	mg/kg	< 0.5			0.5	Pass	
Methoxychlor	mg/kg	< 0.01			0.01	Pass	
N-Nitrosodibutylamine	mg/kg	< 0.5			0.5	Pass	
N-Nitrosodipropylamine	mg/kg	< 0.5			0.5	Pass	
N-Nitrosopiperidine	mg/kg	< 0.5			0.5	Pass	
Nitrobenzene	mg/kg	< 0.5			0.5	Pass	
Pentachlorobenzene	mg/kg	< 0.5			0.5	Pass	
Pentachloronitrobenzene	mg/kg	< 0.5			0.5	Pass	
Pentachlorophenol	mg/kg	< 1			1	Pass	
Phenol	mg/kg	< 0.5			0.5	Pass	
Pronamide	mg/kg	< 0.5			0.5	Pass	
Trifluralin	mg/kg	< 0.5			0.5	Pass	
LCS - % Recovery							

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Polycyclic Aromatic Hydrocarbons (NZ MfE)							
Acenaphthene	%	102			70-130	Pass	
Acenaphthylene	%	101			70-130	Pass	
Anthracene	%	89			70-130	Pass	
Benz(a)anthracene	%	96			70-130	Pass	
Benzo(a)pyrene	%	113			70-130	Pass	
Benzo(b&j)fluoranthene	%	80			70-130	Pass	
Benzo(g.h.i)perylene	%	71			70-130	Pass	
Benzo(k)fluoranthene	%	104			70-130	Pass	
Chrysene	%	100			70-130	Pass	
Dibenz(a.h)anthracene	%	75			70-130	Pass	
Fluoranthene	%	86			70-130	Pass	
Fluorene	%	91			70-130	Pass	
Indeno(1.2.3-cd)pyrene	%	77			70-130	Pass	
Naphthalene	%	106			70-130	Pass	
Phenanthrene	%	86			70-130	Pass	
Pyrene	%	89			70-130	Pass	
LCS - % Recovery							
Semivolatile Organics							
1-Chloronaphthalene	%	128			70-130	Pass	
1-Naphthylamine	%	107			70-130	Pass	
1.2-Dichlorobenzene	%	78			70-130	Pass	
1.2.3-Trichlorobenzene	%	77			70-130	Pass	
1.2.3.4-Tetrachlorobenzene	%	82			70-130	Pass	
1.2.3.5-Tetrachlorobenzene	%	80			70-130	Pass	
1.3-Dichlorobenzene	%	86			70-130	Pass	
1.3.5-Trichlorobenzene	%	71			70-130	Pass	
1.4-Dichlorobenzene	%	72			70-130	Pass	
2-Chloronaphthalene	%	125			70-130	Pass	
2-Chlorophenol	%	64			25-130	Pass	
2-Methyl-4.6-dinitrophenol	%	48			25-130	Pass	
2-Methylnaphthalene	%	72			70-130	Pass	
2-Methylphenol (o-Cresol)	%	59			25-130	Pass	
2-Naphthylamine	%	78			70-130	Pass	
2-Nitrophenol	%	69			25-130	Pass	
2.4-Dichlorophenol	%	51			25-130	Pass	
2.4-Dimethylphenol	%	56			25-130	Pass	
2.4-Dinitrophenol	%	73			25-130	Pass	
2.4.5-Trichlorophenol	%	66			25-130	Pass	
2.4.6-Trichlorophenol	%	96			25-130	Pass	
2.6-Dichlorophenol	%	64			25-130	Pass	
3&4-Methylphenol (m&p-Cresol)	%	56			25-130	Pass	
3-Methylcholanthrene	%	78			70-130	Pass	
4-Aminobiphenyl	%	79			70-130	Pass	
4-Chloro-3-methylphenol	%	57			25-130	Pass	
4-Nitrophenol	%	113			25-130	Pass	
4.4'-DDD	%	101			70-130	Pass	
4.4'-DDE	%	85			70-130	Pass	
4.4'-DDT	%	124			70-130	Pass	
7.12-Dimethylbenz(a)anthracene	%	81			70-130	Pass	
a-HCH	%	83			70-130	Pass	
Acetophenone	%	81			70-130	Pass	
Aldrin	%	80			70-130	Pass	
b-HCH	%	96			70-130	Pass	

Test			Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Benzyl chloride			%	77			70-130	Pass	
Bis(2-chloroethoxy)methane			%	70			70-130	Pass	
Bis(2-chloroisopropyl)ether			%	81			70-130	Pass	
Bis(2-ethylhexyl)phthalate			%	125			70-130	Pass	
Butyl benzyl phthalate			%	119			70-130	Pass	
d-HCH			%	79			70-130	Pass	
Di-n-butyl phthalate			%	73			70-130	Pass	
Di-n-octyl phthalate			%	86			70-130	Pass	
Dieldrin			%	84			70-130	Pass	
Diethyl phthalate			%	70			70-130	Pass	
Dimethyl phthalate			%	74			70-130	Pass	
Dimethylaminoazobenzene			%	78			70-130	Pass	
Diphenylamine			%	73			70-130	Pass	
Endosulfan I			%	95			70-130	Pass	
Endosulfan II			%	105			70-130	Pass	
Endosulfan sulphate			%	92			70-130	Pass	
Endrin			%	81			70-130	Pass	
Endrin aldehyde			%	92			70-130	Pass	
Endrin ketone			%	97			70-130	Pass	
g-HCH (Lindane)			%	115			70-130	Pass	
Heptachlor			%	82			70-130	Pass	
Heptachlor epoxide			%	75			70-130	Pass	
Hexachlorobenzene			%	82			70-130	Pass	
Hexachlorobutadiene			%	72			70-130	Pass	
Methoxychlor			%	104			70-130	Pass	
N-Nitrosopiperidine			%	71			70-130	Pass	
Nitrobenzene			%	100			70-130	Pass	
Pentachlorobenzene			%	70			70-130	Pass	
Pentachloronitrobenzene			%	82			70-130	Pass	
Pentachlorophenol			%	100			25-130	Pass	
Phenol			%	58			25-130	Pass	
Trifluralin			%	80			70-130	Pass	
Test	**Lab Sample ID**	**QA Source**	**Units**	**Result 1**			**Acceptance Limits**	**Pass Limits**	**Qualifying Code**
Spike - % Recovery									
Polycyclic Aromatic Hydrocarbons (NZ MfE)				Result 1					
Acenaphthylene	K22-No0023937	NCP	%	72			70-130	Pass	
Benzo(b&j)fluoranthene	K22-No0023937	NCP	%	70			70-130	Pass	
Benzo(g.h.i)perylene	K22-No0019326	NCP	%	74			70-130	Pass	
Chrysene	K22-No0019326	NCP	%	74			70-130	Pass	
Indeno(1.2.3-cd)pyrene	K22-No0019326	NCP	%	73			70-130	Pass	
Spike - % Recovery									
Semivolatile Organics				Result 1					
a-HCH	K22-No0001195	NCP	%	73			70-130	Pass	
Aldrin	K22-No0001195	NCP	%	76			70-130	Pass	
Endosulfan II	K22-No0023937	NCP	%	70			70-130	Pass	
Endrin	K22-No0007117	NCP	%	75			70-130	Pass	
Heptachlor	K22-No0007117	NCP	%	77			70-130	Pass	
Heptachlor epoxide	K22-No0007117	NCP	%	87			70-130	Pass	
Spike - % Recovery									
Polycyclic Aromatic Hydrocarbons (NZ MfE)				Result 1					
Acenaphthene	K22-No0015976	CP	%	78			70-130	Pass	
Anthracene	K22-No0015976	CP	%	70			70-130	Pass	
Benz(a)anthracene	K22-No0015976	CP	%	71			70-130	Pass	
Benzo(a)pyrene	K22-No0015976	CP	%	81			70-130	Pass	

Test	**Lab Sample ID**	**QA Source**	**Units**	**Result 1**			**Acceptance Limits**	**Pass Limits**	**Qualifying Code**
Benzo(k)fluoranthene	K22-No0015976	CP	%	71			70-130	Pass	
Dibenz(a.h)anthracene	K22-No0015976	CP	%	73			70-130	Pass	
Fluoranthene	K22-No0015976	CP	%	70			70-130	Pass	
Fluorene	K22-No0015976	CP	%	70			70-130	Pass	
Naphthalene	K22-No0015976	CP	%	76			70-130	Pass	
Phenanthrene	K22-No0015976	CP	%	70			70-130	Pass	
Pyrene	K22-No0015976	CP	%	73			70-130	Pass	
Spike - % Recovery									
Semivolatile Organics				Result 1					
1-Chloronaphthalene	K22-No0015976	CP	%	125			70-130	Pass	
2.3.4.6-Tetrachlorophenol	K22-No0015976	CP	%	87			70-130	Pass	
4.4'-DDD	K22-No0015976	CP	%	80			70-130	Pass	
4.4'-DDE	K22-No0015976	CP	%	75			70-130	Pass	
4.4'-DDT	K22-No0015976	CP	%	123			70-130	Pass	
b-HCH	K22-No0015976	CP	%	71			70-130	Pass	
Benzyl chloride	K22-No0015976	CP	%	85			70-130	Pass	
Bis(2-chloroisopropyl)ether	K22-No0015976	CP	%	104			70-130	Pass	
Bis(2-ethylhexyl)phthalate	K22-No0015976	CP	%	91			70-130	Pass	
Butyl benzyl phthalate	K22-No0015976	CP	%	83			70-130	Pass	
d-HCH	K22-No0015976	CP	%	70			70-130	Pass	
Di-n-butyl phthalate	K22-No0015976	CP	%	74			70-130	Pass	
Di-n-octyl phthalate	K22-No0015976	CP	%	92			70-130	Pass	
Dieldrin	K22-No0015976	CP	%	71			70-130	Pass	
Diethyl phthalate	K22-No0015976	CP	%	70			70-130	Pass	
Dimethylaminoazobenzene	K22-No0015976	CP	%	70			70-130	Pass	
Endosulfan I	K22-No0015976	CP	%	76			70-130	Pass	
Endosulfan sulphate	K22-No0015976	CP	%	78			70-130	Pass	
Endrin aldehyde	K22-No0015976	CP	%	85			70-130	Pass	
Endrin ketone	K22-No0015976	CP	%	78			70-130	Pass	
g-HCH (Lindane)	K22-No0015976	CP	%	107			70-130	Pass	
Hexachlorobenzene	K22-No0015976	CP	%	123			70-130	Pass	
Methoxychlor	K22-No0015976	CP	%	85			70-130	Pass	
Pentachloronitrobenzene	K22-No0015976	CP	%	77			70-130	Pass	
Pentachlorophenol	K22-No0015976	CP	%	106			70-130	Pass	
Trifluralin	K22-No0015976	CP	%	71			70-130	Pass	
Spike - % Recovery									
Semivolatile Organics				Result 1					
1-Naphthylamine	K22-No0005712	NCP	%	71			70-130	Pass	
1.2.3.4-Tetrachlorobenzene	K22-No0005712	NCP	%	72			70-130	Pass	
1.3-Dichlorobenzene	K22-No0005712	NCP	%	71			70-130	Pass	
2.4.5-Trichlorophenol	K22-No0005712	NCP	%	91			70-130	Pass	
3-Methylcholanthrene	K22-No0005712	NCP	%	89			70-130	Pass	
4-Aminobiphenyl	K22-No0005712	NCP	%	83			70-130	Pass	
Dibenz(a.j)acridine	K22-No0001205	NCP	%	2.4			70-130	Fail	
Dimethyl phthalate	K22-No0005712	NCP	%	73			70-130	Pass	
Test	**Lab Sample ID**	**QA Source**	**Units**	**Result 1**			**Acceptance Limits**	**Pass Limits**	**Qualifying Code**
Duplicate									
Polycyclic Aromatic Hydrocarbons (NZ MfE)				Result 1	Result 2	RPD			
Acenaphthene	K22-No0015975	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Acenaphthylene	K22-No0015975	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Anthracene	K22-No0015975	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Benz(a)anthracene	K22-No0015975	CP	mg/kg	0.07	0.04	40	30%	Fail	Q15
Benzo(a)pyrene	K22-No0015975	CP	mg/kg	0.06	0.04	26	30%	Pass	
Benzo(b&j)fluoranthene	K22-No0015975	CP	mg/kg	0.04	< 0.03	21	30%	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Duplicate									
Polycyclic Aromatic Hydrocarbons (NZ MfE)				Result 1	Result 2	RPD			
Benzo(g.h.i)perylene	K22-No0015975	CP	mg/kg	< 0.03	0.04	11	30%	Pass	
Benzo(k)fluoranthene	K22-No0015975	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Chrysene	K22-No0015975	CP	mg/kg	0.09	0.07	25	30%	Pass	
Dibenz(a.h)anthracene	K22-No0015975	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Fluoranthene	K22-No0015975	CP	mg/kg	0.11	0.07	39	30%	Fail	Q15
Fluorene	K22-No0015975	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Indeno(1.2.3-cd)pyrene	K22-No0015975	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Naphthalene	K22-No0015975	CP	mg/kg	< 0.1	< 0.1	<1	30%	Pass	
Phenanthrene	K22-No0015975	CP	mg/kg	0.07	< 0.03	110	30%	Fail	Q15
Pyrene	K22-No0015975	CP	mg/kg	0.13	0.07	59	30%	Fail	Q15
Duplicate									
Semivolatile Organics				Result 1	Result 2	RPD			
1-Chloronaphthalene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1-Naphthylamine	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2-Dichlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.3-Trichlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.3.4-Tetrachlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.3.5-Tetrachlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.4-Trichlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.4.5-Tetrachlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.3-Dichlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.3.5-Trichlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.4-Dichlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Chloronaphthalene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Chlorophenol	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Methyl-4.6-dinitrophenol	K22-No0015975	CP	mg/kg	< 5	< 5	<1	30%	Pass	
2-Methylnaphthalene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Methylphenol (o-Cresol)	K22-No0015975	CP	mg/kg	< 0.2	< 0.2	<1	30%	Pass	
2-Naphthylamine	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Nitroaniline	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Nitrophenol	K22-No0015975	CP	mg/kg	< 1	< 1	<1	30%	Pass	
2-Picoline	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.3.4.6-Tetrachlorophenol	K22-No0015975	CP	mg/kg	< 5	< 5	<1	30%	Pass	
2.4-Dichlorophenol	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.4-Dimethylphenol	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.4-Dinitrophenol	K22-No0015975	CP	mg/kg	< 5	< 5	<1	30%	Pass	
2.4-Dinitrotoluene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.4.5-Trichlorophenol	K22-No0015975	CP	mg/kg	< 1	< 1	<1	30%	Pass	
2.4.6-Trichlorophenol	K22-No0015975	CP	mg/kg	< 1	< 1	<1	30%	Pass	
2.6-Dichlorophenol	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.6-Dinitrotoluene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
3&4-Methylphenol (m&p-Cresol)	K22-No0015975	CP	mg/kg	< 0.4	< 0.4	<1	30%	Pass	
3-Methylcholanthrene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
3.3'-Dichlorobenzidine	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
4-Aminobiphenyl	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
4-Bromophenyl phenyl ether	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
4-Chloro-3-methylphenol	K22-No0015975	CP	mg/kg	< 1	< 1	<1	30%	Pass	
4-Chlorophenyl phenyl ether	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
4-Nitrophenol	K22-No0015975	CP	mg/kg	< 5	< 5	<1	30%	Pass	
4.4'-DDD	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
4.4'-DDE	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
4.4'-DDT	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	

