Report

Conceptual Groundwater Model Report

Levin Landfill, Hōkio Beach Road, Levin

Prepared for Horowhenua District Council

Prepared by Earthtech Consulting Limited

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Executive Summary

This report provides a revision to a previous hydrogeological assessment (Earthtech, 2023) of the extent of the existing groundwater plume containing landfill leachate indicators emanating from the two unlined "Old Landfill[1]" areas of the Levin Landfill site. Monitoring data has been used to describe the migration of solutes which have high relative mobility in groundwater. The following landfill leachate indicators in groundwater have been assessed – ammoniacal-nitrogen (ammoniacal-N), boron, chloride and electrical conductivity (EC) plus nickel.

There is much available data from some 30 years of monitoring the Levin site from the boreholes located across and to the north of the landfill property. The previous hydrogeological assessment has been revised with the results of the further groundwater investigations carried out in September 2023 for the detailed design of the remedial works. This report presents a revised conceptual groundwater model for numerical groundwater and transport modelling and remedial works design as part of the Best Practicable Option (BPO) plan.

Groundwater table levels associated with a shallow unconfined aquifer have been assessed and results show that they follow a northerly gradient with heads ranging from RL12.8*m* upgradient of Old Landfill Area 1 falling to RL5*m* at the Hōkio Stream. Between the unconfined and lower confined groundwater systems, a low permeability aquitard is present. Across the aquitard, a slight downward vertical gradient (downward groundwater flow) has been observed south of the landfill, and an upward gradient (upward groundwater flow) has been observed north of the landfill. Deep confined groundwater has shown artesian conditions at BH101C at the edge of Hōkio Beach Road.

Plan plots of the landfill leachate indicators show a broad 550*m* wide groundwater plume downgradient of Old Landfill Areas 1 and 2. The leachate indicator plumes extend from the landfill edge towards the Hōkio Stream. Stream water quality monitoring shows evidence that chloride and ammoniacal-N has reached the Hōkio Stream Elevated ammoniacal-N primarily occurs downgradient of Old Landfill Area 1. Associated cross-section plots show the highest ammoniacal-N concentrations within the upper half of the 14*m* thick shallow sand unconfined aquifer. Based on this distribution and the sensitivity of the Hōkio Stream to ammoniacal-N, 2D groundwater modelling with the consideration of shallow groundwater intercept drains with inverts below RL5*m* (level of Hōkio Stream) is recommended.

The recent increase of ammoniacal-N in the Hōkio Stream at downgradient sampling location HS2 at $2.7 g/m^3$ (upgradient ammoniacal-N = $0.18 g/m^3$) is considered to be due to the effects of the Old Landfill Area 1 ammoniacal-N groundwater plume discharging to the stream. Without the proposed groundwater remedial works, ammoniacal-N is expected to increase in surface water.

The downstream HS3 ammoniacal-N levels are within consented limits but are expected to rise in the future.

[1] Also referred to as the "Old Dump" of the Levin Landfill Site.

Contents

Contents

Figures

Appendices

Conceptual Groundwater Model Report

Levin Landfill, Hōkio Beach Road, Levin

1. Introduction

Earthtech Consulting Limited (Earthtech) has been appointed by the Horowhenua District Council (HDC) to carry out a hydrogeological assessment of the extent of an existing groundwater plume containing landfill leachate indicators (ammoniacal-nitrogen (ammoniacal-N), boron, chloride and electrical conductivity) emanating from the unlined "Old Landfill" areas of the Levin Landfill site. This assessment is aimed at identifying the migration of solutes that can be specifically linked to typical landfill leachate emissions, with the intent of mitigating these emissions through an overall remediation plan or Best Practicable Option (BPO) plan.

This assessment focuses on groundwater effects from the unlined Old Landfill Areas 1 and 2. Potential groundwater effects from the lined landfill area have not been considered.

A first hydrological assessment report has been completed in May 2023 (Earthtech, 2023). Subsequent field investigations were carried out in September 2023 and November 2023, and this report presents the assessment revision based on the new information.

Three reports are to be provided as follows:

i) Conceptual Groundwater Model (this report)
ii) Numerical Groundwater Flow and Contaminant Transport Modelling
iii) Remedial Works Design

This report compiles all the site investigation and water quality testing data for the development of the conceptual groundwater model associated with the solute plumes downgradient of the two unlined landfill areas. The other two reports follow.

2. Background

2.1 Site Overview and Description

The Levin Landfill, located on Hōkio Beach Road, had operated for over 50 years until it closed in November 2021. Located on the property are, in effect, two general waste type landfills, i.e. an old closed landfill which is unlined (also referred to as the Old Landfill) and an engineered lined landfill

facility, lined to Class 1[2] standards. The Old Landfill, which closed in 2004, is an unlined landfill located on sand dunes, and comprises two areas separated by an access road, referred to as Areas 1 and 2, as shown in Figures 1 and 2. We understand that Area 2 was used largely for the disposal of wastewater sludges.

The site area of some 72*ha* is bounded by forest to the west, east and south and established vegetation and dense tree growth along the northern boundary. The site is situated on historical dune sands which overlie gravels at depth, as depicted in Figure 5. The Tatana property borders the site to the north, where the ground is flat with a series of constructed watercourses. Groundwater is close to the surface at approximately 0.5*m* to 1*m* below ground level across this northern area. A constructed drain, termed the Northern Farm Drain (previously referred to as "Tatana Drain"), runs along the northern boundary fence immediately outside the property, as shown in Figures 2 and 3. A swampy area has been identified south of the Tatana property, at the foot of the forest area, and immediately to the east of the landfill entrance. An established cleanfill-type landfill is located on the Tatana property. The Hōkio Stream is situated some 250*m* to the north of the Levin Landfill, flowing in a westerly direction to Hōkio Beach, out-letting to the sea.

2.2 Historic Aerial Photographs

Historic aerial photographs from 1939 to 2016 are presented in Appendix E. These photographs show the swamp area north of the Old Landfill areas to extend to the Tatana property between 1939 and 1957. From 1971, the land cover on the Tatana property appeared to have changed, and the swamp area only remained in the area north of the Old Landfill areas.

The 1939 to 1957 pre-landfill photographs show a low-lying swampy area under the central northern edge of the old unlined landfill area 1. This provides evidence that swampy ground was present within the Old Landfill footprint. It is not known if fill was placed within this area prior to refuse placement.

Cross section 5 (Figure 5) shows the base of the landfill below groundwater table levels within this area. Maximum ammoniacal-N plume levels (Figure 10) correlate to the low-lying swampy area described above.

3. Detailed Field Investigations

Field investigations were carried out from 4 to 8 September 2023 and 28 to 29 November 2023. The investigations were aimed at providing sufficient geological and hydrogeological information for the remedial works design, and to allow the assessment of the effectiveness of these works on mitigating water quality effects on the Hōkio Stream.

The investigations which are shown in Figure 3 are summarised as follows:

[2] For Class 1 type specification refer to WasteMINZ Technical Guidelines for Disposal to Land, Rev. 3, updated 2022.

- Six boreholes at four locations. Named BH101A,B,C, BH102, BH103, BH104. Groundwater level monitoring and permeability testing carried out in these bores.
- Twelve Cone Penetrometer Tests (CPT). Named CPT101 to CPT112.
- Six monitoring standpipes (two lines) installed in the shallow groundwater swampy area between BHB3 and BHC2 and named NM1 to NM6 (see Figure B).

The details of these investigations and associated logs are presented in Appendix A and a photograph of the drilling of BH101 is shown below (Figure A).

Figure A: Drilling of BH101, located north of the Tatana property, 3*m* setback south of Hokio Beach Road. Photograph from 6 September 2023.

Note that when the bores were developed, piezometer construction in BH102 and BH101B was found to be inadequate (broken screen and intake zones leaking formation sand). These bores were replaced on the 4th of November, 2023.

4. Geology

4.1 Revision of the Site Geology

Based on the new information provided by the September 2023 field investigations, the site geology has been revised.

The three different landforms on site (Figure 1) are as follows:

- Undulating sand dunes south of the stream flats and swampy ground from RL12*m* to RL40*m*.
- Dune terraces of RL9*m* to RL12*m* along the northeastern margins of the higher dune topography.
- Partially filled stream flats of RL6*m* to RL8*m* between the Northern Farm Drain and the Hōkio Stream.

A swampy area of approximately 1.4*ha* has been identified south of the Tatana property and north of the terrace dunes (Figure B). This area presents shallow groundwater discharging to the Northern

Farm Drain, and dead trees have been observed on aerial photographs and on site. Another swampy area is located immediately east of the landfill access road.

Figure B: Swampy area south of the Tatana property and north of the terrace dunes. The northern monitoring points (NM1 to NM6) are located in this swampy area and consist of open white standpipes. Photographs from 6 September 2023.

Two vertical cross-sections of the site (Figures 5 and 6.1) have been constructed. Figure 5 with cross-section (A-A') shows the site from south of the old unlined landfill (BHD3rd) to the Northern Farm Drain and Hōkio Stream up north (BHXS1). Figure 6.1, with cross-section (B-B') focusing on the north of the site, has also been constructed from BH103 through the swampy grounds and Tatana property, up to BH101 and Hōkio Stream. Both cross-sections are based on the information from the driller's logs provided by Stantec and the Earthtech logs from the new monitoring bores drilled in September 2023.

The geology from the deepest new monitoring bore log (BH101C) consists of:

- Sand from ground level to RL-8.2*m*.
- Sandy clay from RL-8.2 to RL-9.7*m*.
- Silty gravel underneath the sandy clay formation.

The hydrogeological interpretation is as follows:

- Shallow unconfined aquifer within the sand formation of about 14*m* thickness.
- Separating aquitard consisting of a 1.5*m* thick clay layer (identified in BH101C).
- Deep confined aquifer within the silty gravel and gravel underneath the aquitard.

The unconfined aquifer has groundwater levels between RL12.8*m* to RL5.8*m*, with a flow direction towards the north to discharge to the Northern Farm Drain and Hōkio Stream (which is at about RL5*m*). Groundwater level from the deep aquifer bore BH101C showed a flowing artesian head of

0.7*m* above ground level approximately 16*hrs* after drilling, indicating an upward gradient at this location.

Six boreholes on site describe the gravel layer of the deep aquifer:

- BHE1d (drilled September 1997)
- BHE2d (drilled September 1997)
- BHC2DD (drilled September 1997)
- BHG1D (drilled September 2009)
- BH101C (drilled September 2023)
- BHD3rd (drilled June 2021)

The gravel aquifer depths observed in these boreholes are presented in Table 1 below:

Table 1: Deep gravel aquifer boreholes and gravel layer depths encountered

Borehole	Elevation	Depth	Gravel layer depth
	m RL	*m bgl*	*mRL*
BH101C	6.8	20.0	-9.7
BHE1d	20.9	37.8	-12.1
BHE2d	13.15	28.7	-11.6
BHC2Dd	10.1	18.9	-7.4
BHG1d	24.0	31.5	-7.5
BHD3rd	18.0	32.0	-5.3

The above-level data has been used to define the base of the aquitard in Figures 5 and 6.1.

4.2 Previous Investigations

A previous geological assessment of the Levin Landfill was prepared in September 2019 by Tonkin and Taylor. Their work provided a vertical cross-section from the south through Area 1 of the landfill and to the Hōkio Stream up north (Tonkin and Taylor, 2019). This figure (Figure 12) presented on-site geology as follows:

- Recent dune sands from RL0*m* up to RL30*m*.
- Silts and clay for a 2*m* thick layer from approximately RL0*m* to RL-2*m*.
- Gravels from RL-2*m* to RL-10*m*.

The associated Tonkin and Taylor (2019) hydrogeology interpretation describes a shallow unconfined aquifer within the dune sand formation, 10*m* to 5*m* thick near the Hōkio Stream, and a deep confined aquifer within the deeper gravel layer underneath. The aquifers are described as being separated by the 2*m* thick aquitard. The shallow unconfined aquifer has a groundwater table which generally

follows the ground surface with a horizontal gradient towards the Northern Farm Drain and Hōkio Stream. The deep confined aquifer is reported as being artesian.

5. Groundwater

5.1 Groundwater Chemistry and Solute Flow Paths

The location of all the monitoring bores on the site, upgradient and downgradient of the different landfill areas, are presented in Figure 2.

Electrical conductivity plus three solutes are used as early leachate indicators (due to high relative mobility in groundwater) as follows:

- Electrical Conductivity (EC) in *mS/m*
- Chloride (Cl) in g/m^3
- Boron (B) in g/m^3
- Ammoniacal-Nitrogen (NH_4N) in g/m^3

Figure 4 presents the concentration values for these four solutes in July and October 2023 in the main observation bores. This has allowed us to assess the flow path of their concentration plume with time and their up-to-date location in the area.

Figure 4 shows the majority of bores immediately south and upgradient of the unlined landfill areas to have near background groundwater concentrations of:

- Electrical Conductivity (EC) at < 54*mS/m*
- Chloride (Cl) at 16g/m^3 to 39g/m^3
- Boron (B) at < 0.07g/m^3
- Ammoniacal-Nitrogen (NH_4N) at 0.01g/m^3 to 0.7g/m^3

The concentration contour lines for July and October 2023 monitoring data are presented in Figures 7 to 10.

From the water quality data and these maps, the following observations have been made:

- EC highest concentration in July-September 2023 is 362*mS/m* in NM3 (Figure 7), on the southern margin of the swampy area. This is higher than the 284*mS/m* maximum observed in January 2023 in BHC2.

- EC concentration plume has an elongated shape and the 200*mS/m* contour line captures an area downgradient of both Areas 1 and 2 of the Old Landfill.

- The total width of the EC plume at >100*mS/m* is about 550*m* wide.

- Upgradient and downgradient Hōkio Stream September EC data (Figure 7) does not show a significant discharge influence from the EC plume.

- Chloride highest concentration for July-September 2023 is 380g/m^3 in BHB1 (585g/m^3 in BHG2 in January 2023). The chloride data from 1994 to 2023 shows some variability over time, varying between 100g/m^3 and 700g/m^3 from July 2014 to July 2023 in BHG2, for example. The BHG2 variability is considered to be due to dilution from focussed rainfall recharge into the area of swampy ground adjacent to the landfill entrance.

- The highest chloride concentrations (over 300g/m^3) are located downgradient of Area 2 of the Old Landfill. The 200g/m^3 contour line captures the area downgradient of both Areas 1 and 2 of the Old Landfill.

- The total width of the chloride plume at >100g/m^3 is about 500m wide.

- Upgradient and downgradient Hōkio Stream September chloride data (Figure 8) does not show a significant discharge influence from the chloride plume. There is some evidence of a local plume discharge effect at HS1 located downgradient of the area of peak plume concentrations.

- Boron highest concentration for July-September 2023 is 2.53g/m^3 in BHB2. The maximum value in January 2023 was also similar at 2.2g/m^3 in BHB2.

- Boron concentration plume is located downgradient of both Areas 1 and 2 of the Old Landfill, and the contour lines show that elevated concentrations of boron are still discharging from both Old Landfill areas.

- The total width of the boron plume at >0.5g/m^3 is about 500m wide.

- Upgradient and downgradient Hōkio Stream September boron data (Figure 9) does not show a significant discharge influence from the boron plume.

- The ammoniacal-N highest concentration in July-September 2023 is 210g/m^3 in NM3 (170g/m^3 in BHC2 in January 2023). Ammoniacal-N values between January and July-October 2023 appear stable with no significant variability between summer and winter monitoring.

- Ammoniacal-N concentration plume is mostly located downgradient of Area 1 of the Old Landfill and the most recent data shows that the 150g/m^3 plume is still currently discharging from this area of the Old Landfill. The peak concentration plume matches the EC data, in the NM3 – C2 vicinity.

- The total width of the ammoniacal-N plume at >10g/m^3 is about 370m wide.

- Hōkio Stream September ammoniacal-N data (Figure 10) shows a significant discharge influence from the ammoniacal-N plume with values of $0.18 g/m^3$ to $2.7 g/m^3$ from upgradient and downgradient monitoring, respectively.

From this assessment, NM3 and boreholes BH103 and BHC2 show the highest concentration of ammoniacal-N centrally located downgradient of Old Landfill Area 1. Cross-section B-B' (Figure 6.2) is, therefore, located through a high concentration zone associated with the plume. The Figure C time history plot for BHC2 shows the emergence of elevated ammoniacal-N in 2005 and an overall increasing trend to 2023.

Figure 6.2 shows that elevated leachate indicators, specifically ammoniacal-N, is generally restricted to the upper half of the shallow unconfined aquifer.

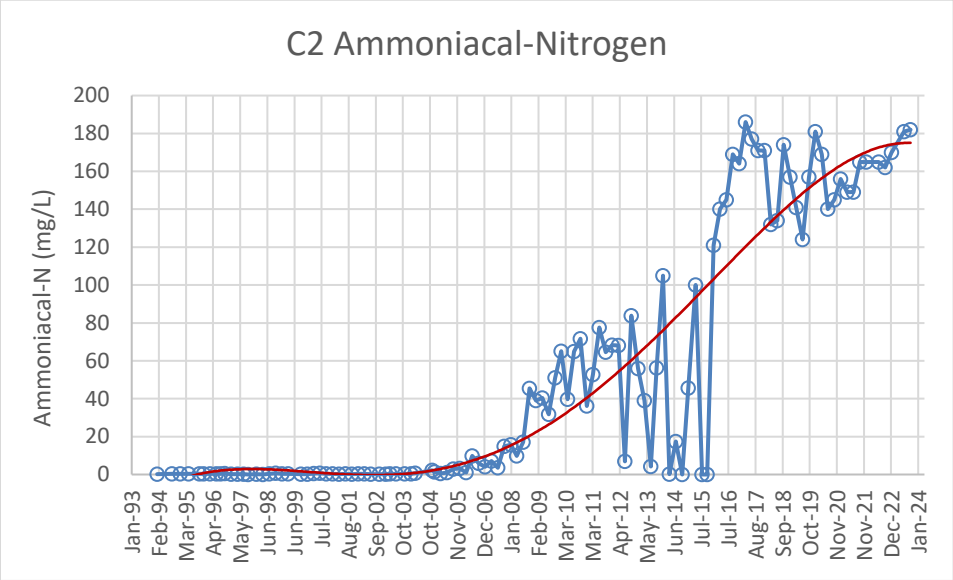

Figure C: Ammoniacal-N concentration over time in the groundwater monitoring borehole BHC2

5.2 Velocities

For EC and the three solutes, their masses will travel within the groundwater, following groundwater flow from the south to the north through the area. The four leachate indicators are expected to have different behaviours in terms of travel time, as all chemical components have different retardation factors. Chloride usually travels faster than boron and ammoniacal-N; therefore, its concentration plume is expected to be located further north than the other solute plumes.

The peak concentrations of each solute have been studied over time, which allowed the estimation of groundwater velocities of the four leachate indicators, as presented in Table 2. An estimation of the time needed for the peak concentrations of the solutes in groundwater to reach Hōkio Stream has been calculated as shown in Figure D below.

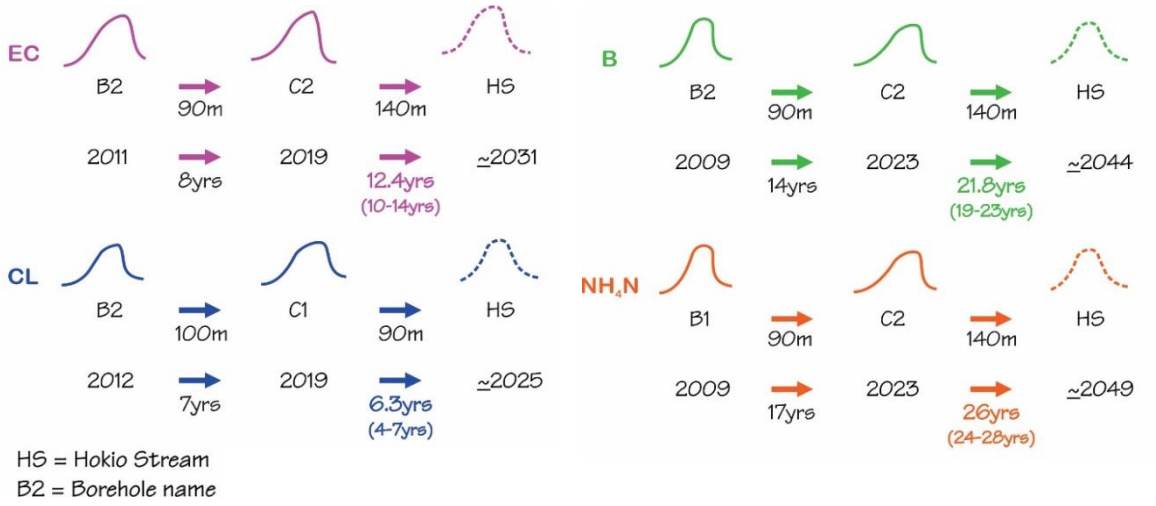

Figure D: Concentration plume peaks travel time

Table 2: Leachate indicator velocities in groundwater

Solute	Electrical Conductivity	Chloride	Boron	Ammoniacal-N
Velocity *(m/yr)*	11.3	14.3	6.4	5.3

Chloride presents the fastest velocity, as this solute generally represents advective flow. It is followed by boron and then ammoniacal-N.

5.3 Permeability

The monitoring boreholes drilled in September 2023 (BH101A, B, BH102, BH103, BH104) and BH101B and BH102 redrilled in November 2023 have been developed, and permeability testing carried out. Rising head slug testing has been carried out, and the results have been analysed with the Bouwer-Rice method (Bouwer, 1989) using AQTESOLV to determine the permeabilities. The site's detailed investigations are presented in Appendix A, and the permeability analysis plots are presented in Appendix C. Test results are shown in Table 3 below.

Table 3: New monitoring bore permeabilities

Borehole	BH101A	BH101B new	BH102 new	BH103	BH104
Horizontal Permeability *(m/d)*	3.21	1.84	0.85	4.40	1.63

These hydraulic conductivity values give the following arithmetic mean for the site area:

- Site Permeability = 2.39*m/d*

Other permeability values obtained for the area are discussed below.

Permeability testing carried out in July 2012 has been provided. Test results present a large range of permeability values, ranging from 0.59*m*/*d* to 498*m*/*d*. This range includes high 100*m*/*d* to 500*m*/*d* permeability conditions outside of that expected for sands; therefore, this test data has low reliability and has been disregarded.