Duplicate									
Semivolatile Organics				Result 1	Result 2	RPD			
7.12-Dimethylbenz(a)anthracene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
a-HCH	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Acetophenone	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Aldrin	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Aniline	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
b-HCH	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Benzyl chloride	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Bis(2-chloroethoxy)methane	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Bis(2-chloroisopropyl)ether	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Bis(2-ethylhexyl)phthalate	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Butyl benzyl phthalate	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
d-HCH	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Di-n-butyl phthalate	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Di-n-octyl phthalate	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dibenz(a.j)acridine	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dibenzofuran	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dieldrin	K22-No0015975	CP	mg/kg	< 0.01	0.01	58	30%	Fail	
Diethyl phthalate	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dimethyl phthalate	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dimethylaminoazobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Diphenylamine	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Endosulfan I	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endosulfan II	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endosulfan sulphate	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endrin	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endrin aldehyde	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endrin ketone	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
g-HCH (Lindane)	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Heptachlor	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Heptachlor epoxide	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Hexachlorobenzene	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Hexachlorobutadiene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Hexachlorocyclopentadiene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Hexachloroethane	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Methoxychlor	K22-No0015975	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
N-Nitrosodibutylamine	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
N-Nitrosodipropylamine	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
N-Nitrosopiperidine	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Nitrobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Pentachlorobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Pentachloronitrobenzene	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Pentachlorophenol	K22-No0015975	CP	mg/kg	< 1	< 1	<1	30%	Pass	
Phenol	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Pronamide	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Trifluralin	K22-No0015975	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
% Moisture	K22-No0015975	CP	%	30	30	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
% Moisture	K22-No0015985	CP	%	32	34	5.9	30%	Pass	

Duplicate									
Polycyclic Aromatic Hydrocarbons (NZ MfE)				Result 1	Result 2	RPD			
Acenaphthene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Acenaphthylene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Anthracene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Benz(a)anthracene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Benzo(a)pyrene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Benzo(b&j)fluoranthene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Benzo(g.h.i)perylene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Benzo(k)fluoranthene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Chrysene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Dibenz(a.h)anthracene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Fluoranthene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Fluorene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Indeno(1.2.3-cd)pyrene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Naphthalene	K22-No0015988	CP	mg/kg	< 0.1	< 0.1	<1	30%	Pass	
Phenanthrene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Pyrene	K22-No0015988	CP	mg/kg	< 0.03	< 0.03	<1	30%	Pass	
Duplicate									
Semivolatile Organics				Result 1	Result 2	RPD			
1-Chloronaphthalene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1-Naphthylamine	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2-Dichlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.3-Trichlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.3.4-Tetrachlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.3.5-Tetrachlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.4-Trichlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.2.4.5-Tetrachlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.3-Dichlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.3.5-Trichlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
1.4-Dichlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Chloronaphthalene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Chlorophenol	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Methyl-4.6-dinitrophenol	K22-No0015988	CP	mg/kg	< 5	< 5	<1	30%	Pass	
2-Methylnaphthalene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Methylphenol (o-Cresol)	K22-No0015988	CP	mg/kg	< 0.2	< 0.2	<1	30%	Pass	
2-Naphthylamine	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Nitroaniline	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2-Nitrophenol	K22-No0015988	CP	mg/kg	< 1	< 1	<1	30%	Pass	
2-Picoline	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.3.4.6-Tetrachlorophenol	K22-No0015988	CP	mg/kg	< 5	< 5	<1	30%	Pass	
2.4-Dichlorophenol	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.4-Dimethylphenol	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.4-Dinitrophenol	K22-No0015988	CP	mg/kg	< 5	< 5	<1	30%	Pass	
2.4-Dinitrotoluene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.4.5-Trichlorophenol	K22-No0015988	CP	mg/kg	< 1	< 1	<1	30%	Pass	
2.4.6-Trichlorophenol	K22-No0015988	CP	mg/kg	< 1	< 1	<1	30%	Pass	
2.6-Dichlorophenol	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
2.6-Dinitrotoluene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
3&4-Methylphenol (m&p-Cresol)	K22-No0015988	CP	mg/kg	< 0.4	< 0.4	<1	30%	Pass	
3-Methylcholanthrene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
3.3'-Dichlorobenzidine	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
4-Aminobiphenyl	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
4-Bromophenyl phenyl ether	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
4-Chloro-3-methylphenol	K22-No0015988	CP	mg/kg	< 1	< 1	<1	30%	Pass	
4-Chlorophenyl phenyl ether	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	

Duplicate									
Semivolatile Organics				Result 1	Result 2	RPD			
4-Nitrophenol	K22-No0015988	CP	mg/kg	< 5	< 5	<1	30%	Pass	
4.4'-DDD	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
4.4'-DDE	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
4.4'-DDT	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
7.12-Dimethylbenz(a)anthracene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
a-HCH	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Acetophenone	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Aldrin	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Aniline	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
b-HCH	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Benzyl chloride	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Bis(2-chloroethoxy)methane	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Bis(2-chloroisopropyl)ether	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Bis(2-ethylhexyl)phthalate	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Butyl benzyl phthalate	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
d-HCH	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Di-n-butyl phthalate	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Di-n-octyl phthalate	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dibenz(a.j)acridine	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dibenzofuran	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dieldrin	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Diethyl phthalate	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dimethyl phthalate	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Dimethylaminoazobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Diphenylamine	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Endosulfan I	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endosulfan II	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endosulfan sulphate	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endrin	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endrin aldehyde	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endrin ketone	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
g-HCH (Lindane)	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Heptachlor	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Heptachlor epoxide	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Hexachlorobenzene	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Hexachlorobutadiene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Hexachlorocyclopentadiene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Hexachloroethane	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Methoxychlor	K22-No0015988	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
N-Nitrosodibutylamine	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
N-Nitrosodipropylamine	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
N-Nitrosopiperidine	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Nitrobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Pentachlorobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Pentachloronitrobenzene	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Pentachlorophenol	K22-No0015988	CP	mg/kg	< 1	< 1	<1	30%	Pass	
Phenol	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Pronamide	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	
Trifluralin	K22-No0015988	CP	mg/kg	< 0.5	< 0.5	<1	30%	Pass	

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	Yes
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Qualifier Codes/Comments

Code	Description
N07	Please note:- These two PAH isomers closely co-elute using the most contemporary analytical methods and both the reported concentration (and the TEQ) apply specifically to the total of the two co-eluting PAHs
Q15	The RPD reported passes Eurofins Environment Testing's QC - Acceptance Criteria as defined in the Internal Quality Control Review and Glossary page of this report.

Authorised by:

Karishma Patel	Analytical Services Manager
Michael Ritchie	Senior Analyst-Organic

Michael Ritchie
Head of Semi Volatiles (Key Technical Personnel)

Final Report – this report replaces any previously issued Report

- Indicates Not Requested

* Indicates IANZ accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request or please click here.

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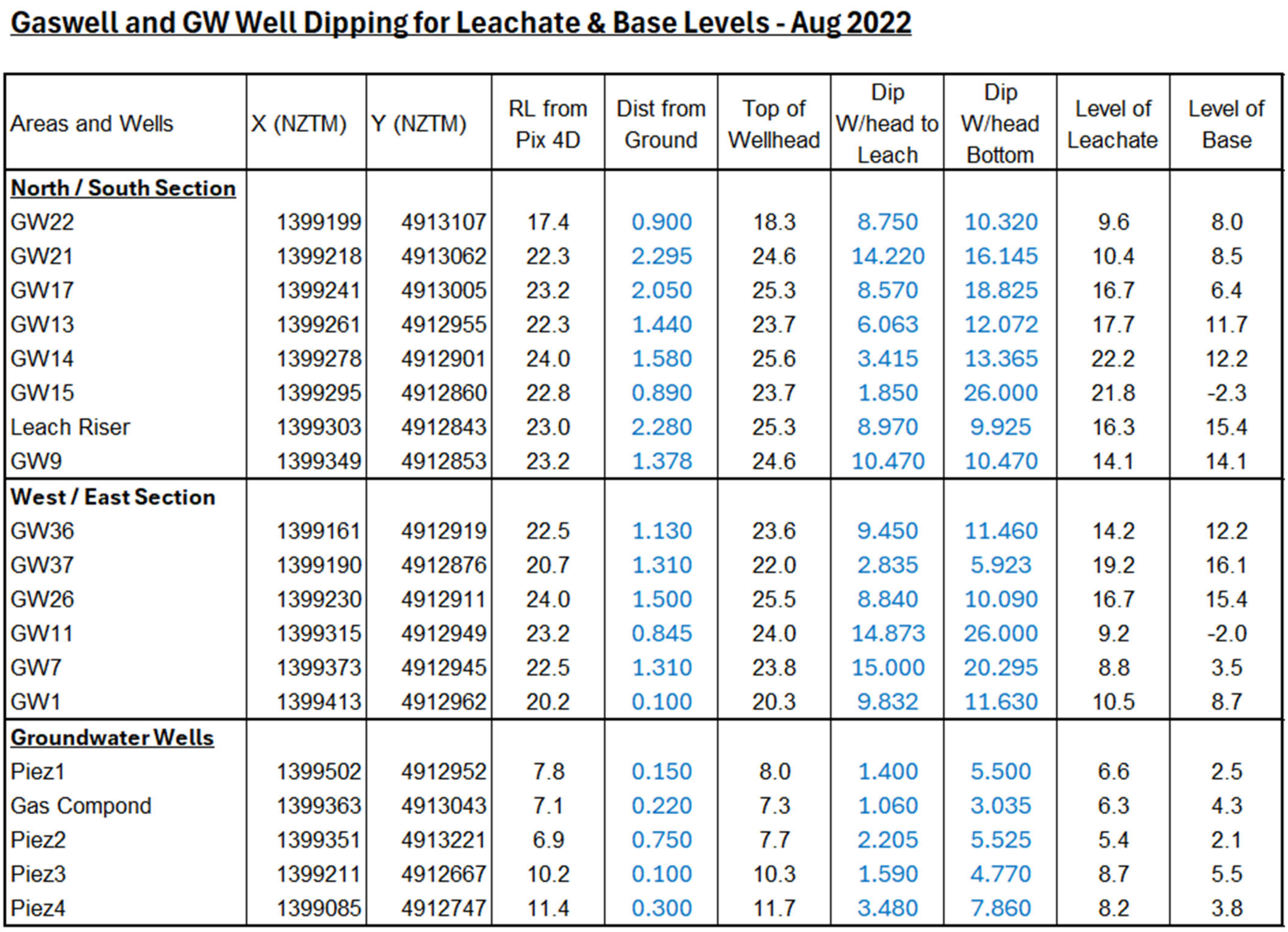
Appendix E

Leachate within the landfill

E-1 Leachate levels within landfill

Gas wells and groundwater monitoring wells within the landfill were dipped to measure the level of leachate within the landfill footprint (August 2022). These measurements are presented below in Table E.1. Figure E.1 shows the location of the wells. The leachate measurements were undertaken by a site contractor, GHD has not verified these measurements.

Table E.1 Leachate measurements



Gaswell and GW Well Dipping for Leachate & Base Levels - Aug 2022

Areas and Wells	X (NZTM)	Y (NZTM)	RL from Pix 4D	Dist from Ground	Top of Wellhead	Dip W/head to Leach	Dip W/head Bottom	Level of Leachate	Level of Base
North / South Section									
GW22	1399199	4913107	17.4	0.900	18.3	8.750	10.320	9.6	8.0
GW21	1399218	4913062	22.3	2.295	24.6	14.220	16.145	10.4	8.5
GW17	1399241	4913005	23.2	2.050	25.3	8.570	18.825	16.7	6.4
GW13	1399261	4912955	22.3	1.440	23.7	6.063	12.072	17.7	11.7
GW14	1399278	4912901	24.0	1.580	25.6	3.415	13.365	22.2	12.2
GW15	1399295	4912860	22.8	0.890	23.7	1.850	26.000	21.8	-2.3
Leach Riser	1399303	4912843	23.0	2.280	25.3	8.970	9.925	16.3	15.4
GW9	1399349	4912853	23.2	1.378	24.6	10.470	10.470	14.1	14.1
West / East Section									
GW36	1399161	4912919	22.5	1.130	23.6	9.450	11.460	14.2	12.2
GW37	1399190	4912876	20.7	1.310	22.0	2.835	5.923	19.2	16.1
GW26	1399230	4912911	24.0	1.500	25.5	8.840	10.090	16.7	15.4
GW11	1399315	4912949	23.2	0.845	24.0	14.873	26.000	9.2	-2.0
GW7	1399373	4912945	22.5	1.310	23.8	15.000	20.295	8.8	3.5
GW1	1399413	4912962	20.2	0.100	20.3	9.832	11.630	10.5	8.7
Groundwater Wells									
Piez1	1399502	4912952	7.8	0.150	8.0	1.400	5.500	6.6	2.5
Gas Compond	1399363	4913043	7.1	0.220	7.3	1.060	3.035	6.3	4.3
Piez2	1399351	4913221	6.9	0.750	7.7	2.205	5.525	5.4	2.1
Piez3	1399211	4912667	10.2	0.100	10.3	1.590	4.770	8.7	5.5
Piez4	1399085	4912747	11.4	0.300	11.7	3.480	7.860	8.2	3.8

**GW15 was re-dipped by GHD, the well depth was measured at 26 m bgl*

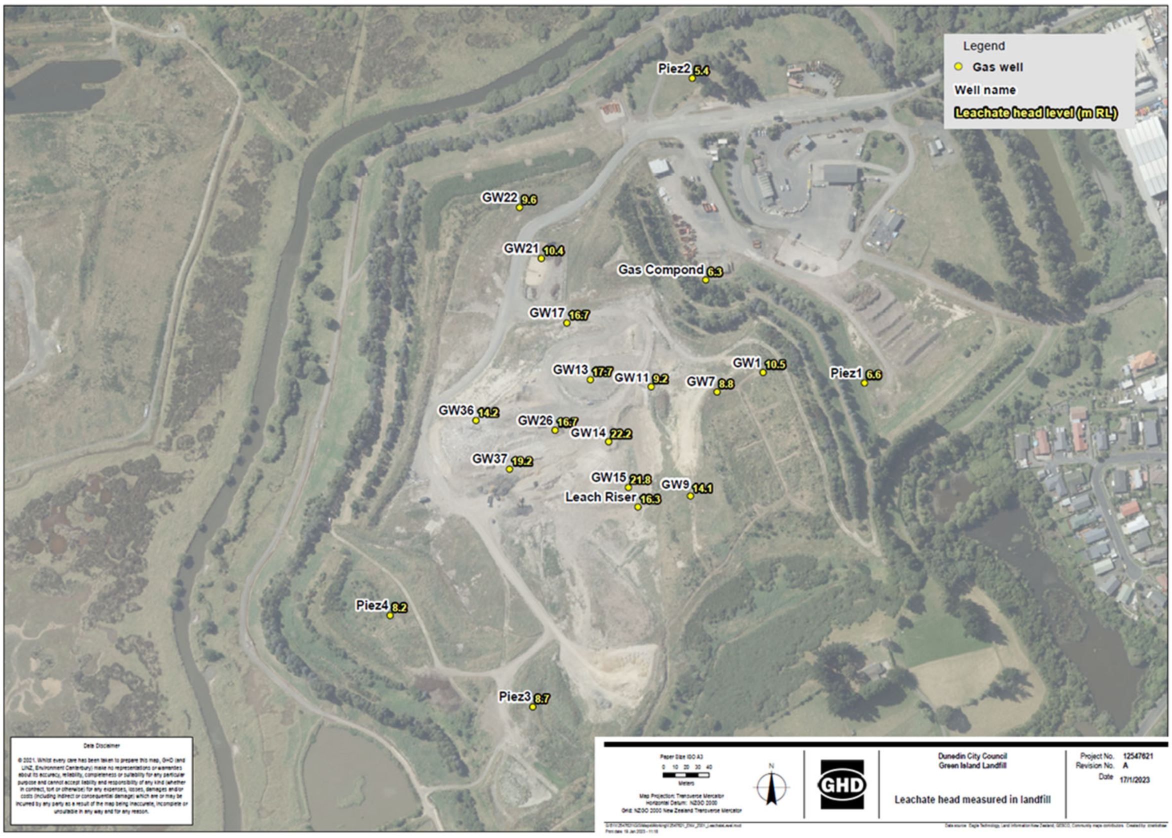


Figure E.1 Gas Well Locations and leachate measurements

Appendix F

HELP modelling assessment

F-1 Introduction

This technical appendix outlines the water balance assessment of rainfall infiltration through the current and proposed cap at Green Island Landfill. The results of this HELP assessment has been incorporated into the SEEP/W modelling (included as Appendix G), which has been prepared to inform an assessment of environmental effects (AEE) of the continued operation and subsequent closure of the landfill.

Rainfall infiltration through the landfill cap 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 landfill 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 liners.

Four different areas of the landfill were modelled to assess leachate generation and leakage. The water balance estimated during the stages of landfill development were used to provide the whole of landfill water balance at different times through the proposed landfill operational lifecycle.

The results of the HELP modelling provide information to support an assessment of environmental effects for continued operation and subsequent closure of Green Island landfill.

F-1.1 Landfill profiles

Four different areas of the landfill, in different phases of landfill development, were considered in predicting the landfill water balance (Figure F.1)

- Area A - Transfer station
  - 87,386 m^2 of final cap
- Area B - Operational landfill - capped area:
    - 50,379 m^2 of waste with final cap
- Area C – Perimeter Bund – capped area
  - 96,330 m^2 of waste overlain by a capping material
- Area D - Operational landfill:
  - Existing conditions through to start of 2022
    - 97,380 m^2 of exposed open waste
  - Following installation of mid-landfill drainage layer
    - 97,380 m^2 of bare soil contoured towards drainage system
  - Future capped landfill
    - 97,380 m^2 of waste with final cap

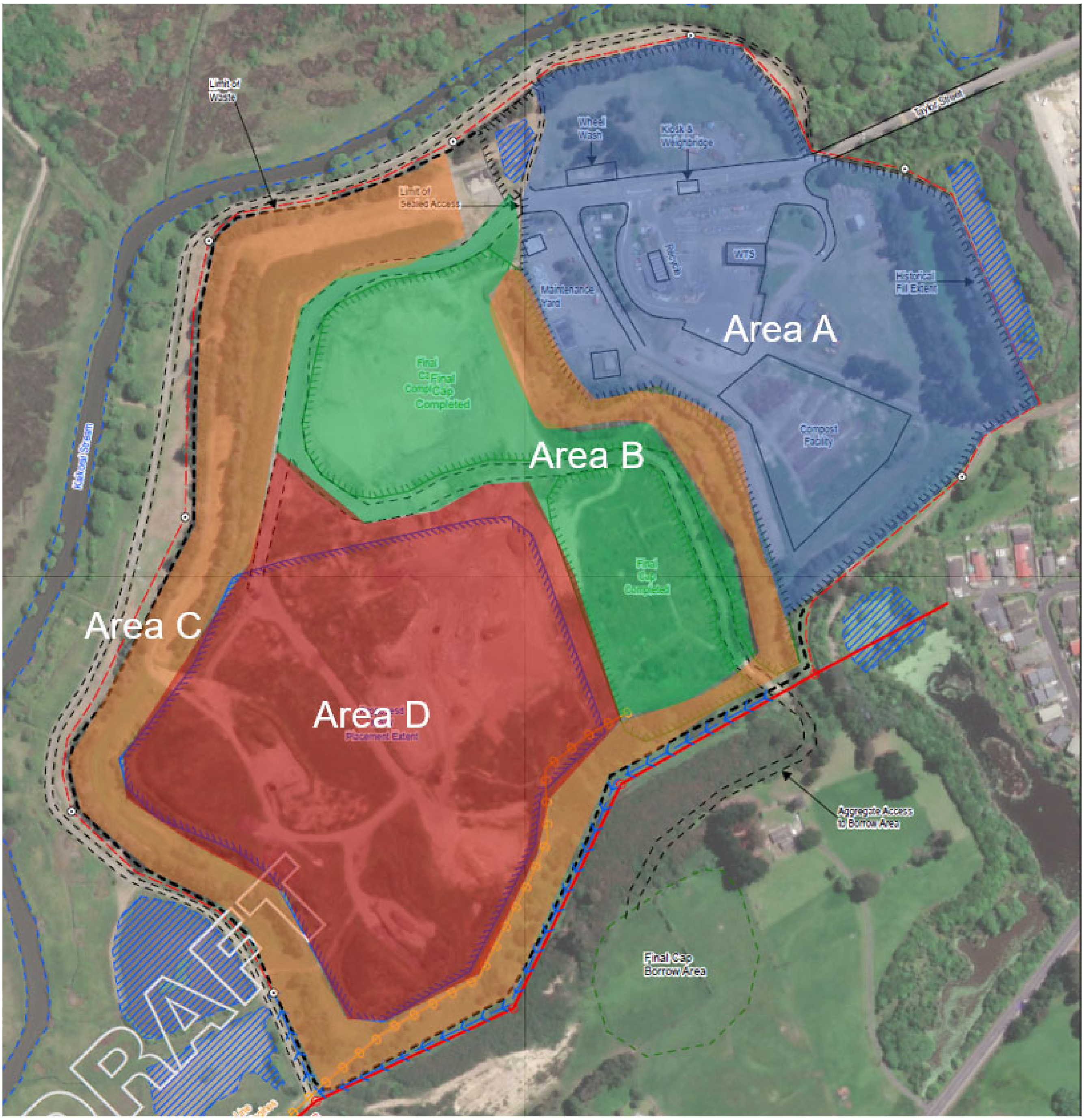


Figure F.1 *Landfill Areas A - D*

The profile characteristics adopted are presented in Tables F.8 – F.11 (attached). 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 F.1. Additional scenarios were also run for Area B and Area D where the hydraulic conductivity of the landfill cap (layer 3) was reduced to undertake sensitivity testing (Table F.2).

Table F.1 ***Justification for adopted soil texture and saturated hydraulic conductivity***

Profile	Soil Unit	Adopted USDA Soil Texture[(1)]	USDA saturated hydraulic conductivity (cm/s)	Adopted saturated hydraulic conductivity (cm/s)	Justification
Area A Transfer Station - capped	Topsoil and cap (layers 1 & 2)	6 – Sandy Loam (slightly compacted)	$1.9x10^{-4}$	$5x10^{-4}$	Described as topsoil overlain by sandy silt or sandy gravel during GHD site investigation (2021).
Area B Operational landfill – existing cap	Topsoil and subsoil (layers 1 & 2)	14 – Silty Clay (slightly compacted)	$2.5x10^{-5}$		No change to USDA value. Top soil and subsoil will be sourced from clean imported soils. Minor compaction and contouring assumed.
	Barrier Clay (layer 3)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-6}$	On site borrow pit material largely described as sandy clayey silt. Laboratory testing results in the order of $1x10^{-9}$ m/s.
	Soil (layer 4)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-4}$	Represents intermediate cover which will be present before placement of final cap.
Area C - Perimeter Bund	Cap (layer 1)	28 – Silty clay – moderately compacted	$1.2x10^{-6}$	$1x10^{-5}$	Adopted to represent perimeter bund capping material
Area D Operational landfill – open waste	Daily / intermediate cover (layer 1)	6 – Sandy Loam (slightly compacted)	$1.9x10^{-4}$	$5x10^{-4}$	Adopted to represent daily or intermediate cover for open waste
Area D Operational landfill – worst case drainage	Drainage layer (layers 1 and 2)	21 – Gravel	$3x10^{-1}$		No change to USDA value. Adopted to represent worst case for rainfall infiltration and collection of leachate from mid-landfill drainage layer.
Area D Operational landfill – worst case drainage and future cap	BSL beneath mid-landfill drainage (layer 3 in worst case profile and layer 7 in future capped profile)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-5}$	Adopted to represent soil layer beneath mid-landfill drainage
Area D Operational landfill – future cap	Topsoil and subsoil (layers 1 & 2)	14 – Silty Clay (slightly compacted)	$2.5x10^{-5}$		No change to USDA value. Top soil and subsoil will be sourced from clean imported soils. Minor compaction and contouring assumed.
	Barrier Clay (layer 3)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-5}$	Cap is designed to meet specification of $1x10^{-7}$ m/s. Moderate compaction assumed.
	Soil (layer 4)	28 – Silty Clay (moderately compacted)	$1.2x10^{-6}$	$1x10^{-4}$	Represents intermediate cover which will be present before placement of final cap.