Permeability values from the Tonkin and Taylor assessment included a range of $2e^{-5}$ to $6e^{-5}$*m/s* (1.7 to 5.2*m*/*d*) for the shallow sand aquifer, with a value of $1.0e^{-5}$*m*/*s* (0.9*m*/*d*) adopted for their assessment (Tonkin and Taylor, 2019).

Field permeabilities (k_h) have also been back-analysed previously by Earthtech (2023) for chloride using its observed velocity of 14.3*m/yr* (Table 3). The method of calculation provided an estimated sand aquifer permeability of 0.39*m/d.*

Figure 6.2 shows a significant reduction in leachate indicator parameters with depth. This could be due to permeability anisotropy within the shallow sand aquifer where vertical permeability is lower than horizontal permeability.

On the basis of the above assessment, a horizontal permeability of 2.39*m*/*d* has been adopted for the unconfined sand aquifer[3]. The on-site test data presented in Table 3 provides reproducible results within a reasonably narrow test range for the uniform sands identified in both the cored boreholes and CPT probes for the plume area. The horizontal permeability of 2.39*m*/*d* is considered to be more reliable than the 0.4*m*/*d* permeability calculated using solute velocities. The 2.39*m*/*d* is equivalent to $2.77e^{-5}$*m*/*s*, representing moderate permeability mid-range values for clean sand (Freeze and Cherry, 1979).

5.4 Groundwater Levels

Groundwater table levels for July-September data are presented in Figure 11. Groundwater levels for various depths are shown in Figures 5 and 6.1. These groundwater levels show the following:

i. Groundwater table levels with northerly gradient with heads ranging from RL12.8*m* upgradient of Old Landfill Area 1 falling to RL5*m* associated with Hōkio Stream. These groundwater levels show northerly flow is dominant with discharge to the Hōkio Stream. Figure 11 shows deflection of the RL8*m* contour caused by local discharge to the swampy ground and Northern Farm Drains. The overall horizontal hydraulic gradient for the flats area is 0.01.

ii. Upgradient of the landfill, there is a slight downward vertical gradient between the unconfined and confined aquifer (see BH03 levels in Figure 5). Downgradient of the landfill, across the stream flats, there is an upward flow between the confined and unconfined systems. At BH101, deep confined groundwater is flowing artesian.

iii. Upward groundwater flow between the deep confined and shallow unconfined aquifers, combined with the presence of the aquitard, prevents landfill discharge effects on deep confined

[3] Permeability is used as an equivalent for Hydraulic Conductivity.

groundwater. This is supported by deep groundwater quality monitoring for the site and specifically BH101C leachate indicators which are at background conditions.

iv. A comparison of groundwater levels from January 2023 (Figure 12 from Earthtech (2023)) and July-September (Figure 12) shows little seasonal change. This lack of seasonal variability is considered to be due to:

- Elevated January 2023 levels from high summer rainfall conditions.
- Groundwater drainage controls associated with swampy ground, Northern Farm Drain and Hōkio Stream.

5.5 Local Bores

A review of the Horizons bore database was carried out on 31 October 2023. No water supply bores are shown to be present in the immediate vicinity of the leachate indicator plumes.

6. Groundwater and Surface Water Interaction

The upper unconfined aquifer discharges to the Hōkio Stream, which runs from east to west to the north of the site. Four surface monitoring points are located at the Hōkio Stream: HS2 and HS3 which are downstream, plus HS1 and HS1A which are upstream. Associated surface water quality data from February 1994 to February 2023 has been reviewed.

A specific effects assessment on the Hōkio Stream will be carried out following the contaminant transport modelling.

6.1 Groundwater and Surface Water Flows

For this assessment, we focused on ammoniacal-N concentrations, as this parameter is the most critical. Groundwater flow has been calculated with Darcy equations as follows:

- Darcy equation: $Q = K * A * i$

- K = 2.39m/d – Aquifer Permeability (Section 5.3)
- i = 0.01 – Hydraulic gradient (From Cross section AA')
- A = 5,180m^2 – Area for a 14m thick aquifer and a 370m wide section (corresponding to the estimated width of the concentration plume for ammoniacal-N > 10g/m^3 from Figure 10).

- Groundwater flow: Q = 124m^3/d

From Horizons online environmental data, a hydrograph of Hōkio Stream level over the last 12 months at its source, the Punahau (Lake Horowhenua) weir, has been observed (Figure E). It shows

general low flow conditions occurring from December 2022 to April 2023, and general high flow conditions occurring between May 2023 and September 2023.

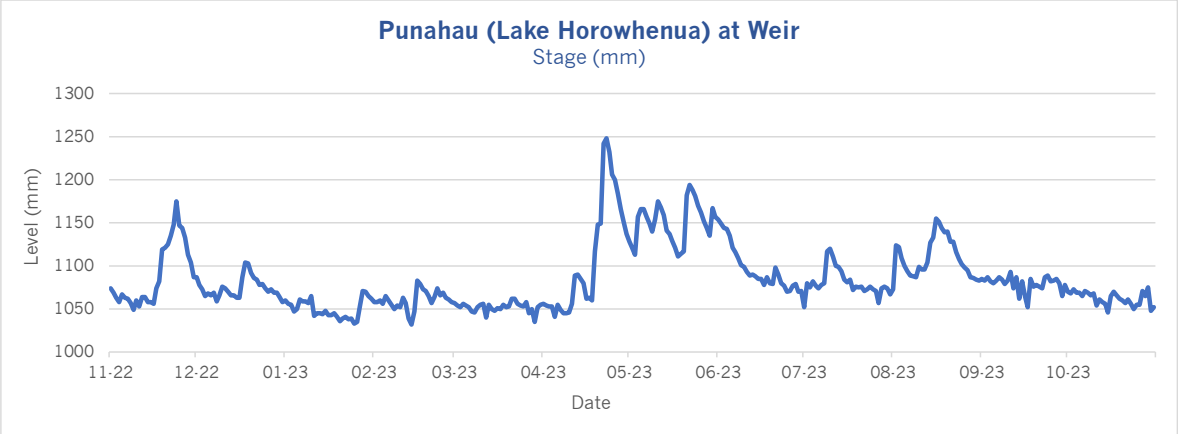

Figure E: Hydrograph of the weir at Punahau (Lake Horowhenua)
Horizons Regional Council Environmental data

The surface flow in the Hōkio Stream is described in the Horizons Council publication (NIWA, 2011) as ranging between $0.3m^3/s$ and $2m^3/s$.

6.2 Groundwater and Surface Water Ammoniacal-N Concentrations

Based on the October 2023 ammoniacal-nitrogen contour map (Figure 10), the average groundwater concentration is estimated to be $<10g/m^3$ at Hōkio Stream for October 2023. A value of $0.7g/m^3$ is assumed to be the ammoniacal-N groundwater background level, outside of the concentration plume.

The following ammoniacal-N concentrations were measured in the surface water monitoring sites of the Hōkio Stream:

- In HS1A: $0.09g/m^3$ Average October 2021 – October 2023
  $0.25g/m^3$ Maximum value for May 2022 (occurring in January 2023)
- In HS2: $0.4g/m^3$ Average October 2021 – October 2023
  $2.71g/m^3$ Maximum value for September 2023
- In HS3: $0.17g/m^3$ Average October 2021 – October 2023 (below HS3 consented limit of $0.4g/m^3$)
  $0.39g/m^3$ Maximum value for October 2023 (below HS3 consented limit of $2.1g/m^3$)

Additionally, the following ammoniacal-N levels have been measured in the Hōkio Stream up and downgradient of the Figure 10 plume during 2023 (these values are presented in Appendix D). High

values of ammoniacal-N occurred in 2023 in the downgradient monitoring site HS2, as shown in Table 4.

Table 4: Ammoniacal-N concentration in surface monitoring points for late 2022 and 2023

	Ammoniacal-N Concentration			
	Upgradient surface water monitoring point		Downgradient surface water monitoring point	
	HS1A	HS1	HS2	HS3
	(g/m^3)	(g/m^3)	(g/m^3)	(g/m^3)
Nov-22	0.16	0.17	**1.37**	0.24
Dec-22	0.09	0.02	0.17	0.18
Jan-23	0.18	0.23	**1.38**	0.29
Feb-23	0.02	0.04	**1.23**	0.14
May-23	0.08	0.11	0.14	0.13
June-23	0.06	0.07	0.08	0.13
July-23	0.05	0.06	0.1	0.14
Sept-23	0.17	0.18	**2.71**	0.37
Oct-23	0.09	0.08	0.19	0.39

Data from May to July 2023 from Stantec (2023).

Table 4 shows the groundwater plume affecting the Hōkio Stream with increases in ammoniacal-N between the upgradient and downgradient surface water sampling locations. Typically, the current increase in ammoniacal-N is from $0.1 g/m^3$ to $1.4 g/m^3$. Higher increases occurred in November 2022, plus January and February 2023. In September 2023, an increase of ammoniacal-N from $0.17 g/m^3$ to $2.7 g/m^3$ occurred.

The consented ammoniacal-N trigger limits in surface water are $2.1 g/m^3$ maximum and $0.4 g/m^3$ average at HS3. The monitoring record shows compliance in terms of these trigger levels at HS3. There are no trigger limits at HS2.

Without mitigation, the ammoniacal-N concentrations in the Hōkio Stream are expected to increase in the future as the associated groundwater plume migrates north. The HS3 ammoniacal-N concentrations are expected to rise towards consented limits.

7. Revised Conceptual Groundwater Model

The revised conceptual groundwater model is summarised as follows:

i. Refuse and other waste was originally placed within two unlined landfill areas located within sand dunes.
ii. The base of both unlined landfills is in close proximity to groundwater.

iii. Groundwater investigations have defined the following conditions:

- Shallow unconfined aquifer of 13*m* to 17*m* saturated thickness within dune sands.
- Separating aquitard consisting of a 1*m* to 2*m* thick clay layer.
- Underlying deep confined gravel aquifer.

iv. The unconfined aquifer has moderate permeability assessed at 2.39*m*/*d* from field testing and flows to the north.

v. Groundwater table levels follow a northerly gradient with heads ranging from RL12.8*m* upgradient of Old Landfill Area 1 falling to RL5*m* associated with the Hōkio Stream. Between the confined and unconfined systems, a slight downward vertical gradient has been observed upgradient of the landfill, and an upward flow has been observed downgradient of the landfill. Deep confined groundwater has shown artesian conditions at BH101.

vi. Based on a review of the Horizons bore database, no water supply bores are shown to be present in the immediate vicinity of the leachate indicator plumes.

vii. Landfill leachate discharge to ground has resulted in leachate indicator groundwater plumes for EC, ammoniacal-N, chloride and boron associated with the unconfined aquifer. The plumes have differing chemistry due to the different landfill sources associated with Old Landfill Areas 1 and 2.

viii. Leachate indicator plumes range in width between 370*m* and 550*m*. Downgradient, the plumes extend across the Tatana property with chloride and ammoniacal-N reaching the Hōkio Stream.

ix. Nested piezometers show that elevated leachate indicators, and specifically ammoniacal-N, are generally restricted to the upper half of the shallow unconfined aquifer downgradient of the unlined landfills. This distribution is considered to be due to aquifer anisotropy ($k_v << k_h$).

x. Hōkio Stream monitoring shows that surface water is being affected by the ammoniacal-N plume with HS2 downstream average and peak values of 0.4g/m^3 2.71g/m^3 respectively. The downstream HS3 ammoniacal-N levels are within consented limits.

xi. Peak plume concentrations have not yet reached the Hōkio Stream, and there is a potential that without mitigation, ammoniacal-N levels will continue to increase.

8. Modelling Recommendations

Based on the distribution of the critical ammoniacal-N within the upper half of the unconfined aquifer, 2D groundwater modelling with consideration of shallow groundwater intercept drains with inverts below RL5*m* (level of Hōkio Stream) is recommended.

A calibrated flow model should initially be constructed followed by contaminant transport modelling. Calibration of the transport model should also be carried out with the plotted plume maps for chloride and ammoniacal-N.

9. References

Bouwer, H. (1989) The Bouwer and Rice slug test - an update. Ground Water, vol. 27, no. 3, pp. 304-309.

Earthtech (2023) Assessment of Groundwater Pollution Plume Mobility and Remediation Plan – Levin Landfill, Hōkio Beach Road, Levin. Dated 31 May 2023, R10009-1 Rev.A.

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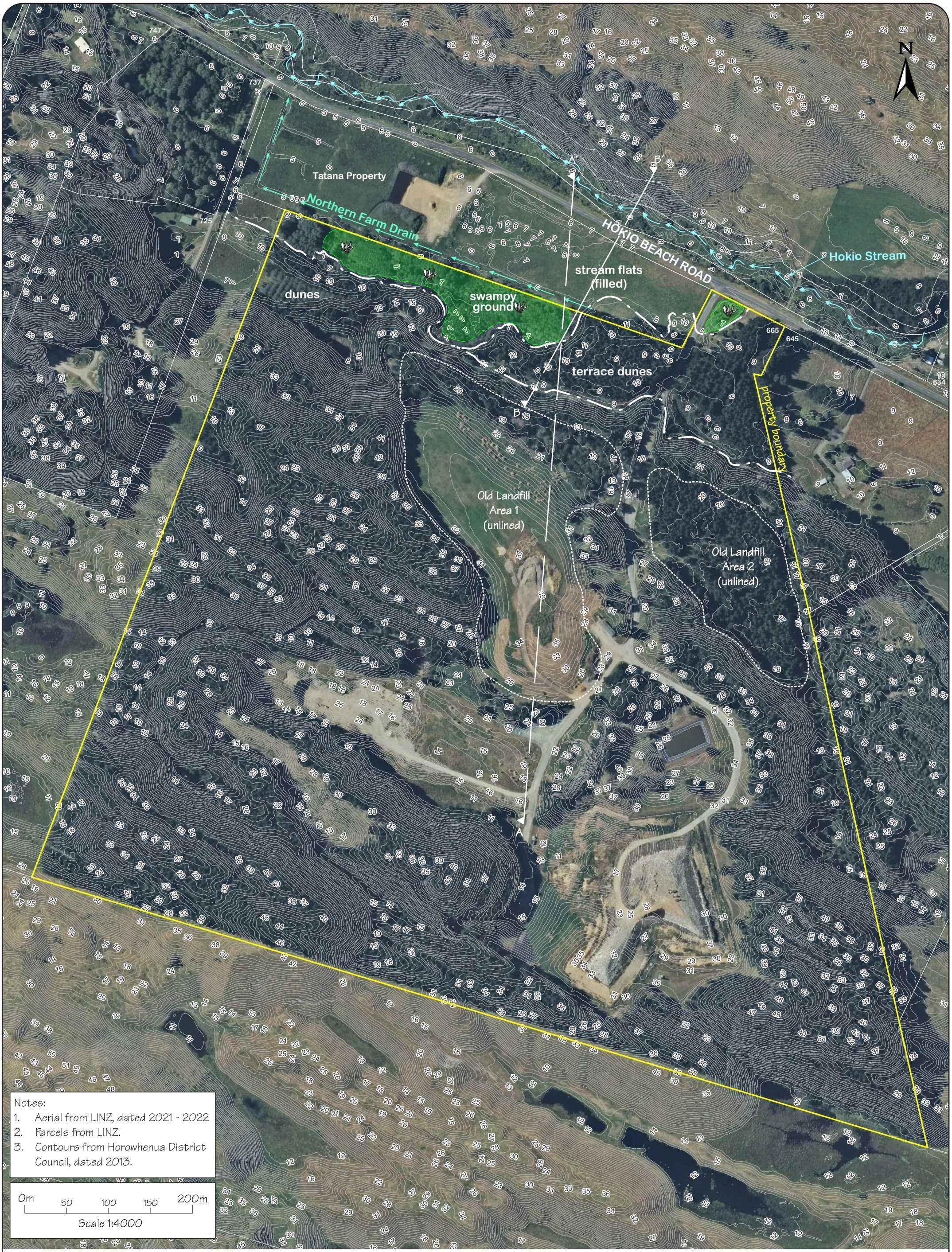
Horizons Regional Council (2022) Annual Compliance Audit Report Horowhenua District Council Levin Landfill, Reporting Period July 2021 – June 2022, December 2022.

NIWA (2011) *Lake Horowhenua Review – Assessment of opportunities to address water quality issues in Lake Horowhenua*. Prepared for Horizons Regional Council. Retrieved from All Publications - Horizons Regional Council.

Stantec (2022) Levin Landfill Annual Compliance Report July 2021 – June 2022 (as required by Resource Consents DP6009, DP6010, DP6011 and DP102259), prepared for Horowhenua District Council, September 2022.

Stantec (2023) Levin Landfill July 2023 Quarterly Groundwater, Surface Water and Leachate Monitoring Report, prepared for Horowhenua District Council, August 2023.

Tonkin and Taylor (2019) Levin Landfill – Summary of leachate option assessment. (Ref 1011583).



NOT FOR CONSTRUCTION

Note: All drawings are to be approved (initialled) before final issue.

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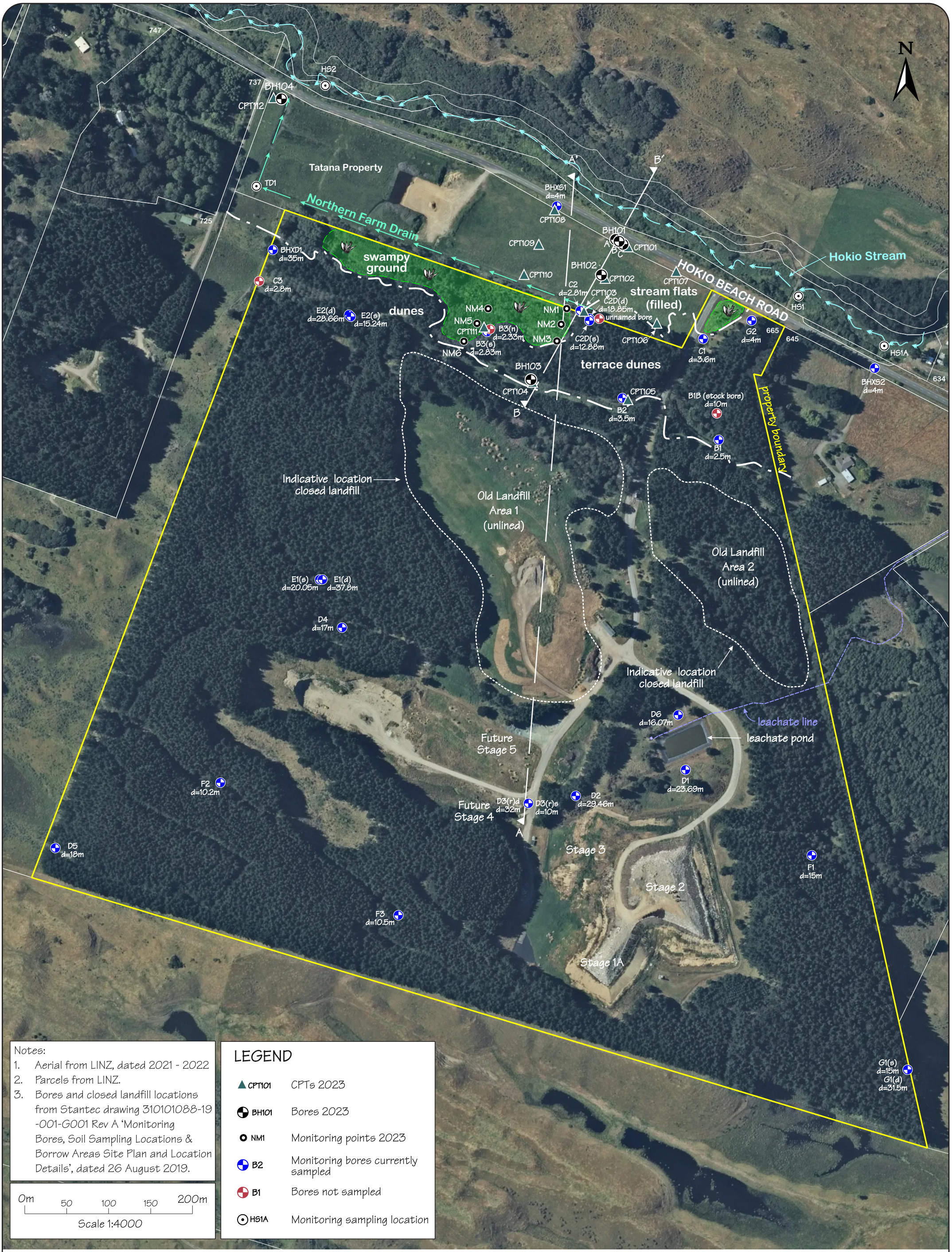
LEVIN LANDFILL
HOKIO BEACH ROAD, LEVIN
Horowhenua District Council

Site Location Plan

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	L.S	L.S	S.SW	
B	10-05-23	FOR FINAL REPORT R10009-1	L.S	L.S	S.SW	
C	31-10-23	FOR REPORT R10009-2	L.S	L.S	S.SW	

DRAWING NO.: FIG. 1
REF: 10009-R2
SCALE: 1:4000
CRS: NZTM
DATUM:



Notes:

1. Aerial from LINZ, dated 2021 - 2022
2. Parcels from LINZ.
3. Bores and closed landfill locations from Stantec drawing 310101088-19-001-G001 Rev A 'Monitoring Bores, Soil Sampling Locations & Borrow Areas Site Plan and Location Details', dated 26 August 2019.