Profile	Soil Unit	Adopted USDA Soil Texture[(1)]	USDA saturated hydraulic conductivity (cm/s)	Adopted saturated hydraulic conductivity (cm/s)	Justification
All Landfill Profiles (landfill waste and natural ground)	Municipal Waste	18 - Municipal Waste (312 kg/m^3)	1x10^{-3}	1x10^{-5}	A large proportion of waste received (approx. 50%) is soils, which has reduced the hydraulic conductivity. Municipal waste at Green Island landfill reported to have density > 1,000 kg/m^3.
	Natural ground	28 – Silty Clay (moderately compacted)	1.2x10^{-6}	5x10^{-7}	UKEM and LKEM units reported horizontal hydraulic conductivity range of 1x10^{-6} – 1x10^{-7} m/s. Significant anisotropy assumed due to variable thin beds of sand, silty sand, sandy silt, silt, clayey silt and silty clay, and value calibrated to recorded leachate head.

1) Schroeder et al., 1994.

2) Berger and Schroeder, 2013.

Table F.2 Scenario testing for landfill cap hydraulic conductivity

Landfill Area	Scenario	Hydraulic conductivity of capping layer (Layer 3) (cm/s)
Area B – Operational landfill – existing cap	1 – Base case (as per Table 1)	1x10^{-6}
	2 – Reduced hydraulic conductivity by 1 order of magnitude	1x10^{-7}
Area D – Operational landfill – future cap	1 – Base case (as per Table 1)	1x10^{-5}
	2 – Reduced hydraulic conductivity by 1 order of magnitude	1x10^{-6}
	3 – Reduced hydraulic conductivity by 2 orders of magnitude	1x10^{-7}

F-1.2 Landfill base and drainage layers

HELP models include the functionality to apply the parameters of slope and flow path distance to lateral drainage layers (LDL) that overlay landfill liners or barrier soil layers (BSL) within the landfill profile. The existing Green Island landfill has no formal landfill liner or internal leachate collection system, however the underlying natural geology demonstrates low vertical permeability. Therefore, although a BSL was included within the landfill profiles to simulate the base of the landfill, the overlying layer of municipal waste was modelled as a vertical percolation layer (VPL), not a LDL. Lateral movement of leachate within the waste immediately above the base of the landfill is not expected to be occurring, particularly as the base of the landfill is inferred to be relatively flat.

The design of the operational area of the landfill (Area D) does however include a barrier soil layer and overlying leachate drainage collection system in the middle of the waste profile, which has been installed to capture leachate generated above this layer. The slope and average flow path distance to the leachate collection drains for the modelled LDL is presented in Table F.3. Sensitivity testing of the average flow path distance within the Area D future capped landfill profile indicated that this parameter has no influence on the results as no perching is expected to occur to generate horizontal flow towards the drains. A distance of 15 m was adopted for the Area D future capped profile. For the Area D worst case landfill drainage profile average flow path distances of both 15 m and 75 m were modelled, with the combined results assuming that 1/3 of Area D represents the average conditions in the southern section and 2/3 the average conditions in the northern section.

LDLs are also incorporated above BSLs representing the landfill cap in all landfill profiles which include capping layers (Table F.3). Due to significant differences in the slope and average flow path distance for the eastern and western sections of Area D, two models were used to assess the two different scenarios. The results for Area D (future capped) averaged the results from these two profiles, as each scenario is assumed to represent conditions across approximately 50% of Area D.

Table F.3 Landfill area and slope of drainage layer

Landfill area and stage	Description of layer	Slope (%)	Average flow path distance to leachate collection / drain (m)
Area D Operational landfill – worst case landfill drainage	Mid-landfill drainage	4.5	15 – South 75 – North
Area D Operational landfill – future capped area			
Area A Transfer station – capped	Drainage above cap	2	100
Area B Operational landfill – existing capped	Drainage above cap	4.5	100
Area D Operational landfill – future capped	Drainage above cap	21 – West 3.8 – East	70 – West 175 – East

F-1.3 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 WGEN to generate inputs for the parameters ‘Solar Radiation’ and ‘Growing Season’. The NIWA weather station located at Musselburgh, Dunedin (Agent numbers 15752 and 5402) was used within WGEN to generate inputs for all other parameters, as described in Table F.4 (NIWA, 2022). Detailed input data are presented in Tables F.15 and F.16 (attached).

Table F.4 WGEN climate input data and sources

Parameter	Source and data period	Input format to WGEN
Precipitation	Daily rainfall NIWA station 5402: (May 1970 – August 1997) NIWA station 15752: (August 1997 – October 2022)	Monthly average
Temperature	Daily Tmax and Tmin NIWA station 5402: (May 1970 – August 1997) NIWA station 15752: (August 1997 – October 2022)	Average of daily Tmax and Tmin input as monthly average
Solar radiation	Taulis and Milke (2005) derived parameter for Dunedin, Otago (latitude -45.9)	Annual average solar radiation
Growing season	Taulis and Milke (2005) derived parameter for Dunedin, Otago (latitude -45.9).	'Start day' and 'End day' (Julian date) input to evapotranspiration parameter
Wind speed	Mean wind speed (annual): NIWA station 5402 (1982, 1988, 1989) NIWA station 15752 (1988 – 2021)	Annual average input to evapotranspiration parameter
Relative humidity	Monthly mean of 9am relative humidity: NIWA station 5402 (Jan 1972 – Aug 1997) NIWA station 15752 (Sep 1997 – Oct 2022)	Average per quarter input to evapotranspiration parameter

In developing the HELP climate data, the user defined parameters and values presented in Table F.5 were also included within the input data for evapotranspiration:

Table F.5 Evapotranspiration input data for WGEN

Landfill area and stage	Maximum leaf area index	Evaporative zone depth (cm)
Area A – Transfer station (capped)	1	20
Area B – Operational landfill (existing capped)	2	10
Area C – Perimeter bund (existing capped)	2	20
Area D – Operational landfill (existing open waste)	0	10
Area D – Operational landfill (worst case drainage)	0	10
Area D – Operational landfill (future capped)	3.5	15

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 modelled landfill profile are presented in Table F.6. As discussed in the previous section, the results for the Area D worst case drainage scenario assume the southern area represents average conditions across 1/3 of Area D and the northern area represents average conditions across 2/3 of Area D. The results for the Area D future capped scenario assume a 50% distribution of the average conditions in the east and west.

Table F.6 ***Parameters for determination of runoff curve number for each landfill area and development stage***

Landfill area and stage	Soil Texture	Average Surface Flow Path Length (m)	Surface slope	Surface Vegetation
Area A – Transfer station (capped)	Sandy loam – slightly compacted	100	2%	Poor grass
Area B – Operational landfill (existing capped)	Silty clay – slightly compacted	100	4.5%	Fair grass
Area C – Perimeter bund (existing capped)	Silty clay – moderately compacted	20	20%	Fair grass
Area D – Operational landfill (existing open waste)	Sandy loam – slightly compacted	60	0.1%	Bare soil
Area D – Operational landfill (worst case drainage)	Gravel	15 – South 75 – North	5%	Bare soil
Area D – Operational landfill (future capped)	Silty clay – slightly compacted	70 – West 175 – East	21% – West 3.8% – East	Good grass

F-2 Results

The results of the HELP modelling are presented in Tables F.17 and F.18 (attached). The reported results represent the annual average output values over the entire model period which incorporates the 50-year stochastic weather files. The results are therefore anticipated to increase or decrease in response to above or below average climatic conditions.

F-2.1 Infiltration

Infiltration as a percentage of total rainfall across the different landfill areas and scenarios are presented in Table F.7.

Table F.7 Infiltration as a percentage of total rainfall

Landfill area and stage	Scenario	Infiltration (%)
Area A – Transfer station (capped)	1 – Base case	32
Area B - Operational landfill (existing capped)	1 – Base case	26
	2 – Reduced hydraulic conductivity by 1 order of magnitude	5
Area C - Perimeter bund (existing capped)	1 – Base case	20
Area D - Operational landfill (existing open waste)	1 – Base case	32
Area D - Operational landfill (worst case drainage) (South)	1 – Base case	34
Area D - Operational landfill (worst case drainage) (North)	1 – Base case	47
Area D - Operational landfill (future capped) (West and East)	1 – Base case	33
	2 – Reduced hydraulic conductivity by 1 order of magnitude	28
	3 – Reduced hydraulic conductivity by 2 orders of magnitude	6

F-2.2 Consideration of climate change

A review of the estimated changes in precipitation, temperature and relative humidity for Dunedin was undertaken using the NIWA 'Our future climate New Zealand' online tool (NIWA, 2023) and compared against the adopted site climate data from Musselburgh, Dunedin (NIWA, 2022) used to generate the synthetic weather files in WGEN (Section F-1.3). The NIWA (2023) data considered was from the lower end of annual mean change for 2090 (representing end century 2081 – 2100) for the six-model-average RCP8.5. This is considered conservative due to the post-closure consent being due to expire in 2064. The results are presented in Table F.8, Table F.9 and Table F.10. The results indicate approximately a 10% increase in annual mean rainfall between 1995 and 2090, up to 2 degrees C increase in temperature and minimal reductions in relative humidity.

Table F.8 Estimated rainfall change

Month	Average monthly rainfall (mm) (1)	Season	Estimated rainfall change (%) (2)	Estimated monthly rainfall (mm)
January	70	Summer	0%	70
February	61	Summer	0%	61
March	60	Autumn	10%	66
April	57.4	Autumn	10%	63.14

Month	Average monthly rainfall (mm) (1)	Season	Estimated rainfall change (%) (2)	Estimated monthly rainfall (mm)
May	67.2	Autumn	10%	73.92
June	65.2	Winter	20%	78.24
July	63.8	Winter	20%	76.56
August	57.9	Winter	20%	69.48
September	48.7	Spring	10%	53.57
October	64	Spring	10%	70.4
November	60.5	Spring	10%	66.55
December	74	Summer	0%	74
Annual Total	749.7			822.86

1) Site climate data from Musselburgh, Dunedin (NIWA, 2022).
2) Our Future Climate New Zealand NIWA (2023). Assumptions for estimated change: RCP8.5, Six-model-average. Adopted change from lower end of annual mean change for 2090 (representing end-century 2081 - 2100).

Table F.9 Estimated temperature change

Month	Average mean monthly temperature (C) (1)	Season	Estimated temperature change (C) (2)	Estimated monthly temperature (C)
January	15.2	Summer	1	16.2
February	15.2	Summer	1	16.2
March	14	Autumn	2	16
April	12	Autumn	2	14
May	9.5	Autumn	2	11.5
June	7.4	Winter	2	9.4
July	6.7	Winter	2	8.7
August	7.8	Winter	2	9.8
September	9.4	Spring	1	10.4
October	10.9	Spring	1	11.9
November	12.4	Spring	1	13.4
December	14.1	Summer	1	15.1

1) Site climate data from Musselburgh, Dunedin (NIWA, 2022).
2) Our Future Climate New Zealand NIWA (2023). Assumptions for estimated change: RCP8.5, Six-model-average. Adopted change from lower end of annual mean change for 2090 (representing end-century 2081 - 2100).

Table F.10 Estimated temperature change

Quarter	Relative Humidity (1)	Season	Estimated humidity change % (2)	Estimated relative humidity %
First quarter	75.82%	Summer	0%	75.82%
Second quarter	78.47%	Autumn	0%	78.47%
Third quarter	76.54%	Winter	-2.5%	74.04%
Fourth quarter	71.50%	Spring	-5.0%	66.50%

1) Site climate data from Musselburgh, Dunedin (NIWA, 2022).

Quarter	Relative Humidity (1)	Season	Estimated humidity change % (2)	Estimated relative humidity %

2) Our Future Climate New Zealand NIWA (2023). Assumptions for estimated change: RCP8.5, Six-model-average. Adopted change from lower end of annual mean change for 2090 (representing end-century 2081 - 2100).

The 50-year synthetic weather data generated using WGEN (Section F-1.3) is already considered to include climate variability, with the 50-year rainfall data set reporting an average annual precipitation of 754.6 mm, with standard deviation of 93.9 mm. As presented in Figure F.2, annual average rainfall greater than the approximate 10% annual increase estimated by end-century as a result of climate change has already been modelled within the existing results for 12 of the 50 years.