0m 50 100 150 200m

Scale 1:4000

LEGEND

CPT101	CPTs 2023
BH101	Bores 2023
NM1	Monitoring points 2023
B2	Monitoring bores currently sampled
B1	Bores not sampled
HS1A	Monitoring sampling location

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Site Investigation Location Plan

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	L.S	L.S	S.SW	
B	10-05-23	FOR FINAL REPORT R10009-1	L.S	L.S	S.SW	
C	31-10-23	FOR REPORT R10009-2	L.S	P.K	S.SW	

DRAWING NO.: **FIG. 2**

REF: 10009-R2

SCALE: 1:4000

CRS: NZTM

DATUM:

LEGEND

2023 Investigations

- BH101 Borehole
- CPT111 Cone Penetrometer Test
- NM4 Monitoring Points

Existing Investigations

- B2 Monitoring bores currently sampled
- B1 Bores not sampled
- HS1A Monitoring sampling location
- s Shallow piezometer
- d Deep piezometer

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LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Monitoring Points North of Old Landfill

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	L.S	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT	L.S	P.K	S.SW	
C	31-10-23	FOR REPORT R10009-2	L.S	P.K	S.SW	

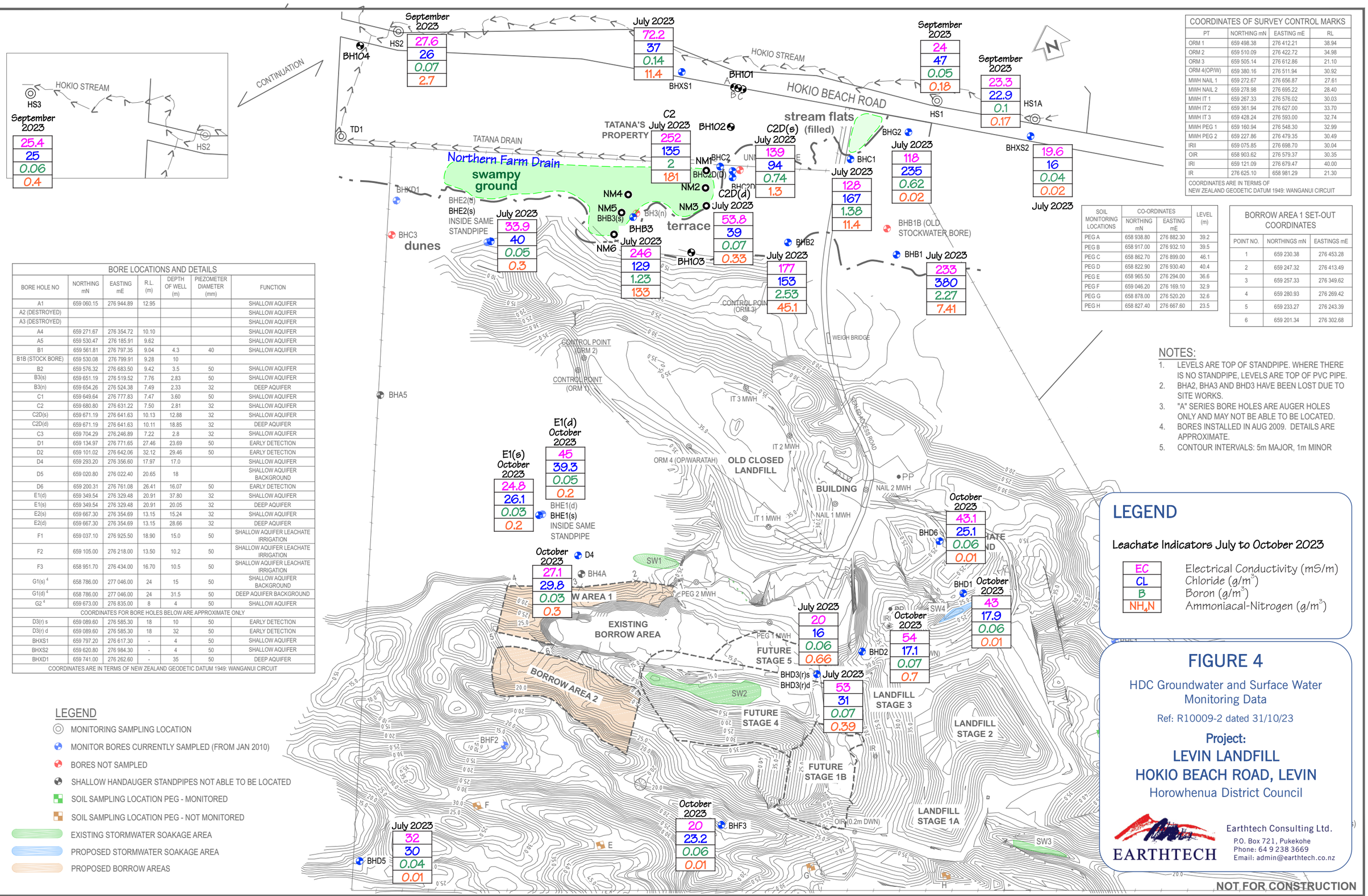
DRAWING NO.: FIG. 3

REF: 10009-R2

SCALE: 1:2000

CRS: NZTM

DATUM:



COORDINATES OF SURVEY CONTROL MARKS			
PT	NORTHING mN	EASTING mE	RL
ORM 1	659 498.38	276 412.21	38.94
ORM 2	659 510.09	276 422.72	34.98
ORM 3	659 505.14	276 612.86	21.10
ORM 4(OP/W)	659 380.16	276 511.94	30.92
MWH NAIL 1	659 272.67	276 656.87	27.61
MWH NAIL 2	659 278.98	276 695.22	28.40
MWH IT 1	659 267.33	276 576.02	30.03
MWH IT 2	659 361.94	276 627.00	33.70
MWH IT 3	659 428.24	276 593.00	32.74
MWH PEG 1	659 160.94	276 548.30	32.99
MWH PEG 2	659 227.86	276 479.35	30.49
IRII	659 075.85	276 698.70	30.04
OIR	658 903.62	276 579.37	30.35
IRI	659 121.09	276 679.47	40.00
IR	276 625.10	658 981.29	21.30
COORDINATES ARE IN TERMS OF NEW ZEALAND GEODETIC DATUM 1949: WANGANUI CIRCUIT			

SOIL MONITORING LOCATIONS	CO-ORDINATES		LEVEL (m)
	NORTHING mN	EASTING mE	
PEG A	658 938.80	276 882.30	39.2
PEG B	658 917.00	276 932.10	39.5
PEG C	658 862.70	276 899.00	46.1
PEG D	658 822.90	276 930.40	40.4
PEG E	658 965.50	276 294.00	36.6
PEG F	659 046.20	276 169.10	32.9
PEG G	658 878.00	276 520.20	32.6
PEG H	658 827.40	276 667.60	23.5

BORROW AREA 1 SET-OUT COORDINATES		
POINT NO.	NORTHINGS mN	EASTINGS mE
1	659 230.38	276 453.28
2	659 247.32	276 413.49
3	659 257.33	276 349.62
4	659 280.93	276 269.42
5	659 233.27	276 243.39
6	659 201.34	276 302.68

BORE LOCATIONS AND DETAILS						
BORE HOLE NO	NORTHING mN	EASTING mE	R.L. (m)	DEPTH OF WELL (m)	PIEZOMETER DIAMETER (mm)	FUNCTION
A1	659 060.15	276 944.89	12.95			SHALLOW AQUIFER
A2 (DESTROYED)						SHALLOW AQUIFER
A3 (DESTROYED)						SHALLOW AQUIFER
A4	659 271.67	276 354.72	10.10			SHALLOW AQUIFER
A5	659 530.47	276 185.91	9.62			SHALLOW AQUIFER
B1	659 561.81	276 797.35	9.04	4.3	40	SHALLOW AQUIFER
B1B (STOCK BORE)	659 530.08	276 799.91	9.28	10		
B2	659 576.32	276 683.50	9.42	3.5	50	SHALLOW AQUIFER
B3(s)	659 651.19	276 519.52	7.76	2.83	50	SHALLOW AQUIFER
B3(n)	659 654.26	276 524.38	7.49	2.33	32	DEEP AQUIFER
C1	659 649.64	276 777.83	7.47	3.60	50	SHALLOW AQUIFER
C2	659 680.80	276 631.22	7.50	2.81	32	SHALLOW AQUIFER
C2D(s)	659 671.19	276 641.63	10.13	12.88	32	SHALLOW AQUIFER
C2D(d)	659 671.19	276 641.63	10.11	18.85	32	DEEP AQUIFER
C3	659 704.29	276.246.89	7.22	2.8	32	SHALLOW AQUIFER
D1	659 134.97	276 771.65	27.46	23.69	50	EARLY DETECTION
D2	659 101.02	276 642.06	32.12	29.46	50	EARLY DETECTION
D4	659 293.20	276 356.60	17.97	17.0		SHALLOW AQUIFER
D5	659 020.80	276 022.40	20.65	18		SHALLOW AQUIFER BACKGROUND
D6	659 200.31	276 761.08	26.41	16.07	50	EARLY DETECTION
E1(d)	659 349.54	276 329.48	20.91	37.80	32	SHALLOW AQUIFER
E1(s)	659 349.54	276 329.48	20.91	20.05	32	DEEP AQUIFER
E2(s)	659 667.30	276 354.69	13.15	15.24	32	SHALLOW AQUIFER
E2(d)	659 667.30	276 354.69	13.15	28.66	32	DEEP AQUIFER
F1	659 037.10	276 925.50	18.90	15.0	50	SHALLOW AQUIFER LEACHATE IRRIGATION
F2	659 105.00	276 218.00	13.50	10.2	50	SHALLOW AQUIFER LEACHATE IRRIGATION
F3	658 951.70	276 434.00	16.70	10.5	50	SHALLOW AQUIFER LEACHATE IRRIGATION
G1(s) [4]	658 786.00	277 046.00	24	15	50	SHALLOW AQUIFER BACKGROUND
G1(d) [4]	658 786.00	277 046.00	24	31.5	50	DEEP AQUIFER BACKGROUND
G2 [4]	659 673.00	276 835.00	8	4	50	SHALLOW AQUIFER
COORDINATES FOR BORE HOLES BELOW ARE APPROXIMATE ONLY						
D3(r) s	659 089.60	276 585.30	18	10	50	EARLY DETECTION
D3(r) d	659 089.60	276 585.30	18	32	50	EARLY DETECTION
BHXS1	659 797.20	276 617.30	-	4	50	SHALLOW AQUIFER
BHXS2	659 620.80	276 984.30	-	4	50	SHALLOW AQUIFER
BHXD1	659 741.00	276 262.60	-	35	50	DEEP AQUIFER
COORDINATES ARE IN TERMS OF NEW ZEALAND GEODETIC DATUM 1949: WANGANUI CIRCUIT						

NOTES:

1. LEVELS ARE TOP OF STANDPIPE. WHERE THERE IS NO STANDPIPE, LEVELS ARE TOP OF PVC PIPE.
2. BHA2, BHA3 AND BHD3 HAVE BEEN LOST DUE TO SITE WORKS.
3. "A" SERIES BORE HOLES ARE AUGER HOLES ONLY AND MAY NOT BE ABLE TO BE LOCATED.
4. BORES INSTALLED IN AUG 2009. DETAILS ARE APPROXIMATE.
5. CONTOUR INTERVALS: 5m MAJOR, 1m MINOR

LEGEND

- MONITORING SAMPLING LOCATION
- MONITOR BORES CURRENTLY SAMPLED (FROM JAN 2010)
- BORES NOT SAMPLED
- SHALLOW HANDAUGER STANDPIPES NOT ABLE TO BE LOCATED
- SOIL SAMPLING LOCATION PEG - MONITORED
- SOIL SAMPLING LOCATION PEG - NOT MONITORED
- EXISTING STORMWATER SOAKAGE AREA
- PROPOSED STORMWATER SOAKAGE AREA
- PROPOSED BORROW AREAS

LEGEND

Leachate Indicators July to October 2023

EC	Electrical Conductivity (mS/m)
CL	Chloride (g/m^3)
B	Boron (g/m^3)
NH_4N	Ammoniacal-Nitrogen (g/m^3)

FIGURE 4

HDC Groundwater and Surface Water Monitoring Data

Ref: R10009-2 dated 31/10/23

Project:

LEVIN LANDFILL

HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

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REV	REVISIONS	DRN	CHK	APP	DATE
E	FOR INFORMATION - BHD3(r)s AND BHD3(r)d ADDED, AND CONTOURS UPDATED FROM JULY 2021 SURVEY	BCJ	PSL	PSL	24.09.21
D	FOR INFORMATION - BORROW AREA 2 RELOCATED, DEFINED AREAS OF FUTURE STAGES 1B, 4 AND 5	BCJ	PSL	PSL	01.06.21
C	FOR INFORMATION - BORROW AREA AND LANDFILL AREA UPDATES AND BORE HOLES AND SAMPLING LOCATIONS ADDED FOR HOKIO STREAM AND TATANA DRAIN	BCJ	PSL	PSL	24.03.21
B	FOR INFORMATION - BORROW AREA AND LANDFILL AREA UPDATES	BCJ	PSL	PSL	22.09.20
A	FOR INFORMATION	BCJ	PSL	PSL	26.08.19

SURVEYED	MWH	
DESIGNED	N/A	-
DRAWN	Brent James	08.2019
CAD REVIEW	Brent James	23.09.21
APPROVED	Phil Landmark	23.09.21
PROF REGISTRATION:		

Stantec

Client:

HOROWHENUA DISTRICT COUNCIL
LEVIN LANDFILL

MONITORING BORES, SOIL SAMPLING LOCATIONS & BORROW AREAS
SITE PLAN, LOCATION AND DETAILS

Status Stamp: FOR INFORMATION ONLY
Date Stamp: 24.09.21
Scales: 1:2000 (A1) 1:4000 (A3)
Drawing No.: 310101088-19-001-G001
Rev.: E

pw:\\stantec-ap-pw.bentley.com:stantec-ap-pw-01\Documents\New Zealand Clients\Horowhenua District Council\80500724 (310101088) - Levin Landfill Volumes\2019\General\310101088-19-001-G001

26/08/2019 9:35 a.m.

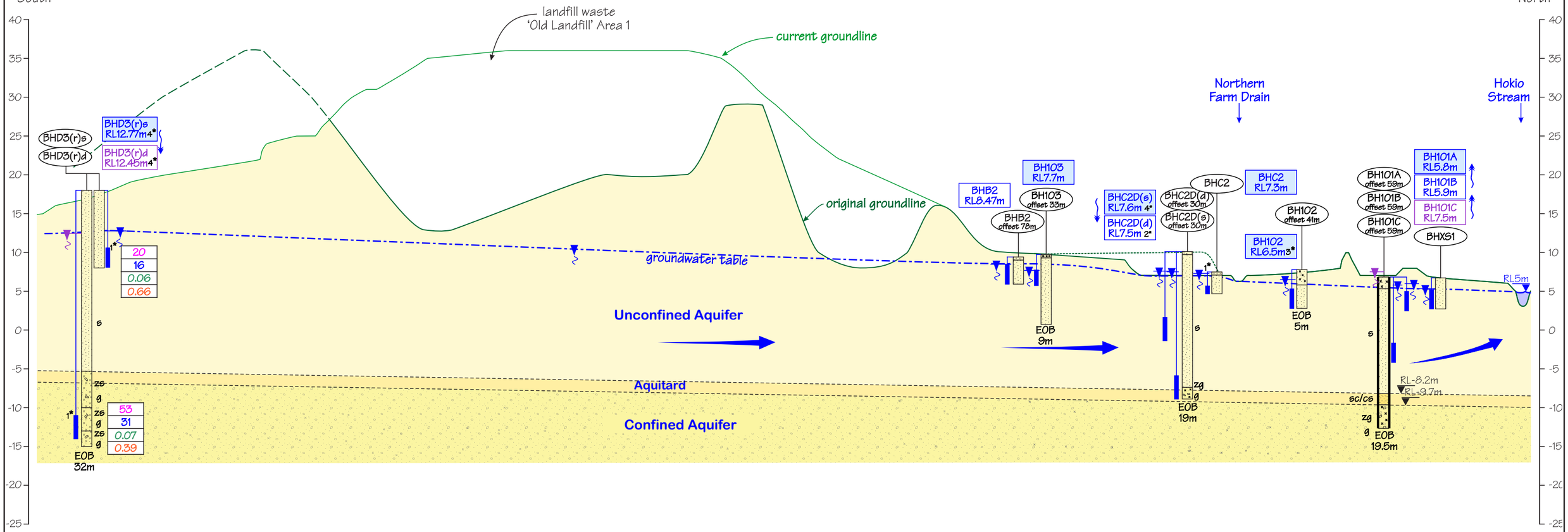
ORIGINAL SIZE A1

DO NOT SCALE - IF IN DOUBT, ASK

Landfill (Area 1) Extent

A
South

A'
North



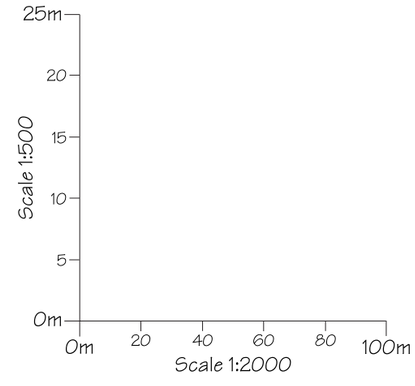
Notes:

1. Original groundline from original site topography and aerial photography from N.Z Aerial mapping, dated 27 April 1981.
2. Current groundline from Stantec drawing 310101088-19-001-G001 Rev E ' Monitoring bores, Soil Sampling Locations & Borrow Areas Site Plan, Location and Details', dated 24 September 2021.
3. 1* Intake details inferred.
4. Water level (RL) from September 2023.
5. 2* Water level (RL) from October 2022.
6. 3* Low level of reliability due to poor piezometer construction.
7. 4* Water level (RL) from July 2023.
8. Extent of aquitard based on BH101C logs.

LEGEND

Leachate indicators July 2023

EC	Electrical Conductivity (mS/m)
CL	Chloride (g/m^3)
B	Boron (g/m^3)
NH_4N	Amoniacal Nitrogen (g/m^3)



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Horowhenua District Council

Cross-Section A-A' with BHD3(r) Leachate Indicators

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	31-10-23	FOR REPORT R10009-2	P.K	P.K	S.SW	

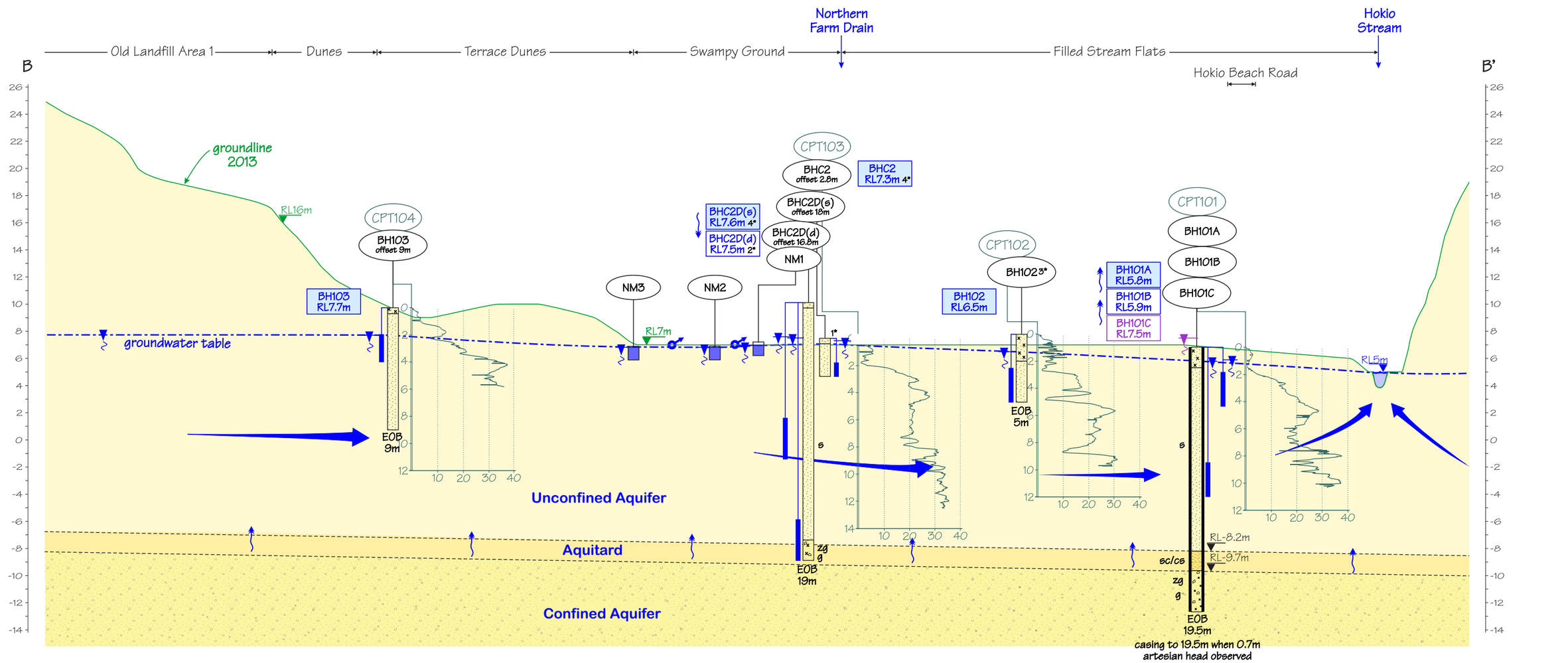
DRAWING NO.: FIG. 5

REF: 10009-R2

SCALE: 1:2000(h) 1:500(v)

CRS: Wanganui 1949

DATUM:



Notes:

1. Groundline inferred from Horowhenua District Council Contours, dated 2013.
2. 1* Intake details inferred.
3. Water level (RL) from September 2023.
4. 2* Water level (RL) from October 2022.
5. CPT plots show Cone Resistance (MPa) as a function of depth.
6. 3* Low level of reliability due to poor piezometer construction.
7. 4* Water level (RL) from July 2023.