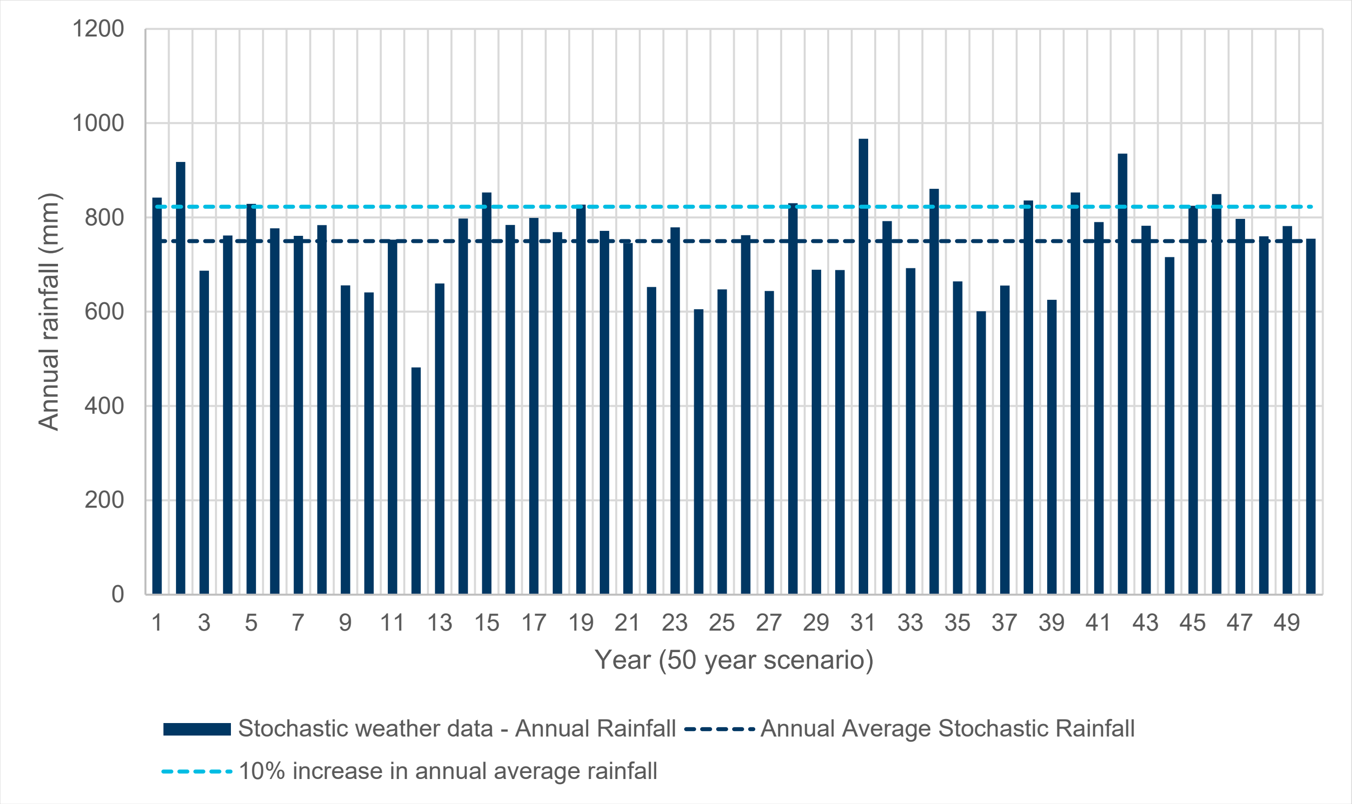


Figure F.2 ***Stochastic 50-year annual rainfall compared against annual average and 10% increase in annual average.***

The greatest rates of leachate generation (through infiltration of rainfall into the landfill waste) are estimated to occur during the Area D ‘worst case drainage’ scenario. However following capping of Area D the rate of leachate generation is estimated to reduce (Section F-2.1). As capping of the landfill is proposed to be complete by 2029, only the capped landfill will be subject to the estimated changes in climate. The estimated increase in precipitation as a result of climate change is therefore considered likely to result in rates of leachate generation no greater than estimated prior to completion of landfill capping.

F-2.3 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.

NIWA, 2022. The national climate database. **https://cliflo.niwa.co.nz/** [Accessed November 2022]

NIWA, 2023. Our Future Climate New Zealand. **https://ofcnz.niwa.co.nz/#/home** [Accessed July 2023].

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

Table F.11 Area A Transfer Station HELP Model soil profile

Scenario	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)
Transfer Station - Capped	1	Topsoil	Sandy loam – slightly compacted	VPL	20	5.0E-04	0.452	0.19	0.085
	2	Cap	Sandy loam – slightly compacted	BSL	50	5.0E-04	0.453	0.19	0.085
	3	Municipal waste	Municipal waste	VPL	700	1.0E-05	0.671	0.292	0.077
	4	Natural ground	Silty clay - moderately compacted	BSL	500	5.0E-07	0.452	0.411	0.311

* U.S. Department of Agriculture (USDA) soil textural classification system reported in Schroeder et al., (1994).

** VPL = Vertical Percolation Layer. BSL = Barrier Soil Layer.

Table F.12 Area B Operational landfill – existing capped HELP Model soil profile

Scenario	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)
Operational landfill – capped area	1	Topsoil	Silty clay - slightly compacted	VPL	10	2.5E-05	0.479	0.371	0.251
	2	Subsoil	Silty clay - slightly compacted	LDL	10	2.5E-05	0.479	0.371	0.251
	3	Clay cap	Silty clay – moderately compacted	BSL	150	1.0E-06	0.452	0.411	0.311
	4	Soil	Silty clay - slightly compacted	VPL	30	2.5E-05	0.479	0.371	0.251
	5	Municipal waste	Municipal waste	VPL	2000	1.0E-05	0.671	0.292	0.077
	6	Natural ground	Silty clay - moderately compacted	BSL	500	5.0E-07	0.452	0.411	0.311

* U.S. Department of Agriculture (USDA) soil textural classification system reported in Schroeder et al., (1994).

** VPL = Vertical Percolation Layer. LDL = Lateral Drainage Layer. BSL = Barrier Soil Layer.

Table F.13 *Area C Perimeter Bund HELP Model soil profile*

Scenario	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)
Operational landfill – capped area	1	Cap	Silty clay – moderately compacted	VPL	500	1.0E-05	0.452	0.411	0.311
	2	Municipal waste	Municipal Waste	VPL	500	1.0E-05	0.671	0.292	0.077
	3	Natural ground	Silty clay - moderately compacted	BSL	500	5.0E-07	0.452	0.411	0.311

* U.S. Department of Agriculture (USDA) soil textural classification system reported in Schroeder et al., (1994).

** VPL = Vertical Percolation Layer. BSL = Barrier Soil Layer.

Table F.14 *Area D Operational landfill – open waste, worst case drainage and future capped HELP Model soil profiles*

Scenario	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)
Operational landfill – open waste	1	Daily / intermediate cover	Sandy loam – slightly compacted	VPL	10	5.0E-04	0.452	0.19	0.085
	2	Municipal waste	Municipal waste	VPL	1000	1.0E-05	0.671	0.292	0.077
	3	Natural ground	Silty clay - moderately compacted	BSL	500	5.0E-07	0.452	0.411	0.311
Operational landfill – worst case drainage	1	Drainage layer	Gravel	VPL	10	3.0E-01	0.397	0.032	0.013
	2	Drainage layer	Gravel	LDL	20	3.0E-01	0.397	0.032	0.013
	3	Soil below drainage	Silty clay – Moderately compacted	BSL	500	1.0E-05	0.452	0.411	0.311
	4	Municipal waste	Municipal waste	VPL	1000	1.0E-05	0.671	0.292	0.077
	5	Natural ground	Silty clay - moderately compacted	BSL	500	5.0E-07	0.452	0.411	0.311
Operational landfill – future capping	1	Topsoil	Silty clay - slightly compacted	VPL	15	2.5E-05	0.479	0.371	0.251
	2	Subsoil	Silty clay - slightly compacted	LDL	20	2.5E-05	0.479	0.371	0.251
	3	Clay cap	Silty clay – moderately compacted	BSL	60	1.0E-05	0.452	0.411	0.311
	4	Intermediate cap	Silty clay - slightly compacted	VPL	30	2.5E-05	0.479	0.371	0.251
	5	Municipal Waste	Municipal waste	VPL	1000	1.0E-05	0.671	0.292	0.077
	6	Drainage layer	Municipal waste	LDL	200	1.0E-05	0.671	0.292	0.077
	7	Soil below drainage	Silty clay – Moderately compacted	BSL	500	1.0E-05	0.452	0.411	0.311
	8	Municipal waste	Municipal waste	VPL	1000	1.0E-05	0.671	0.292	0.077
	9	Natural ground	Silty clay - moderately compacted	BSL	500	5.0E-07	0.452	0.411	0.311

* U.S. Department of Agriculture (USDA) soil textural classification system reported in Schroeder et al., (1994).

** VPL = Vertical Percolation Layer. LDL = Lateral Drainage Layer. BSL = Barrier Soil Layer.

Table F.15 ***Average monthly values used in 50 – year synthetic weather file generation for daily precipitation and daily mean temperature (WGEN)***

Month	Average monthly rainfall (mm) (1)	Average mean monthly temperature (C) (1)
January	70.0	15.2
February	61.0	15.2
March	60.0	14.0
April	57.4	12.0
May	67.2	9.5
June	65.2	7.4
July	63.8	6.7
August	57.9	7.8
September	48.7	9.4
October	64.0	10.9
November	60.5	12.4
December	74.0	14.1
1) Data from Musselburgh, Dunedin. May 1970 – October 2022 (NIWA, 2022)		

Table F.16 ***Parameter values adopted in the solar radiation and evapotranspiration input data files***

Parameter	Adopted values	Data source
Solar radiation	12.2	Taulis and Milke (2005) value for Dunedin, Otago based on latitude of -45.9
Growing season (Julian date)	Start day: 274 End day: 171	
Wind speed	Yearly average: 13.3 km/hour	Musselburgh, Dunedin (1982 1988, 1989, 1998 – 2021) (NIWA, 2022)
Average relative humidity	First quarter: 75.82% Second quarter: 78.47% Third quarter: 76.54% Fourth quarter: 71.5%	Musselburgh, Dunedin (January 1972 – October 2022) (NIWA, 2022)

Table F.17 HELP Model Leachate Results for closed landfill areas

Landfill Area and Stage	Scenario	Average annual total runoff (mm/year) / m^2	Average annual evapotranspiration (mm/year) / m^2	Average annual percolation to waste (mm/year) / m^2
Area A Transfer Station - capped	1 – Base case	0.60	516.20	237.75
Area B Operational Landfill – existing capped area	1 – Base case	84.93	475.23	193.88
	2 – Reduced hydraulic conductivity by 1 order of magnitude	212.73	506.35	34.31
Area C Perimeter Bund	1 – Base case	94.32	493.25	153.01
Area D Operational Landfill – future capped area (West)	1 – Base case	9.32	498.03	247.12
	2 – Reduced hydraulic conductivity by 1 order of magnitude	40.96	497.65	211.67
	3 – Reduced hydraulic conductivity by 2 orders of magnitude	182.25	512.68	44.43
Area D Operational Landfill – future capped area (East)	1 – Base case	6.94	497.95	249.66
	2 – Reduced hydraulic conductivity by 1 order of magnitude	41.75	497.73	214.74
	3 – Reduced hydraulic conductivity by 2 orders of magnitude	196.09	512.5	44.83

Table F.18 HELP Model leachate results for operational landfill areas

Landfill Area and Stage	Scenario	Average annual total runoff (mm/year) / m^2	Average annual evapotranspiration (mm/year) / m^2	Average annual percolation to waste (mm/year) / m^2
Area D Operational Landfill – open waste	1 – Base case	4.19	471.41	240.75
Area D Operational landfill – worst case drainage (South)	1 – Base case	0.26	308.41	258.18
Area D Operational landfill – worst case drainage (North)	1 – Base case	0.19	300.11	356.86

Appendix G

SEEP/W modelling

G-1 Groundwater modelling (SEEP/W)

G-1.1 Model set-up

The groundwater assessment included 2D modelling using Geostudio 2021 SEEP/W finite element modelling software. Modelling was undertaken to estimate the seepage into the leachate collection drain and to simulate the leachate head within the landfill.

Two SEEP/W cross-sections were created to model the landfill. The location of the cross-section lines is shown in Figure G.1. The models were created based on a drone survey provided by DCC. Each model was initially run under steady-state conditions to simulate the interpreted baseline groundwater conditions. Model were calibrated to:

- Measured leachate head within the landfill (average level).
- Combined pump station flows (from leachate collection trench), under dry weather conditions.

Steady state model scenarios were then run to simulate future conditions at closure, in particular, capping of the landfill and installation of a leachate collection drain in the southern valley. The Line 2 future scenarios include additional filling as outlined in the design report.

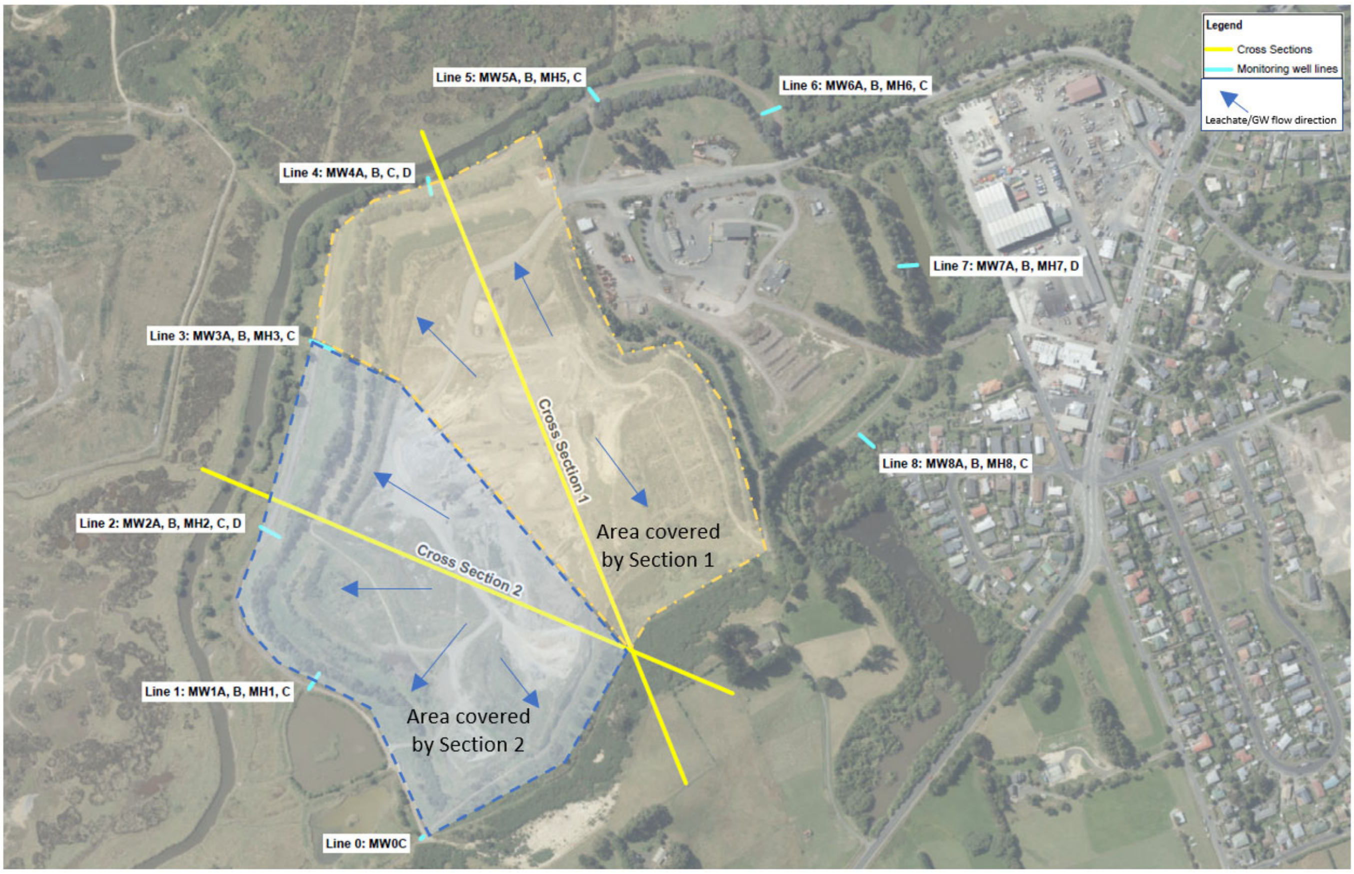


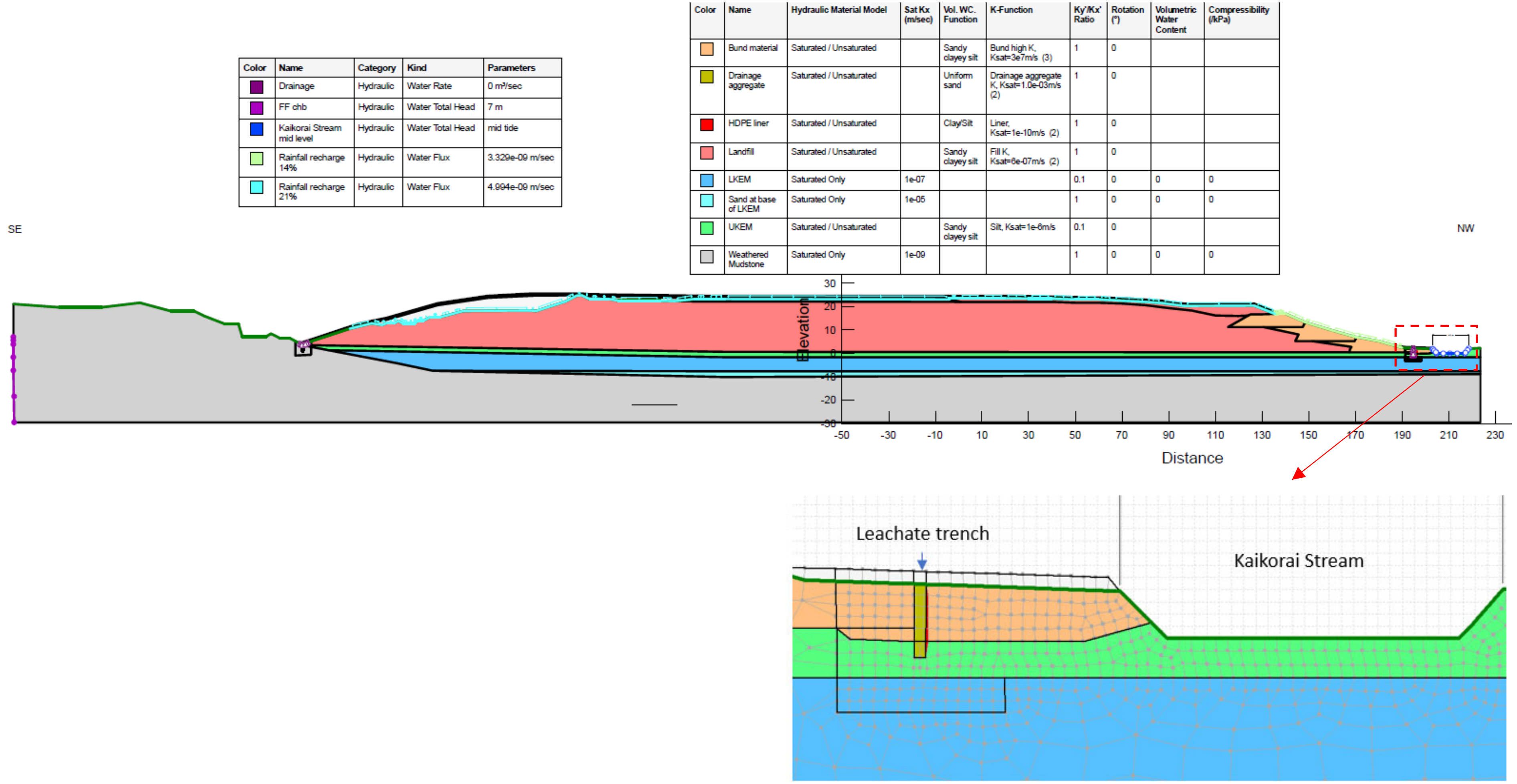
Figure G.1 Location of SEEP/W cross sections

The SEEP/W models adopt the recharge rates as calculated from the HELP modelling assessment (Appendix F), however the recharge rates have been scaled to reflect the actual area and volume of landfill covered by each cross section (Figure G.2 and G.3). The recharge applied in the model reflects to the proportion of rainfall that infiltrates the proposed landfill cap, and has been applied to the layer below the landfill cap (except in un-capped areas where it has been applied to surface). Recharge rates and scaling factors are described in Section G.1.3.

Both model cross sections intercept the existing leachate trench and proposed southern valley trench. The estimated flow rates (per 1 m of trench) into these trenches are presented in the results. These results have been scaled up by the length of the trench.

To augment the leachate interception trench, the current landfill operation has progressively installed trenched leachate drains over the intermediate cover soils in the location of the southern progression of waste placement as well as in the northern sector of waste placed in 2019-2022. It is proposed that additional shallow (0.5 m) leachate drains will be installed in the fill material in the southern portion of the landfill – the area intersected by Line 2. However, given the heterogeneity of the fill materials it is considered that the effect of the drains may be localised. The steady-state model used in this assessment does not simulate variable recharge (from rain events) nor the fill heterogeneity and therefore may overestimate the effect of the drains in reducing leachate head within the fill. For this reason, the future modelling scenarios exclude the shallow leachate drains.

The effect of future sea level rise was considered in the future modelling scenarios. Sea level rise effects were modelled with a higher (0.5 m) river level boundary condition. For this scenario the road/bund level was also increased by 0.5 m as recommended in the *Design Report*.



Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
🟪	FF chb	Hydraulic	Water Total Head	7 m
🟦	Kaikorai Stream mid level	Hydraulic	Water Total Head	mid tide
🟩	Rainfall recharge 14%	Hydraulic	Water Flux	3.329e-09 m/sec
🟦	Rainfall recharge 21%	Hydraulic	Water Flux	4.994e-09 m/sec

Color	Name	Hydraulic Material Model	Sat Kx (m/sec)	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Compressibility (/kPa)
🟧	Bund material	Saturated / Unsaturated		Sandy clayey silt	Bund high K, Ksat=3e7m/s (3)	1	0		
🟨	Drainage aggregate	Saturated / Unsaturated		Uniform sand	Drainage aggregate K, Ksat=1.0e-03m/s (2)	1	0		
🟥	HDPE liner	Saturated / Unsaturated		Clay/Silt	Liner, Ksat=1e-10m/s (2)	1	0		
🟥	Landfill	Saturated / Unsaturated		Sandy clayey silt	Fill K, Ksat=6e-07m/s (2)	1	0		
🟦	LKEM	Saturated Only	1e-07			0.1	0	0	0
🟦	Sand at base of LKEM	Saturated Only	1e-05			1	0	0	0
🟩	UKEM	Saturated / Unsaturated		Sandy clayey silt	Silt, Ksat=1e-6m/s	0.1	0		
⬜	Weathered Mudstone	Saturated Only	1e-09			1	0	0	0

Figure G.2 Line 1 – SEEP/W model set up (current scenario)

Color	Name	Hydraulic Material Model	Sat Kx (m/sec)	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Compressibility (/kPa)
🟧	Bund material	Saturated / Unsaturated		Sandy clayey silt	Bund high K, Ksat = 3e-07m/s (2)	1	0		
🟫	Drainage aggregate	Saturated / Unsaturated		Uniform sand	Drainage aggregate, Ksat=1e-03m/s	1	0		
🟨	Fill	Saturated / Unsaturated		Sandy clayey silt	Fill, Ksat = 3e-07 m/s	1	0		
🟥	HDPE liner	Saturated / Unsaturated		Clay/Silt	Liner, Ksat = 1e-10 m/s	1	0		
🟥	Landfill	Saturated / Unsaturated		Sandy clayey silt	Fill, high k Ksat =6e-07 m/s (2)	1	0		
🟦	LKEM	Saturated Only	1e-07			0.1	0	0	0
🟦	sand at base of LKEM	Saturated Only	1e-05			1	0	0	0
🟩	UKEM	Saturated / Unsaturated		Sandy clayey silt	Silt, Ksat=1e-6m/s	0.1	0		
⬜	Weathered Mudstone	Saturated Only	1e-09			1	0	0	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
🟥	FF chb	Hydraulic	Water Total Head	7 m
🟦	Rainfall recharge 13%	Hydraulic	Water Flux	3.091e-09 m/sec
🟩	Rainfall recharge 16%	Hydraulic	Water Flux	3.805e-09 m/sec
🟦	River level	Hydraulic	Water Total Head	mid level

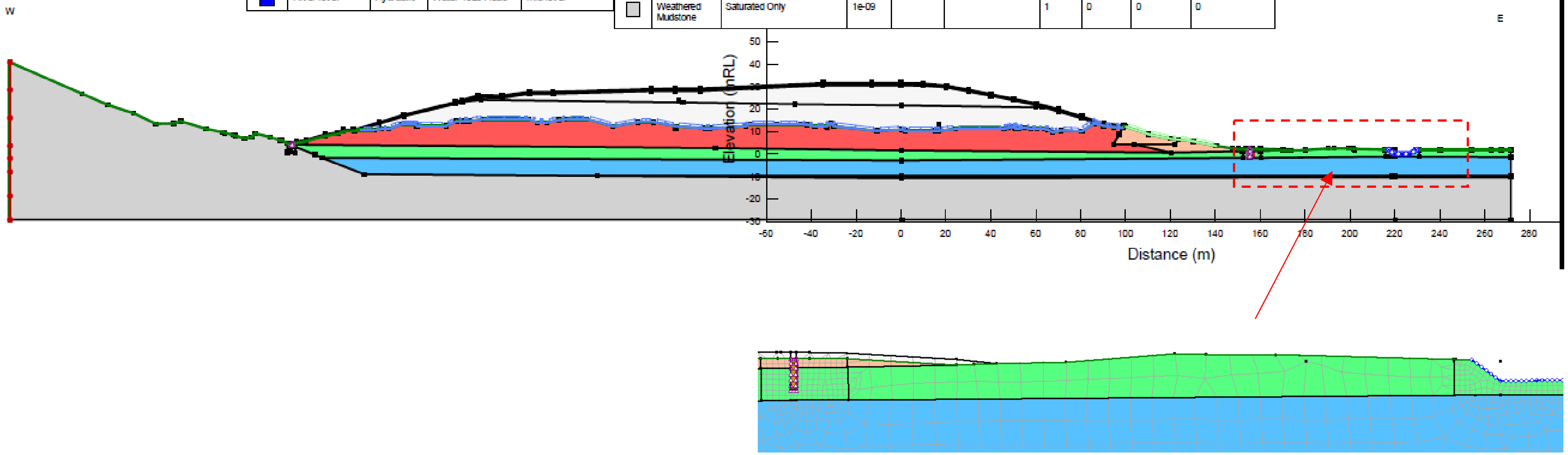


Figure G.3 Line 2 – SEEP/W model set up (current scenario)

G-1.2 Material Properties

Material properties used in the model scenarios considered are summarised in Table G.1.