LEGEND

BH102 RL6.5m — Groundwater table levels

Groundwater flow direction

Scale 1:300: 15m, 12, 9, 6, 3, 0m

Scale 1:1000: 0m, 10, 20, 30, 40, 50m

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Horowhenua District Council

Cross-Section B-B' Groundwater Flow (July and September 2023)

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	31-10-23	FOR REPORT R10009-2	P.K	P.K	S.SW	

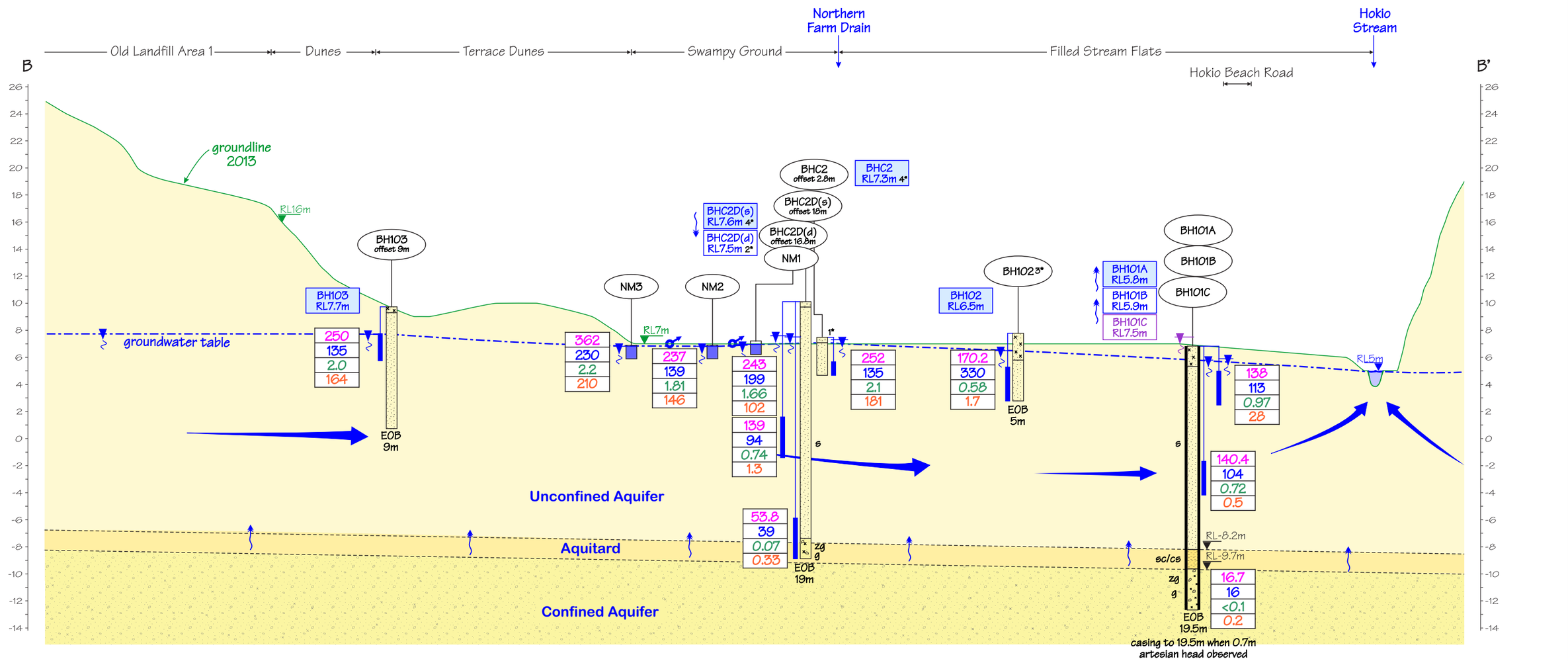
DRAWING NO.: FIG. 6.1

REF: 10009

SCALE: 1:1000(h) 1:300(v)

CRS: Wanganui 1949

DATUM:



LEGEND

BH102 RL6.5m — Groundwater table levels

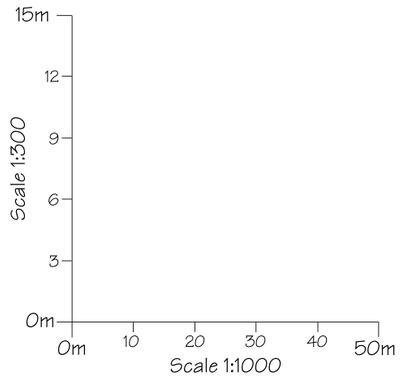
Leachate indicators September 2023

EC	Electrical Conductivity (mS/m)
CL	Chloride (g/m^3)
B	Boron (g/m^3)
NH_4N	Amoniacal Nitrogen (g/m^3)

BHC2, BHC2D(s) and BHC2D(d) leachate indicators from July 2023

Notes:

1. Groundline inferred from Horowhenua District Council Contours, dated 2013.
2. 1* Intake details inferred.
3. Water level (RL) from September 2023.
4. 2* Water level (RL) from October 2022.
5. 3* Low level of reliability due to poor piezometer construction.
6. 4* Water level (RL) from July 2023.



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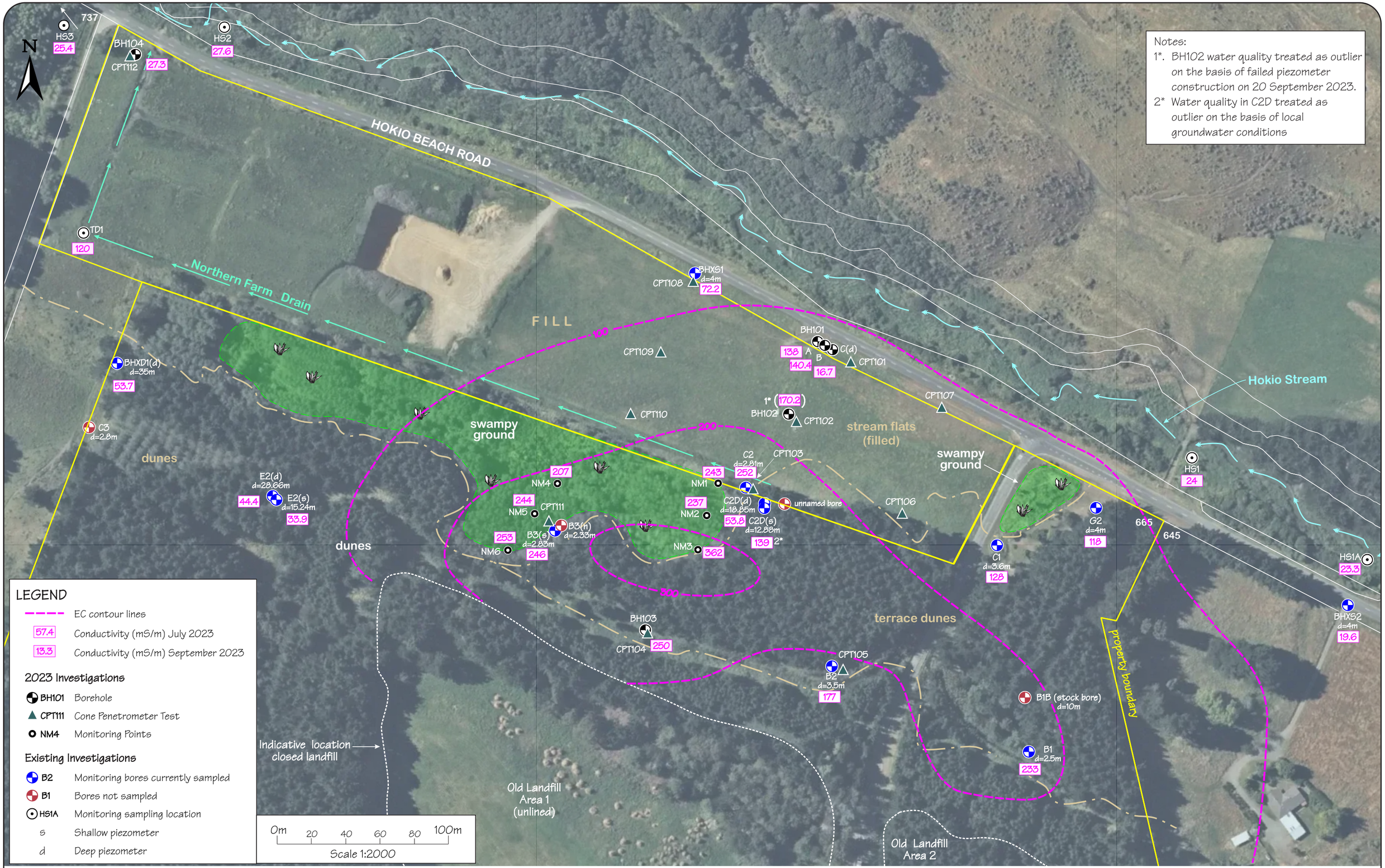
Cross-Section B-B' with Leachate Indicators

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	31-10-23	FOR REPORT R10009-2	P.K	P.K	S.SW	

DRAWING NO.: FIG. 6.2
REF: 10009-R2
SCALE: 1:1000(h) 1:300(v)
CRS: Wanganui 1949
DATUM:



Notes:

1*. BH102 water quality treated as outlier on the basis of failed piezometer construction on 20 September 2023.

2* Water quality in C2D treated as outlier on the basis of local groundwater conditions

LEGEND

- EC contour lines
- 57.4 Conductivity (mS/m) July 2023
- 13.3 Conductivity (mS/m) September 2023

2023 Investigations

- BH101 Borehole
- CPT111 Cone Penetrometer Test
- NM4 Monitoring Points

Existing Investigations

- B2 Monitoring bores currently sampled
- B1 Bores not sampled
- HS1A Monitoring sampling location
- s Shallow piezometer
- d Deep piezometer

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LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Electrical Conductivity Plume - September 2023

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	M.F	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT R10009-1	M.F	P.K	S.SW	
C	31-10-23	FOR REPORT R10009-2	M.F	P.K	S.SW	

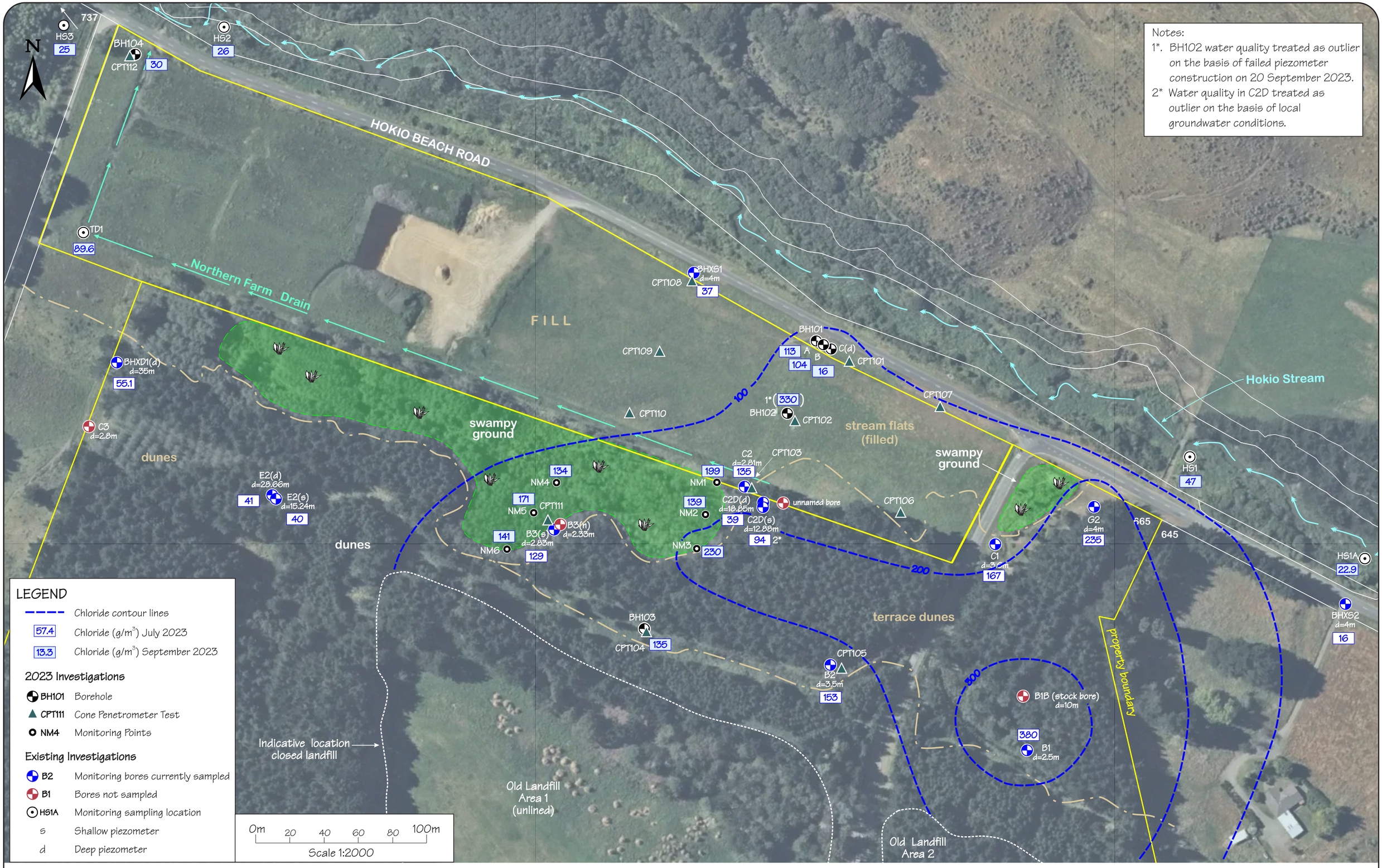
DRAWING NO.: FIG. 7

REF: 10009-R2

SCALE: 1:2000

CRS: NZTM

DATUM:



Notes:

1*. BH102 water quality treated as outlier on the basis of failed piezometer construction on 20 September 2023.

2* Water quality in C2D treated as outlier on the basis of local groundwater conditions.

LEGEND

- Chloride contour lines
- 57.4 Chloride (g/m³) July 2023
- 13.3 Chloride (g/m³) September 2023

2023 Investigations

- BH101 Borehole
- CPT111 Cone Penetrometer Test
- NM4 Monitoring Points

Existing Investigations

- B2 Monitoring bores currently sampled
- B1 Bores not sampled
- HS1A Monitoring sampling location
- s Shallow piezometer
- d Deep piezometer

NOT FOR CONSTRUCTION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH

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Email: admin@earthtech.co.nz

LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Chloride Plume - September 2023

DRAWING NO.: FIG. 8

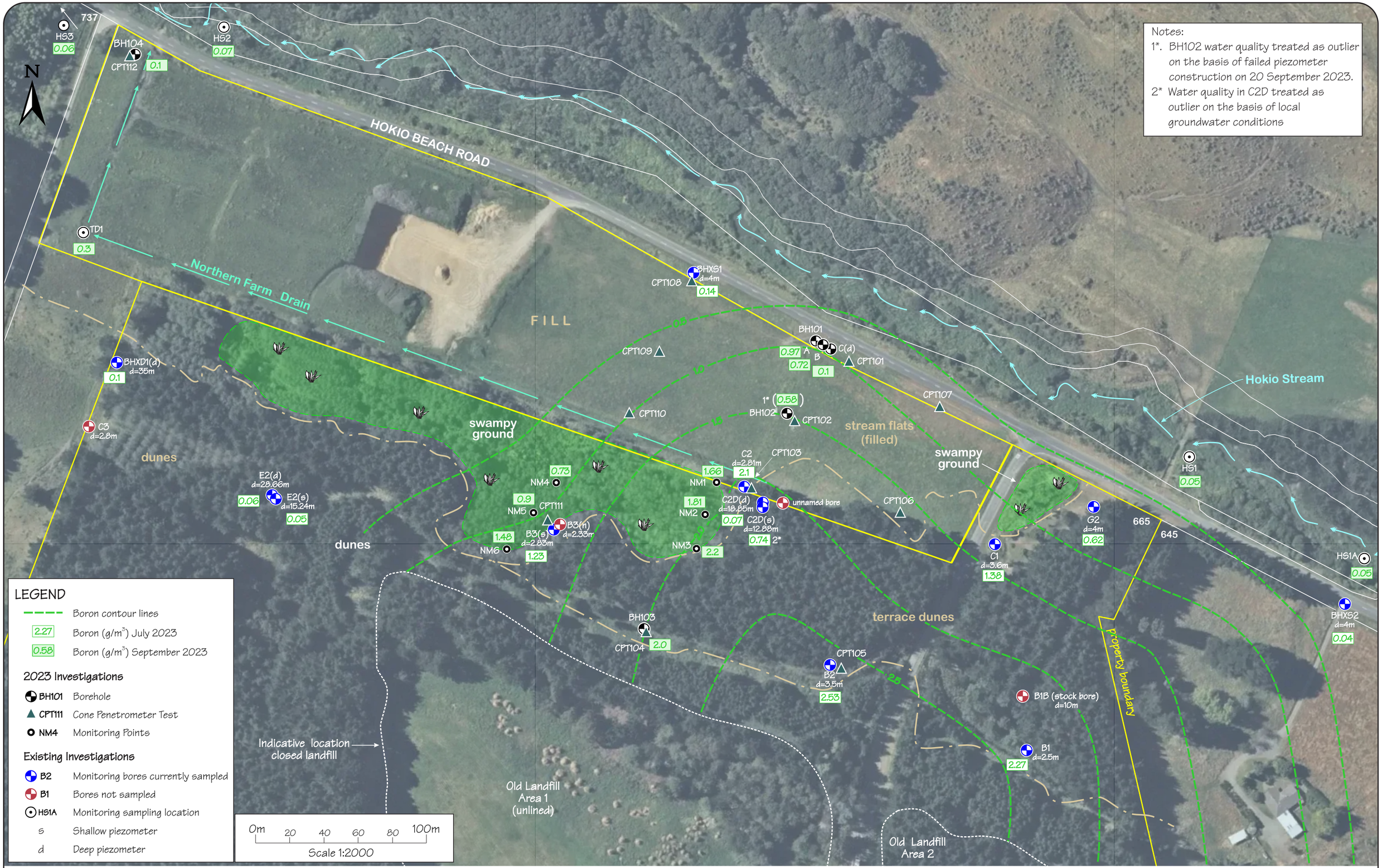
REF: 10009-R2

SCALE: 1:2000

CRS: NZTM

DATUM:

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	M.F	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT R10009-1	M.F	P.K	S.SW	
C	31-10-23	FOR REPORT R10009-2	M.F	P.K	S.SW	



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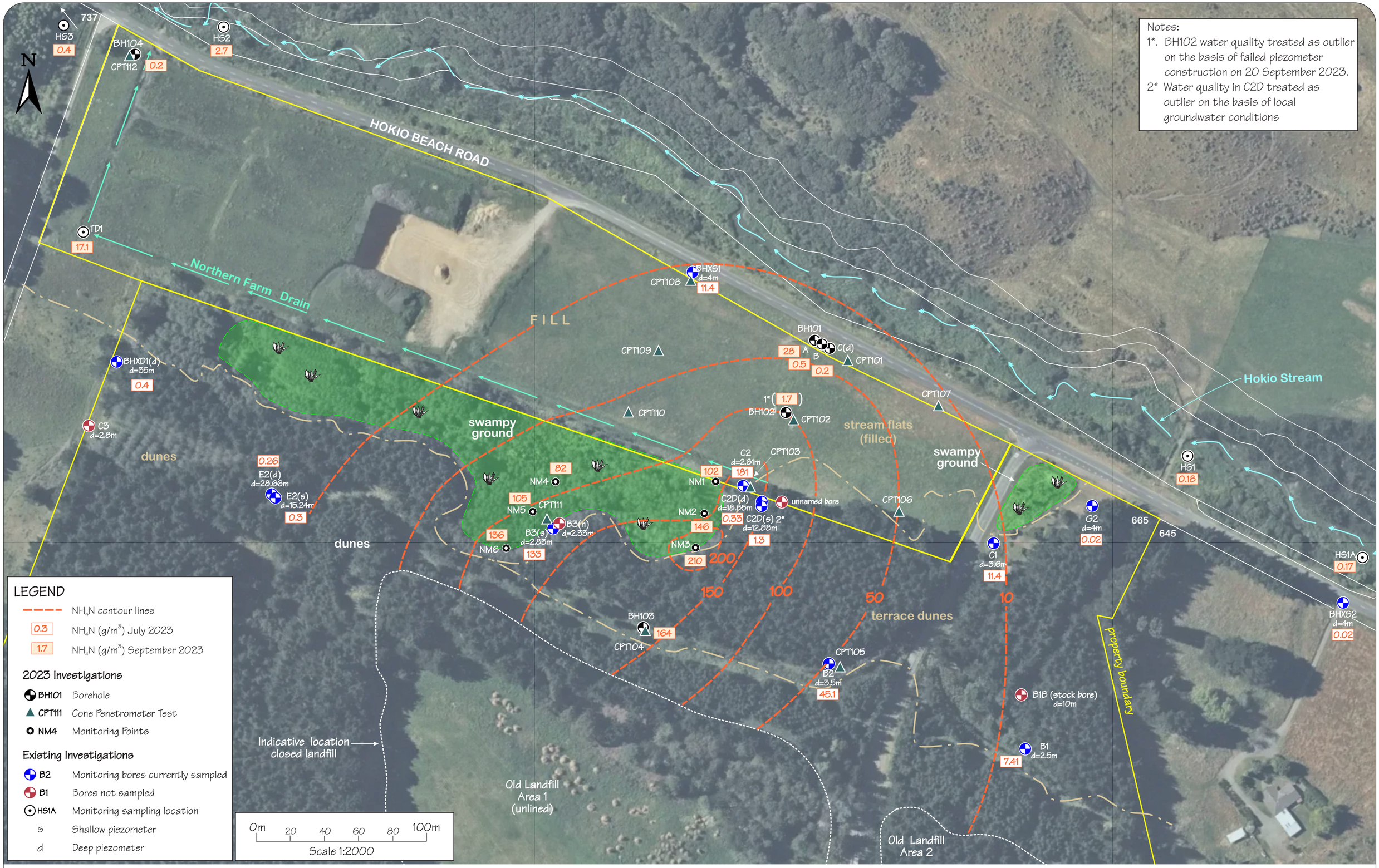
LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Boron Plume - September 2023

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	M.F	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT R10009-1	M.F	P.K	S.SW	
C	26-10-23	FOR REPORT R10009-2	M.F	P.K	S.SW	

DRAWING NO.: FIG. 9
REF: 10009-R2
SCALE: 1:2000
CRS: NZTM
DATUM:



Notes:

1*. BH102 water quality treated as outlier on the basis of failed piezometer construction on 20 September 2023.

2* Water quality in C2D treated as outlier on the basis of local groundwater conditions

LEGEND

- NH_4N contour lines
- 0.3 NH_4N (g/m^3) July 2023
- 1.7 NH_4N (g/m^3) September 2023

2023 Investigations

- BH101 Borehole
- CPT111 Cone Penetrometer Test
- NM4 Monitoring Points

Existing Investigations

- B2 Monitoring bores currently sampled
- B1 Bores not sampled
- HS1A Monitoring sampling location
- s Shallow piezometer
- d Deep piezometer

NOT FOR CONSTRUCTION

Note: All drawings are to be approved (initialled) before final issue.

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LEVIN LANDFILL, HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Ammoniacal Nitrogen Plume - September 2023

DRAWING NO.: FIG. 10

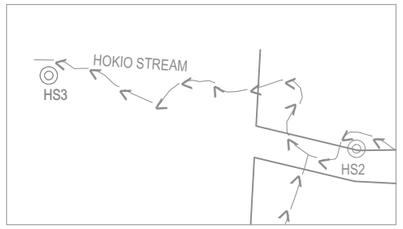
REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	08-05-23	DRAFT FOR COMMENT	M.F	P.K	S.SW	
B	10-05-23	FOR FINAL REPORT R10009-1	M.F	P.K	S.SW	
C	06-10-23	DRAFT FOR REPORT R10009-2	M.F	P.K	S.SW/C.M	
D	31-10-23	FOR REPORT R10009-2	M.F	P.K	S.SW/C.M	

REF: 10009-R2

SCALE: 1:2000

CRS: NZTM

DATUM:



BORE LOCATIONS AND DETAILS

BORE HOLE NO	NORTHING mN	EASTING mE	R.L. (m)	DEPTH OF WELL (m)	PIEZOMETER DIAMETER (mm)	FUNCTION
A1	659 060.15	276 944.89	12.95			SHALLOW AQUIFER
A2 (DESTROYED)						SHALLOW AQUIFER
A3 (DESTROYED)						SHALLOW AQUIFER
A4	659 271.67	276 354.72	10.10			SHALLOW AQUIFER
A5	659 530.47	276 185.91	9.62			SHALLOW AQUIFER
B1	659 561.81	276 797.35	9.04	4.3	40	SHALLOW AQUIFER
B1B (STOCK BORE)	659 530.08	276 799.91	9.28	10		
B2	659 576.32	276 683.50	9.42	3.5	50	SHALLOW AQUIFER
B3(s)	659 651.19	276 519.52	7.76	2.83	50	SHALLOW AQUIFER
B3(n)	659 654.26	276 524.38	7.49	2.33	32	DEEP AQUIFER
C1	659 649.64	276 777.83	7.47	3.60	50	SHALLOW AQUIFER
C2	659 680.80	276 631.22	7.50	2.81	32	SHALLOW AQUIFER
C2D(s)	659 671.19	276 641.63	10.13	12.88	32	SHALLOW AQUIFER
C2D(d)	659 671.19	276 641.63	10.11	18.85	32	DEEP AQUIFER
C3	659 704.29	276.246.89	7.22	2.8	32	SHALLOW AQUIFER
D1	659 134.97	276 771.65	27.46	23.69	50	EARLY DETECTION
D2	659 101.02	276 642.06	32.12	29.46	50	EARLY DETECTION
D4	659 293.20	276 356.60	17.97	17.0		SHALLOW AQUIFER
D5	659 020.80	276 022.40	20.65	18		SHALLOW AQUIFER BACKGROUND
D6	659 200.31	276 761.08	26.41	16.07	50	EARLY DETECTION
E1(d)	659 349.54	276 329.48	20.91	37.80	32	SHALLOW AQUIFER
E1(s)	659 349.54	276 329.48	20.91	20.05	32	DEEP AQUIFER
E2(s)	659 667.30	276 354.69	13.15	15.24	32	SHALLOW AQUIFER
E2(d)	659 667.30	276 354.69	13.15	28.66	32	DEEP AQUIFER
F1	659 037.10	276 925.50	18.90	15.0	50	SHALLOW AQUIFER LEACHATE IRRIGATION
F2	659 105.00	276 218.00	13.50	10.2	50	SHALLOW AQUIFER LEACHATE IRRIGATION
F3	658 951.70	276 434.00	16.70	10.5	50	SHALLOW AQUIFER LEACHATE IRRIGATION
G1(s) [4]	658 786.00	277 046.00	24	15	50	SHALLOW AQUIFER BACKGROUND
G1(d) [4]	658 786.00	277 046.00	24	31.5	50	DEEP AQUIFER BACKGROUND
G2 [4]	659 673.00	276 835.00	8	4	50	SHALLOW AQUIFER
COORDINATES FOR BORE HOLES BELOW ARE APPROXIMATE ONLY						
D3(r) s	659 089.60	276 585.30	18	10	50	EARLY DETECTION
D3(r) d	659 089.60	276 585.30	18	32	50	EARLY DETECTION
BHXS1	659 797.20	276 617.30	-	4	50	SHALLOW AQUIFER
BHXS2	659 620.80	276 984.30	-	4	50	SHALLOW AQUIFER
BHXD1	659 741.00	276 262.60	-	35	50	DEEP AQUIFER
COORDINATES ARE IN TERMS OF NEW ZEALAND GEODETIC DATUM 1949: WANGANUI CIRCUIT						

COORDINATES OF SURVEY CONTROL MARKS

PT	NORTHING mN	EASTING mE	RL
ORM 1	659 498.38	276 412.21	38.94
ORM 2	659 510.09	276 422.72	34.98
ORM 3	659 505.14	276 612.86	21.10
ORM 4(OP/W)	659 380.16	276 511.94	30.92
MWH NAIL 1	659 272.67	276 656.87	27.61
MWH NAIL 2	659 278.98	276 695.22	28.40
MWH IT 1	659 267.33	276 576.02	30.03
MWH IT 2	659 361.94	276 627.00	33.70
MWH IT 3	659 428.24	276 593.00	32.74
MWH PEG 1	659 160.94	276 548.30	32.99
MWH PEG 2	659 227.86	276 479.35	30.49
IRII	659 075.85	276 698.70	30.04
OIR	658 903.62	276 579.37	30.35
IRI	659 121.09	276 679.47	40.00
IR	276 625.10	658 981.29	21.30

COORDINATES ARE IN TERMS OF NEW ZEALAND GEODETIC DATUM 1949: WANGANUI CIRCUIT

SOIL MONITORING LOCATIONS	CO-ORDINATES		LEVEL (m)
	NORTHING mN	EASTING mE	
PEG A	658 938.80	276 882.30	39.2
PEG B	658 917.00	276 932.10	39.5
PEG C	658 862.70	276 899.00	46.1
PEG D	658 822.90	276 930.40	40.4
PEG E	658 965.50	276 294.00	36.6
PEG F	659 046.20	276 169.10	32.9
PEG G	658 878.00	276 520.20	32.6
PEG H	658 827.40	276 667.60	23.5

BORROW AREA 1 SET-OUT COORDINATES

POINT NO.	NORTHINGS mN	EASTINGS mE
1	659 230.38	276 453.28
2	659 247.32	276 413.49
3	659 257.33	276 349.62
4	659 280.93	276 269.42
5	659 233.27	276 243.39
6	659 201.34	276 302.68

NOTES:

1. LEVELS ARE TOP OF STANDPIPE. WHERE THERE IS NO STANDPIPE, LEVELS ARE TOP OF PVC PIPE.
2. BHA2, BHA3 AND BHD3 HAVE BEEN LOST DUE TO SITE WORKS.
3. "A" SERIES BORE HOLES ARE AUGER HOLES ONLY AND MAY NOT BE ABLE TO BE LOCATED.
4. BORES INSTALLED IN AUG 2009. DETAILS ARE APPROXIMATE.
5. CONTOUR INTERVALS: 5m MAJOR, 1m MINOR

LEGEND

- MONITORING SAMPLING LOCATION
- MONITOR BORES CURRENTLY SAMPLED (FROM JAN 2010)
- BORES NOT SAMPLED
- SHALLOW HANDAUGER STANDPIPES NOT ABLE TO BE LOCATED
- SOIL SAMPLING LOCATION PEG - MONITORED
- SOIL SAMPLING LOCATION PEG - NOT MONITORED
- EXISTING STORMWATER SOAKAGE AREA
- PROPOSED STORMWATER SOAKAGE AREA
- PROPOSED BORROW AREAS

LEGEND

- Groundwater table contours
- Shallow aquifer bore
- Deep groundwater aquifer bore
- 8.85 Groundwater table level mRL
- 8.85 Water level mRL July 2023
- 8.85 Water level mRL September 2023

FIGURE 11

Groundwater Table Contours

Ref: R10009-1 dated 17/11/23

Project:
LEVIN LANDFILL
HOKIO BEACH ROAD, LEVIN
Horowhenua District Council

EARTHTECH
Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
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NOT FOR CONSTRUCTION

REV	REVISIONS	DRN	CHK	APP	DATE
E	FOR INFORMATION - BHD3(r)s AND BHD3(r)d ADDED, AND CONTOURS UPDATED FROM JULY 2021 SURVEY	BCJ	PSL	PSL	24.09.21
D	FOR INFORMATION - BORROW AREA 2 RELOCATED, DEFINED AREAS OF FUTURE STAGES 1B, 4 AND 5	BCJ	PSL	PSL	01.06.21
C	FOR INFORMATION - BORROW AREA AND LANDFILL AREA UPDATES AND BORE HOLES AND SAMPLING LOCATIONS ADDED FOR HOKIO STREAM AND TATANA DRAIN	BCJ	PSL	PSL	24.03.21
B	FOR INFORMATION - BORROW AREA AND LANDFILL AREA UPDATES	BCJ	PSL	PSL	22.09.20
A	FOR INFORMATION	BCJ	PSL	PSL	26.08.19

SURVEYED	MWH	
DESIGNED	N/A	-
DRAWN	Brent James	08.2019
CAD REVIEW	Brent James	23.09.21
APPROVED	Phil Landmark	23.09.21
PROF REGISTRATION:		

Stantec

Client:

HOROWHENUA DISTRICT COUNCIL
LEVIN LANDFILL

MONITORING BORES, SOIL SAMPLING LOCATIONS & BORROW AREAS
SITE PLAN, LOCATION AND DETAILS

Status Stamp: FOR INFORMATION ONLY
Date Stamp: 24.09.21
Scales: 1:2000 (A1) 1:4000 (A3)
Drawing No.: 310101088-19-001-G001
Rev.: E

pw:\\stantec-ap-pw.bentley.com:stantec-ap-pw-01\Documents\New Zealand Clients\Horowhenua District Council\80500724 (310101088) - Levin Landfill Volumes\2019\General\310101088-19-001-G001

26/08/2019 9:35 a.m.

ORIGINAL SIZE A1

DO NOT SCALE - IF IN DOUBT, ASK

T:\Wellington\TT Projects\1011583\WorkingMaterial\Conceptual site model\Working files\Figures.dwg 2019-Sep-26 9:49:04 AM Plotted By: DAVID UMBERG

FIGURE 12

Tonkin and Taylor Cross-Section

Ref: R10009-2 dated 17/11/23

Project:

LEVIN LANDFILL

HOKIO BEACH ROAD, LEVIN

Horowhenua District Council

Earthtech markups in green.

EARTHTECH

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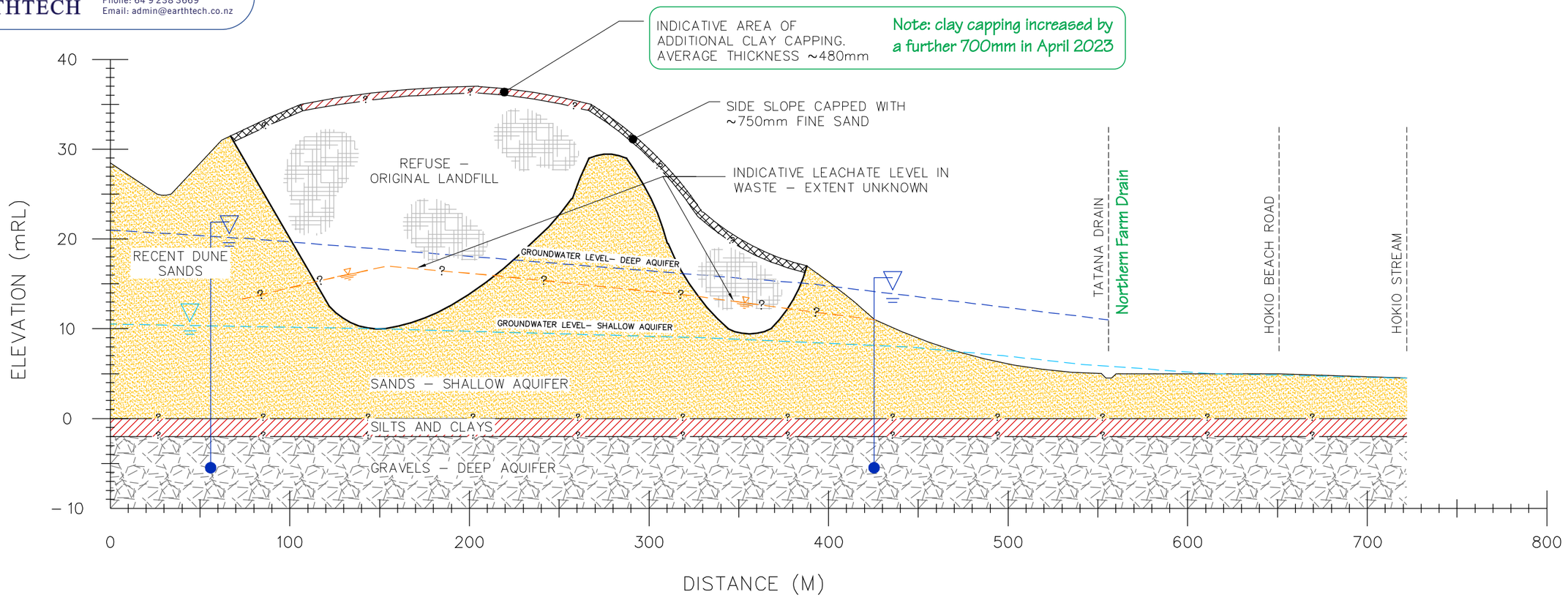
NOTES:
1. LOCATIONS ARE BASED ON REVIEW OF EXISTING INFORMATION AND ARE APPROXIMATELY. LAYOUT PROVIDED AS CONCEPT SITE MODEL ONLY.
2. EXISTING TOPOGRAPHY IS BASED ON: STANTEC, 2018: "LEVIN LANDFILL ANNUAL COMPLIANCE REPORT JULY 2017 - JUNE 2018", DATED SEPTEMBER 2018.
2. ORIGINAL SITE TOPOGRAPHY AND AERIAL PHOTOGRAPHY FROM N.Z. AERIAL MAPPING, DATED 27 APRIL 1981.
3. SHALLOW GROUNDWATER LEVELS BASED ON INTERPRETATION PROVIDED BY STEPHEN DOUGLASS, DATED OCTOBER 2018.



5: 1 VERTICAL EXAGGERATION

SCALE 1: 4000 (H)

0 40 80 120 160 200 (m)

Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

0	DRAFT FOR DISCUSSION	DAUM	SEPT 2019

PROJECT No.		
DESIGNED	DAUM	SEPT 19
DRAWN		
CHECKED		
APPROVED	DATE	

CLIENT **HOROWHENUA DISTRICT COUNCIL**

PROJECT **LEVIN LANDFILL**

TITLE LEACHATE BEST PRACTICABLE OPTION ASSESSMENT CONCEPT CROSS SECTION

UNDER REVISION

SCALE (A3) 1:4000(H) 1:800(V) JOB No. 1011583-002 REV 0

Conceptual Groundwater Model Report

Levin Landfill, Hōkio Beach Road, Levin

Appendix A

Site Investigation Logs and Detailed Observations

DRILL HOLE LOG

EARTHTECH

Bore No.:	BH101-A
Project No.:	10009
Sheet:	1 of 1

Client:	Horowhenua District Council	Coordinates:	1787211.221mE, 5503048.673mN
Project:	Levin Landfill	CRS:	NZTM
Location:	Hokio Beach Road	Elevation:	RL6.78m
Test Location:		Located by:	Survey
Test Date:	07/09/2023		
Logged by:	MF		
Prepared by:	SSW		
Checked by:	PK		

Drilling Progress	Sample Type	Casing Depth (m)	Drill Run (m)	TCR (25 50 75)	Weathered (rock only) (sw mw hw)	Fracture Log (cm) (50 10 5 1)	Drill Water Loss (%) (25 50 75)	Piezometer Construction	Depth (m)	Legend	DESCRIPTION OF STRATA	Geology
	PQ		0.0m								0m to 2m Core not retrieved (logging interpretation from CPTs). Silty SAND to Sandy SILT. Loose. 1.2m-1.5m: CLAY to Silty CLAY. Loose. 1.5m-1.9m: Silty SAND to Sandy SILT. Loose to medium dense.	
	PQ		2.0m								Very fine to fine well graded SAND with minor silt; grey/beige. Dense; moist.	
	PQ		3.0m								Very fine to fine well graded SAND; grey. Dense; moist.	
	PQ		4.5m								Very fine to fine well graded SAND; dark grey. Very dense; moist.	
			5.0m								EOB @ 5m	

Piezometer Construction:

Grout plug	GL to 1.5m
Bentonite pellets	0.5m to 1.5m
Blinding sand	1.5m to 2.0m
Filter pack	2.0m to 5.0m
Screen	2.5m to 5.0m
PVC pipe	GL to 5.0m

Remarks:

Sand strengths interpreted from the closest CPT (Cone Penetrometer Test).
Flush toby box.

Water Level Observations During Drilling

Date	Time	Depth of Hole	Depth of Casing	Depth of Water

DRILL HOLE LOG

EARTHTECH

Bore No.: BH101-C
Project No.: 10009
Sheet: 1 of 2

Client: Horowhenua District Council
Project: Levin Landfill
Location: Hokio Beach Road
Test Location:

Coordinates: 1787219.91mE, 5503044.05mN
CRS: NZTM
Elevation: RL6.822m
Located by: Estimate from BH101-B Survey

Test Date: 06/09/2023
Logged by: MF
Prepared by: SSW
Checked by: PK

Drilling Progress	Sample Type	Casing Depth (m)	Drill Run (m)	TCR (25 50 75)	Weathered (rock only) (sw mw hw)	Fracture Log (cm) (50 10 5 1)	Drill Water Loss (%) (25 50 75)	Piezometer Construction	Depth (m)	Legend	DESCRIPTION OF STRATA	Geology
	by hand spade		0.0m								Digged by hand (spade). Interpretation from CPT. SILT and SAND. Loose.	
	PQ		0.5m								Fine to medium SAND; brown orange. Loose; moist.	
									1		Fine to medium Silty SAND, well graded; dark grey. Loose; moist.	
											Sandy SILT; dark grey/black. Soft; loose; moist; moderately plastic.	
											Fine to medium Silty SAND; light grey/beige. Loose; moist.	
	PQ		1.5m						2		Fine to medium SAND, well graded with some minor silt; grey with some orange. Medium dense to dense	
									3			
	PQ		4.5m						4		Fine to medium SAND with minor silt, well graded; light grey. Dense; moist.	
									5		Fine to coarse SAND, well graded; light grey. Dense; moist.	
	PQ		5.45m								Fine to medium SAND, well graded; grey. Very dense; moist.	
	PQ		6.0m						6		6.0m: dense	
									7		7.2m: very dense	
	PQ		7.5m									
	PQ		7.85m						8			
	PQ		9.0m						9			
									10			
	PQ		10.2m									
	PQ		10.5m						11			

Remarks:
Sand strengths interpreted from the closest CPT (Cone Penetrometer Test)

Water Level Observations During Drilling

Date	Time	Depth of Hole	Depth of Casing	Depth of Water

DRILL HOLE LOG

EARTHTECH

Bore No.: BH101-C
Project No.: 10009
Sheet: 2 of 2

Client: Horowhenua District Council
Project: Levin Landfill
Location: Hokio Beach Road
Test Location:

Coordinates: 1787219.91mE, 5503044.05mN
CRS: NZTM
Elevation: RL6.822m
Located by: Estimate from BH101-B Survey

Test Date: 06/09/2023
Logged by: MF
Prepared by: SSW
Checked by: PK

Drilling Progress	Sample Type	Casing Depth (m)	Drill Run (m)	TCR (25 50 75)	Weathered (rock only) (sw mw hw)	Fracture Log (cm) (50 10 5 1)	Drill Water Loss (%) (25 50 75)	Piezometer Construction	Depth (m)	Legend	DESCRIPTION OF STRATA	Geology
	PQ		12.0m						13		Very fine to fine SAND, well graded with minor gravel; light grey.	
	PQ		12.6m									
	PQ		13.5m						14			
											Sandy CLAY with some hard clay inclusions (2mm-4mm); grey. Moist; highly plastic.	
											Very fine to fine SAND, well graded with minor gravels; light grey.	
	PQ		15.0m						15		Sandy CLAY, well graded with some gravels; brown. Moist.	
	PQ		15.5m								Sandy CLAY with some layers of black organic matter and some gravels (2mm-1cm); brown. Firm; moist; moderately plastic.	
	PQ		16.5m						16			
											Silty medium to coarse GRAVEL; light grey. Moist.	
	PQ		18.0m						17			
									18		Sandy CLAY with some gravels; brown/grey/orange. Firm; moist; moderately plastic.	
											Silty medium to coarse GRAVEL; light grey. Moist.	
									19		19.3m to 19.5m: medium to coarse GRAVEL.	
											EOB @ 19.5m	
									20		No Piezometer:	
											Bore grouting: Bentonite grout 1.0m to 15.0m Bentonite plug 15.0m to 16.5m Pea metal 16.5m to 19.5m	
									21			
									22			
									23			

Remarks:
Sand strengths interpreted from the closest CPT (Cone Penetrometer Test).
Artesian head in deep gravel aquifer of 0.7m (700mm) 18hrs after drilling.