Hydraulic conductivity values used in modelling were based on the results of hydraulic conductivity testing undertaken as part of the site investigations. In soil units where test results were not available, widely reported in the literature values were used to approximate hydraulic conductivity values.

It is likely that the waste material is highly heterogeneous, with some areas having a higher hydraulic conductivity than other areas depending on the type of waste materials and the degree of compaction undertaken. Hydraulic conductivities of municipal solid waste (MSW) reported in the literature vary between 1 x 10^{-}3 and 1 x 10^{-9} m/s, although most values are in the range of 10^{-5} to 10 $^{-6}$ m/s (LANDSS[10]). It is understood that soil makes up a significant proportion of the waste material at GILF, which is likely to reduce the bulk hydraulic conductivity of the landfill material. The best calibration was achieved using a waste hydraulic conductivity of 6 x 10 $^{-7}$ m/s.

In general, for natural soils/materials, the hydraulic conductivity perpendicular to the soil layers is slower than the conductivity parallel to soil layers. Therefore, the underlying estuarine and marine sediments (UKEM/LKEM) were assigned a Ky/Kx ratio (anisotropy) of 0.1.

A section of the landfill has recently been capped (2022), however the base case model scenarios do not include the final capping material as the current leachate head level is unlikely to reflect these recent changes.

Table G.1 Material properties

Material	Hydraulic material model	Volumetric water content function	Hydraulic conductivity (m/s)	K_y/K_x
Bund Material	Saturated/Unsaturated	Sandy clayey silt	3 x 10^{-7}	1
Landfill material	Saturated/Unsaturated	Sandy clayey silt	6 x 10^{-7}	1
Drainage Aggregate (trench)	Saturated/Unsaturated	Uniform sand	1 x 10^{-3}	1
HDPE liner	Saturated/Unsaturated	Clay/silt	1 x 10^{-10}	1
UKEM	Saturated/Unsaturated	Sandy clayey silt	1 x 10^{-6}	0.1
LKEM	Saturated only	-	1 x 10^{-7}	0.1
Sand at base of LKEM	Saturated only	-	1 x 10^{-5}	1
Weathered Mudstone	Saturated only	-	1 x 10^{-9}	1
Topsoil	Saturated/Unsaturated	Silt Loam	7 x 10^{-7}	1
Cap (10^{-7})	Saturated/Unsaturated	Clay/Silt	1 x 10^{-7}	1
Cap (10^{-8})	Saturated/Unsaturated	Clay/Silt	1 x 10^{-8}	1
Cap (10^{-9})	Saturated/Unsaturated	Clay/Silt	1 x 10^{-9}	1

G-1.3 Boundary Conditions

Far field constant head boundaries were set on the landward edge of the model to approximate inferred groundwater level. River level was inferred based on site observations (average water level when the estuary mouth is not blocked) (Table G.2).

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[10] Landfill (Aftercare) Decision Support System, University of Southampton **https://landss.soton.ac.uk/**

Table G.2 Boundary conditions used in SEEP/W modelling

Type	Value	Details
Constant head (Groundwater head)	7 m RL	Applied to landward (Southern) edge of model
Constant head with potential seepage face applied (Stream level)	Line 1 – 1.1 m RL Line 2 – 0.8 m RL	Approximate river level Applied on creek/stream beds to represent water level when the estuary mouth is not blocked*.
	Line 1 – 1.6 m RL Line 2 – 1.3m RL	Sea level rise scenario Applied on creek/stream beds to represent water level when the estuary mouth is not blocked*.
Seepage face	0 m^3/s with potential seepage face applied	Applied to leachate collection trench to simulate pumping from leachate collection system

*Higher river levels occur from time to time when the river/estuary mouth is blocked

Rainfall recharge was applied to both the landfill and bund surfaces. For the future capped landfill scenarios, the rainfall infiltration was applied to the underside of the landfill cap, as this value represented the rainfall going through the cap (taking into account rainfall and evapotranspiration). The amount of rainfall recharge was based on the outputs of the HELP modelling assessment. However, as the SEEP/W modelling assessment utilises two cross sections to represent a 3D landform, the recharge was scaled down to reflect the average infiltration rate over each landfill sub-area. Without scaling, the models would have overestimated the infiltration into the landfill material and leachate trench flow rates. However, this approach (averaging of rainfall recharge) may underestimate the leachate head level in the centre of the landfill. Scale factors are shown in Table G.3 with scaled infiltration rates included in Table G.4.

Table G.3 Recharge scale factors

Area		Area (ha)	Landfill section length (in model, m)	Length of trench covered by model section (m)	Area represented by model (ha)	Recharge scale factor
Area 1 (Section Line 1)	Landfill	12.9	480	400	19.2	0.67
	Bund	1.4	50		2.0	0.7
Area 2 (Section Line 2)	Landfill	11.0	420	620	26.0	0.42
	Bund	2.5	50		3.1	0.8

Table G.4 Scaled rainfall recharge applied in SEEP/W models

Section Line	Material / Surface	Scaled infiltration rate (% of annual rainfall)
Section Line 1	Uncapped	21%
	Cap (10^{-7} m/s)	21%
	Cap (10^{-8} m/s)	17.5%
	Cap (10^{-9} m/s)	3%
	Bund	14%
Section Line 2	Uncapped	13%
	Cap (10^{-7} m/s)	13%
	Cap (10^{-8} m/s)	12%
	Cap (10^{-9} m/s)	2.5%
	Bund	16%

G-1.4 Model assumptions and limitations

- It is assumed that hydraulic conductivities for the landfill and bund materials adopted in the model simulations are appropriate average values, given the likely heterogeneity of the fill materials.
- The field investigations have identified significant variation in the underlying marine and estuarine sedimentary deposits (UKEM/LKEM). Bulk hydraulic conductivities have been applied to simulate the measured pumping rates, however it is still possible that there may be localised deviation from the simulated results.
- It is assumed that the underlying sedimentary deposits are anisotropic given the nature of the depositional environment.

G-1.5 Model results – existing conditions

Leachate Trench

The results of the modelling for the base case (current) simulations are summarised in Table G.5. The average combined flow rate to the leachate trench is approximately 1-2 L/s, this equates to a rate between 6×10^{-7} m^3/s and 1.2×10^{-6} m^3/s per metre of trench (based on a trench length of 1674 m). The results of the base case simulations are within this range, slightly higher flow rates are estimated for Section Line 1, likely due to the proximity to Kaikorai Stream.

As noted in section, 2.2.3, higher flows do occur periodically, associated with wet conditions and additional stormwater flows which are diverted to the leachate system.

Table G.5 Model results – flow into leachate collection trench

Section	Modelled flow rate into trench (m^3/m of trench)
Line 1	1.4×10^{-6}
Line 2	7.5×10^{-7}

The relative proportion of flows from each side of the trench was calculated from the models (Table G.6). Approximately 70% of the flow to the trench comes from the landfill (and underlying groundwater) and 30% from the direction of the stream. The presence of the HDPE liner in the trench limits flows from surface water, however the model indicates water flow from the stream side into the base of the trench.

Table G.6 Relative proportion of flows into leachate collection trench

Section Line	Proportion from landfill side	Proportion from stream side
Line 1	0.68	0.32
Line 2	0.73	0.27

The models were used to test the effect on surface and groundwater if the leachate trench was not operational (i.e pumps turned off). As the modelling has been undertaken on a steady state basis, the model assumes that the leachate trench has never been operational, when in reality it is likely to be short term failure only. Therefore, the leachate breakout shown in Figure G.4 is unlikely to be realised with a short term failure. Furthermore, it is considered unlikely that all pump stations would be out of action for an extended period given historical performance and additional mitigation measures that are proposed in the *Design Report*. However, for the purposes of this assessment, the models can be used to estimate the rate of seepage into surface water based on the permeability of the sedimentary units. The model estimates a seepage rate between 4.2×10^{-7} and 4.7×10^{-7} m^3/s per m of stream, this equates to a rate of ~0.5 L/s for the entire stream adjacent to the site (approximately length of 1 km).

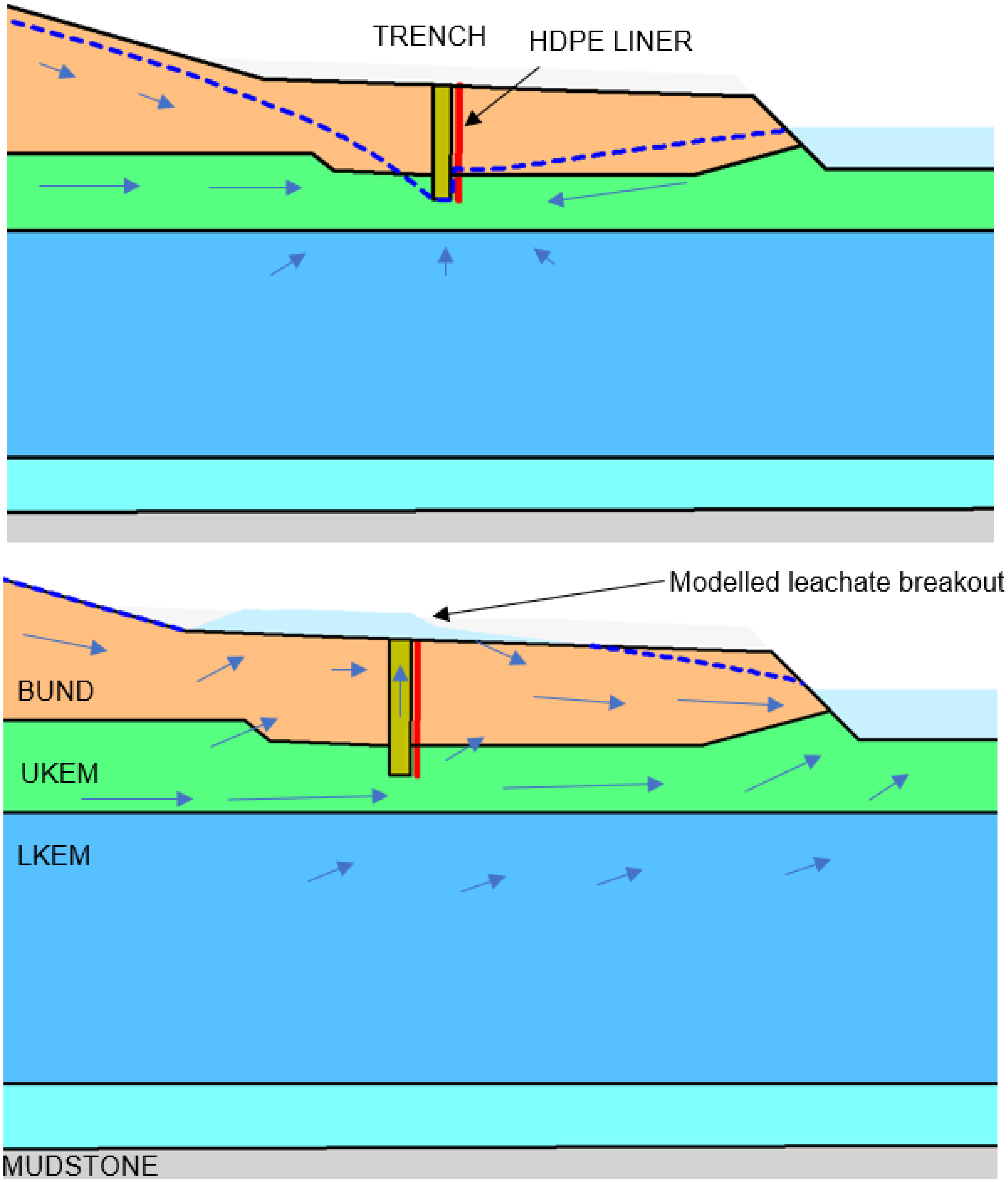

Figure G.4 Section Line 1 – leachate and groundwater flow paths with (top) and without trench (bottom) operational.