Water Level Observations During Drilling

Date	Time	Depth of Hole	Depth of Casing	Depth of Water

DRILL HOLE LOG

EARTHTECH

Bore No.:	BH103
Project No.:	10009
Sheet:	1 of 1

Client:	Horowhenua District Council	Coordinates:	178710.688mE, 5502880.366mN
Project:	Levin Landfill	CRS:	NZTM
Location:	Hokio Beach Road	Elevation:	RL9.41m
Test Location:		Located by:	Survey
Test Date:	05/09/2023		
Logged by:	MF		
Prepared by:	SSW		
Checked by:	PK		

Drilling Progress	Sample Type	Casing Depth (m)	Drill Run (m)	TCR (25 50 75)	Weathered (rock only) (sw mw hw)	Fracture Log (cm) (50 10 5 1)	Drill Water Loss (%) (25 50 75)	Piezometer Construction	Depth (m)	Legend	DESCRIPTION OF STRATA	Geology
	PQ		0.0m						0		Sandy SILT; dark brown. Soft; loose; moist; high plasticity.	
											Silty very fine to fine SAND, well graded; brown/orange. Loose; moist.	
									1		Very fine to fine SAND, well graded; brown/orange. Loose; moist.	
	PQ		2.0m						2		Silty very fine to fine SAND, well graded; brown/orange. Medium dense to dense; moist.	
											Very fine to fine SAND, well graded; grey. Medium dense to dense; moist.	
	PQ		3.0m						3			
									4			
	PQ		4.5m									
	PQ		5.1m						5		5.1m: very dense	
	PQ		6.0m						6		Very fine to medium SAND, well graded; grey. Moist.	
									7			
	PQ		7.5m						8		8.4m-8.6m: layer of fine to medium SAND, well graded; dark grey.	
									9			
			9.0m								EOB @ 9m	
									10		Piezometer Construction:	
									11		Bentonite pellets 0.0m to 1.5m Blinding sand 1.5m to 1.75m Filter pack 1.75m to 4.0m Screen 2.0m to 4.0m PVC pipe GL to 4.0m Upstand 0.35m agl Top of pipe RL9.756m	

Remarks:

Sand strengths interpreted from the closest CPT (Cone Penetrometer Test).
Upstand 0.35m.

Water Level Observations During Drilling

Date	Time	Depth of Hole	Depth of Casing	Depth of Water

DRILL HOLE LOG

Bore No.:	BH104
Project No.:	10009
Sheet:	1 of 1

Client:	Horowhenua District Council	Coordinates:	1786813.332mE, 5503216.439mN
Project:	Levin Landfill	CRS:	NZTM
Location:	Hokio Beach Road	Elevation:	RL6.072m (ground level)
Test Location:		Located by:	Survey

Test Date:	08/09/2023
Logged by:	MF
Prepared by:	SSW
Checked by:	PK

Drilling Progress	Sample Type	Casing Depth (m)	Drill Run (m)	TCR (25 50 75)	Weathered (rock only) (sw mw hw)	Fracture Log (cm) (50 10 5 1)	Drill Water Loss (%) (25 50 75)	Piezometer Construction	Depth (m)	Legend	DESCRIPTION OF STRATA	Geology
	PQ		0.0m								0m to 2m Core not retrieved for logging. Interpretation from CPTs CLAY to silty CLAY	
									1		Silty SAND to sandy SILT. Loose.	
											CLAY to silty CLAY. Loose.	
									2		Silty SAND to sandy SILT. Loose.	
	PQ		2.0m								Very fine to fine SAND, well graded; grey/brown. loose to medium dense; moist.	
	PQ		3.0m						3		Very fine to fine SAND, well graded; grey. Medium dense to dense; moist to saturated.	
	PQ		4.5m						4			
			5.0m						5		EOB @ 5m Piezometer Construction: Grout plug 0.0m to 1.5m Bentonite pellets 0.5m to 1.5m Blinding sand 1.5m to 2.0m Filter pack 2.0m to 5.0m Screen 2.5m to 5.0m PVC pipe GL to 5.0m Upstand 0.23m agl Top of pipe RL6.3m	
									6			
									7			
									8			
									9			
									10			
									11			

Remarks:

Sand strengths interpreted from the closest CPT (Cone Penetrometer Test).

Water Level Observations During Drilling

Date	Time	Depth of Hole	Depth of Casing	Depth of Water

GRIFFITHS DRILLING
RESULT DRIVEN GEOTECHNICAL SPECIALISTS

SITE INVESTIGATION BORELOG

BH#	101 B (reconstructed)
JOB#	-

134 State Highway 58
Pauatahanui
P: 045277346
F: 045277347

www.griffithsdrilling.co.nz

Project:	Levin Landfill			**NZTM Grid Ref:**	N: 5503046.365
Location:	Hokio Beach Road, Levin				E: 1787215.489
Client:	Earthtech	**Operator:**	Bill		
DATE Start:	07/09/23 (reconstructed 04/11/23)	**DATE Finish:**	04/11/23	**Page:**	1 **of** 1

Drill Rig:	Fraste Sonic ML	**SPT Hammer #:**	Auto
Drilling Method:	Sonic	**Flushing Type:**	Water / Polymer
Bore Diameter:	145mm	**Casing Diameter / Type:**	Sonic
Bore Final Depth:	13.5m (12.0m redrill)	**Casing Final Depth:**	13.5m

Formation Drill Conditions
(L) – Loose, Unstable **(B)** – Bands of hard and soft
(S) – Soft, Stable **(M)** – Moderately Firm.
(F) – Firm, Stable **(H)** – Hard to penetrate

Fluids:
(TL) Total Loss; **(SL)** Slow Loss; **(WS)** Water Struck; **(NL)** No Loss

Geological Description
Must Include: Colour, Texture, Composition, Fractures, Boundary type (gradual, abrupt?)

Layer Change Depth (mbgl)	Geological Description	Core Samples & Recovery: From (m)	To (m)	Recovery (mm)
1.5	Brown SAND (S) (SL)	0.5	1.5	1500
		1.5	3.0	1500
3.0	Grey SAND (S) (SL)	3.0	4.5	1500
		4.5	6.0	1500
		6.0	7.5	1500
		7.5	9.0	1500
		9.0	10.5	1500
		10.5	12.0	1500
13.5	EOH	12.0	13.5	1500
	*redrilled to 12.0m (no core) – SAND encountered to depth, water return all the way.			

Standard Penetration Test (SPT)

Cone Type	Depth	SPT Counts	N Value	Sample (mm)
N/A – SPT not in scope				

Installation

50mm Piezo install as per specification, reconstructed.

- Blank 0.0-7m bgl
- Slotted screen 7-12m bgl

Water Level	Date / Time	Hole Depth	Water Level	Date / Time	Hole Depth
3.1m	07/09/23 1:00pm	13.5m	4.3m	04/11/23 10.30am	12.0m

GRIFFITHS DRILLING
RESULT DRIVEN GEOTECHNICAL SPECIALISTS

SITE INVESTIGATION BORELOG

BH#	102 (reconstructed)
JOB#	-

134 State Highway 58
Pauatahanui
P: 045277346
F: 045277347

www.griffithsdrilling.co.nz

Project:	Levin Landfill			**NZTM Grid Ref:**	N: 5503005.955
Location:	Hokio Beach Road, Levin				E: 1787189.724
Client:	Earthtech	**Operator:**	Bill		
DATE Start:	08/09/23 (reconstructed 04/11/23)	**DATE Finish:**	04/11/23	**Page:**	1 **of** 1

Drill Rig:	Fraste Sonic ML	**SPT Hammer #:**	Auto
Drilling Method:	Sonic	**Flushing Type:**	Water / Polymer
Bore Diameter:	145mm	**Casing Diameter / Type:**	Sonic
Bore Final Depth:	6.0m (6.0m redrill)	**Casing Final Depth:**	6.0m

Layer Change Depth (mbgl)	Formation Drill Conditions / Geological Description	Core Samples & Recovery: From (m)	To (m)	Recovery (mm)	Standard Penetration Test (SPT): Cone Type	Depth	SPT Counts	N Value	Sample (mm)
0.0	Brown SAND (S) (SL)	0.0	1.5	1500	N/A – SPT not in scope				
		1.5	3.0	1500					
3.0	Grey SAND (S) (SL)	3.0	4.5	1500					
		4.5	6.0	1500					
6.0	EOH								
					Installation				
	*redrilled to 6.0m – materials encountered brown organics to 1.0m, then SAND to depth, full water return.				50mm Piezo install as per specification, reconstructed • Blank 0.0-2.0m bgl • Screen 3.0-5.0m bgl				

Formation Drill Conditions
(L) – Loose, Unstable **(B)** – Bands of hard and soft
(S) – Soft, Stable **(M)** – Moderately Firm.
(F) – Firm, Stable **(H)** – Hard to penetrate

Fluids:
(TL) Total Loss; **(SL)** Slow Loss; **(WS)** Water Struck; **(NL)** No Loss

Geological Description
Must Include: Colour, Texture, Composition, Fractures, Boundary type (gradual, abrupt?)

Water Level	Date / Time	Hole Depth	Water Level	Date / Time	Hole Depth
2.7m	08/09/23	6.0m	1.6m	04/11/23 12pm	6.0m

Appendix A

New Monitoring Boreholes

The details of the six new boreholes are as follows:

Table A1: New monitoring boreholes details

Borehole	Depth	Intake zone	Stickup
	m bgl	*m bgl*	*m agl*
BH101A	5	2 to 5	0
BH101B	13	10 to 13	0
BH101B new	13.5	7 to 12	0
BH101C	19.5	-	0
BH102	5	2 to 5	0.25
BH102 new	6	3 to 5	0
BH103	5	1.75 to 4	0.35
BH104	5	2 to 5	0.23

All bore logs are presented below in Appendix A.

Due to poor bore construction, BH102 and BH101C were redrilled and replaced in November 2023.

Bore development has been undertaken by Earthtech on 20 and 21 September 2023 on BH101A, B, BH102, BH103 and BH104 and on 28 and 29 November 2023 on Bores BH101B new and BH102 new. BH101C has reached the deep groundwater system, which is separated from the shallow, unconfined sand aquifer by a clay aquitard. The deep aquifer showed flowing artesian conditions, with a 700*mm* head (above ground level) approximately 16 hours after drilling. This borehole has been sealed with bentonite grout through the aquitard layer to ensure no mixing of the shallow and deep aquifer waters. The BH101C monitoring bore was not constructed, however, water quality and groundwater levels were assessed during drilling.

The following bore development has been carried out:

Table A2: Field investigations - borehole development details

Borehole	Development Details	Bore Depth Post-Development
		m bgl
BH101A	Bailed and pumped for 0.5*hr*	4.3
BH101B	Bailed and pumped for 0.5*hr*	10.95
BH101B new	Pumped for 0.3*hr*	10.85
BH102	Bailed for 1.5*hr*	2.44
BH102 new	Pumped for 0.8*hr*	4.89
BH103	Bailed for 0.2*hr*	4.01
BH104	Pumped and bailed for 1*hr*	5.06

Cone Penetrometer Tests

The twelve CPTs have been conducted on three lines throughout the Tatana property from 4 to 6 September 2023. Their locations are presented in Figure 3. The refusal depths encountered for each CPT are shown in Table 3 below.

All CPTs refused within the very dense sands associated with the shallow unconfined sand aquifer apart from CPT107 which extended to the aquitard.

Table A3: CPT refusal depths

CPT101	CPT102	CPT103	CPT104	CPT105	CPT106
m bgl	*m bgl*	*m bgl*	*m bgl*	*m bgl*	*m bgl*
10	9.8	12.5	5.8	5.3	5.3
CPT107	**CPT108**	**CPT109**	**CPT110**	**CPT111**	**CPT112**
m bgl	*m bgl*	*m bgl*	*m bgl*	*m bgl*	*m bgl*
16.3	11	16	11	5.3	12.5

Shallow Water Monitoring Probes

A swampy area has been observed south of the Tatana property, north of the old Levin Landfill. Six monitoring probes have been installed in this area as two lines of three pipes, each of them measuring 1*m* in total, and installed 0.5*m* deep in the swampy area. Field chemistry has been tested on water samples retrieved from these pipes on 5 and 7 September 2023 and the results are presented in Table 4 below.

Table A4: Northern monitoring probes details and field chemistry testing results

Monitoring Point	Area	Date of installation	EC	EC	NH4-N
			µmS/cm	mS/m	mg/l
NM1	BHC2 line	7-Sep-23	1,212	121.2	110
NM2			1,277	127.7	300
NM3			2,095	209.5	380
NM4	BHB3 line		924	92.4	120
NM5			1077	107.7	160
NM6			1420	142	350

Water sample quality has been tested, and the results from Hill Laboratories are presented in Table 5 below and in Appendix B.

Table A5: Shallow water monitoring probes – chemistry

Monitoring Point	pH	NH_4-N	EC	Cl	B (dissolved)	Tot. Alk.	Bicar-bonate
	-	mg/l	mS/m	mg/l	mg/l	mg/l	mg/l
NM1	7.1	102	243.0	199	1.66	1,010	1,230
NM2	7.1	146	237.0	139	1.81	1,010	1,230
NM3	7.2	210	362.0	230	2.20	1,580	1,930
NM4	7.0	82	207.0	134	0.73	910	1,100
NM5	7.1	105	244.0	171	0.90	1,040	1,270
NM6	7.1	136	253.0	141	1.48	1,100	1,340

Conceptual Groundwater Model Report

Levin Landfill, Hōkio Beach Road, Levin

Appendix B

Water Quality Test Data

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

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Certificate of Analysis

Client:	Earthtech Consulting Limited	**Lab No:**	3362159	SPv1
Contact:	Wilbe Blay	**Date Received:**	12-Sep-2023	
	C/- Earthtech Consulting Limited	**Date Reported:**	19-Sep-2023	
	PO Box 721	**Quote No:**	126263	
	Pukekohe 2340	**Order No:**		
		Client Reference:		
		Submitted By:	Wilbe Blay	

Sample Type: Aqueous

	Sample Name:	BH101C 07-Sep-2023	BH101C [A] 07-Sep-2023	NM1 08-Sep-2023	NM2 08-Sep-2023	NM3 08-Sep-2023
	Lab Number:	3362159.1	3362159.2	3362159.3	3362159.4	3362159.5
pH	pH Units	8.1	8.0	7.3	7.3	7.3
Total Alkalinity	g/m³ as $CaCO_3$	55	53	990	1,040	1,600
Electrical Conductivity (EC)	mS/m	16.4	16.7	236	243	363
Dissolved Boron	g/m³	< 0.10	< 0.10	1.55	1.92	2.4
Chloride	g/m³	16	15	200	144	220
Total Ammoniacal-N	g/m³	0.19	0.18	84	147	220

	Sample Name:	NM4 08-Sep-2023	NM5 08-Sep-2023	NM6 08-Sep-2023
	Lab Number:	3362159.6	3362159.7	3362159.8
pH	pH Units	7.2	7.3	7.4
Total Alkalinity	g/m³ as $CaCO_3$	890	960	1,120
Electrical Conductivity (EC)	mS/m	200	226	251
Dissolved Boron	g/m³	0.82	1.07	1.71
Chloride	g/m³	132	161	139
Total Ammoniacal-N	g/m³	85	105	132

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-8
pH	pH meter. APHA 4500-H^+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-8
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1-8
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1-8
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23rd ed. 2017.	-	1-8
Dissolved Boron	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.10 g/m³	1-8
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1-8
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m³	1-8

This Laboratory is accredited 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 reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 13-Sep-2023 and 19-Sep-2023. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Kim Harrison MSc
Client Services Manager - Environmental

R J Hill Laboratories Limited
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Certificate of Analysis

Client:	Earthtech Consulting Limited	**Lab No:**	3369990	SPv2
Contact:	Wilbe Blay	**Date Received:**	22-Sep-2023	
	C/- Earthtech Consulting Limited	**Date Reported:**	29-Sep-2023	**(Amended)**
	PO Box 721	**Quote No:**	126263	
	Pukekohe 2340	**Order No:**	10009	
		Client Reference:		
		Submitted By:	Wilbe Blay	

Sample Type: Aqueous

	Sample Name:	BH104 20-Sep-2023 10:55 am	BH101 A 20-Sep-2023 1:14 pm	BH101 B 20-Sep-2023 1:51 pm	BH102 20-Sep-2023 9:10 am	BH103 20-Sep-2023 4:23 pm
	Lab Number:	3369990.1	3369990.2	3369990.3	3369990.4	3369990.5
pH	pH Units	7.3	6.9	6.9	6.7	7.1
Total Alkalinity	g/m³ as $CaCO_3$	80	560	630	280	1,060
Bicarbonate	g/m³ at 25°C	98	680	770	340	1,290
Electrical Conductivity (EC)	mS/m	27.3	138.0	140.4	170.2	250
Dissolved Boron	g/m³	< 0.10	0.97	0.72	0.58	2.0
Dissolved Calcium	g/m³	9.3	65	107	101	74
Chloride	g/m³	30	113	104	330	135
Total Ammoniacal-N	g/m³	0.150	28	0.48	1.69	164

	Sample Name:	Nm1 21-Sep-2023 12:04 pm	Nm2 21-Sep-2023 12:10 pm	Nm3 21-Sep-2023 12:15 pm	Nm4 21-Sep-2023 12:31 pm	Nm5 21-Sep-2023 12:27 pm
	Lab Number:	3369990.6	3369990.7	3369990.8	3369990.9	3369990.10
pH	pH Units	7.1	7.1	7.2	7.0	7.1
Total Alkalinity	g/m³ as $CaCO_3$	1,010	1,010	1,580	910	1,040
Bicarbonate	g/m³ at 25°C	1,230	1,230	1,930	1,100	1,270
Electrical Conductivity (EC)	mS/m	243	237	362	207	244
Dissolved Boron	g/m³	1.66	1.81	2.2	0.73	0.90
Chloride	g/m³	199	139	230	134	171
Total Ammoniacal-N	g/m³	102	146	210	82	105

	Sample Name:	Nm6 21-Sep-2023 12:23 pm
	Lab Number:	3369990.11
pH	pH Units	7.1
Total Alkalinity	g/m³ as $CaCO_3$	1,100
Bicarbonate	g/m³ at 25°C	1,340
Electrical Conductivity (EC)	mS/m	253
Dissolved Boron	g/m³	1.48
Chloride	g/m³	141
Total Ammoniacal-N	g/m³	136

Analyst's Comments

Amended Report: This certificate of analysis replaces report '3369990-SPv1' issued on 28-Sep-2023 at 4:15 pm.
Reason for amendment: At the client's request, testing has been added.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-11
pH	pH meter. APHA 4500-H^+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-11
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m³ as $CaCO_3$	1-11
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 23rd ed. 2017.	1.0 g/m³ at 25°C	1-11
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1-11
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23rd ed. 2017.	-	1-11
Dissolved Boron	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.10 g/m³	1-5
Dissolved Boron	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.005 g/m³	6-11
Dissolved Calcium	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	1.0 g/m³	1-5
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1-11
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m³	1-11

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 22-Sep-2023 and 29-Sep-2023. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Client Services Manager - Environmental

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Certificate of Analysis

Client:	Earthtech Consulting Limited	**Lab No:**	3419343	SSSEP-1v1
Contact:	Wilbe Blay	**Date Received:**	01-Dec-2023	
	C/- Earthtech Consulting Limited	**Date Reported:**	15-Dec-2023	
	PO Box 721	**Quote No:**	127765	
	Pukekohe 2340	**Order No:**		
		Client Reference:	10009	
		Submitted By:	Wilbe Blay	

Sample Type: Aqueous

	Sample Name:	BH101b New 29-Nov-2023 4:01 pm
	Lab Number:	3419343.1
pH	pH Units	7.4
Total Alkalinity	g/m³ as $CaCO_3$	590
Bicarbonate	g/m³ at 25°C	720
Electrical Conductivity (EC)	mS/m	109.1
Dissolved Boron	g/m³	0.66
Dissolved Calcium	g/m³	94
Chloride	g/m³	71
Total Ammoniacal-N	g/m³	0.48

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
pH	pH meter. APHA 4500-H^+ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) : Online Edition.	1.0 g/m³ as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m³ at 25°C	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B : Online Edition.	0.1 mS/m	1
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	1
Dissolved Boron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.005 g/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	1
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) : Online Edition.	0.010 g/m³	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 04-Dec-2023 and 15-Dec-2023. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

0508 HILL LAB (44 555 22)
+64 7 858 2000
mail@hill-labs.co.nz
www.hill-labs.co.nz

Certificate of Analysis

Client:	Earthtech Consulting Limited	**Lab No:**	3419343	SSSEP-2v1
Contact:	Wilbe Blay	**Date Received:**	01-Dec-2023	
	C/- Earthtech Consulting Limited	**Date Reported:**	15-Dec-2023	
	PO Box 721	**Quote No:**	127765	
	Pukekohe 2340	**Order No:**		
		Client Reference:	10009	
		Submitted By:	Wilbe Blay	

Sample Type: Aqueous

	Sample Name:	BH102 New 29-Nov-2023 1:20 pm
	Lab Number:	3419343.2
pH	pH Units	7.1
Total Alkalinity	g/m³ as $CaCO_3$	260
Bicarbonate	g/m³ at 25°C	320
Electrical Conductivity (EC)	mS/m	112.9
Dissolved Boron	g/m³	0.38
Dissolved Calcium	g/m³	82
Chloride	g/m³	171
Total Ammoniacal-N	g/m³	1.33

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	2
pH	pH meter. APHA 4500-H^+ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	2
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) : Online Edition.	1.0 g/m³ as $CaCO_3$	2
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m³ at 25°C	2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B : Online Edition.	0.1 mS/m	2
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	2
Dissolved Boron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.005 g/m³	2
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	2
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	2
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) : Online Edition.	0.010 g/m³	2

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 04-Dec-2023 and 07-Dec-2023. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Certificate of Analysis

Client:	Earthtech Consulting Limited	**Lab No:**	3419343	SSSEP-3v1
Contact:	Wilbe Blay	**Date Received:**	01-Dec-2023	
	C/- Earthtech Consulting Limited	**Date Reported:**	15-Dec-2023	
	PO Box 721	**Quote No:**	127765	
	Pukekohe 2340	**Order No:**		
		Client Reference:	10009	
		Submitted By:	Wilbe Blay	

Sample Type: Aqueous

	Sample Name:	Rinsate 29-Nov-2023 2:10 pm
	Lab Number:	3419343.3
pH	pH Units	7.5
Total Alkalinity	g/m³ as $CaCO_3$	17.9
Bicarbonate	g/m³ at 25°C	22
Electrical Conductivity (EC)	mS/m	8.8
Dissolved Boron	g/m³	0.017
Dissolved Calcium	g/m³	4.7
Chloride	g/m³	12.6
Total Ammoniacal-N	g/m³	< 0.010

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	3
pH	pH meter. APHA 4500-H^+ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) : Online Edition.	1.0 g/m³ as $CaCO_3$	3
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m³ at 25°C	3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B : Online Edition.	0.1 mS/m	3
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	3
Dissolved Boron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.005 g/m³	3
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	3
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	3
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) : Online Edition.	0.010 g/m³	3

This Laboratory is accredited 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 reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

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Testing was completed between 04-Dec-2023 and 07-Dec-2023. For completion dates of individual analyses please contact the laboratory.

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Certificate of Analysis

Client:	Earthtech Consulting Limited	**Lab No:**	3419343	SSSEP-4v1
Contact:	Wilbe Blay	**Date Received:**	01-Dec-2023	
	C/- Earthtech Consulting Limited	**Date Reported:**	15-Dec-2023	
	PO Box 721	**Quote No:**	127765	
	Pukekohe 2340	**Order No:**		
		Client Reference:	10009	
		Submitted By:	Wilbe Blay	

Sample Type: Aqueous

		Sample Name:	Rinsate Blank 29-Nov-2023 7:30 am
		Lab Number:	3419343.4
pH	pH Units		7.5
Total Alkalinity	g/m³ as $CaCO_3$		17.4
Bicarbonate	g/m³ at 25°C		21
Electrical Conductivity (EC)	mS/m		8.7
Dissolved Boron	g/m³		0.017
Dissolved Calcium	g/m³		4.8
Chloride	g/m³		12.5
Total Ammoniacal-N	g/m³		< 0.010

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	4
pH	pH meter. APHA 4500-H^+ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	4
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) : Online Edition.	1.0 g/m³ as $CaCO_3$	4
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D : Online Edition.	1.0 g/m³ at 25°C	4
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B : Online Edition.	0.1 mS/m	4
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	4
Dissolved Boron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.005 g/m³	4
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m³	4
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	4
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) : Online Edition.	0.010 g/m³	4

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 04-Dec-2023 and 07-Dec-2023. For completion dates of individual analyses please contact the laboratory.

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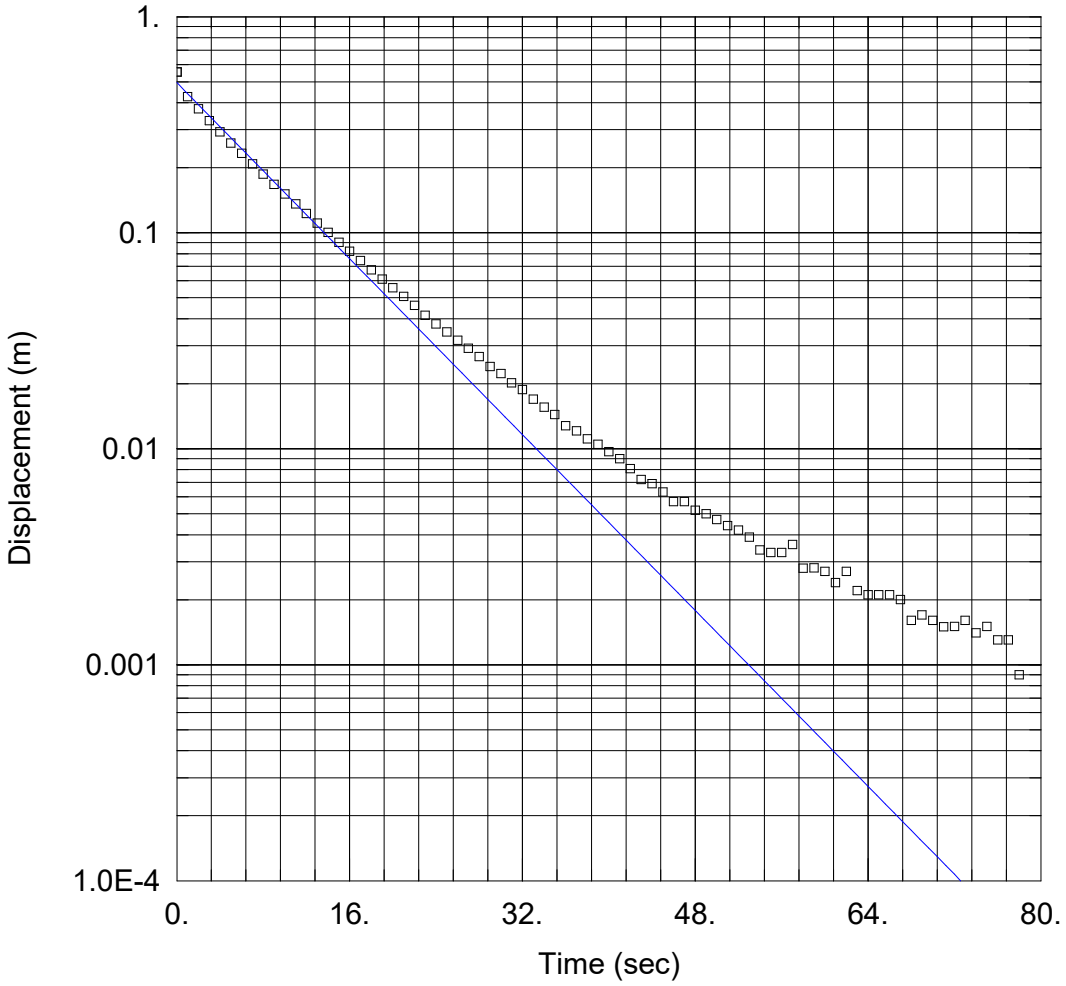
Client Services Manager - Environmental

Conceptual Groundwater Model Report

Levin Landfill, Hōkio Beach Road, Levin

Appendix C

Permeability Test Analyses



WELL TEST ANALYSIS

Data Set: C:\...\BH101A.aqt
Date: 12/01/23 Time: 12:54:00

PROJECT INFORMATION

Company: Earthtech
Client: Horowhenua District Council
Project: 10009
Location: Levin
Test Well: BH101A
Test Date: 20/09/2023

AQUIFER DATA

Saturated Thickness: 14.4 m Anisotropy Ratio (Kz/Kr): 1.

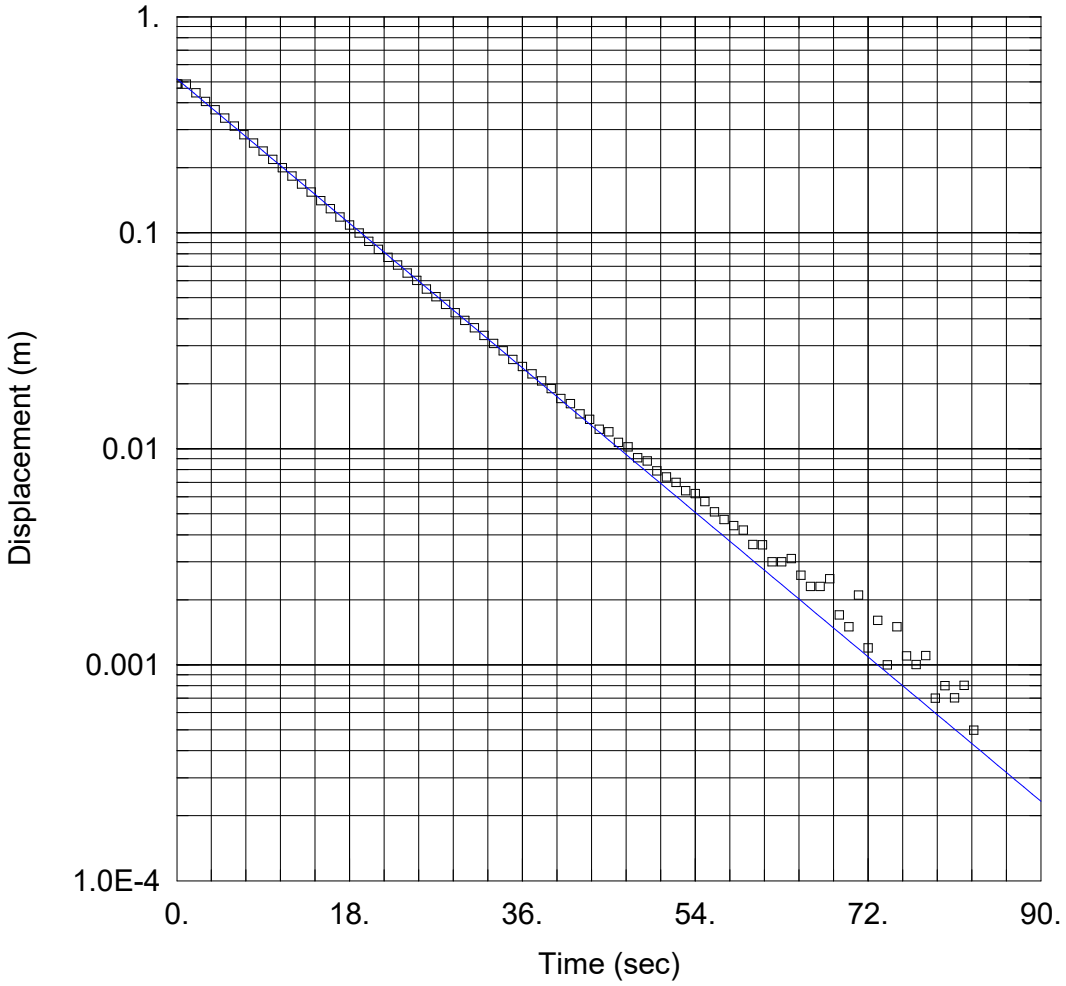
WELL DATA (BH101A)

Initial Displacement: 0.5551 m
Total Well Penetration Depth: 3.4 m
Casing Radius: 0.025 m
Static Water Column Height: 3.4 m
Screen Length: 2.3 m
Well Radius: 0.0725 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.208 m/day
y0 = 0.4951 m



WELL TEST ANALYSIS

Data Set: C:\...\BH101B new.aqt
Date: 12/01/23 Time: 12:54:56

PROJECT INFORMATION

Company: Earthtech
Client: Horowhenua District Council
Project: 10009
Location: Levin
Test Well: BH101A
Test Date: 20/09/2023

AQUIFER DATA

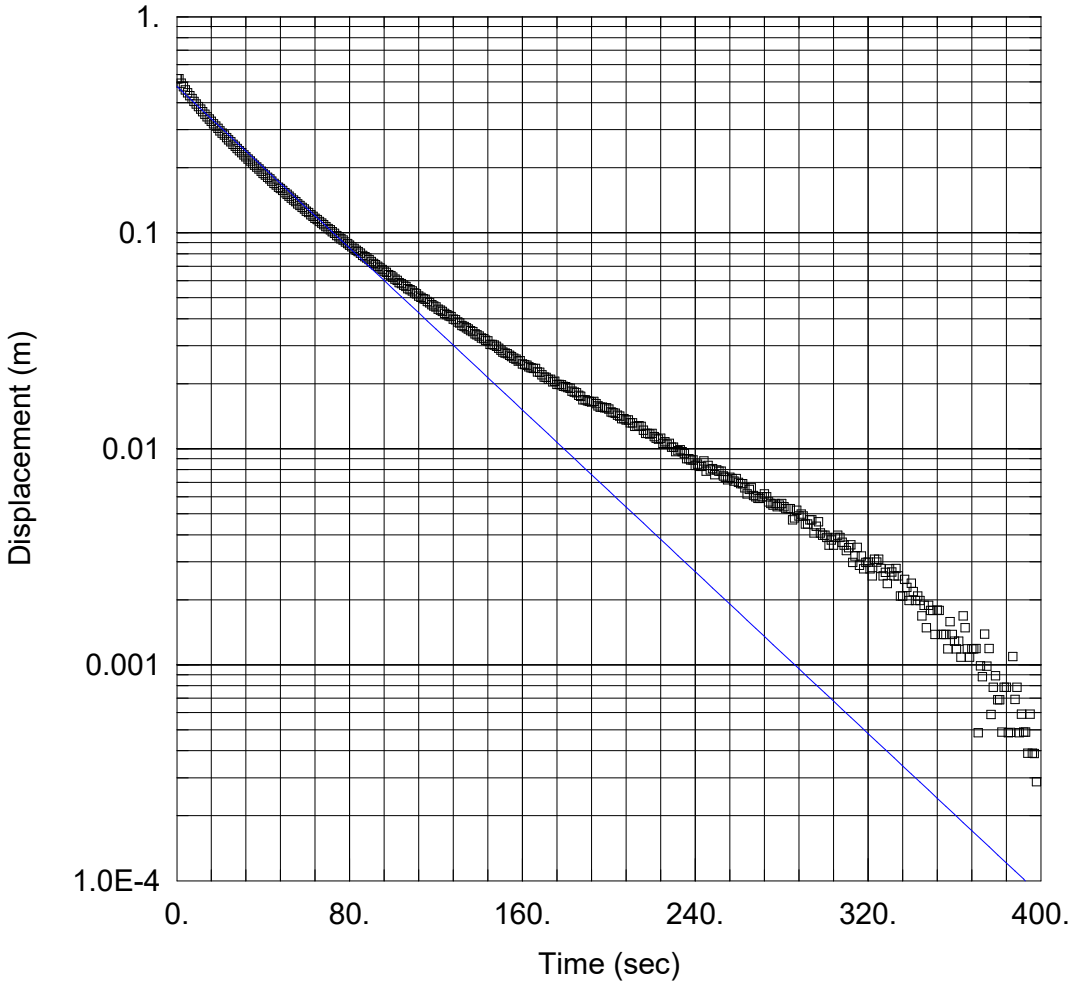
Saturated Thickness: 14.4 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH101B new)

Initial Displacement: 0.49 m Static Water Column Height: 9.8 m
Total Well Penetration Depth: 9.9 m Screen Length: 3.9 m
Casing Radius: 0.025 m Well Radius: 0.0725 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 1.838 m/day y0 = 0.5161 m



WELL TEST ANALYSIS

Data Set: C:\...\BH102 new.aqt
Date: 12/01/23 Time: 12:55:50

PROJECT INFORMATION

Company: Earthtech
Client: Horowhenua District Council
Project: 10009
Location: Levin
Test Well: BH101A
Test Date: 20/09/2023

AQUIFER DATA

Saturated Thickness: 15.2 m Anisotropy Ratio (Kz/Kr): 1.

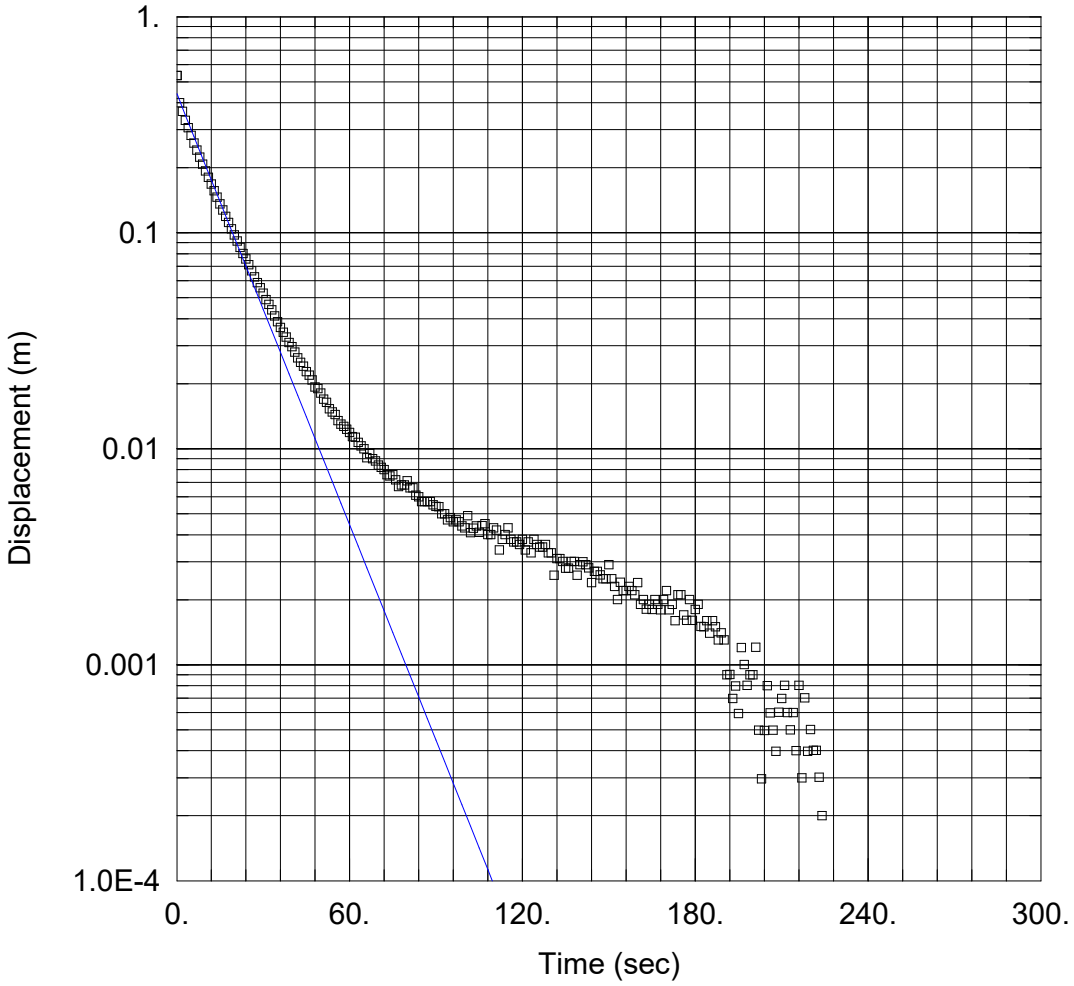
WELL DATA (BH102 new)

Initial Displacement: 0.5169 m
Total Well Penetration Depth: 3.2 m
Casing Radius: 0.025 m
Static Water Column Height: 3.7 m
Screen Length: 1.4 m
Well Radius: 0.0725 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.8508 m/day y0 = 0.4765 m



WELL TEST ANALYSIS

Data Set: C:\...\BH103.aqt
Date: 12/01/23 Time: 12:56:45

PROJECT INFORMATION

Company: Earthtech
Client: Horowhenua District Council
Project: 10009
Location: Levin
Test Well: BH101A
Test Date: 20/09/2023

AQUIFER DATA

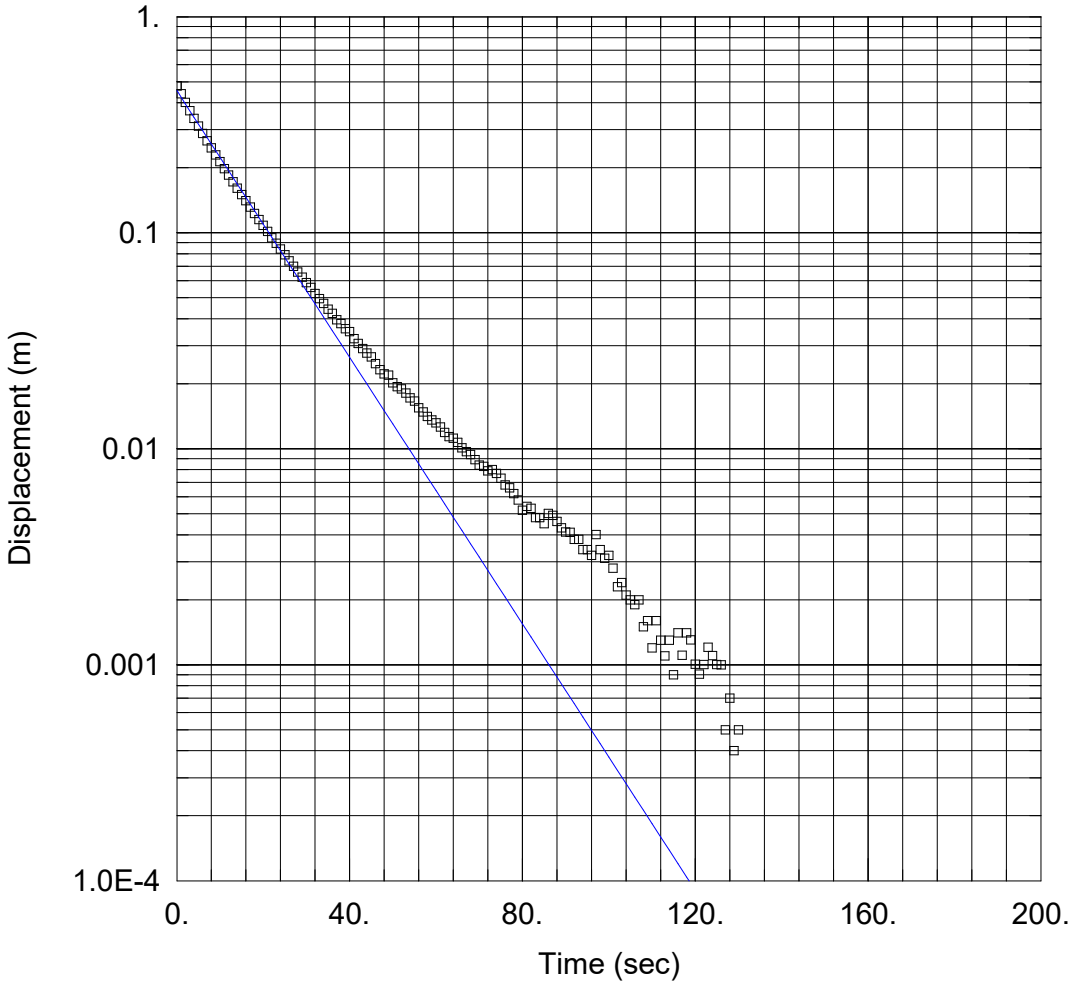
Saturated Thickness: 16.6 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH103)

Initial Displacement: 0.534 m
Total Well Penetration Depth: 2.34 m
Casing Radius: 0.03764 m
Static Water Column Height: 2.3 m
Screen Length: 2.3 m
Well Radius: 0.0725 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 4.401 m/day
y0 = 0.4407 m



WELL TEST ANALYSIS

Data Set: C:\...\BH104.aqt
Date: 12/01/23 Time: 12:59:00

PROJECT INFORMATION

Company: Earthtech
Client: Horowhenua District Council
Project: 10009
Location: Levin
Test Well: BH101A
Test Date: 20/09/2023

AQUIFER DATA

Saturated Thickness: 14.2 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH104)

Initial Displacement: 0.4791 m Static Water Column Height: 4.4 m
Total Well Penetration Depth: 4.3 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.0725 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