Leachate Head (in landfill)

The simulated water level (representing landfill leachate) in shown in Figure G.5. The modelled leachate level in the centre of the land fill is 16 m RL in Section Line 1. This is similar to the level recorded in gas wells GW17, 13 and the leach riser (16-17 m RL) (see Appendix D) but less than recorded in GW14 and GW 15 (22 m RL). As noted above, the rainfall recharge rates were scaled to represent the actual area represented by the model section. This approach may result in averaging or flattening of the modelled leachate head. However, in general the models predict leachate close to the surface in the bund materials. Observations made during a test pit investigation of the bund materials (Tonkin and Taylor, 2020) suggest that the leachate level is close to the surface in some areas. It is understood that leachate breakout from the bund has occurred from time to time, but has been addressed by the installation of gravel drains in these areas.

In Line 2, the simulated leachate level in the centre of the section is approximately 10 m RL. As the leachate survey focussed on older parts of the landfill, there is limited information available for calibration in this area. The leachate level recorded in Piezo 3 and Piezo 4, located south of the section line, was 8.7 and 8.2 m RL respectively.

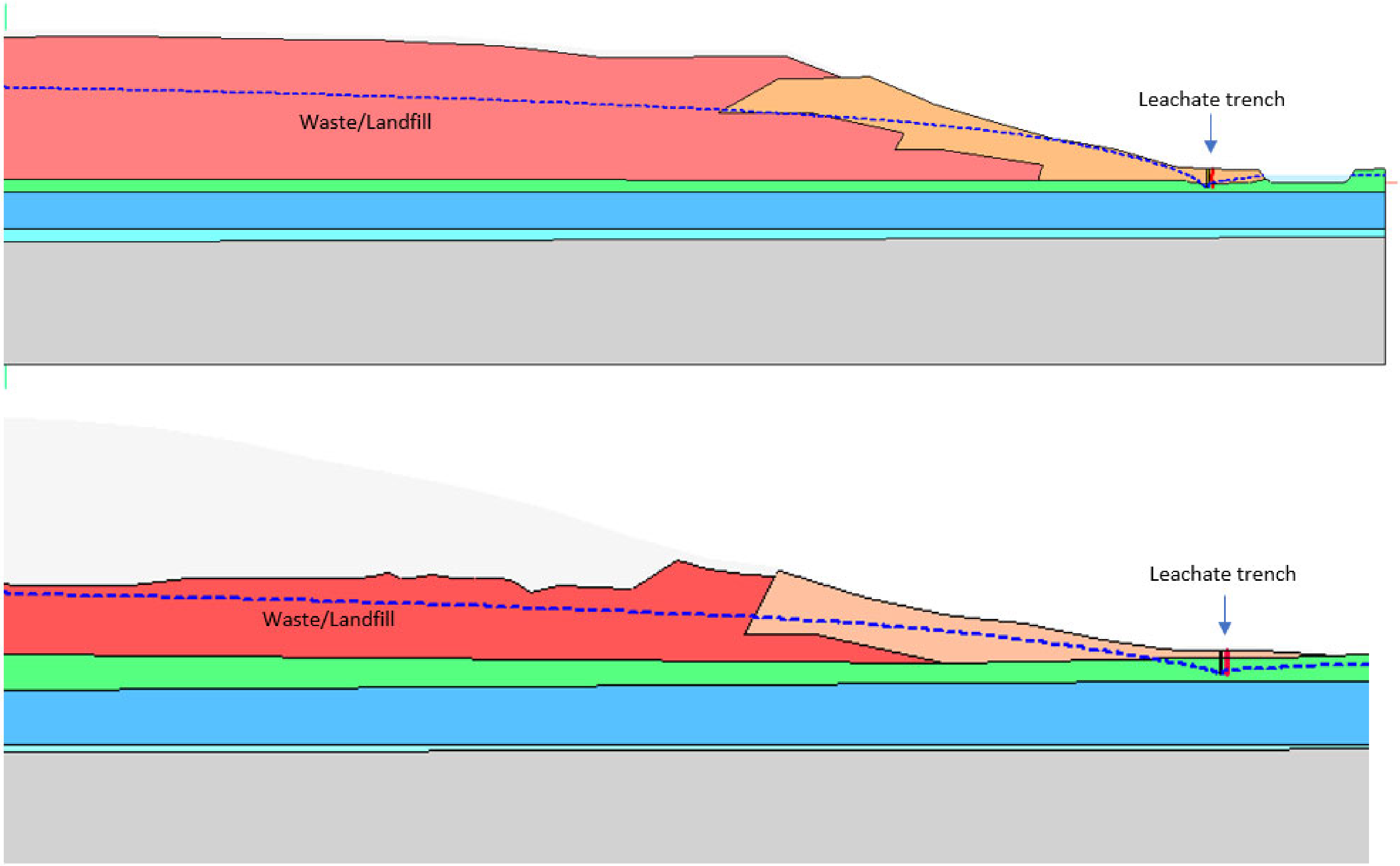

Figure G.5 Leachate head in landfill -Line 1 (top) and Line 2 (bottom) – current scenario

G-1.6 Future modelling scenarios

The base case SEEP/W models were modified to simulate conditions at closure (capping and leachate management). The future scenarios tested three different cap permeabilities (10^{-7} to 10^{-9} m/s). Additional scenarios were run to test the effect of trench failure and sea level rise effects. The model scenarios are listed in Table G.7. The future modelling scenarios include the installation of the proposed southern valley trench.

Table G.7 Future modelling scenarios

Scenario Number	Hydraulic conductivity of cap		Description
	Currently uncapped*	**Capped areas (north/central, applies- Section Line 1 only)**	
1A	1 x 10^{-7} m/s	1 x 10^{-8} m/s	Leachate trenches operational
1B	1 x 10^{-7} m/s	1 x 10^{-8} m/s	Trench" turned off"
1C	1 x 10^{-7} m/s	1 x 10^{-8} m/s	Trench operational, Sea level rise (+ 0.5 m) applied to river boundary.
2A	1 x 10^{-8} m/s (all areas)		Leachate trenches operational
2B	1 x 10^{-8} m/s (all areas)		Trench" turned off"
2C	1 x 10^{-8} m/s (all areas)		Trench operational, Sea level rise (+ 0.5 m) applied to river boundary.
3A	1 x 10^{-9} m/s (all areas)		Leachate trenches operational

*Only applies to areas not currently capped. It is understood that the northern and central part of the landfill (Zone B in Figure G.1, Appendix G) has recently been capped with low permeability materials (achieving 10^{-8} 10^{-9} m/s in lab tests). For the purpose of this assessment, it has been assumed that the hydraulic conductivity is 10^{-8} of this new cap is at least 10^{-8} m/s.

Current and future scenario modelling results are summarised in Tables G.8 and G.9. Model flow rates (per metre) are scaled up by the length of trench each model section covers. This does not include the leachate trench flows from pump stations 5 to 8 (transfer station area) which contribute to the overall dry weather flow rate of 1-2 L/s. However, trench flow rates are expected to be lower than in the modelled sections, as the volume (and height) of filling is less.

Surface water interaction

The models were used to estimate the flow rate into or from (stream depletion) Kaikorai Stream. These results are shown Table G.9. In Section Line 1, the interaction with the stream is reversed depending on whether the leachate drain is "turned on".

For Section Line 2, the model predicts flows from groundwater into the stream in all model scenarios. The flow rate is more than an order of magnitude higher when the drain is turned off than when it is operating, showing that the leachate trench is effective in intercepting leachate/groundwater from the landfill. When the leachate trench is operating, flow vectors indicate the groundwater flow into the stream (~2 x 10 $^{-8}$ m^3/s per m, 0.01 L/s for a 600 m length) represents upward groundwater seepage from the underlying estuarine sediments. The stream is located ~70 m from the trench, therefore while the trench appears be effective at intercepting leachate from the landfill, it does not result in stream depletion and does not influence groundwater levels immediately adjacent to the stream.

Table G.8 SEEP/W model results – leachate trench and leachate head

Scenario	Section	Perimeter leachate drain flow rate		Southern Valley leachate drain flow rate		Modelling leachate head in fill (m RL)
		m^3/s per m of trench	L/s for length of trench modelled*	m^3/s per m of trench	L/s for length of trench modelled*	
Current	Line 1	1.4 x 10^{-6}	0.5	-		16
	Line 2	7.5 x 10^{-7}	0.5	-		10.2
1A	Line 1	1.3 x 10^{-6}	0.5	7.4 x 10^{-7}	0.1	15.4
	Line 2	7.0 x 10^{-7}	0.4	5.0 x 10^{-7}	0.2	9.8
1C	Line 1	1.4 x 10^{-6}	0.6	7.4 x 10^{-7}	0.1	15.4
	Line 2	7.3 x 10^{-7}	0.5	5.0 x 10^{-7}	0.2	9.9
2A	Line 1	1.3 x 10^{-6}	0.5	6.4 x 10^{-7}	0.1	14
	Line 2	6.6 x 10^{-7}	0.4	4.5 x 10^{-7}	0.1	9.3
2C	Line 1	1.4 x 10^{-6}	0.6	6.4 x 10^{-7}	0.1	14
	Line 2	7.0 x 10^{-7}	0.4	4.5 x 10^{-7}	0.1	9.3
3A	Line 1	6.2 x 10^{-7}	0.3	7.8 x 10^{-8}	0.01	4
	Line 2	3.0 x 10^{-7}	0.2	7.2 x 10^{-8}	0.02	3

Flow rate (per metre) multiplied by length of trench represented by each section:

Line 1 – Perimeter trench, 400 m, Southern Valley trench (150 m)

Line 2 – Perimeter trench, 620 m, Southern Valley trench (300 m)

Table G.9 SEEP/W model results – leachate trench and leachate head

Scenario	Section	Flow from stream (stream depletion)		Flow to stream	
		m^3/s per m of trench	L/s for length of trench modelled*	m^3/s per m of trench	L/s for length of trench modelled*
Current	Line 1	1.2×10^{-7}	0.05	-	-
	Line 2	-	-	2.1×10^{-8}	0.01
Current (trench off)	Line 1	-	-	4.2×10^{-7}	0.2
	Line 2	-	-	4.7×10^{-7}	0.3
1A	Line 1	1.2×10^{-7}	0.05	-	-
	Line 2	-	-	1.6×10^{-8}	0.01
1B (trench off)	Line 1	-	-	5.4×10^{-7}	0.2
	Line 2	-	-	8.9×10^{-7}	0.5
1C	Line 1	2.4×10^{-7}	0.05	-	-
	Line 2	-	-	1.2×10^{-8}	0.01
2A	Line 1	1.4×10^{-7}	0.1	-	-
	Line 2	-	-	1.2×10^{-8}	0.01
2B (trench off)	Line 1	-	-	6.7×10^{-7}	0.3
	Line 2	-	-	8.3×10^{-7}	0.5
2C	Line 1	2.5×10^{-7}	0.1	-	-
	Line 2	-	-	1.7×10^{-8}	0.01
3A	Line 1	2.5×10^{-7}	0.1	-	-
	Line 2	-	-	3.9×10^{-8}	0.02

Flow rate (per metre) multiplied by length of stream/trench represented by each section:

Line 1 – Perimeter trench, 400 m

Line 2 – Perimeter trench, 620 m

G-1.7 SEEP/W Modelling Summary

A summary of the key finding from the modelling assessment is provided below in Table G.10.

Table G.10 Modelling summary

Feature	Summary
Cap permeability	Decrease in leachate flow rate and leachate head level when a lower permeability cap is applied. This effect is most pronounced when a cap hydraulic conductivity (K) of 10^{-9} m/s is applied. The difference between leachate flow and head for the K 10^{-7} and 10^{-8} m/s scenarios is small
River side leachate trench	The trench is effective at drawing down leachate levels and intercepting flows to the stream. When the trench drainage boundary condition is "turned off" for modelling purposes the flow rate to stream is estimated to be between 0.5-0.8 L/s. Modelled flow rates are similar to current dry weather leachate trench pump rates.
Southern valley trench	Estimated flow rates to the southern trench are 0.2-0.3 L/s (0.03 L/s for low permeability cap scenario).
Surface water interaction	The modelling indicates that stream water (and shallow groundwater) is intercepted by the leachate trench. Stream depletion rates are estimated to be in the order of 0.1 L/s for Section 1. Stream depletion rates are higher in the sea level rise scenarios due to the higher water levels. However, the Section 2 model indicates flow (at a very low rate, 0.01 L/s) into the stream from shallow groundwater adjacent to the stream. This is much lower than the flow to the stream (0.3-0.5 L/s) if the trench was "turned off" showing that the trench is effective at intercepting leachate. The small inflow (0.01 L/s) to the stream under operating conditions is interpreted to represent groundwater seeping from the stream bed and adjacent river bank as due to the distance the operation of the leachate trench does not influence groundwater levels immediately adjacent to the stream.

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