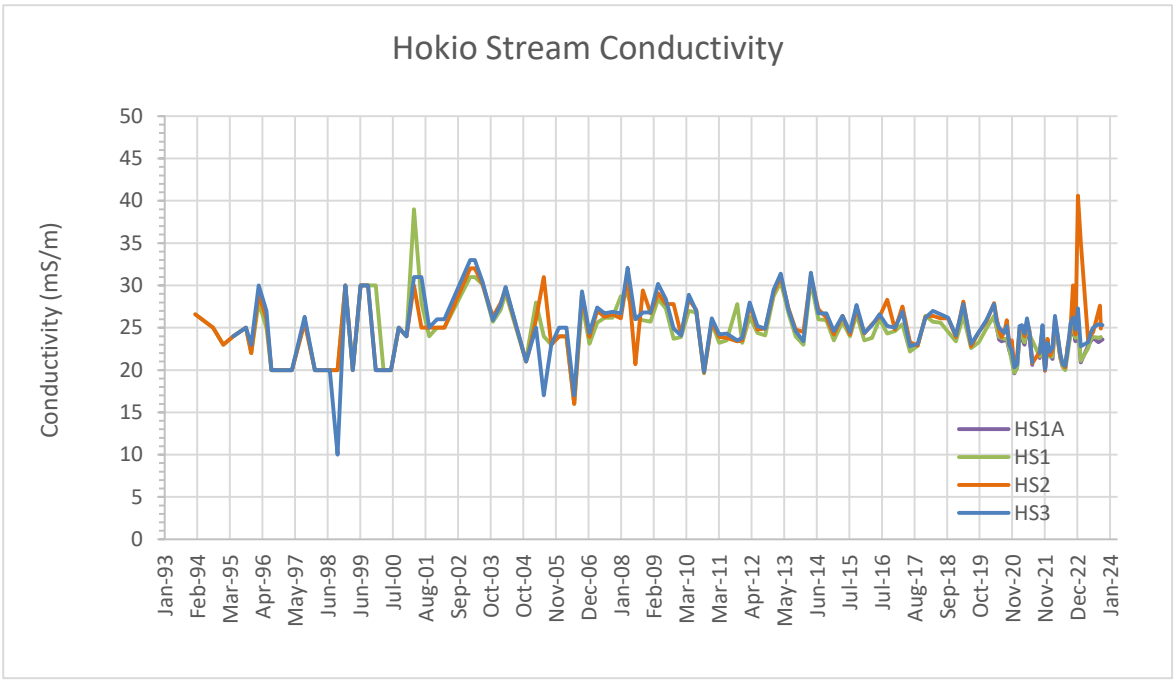
K = 1.634 m/day y0 = 0.4549 m

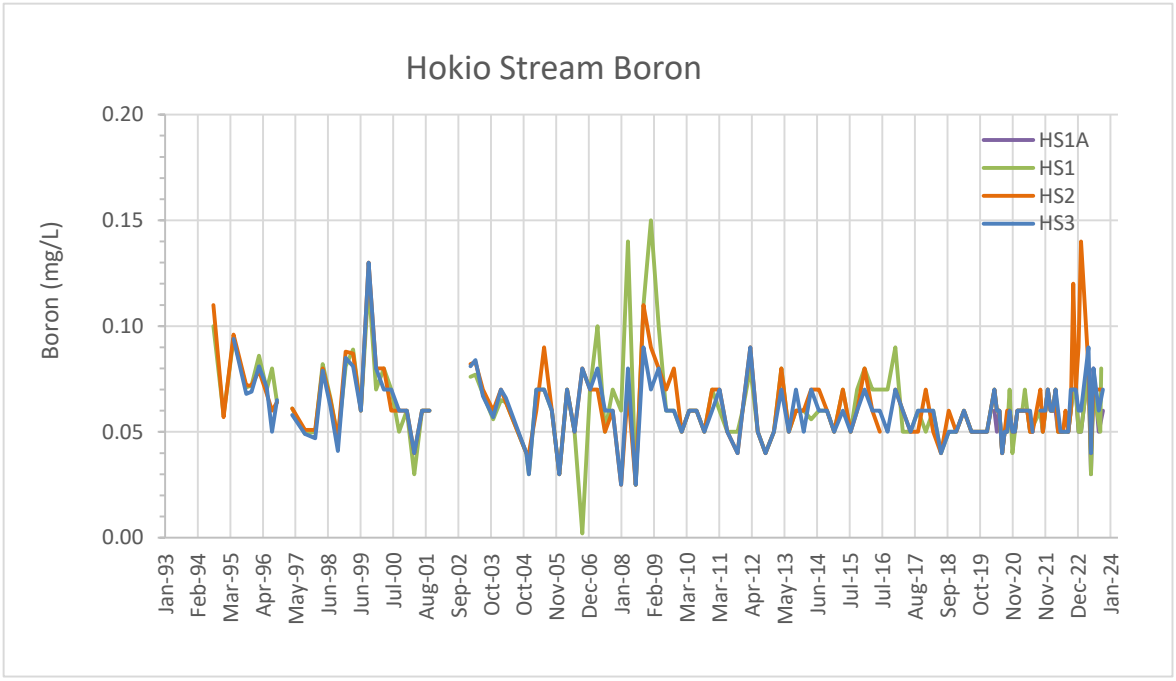
Conceptual Groundwater Model Report

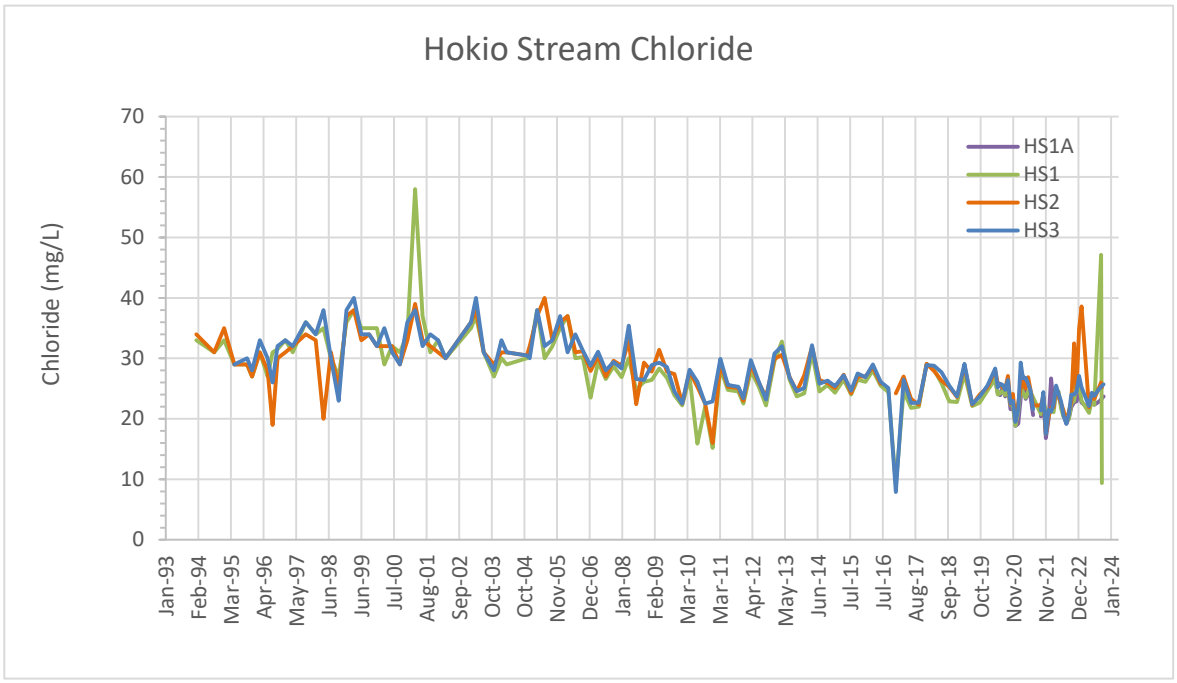
Levin Landfill, Hōkio Beach Road, Levin

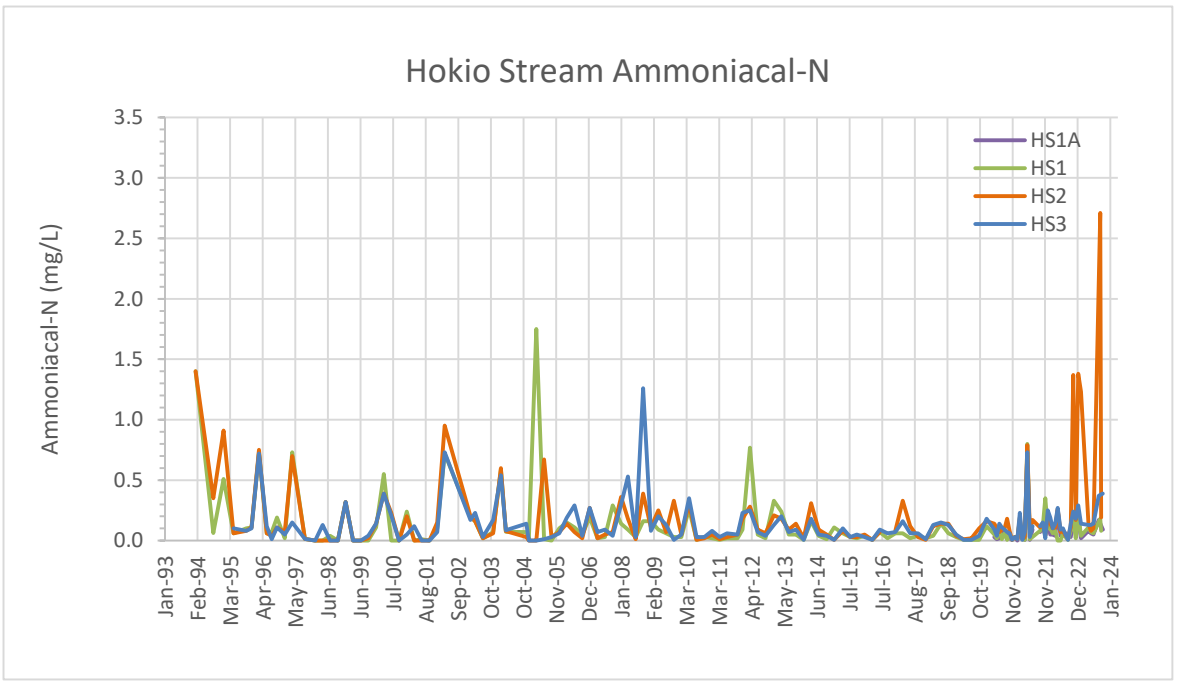
Appendix D

Surface Water Ammoniacal-Nitrogen Plots


Hokio Stream Conductivity
Conductivity (mS/m)
50
45
40
35
30
25
20
15
10
5
0
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24
HS1A
HS1
HS2
HS3


Hokio Stream Boron
Boron (mg/L)
0.20
0.15
0.10
0.05
0.00
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24
HS1A
HS1
HS2
HS3


Hokio Stream Chloride
Chloride (mg/L)
70
60
50
40
30
20
10
0
HS1A
HS1
HS2
HS3
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

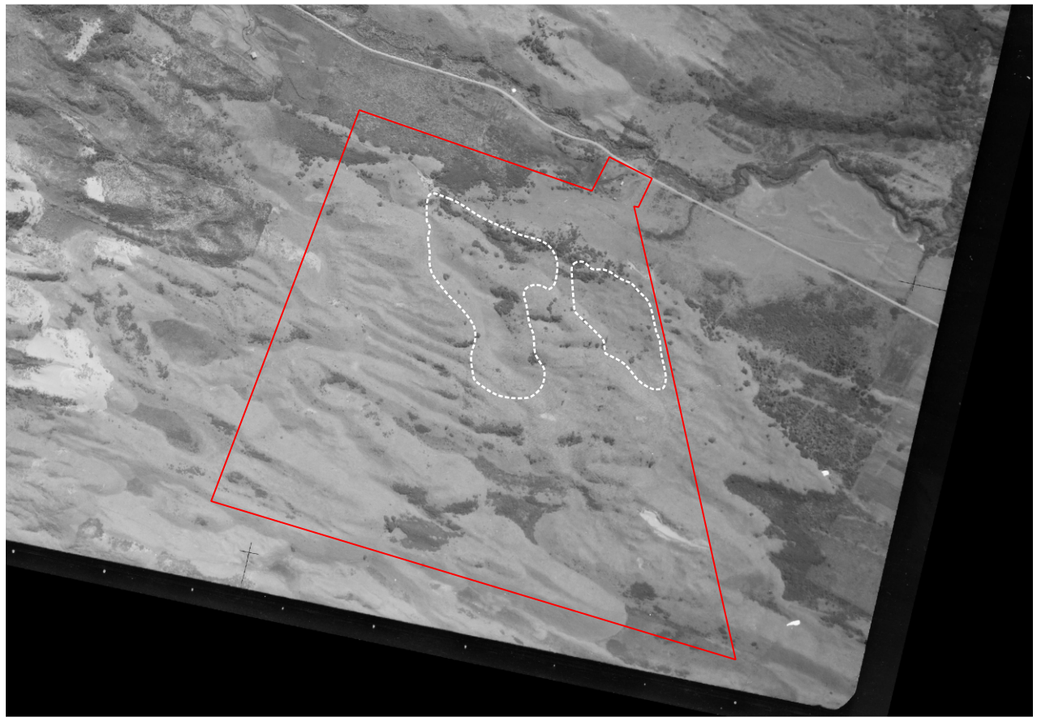

Hokio Stream Ammoniacal-N
Ammoniacal-N (mg/L)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
HS1A
HS1
HS2
HS3
Jan-93
Feb-94
Mar-95
Apr-96
May-97
Jun-98
Jun-99
Jul-00
Aug-01
Sep-02
Oct-03
Oct-04
Nov-05
Dec-06
Jan-08
Feb-09
Mar-10
Mar-11
Apr-12
May-13
Jun-14
Jul-15
Jul-16
Aug-17
Sep-18
Oct-19
Nov-20
Nov-21
Dec-22
Jan-24

Conceptual Groundwater Model Report

Levin Landfill, Hōkio Beach Road, Levin

Appendix E

Historic Aerial Photographs 1939 - 2016



1939

1957

1971

1983

FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH

Earthtech Consulting Ltd.

P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

LEVIN LANDFILL, HOKIO BEACH ROAD

Horowhenua District Council

Historic Images 1939 to 1983

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	07-09-23	DRAFT FOR COMMENT	P.K	P.K	S.SW	
B	31-10-23	UPDATE OLD LANDFILL AREAS	P.K	P.K	S.SW	

DRAWING NO.: FIG. A

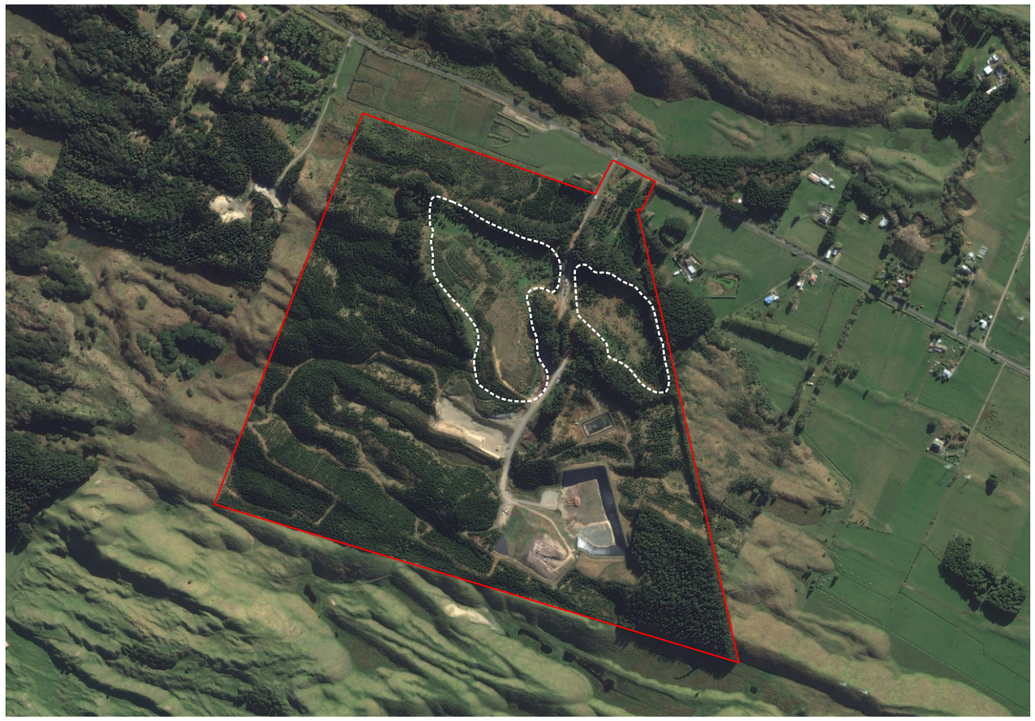
REF: 10009

SCALE: nts

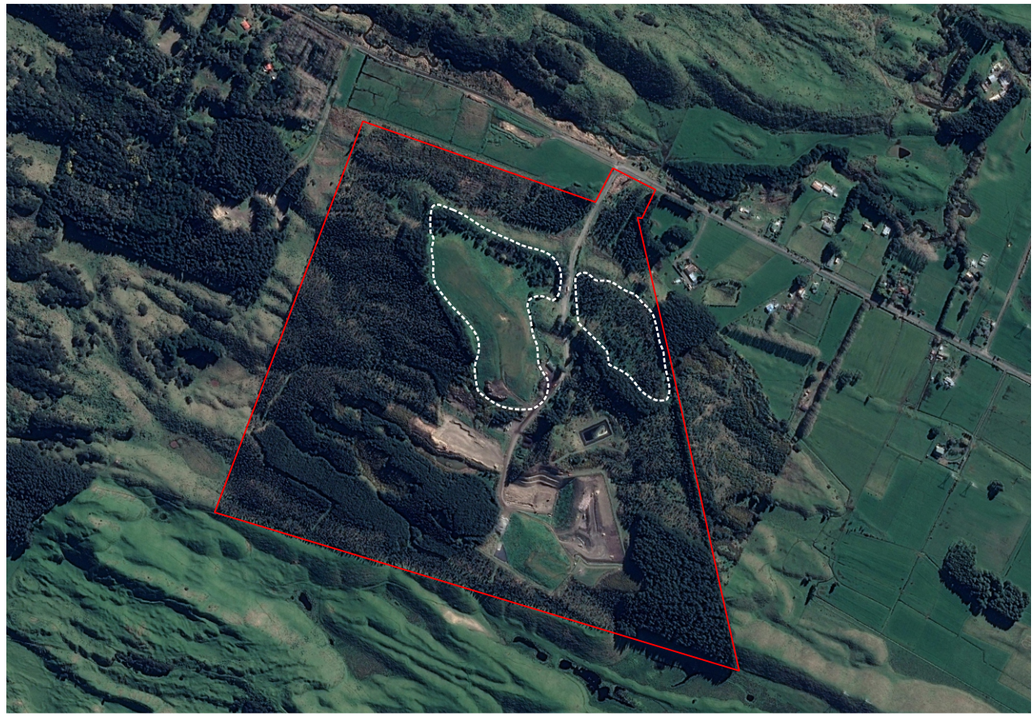
CRS: NZTM

DATUM:

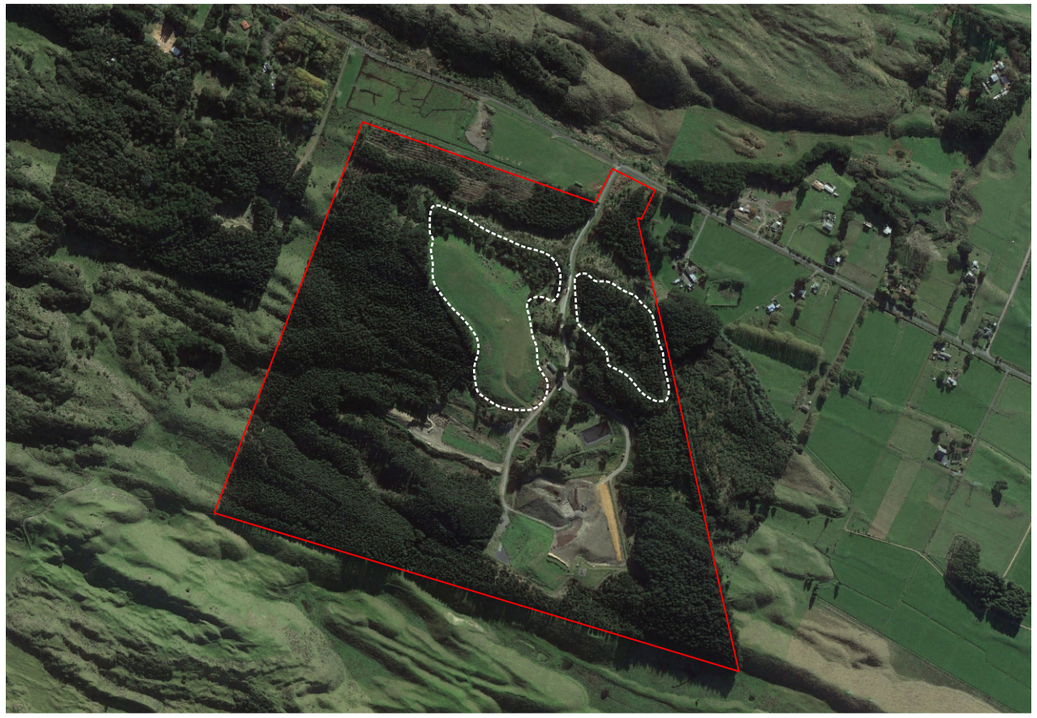
2005



2010



2013



2016

FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH

Earthtech Consulting Ltd.

P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

LEVIN LANDFILL, HOKIO BEACH ROAD

Horowhenua District Council

Historic Images 2005 to 2016

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	07-09-23	DRAFT FOR COMMENT	P.K	P.K	S.SW	
B	31-10-23	UPDATE OLD LANDFILL AREAS	P.K	P.K	S.SW	

DRAWING NO.: FIG. B

REF: 10009

SCALE: nts

CRS: NZTM

DATUM: