Tonkin+Taylor

Job No: 1011583
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Horowhenua District Council
C/- Catalyst group
Level 3, 31 George Street
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Attention: Greg Carlyon

Dear Greg

Levin Landfill - Summary of leachate options assessment

1 Introduction

Horowhenua District Council (HDC) has engaged Tonkin & Taylor Ltd (T+T) to undertake a leachate Best Practicable Options (BPO) assessment for the Levin Landfill (the site). This brief letter report summarises the outcome of this assessment.

Specifically, our scope involves review of options that might reduce the impacts from discharge of leachate from the Original Landfill to Tatana Drain and Hokio Stream. This BPO assessment considered options that may (i) reduce the generation of leachate at the Original Landfill, (ii) capture leachate which has been generated, and (iii) reduce the effects of leachate discharge.

This report presents our understanding of the site, describes the development of a conceptual site model to inform the BPO assessment, provides a description of the considered options, and summarises outcomes from this review.

This letter report is complemented by separate reports that provides comment on the technical and commercial implications associated with closure of the Current Landfill.

This review has been completed in accordance with our Letter of Engagement dated 25 July 2019 and consistent with the Agreement in Relation to the Levin Landfill (Landfill Agreement) dated 13 March 2019[1].

2 Background

2.1 General

Levin Landfill is an existing municipal solid waste landfill located to the south of Hokio Beach Road, approximately 4 km west of Levin. The site is located amongst pastoral land approximately 3 km east

[1] Environment Court, 2019, "Agreement in Relation to the Levin Landfill" Horowhenua District Council, Hokio Environmental Kaitaiki Alliance Incorporated, Horowhenua District Ratepayers and Residents Association Incorporated, s274 Parties" 13 March.

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of the coastline. The landfill is owned by HDC and operated by EnviroWaste Services Ltd. (EnviroWaste), under subcontract to Midwest Disposals Ltd.

The site layout is shown in Figure 1. Levin Landfill consists of two landfills, the old, unlined "Original Landfill" and the new, lined "Current Landfill". The Original Landfill was established in the 1950s and consists of two areas. Area 1 was the primary disposal area for municipal solid waste until 2004. This disposal area was formed by filling in adjacent inter-dune depressions. We understand[2] that Area 2 is located to the east of Area 1 and was used for disposal of materials that could not easily be disposed in Area 1, including liquid waste, offal, and tree trunks. Waste filling in the Original Landfill continued until 2004. The Original Landfill was closed and capped following construction of Stage 1A at the Current Landfill.

The original topography prior to landfill development is shown in the aerial photo provided as Figure 2.

The Current Landfill is lined and not is thought to be a significant source of leachate discharge, as discussed in Section 2.4.3. The remainder of this leachate BPO assessment is focused on the Original Landfill, which we consider to be the primary source of leachate discharge at the site.

2.2 Original Landfill capping

We understand[2] that Areas 1 and 2 of the Original Landfill were closed by capping the waste with sand and planting with grasses, as was required by the consent conditions in place at the time. Larger vegetation, including trees, were established within Area 2 and portions of Area 1, although the pine trees planted in Area 1 were required to be removed as part of the 2009-2010 consent condition review. Trees still appear to be present along the northern perimeter of Area 1, although there is uncertainty regarding the limits of waste in this area.

The quality of the Area 1 cap was identified as an area of concern in the 2009-2010 consent review, as test pit investigations had indicated that the landfill had not been capped to the required 700mm thickness. The revised consent conditions required additional capping at the top deck of Area 1, including placement of additional material to achieve the minimum 700mm cap thickness. The additional capping material was required to have a permeability of no greater than 1×10^{-7}m/s. The additional capping was completed in 2010 and 2011[3].

2.3 Site geology and hydrogeology

The published literature[4] suggests the site is located within an area of Holocene stable sand dune deposits. The dunes range in height from 20 to 30m and comprise fine to medium sand. Peat lenses have also been observed in the sand deposits. Beneath the sand, the site is underlain at depth by the Ohakea Gravels which comprise poorly to moderately sorted gravel with minor sand and silt. A ~2 m thick layer of silt and clay separate the upper sand layer and lower Ohakea Gravels.

Key surface water feature in the region include the Tatana Drain located approximately 150m to the north of the Original Landfill, and the Hokio Stream located approximately 270m to the north of Hokio Beach Road. The Tatana Drain discharges to the Hokio Stream, which flows west towards the coast.

[2] Landmark, P.S., 2016, "Statement of Evidence of Phillip Sverre Landmark (Design/Operations) on Behalf of the Consent Holder", Consent Holder: Horowhenua District Council, 2 September.
[3] For design of additional capping, refer: MWH, 2010, "Design Details for Old Landfill Capping", 9 September.
[4] Begg, J.G., Johnston, M.R. (compliers) 2000, "Geology of the Wellington area." Institute of Geological and Nuclear Sciences 1:250,000 geological map 10. 1 sheet + 64p. Lower Hutt, New Zealand.

Two aquifers are inferred to be present beneath the site; a shallow aquifer within the sand layer, and a deep gravel aquifer within the Ohakea Gravels[5].

Groundwater within the shallow sand aquifer flows towards the north - northwest. The shallow groundwater levels is variable and influenced by surface water courses and topography. Shallow groundwater levels are inferred to intersect the valley lines formed by adjacent sand dunes, although waste filling and development may locally influence the groundwater levels. To the north of the site, Tatana Drain partially intercepts the shallow groundwater. Some shallow groundwater is also believed by bypass the Tatana Drain and continue directly to Hokio Stream. The hydraulic conductivity of the shallow aquifer is estimated to be in the range of 2×10^{-5} and 6×10^{-5}m/s, which is typical of fine sands[5].

Groundwater within the deep gravel aquifer is thought to flow towards the west (i.e., towards the coast). This deep aquifer is thought to be confined to semi-confined. Based on recent groundwater levels measurements, the deep aquifer is believed to be subject to artesian conditions[6]. An upward gradient exists between the deep and shallow aquifers.

2.4 Water quality

The following reports were referenced as sources of water quality information regarding the Levin Landfill:

- Stantec, 2018 “Levin Landfill Annual Compliance Report July 2017 – June 2018,” September;
- Stantec, 2017, “Levin Landfill Annual Compliance Report July 2016 – June 2017,” September;
- Douglass, S.J., 2016, “Statement of Evidence of Stephen John Douglass on Behalf of Horowhenua District Council”, 2 September; and
- Douglass, S.J., 2018, “Statement of Evidence of Stephen John Douglass on Behalf of Horowhenua District Council”, 16 November.

Water quality results are discussed below.

2.4.1 Groundwater quality

The groundwater bore monitoring locations are shown on Figure 3. Groundwater water quality data included in the annual compliance reports indicate that:

- Leachate water chemistry is distinct from groundwater;
- Leachate may be characterised by elevated ammoniacal-N, Boron and Chloride. Potential leachate impacts can be identified by comparing the concentration of these contaminants between upgradient and downgradient wells[1];
- Potential leachate impacts have been identified in shallow groundwater wells immediately north of the site between the site and Tatana drain. Lines of evidence for leachate impacts exist at shallow groundwater bores B1, B2, B3, C1, C2[7]. These bores are all located hydraulically down-gradient of the Original Landfill; and
- Discernible leachate impacts have not been identified in any of the deep aquifer bores[6]. We note that leachate impacts in the deep groundwater aquifer is not likely given the observed upward gradient between the deep and shallow aquifers.

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[5] Douglass, S.J., 2016 “Statement of Evidence of Stephen John Douglass on Behalf of Horowhenua District Council”, 2 September.

[6] Douglass, S.J., 2018, “Statement of Evidence of Stephen John Douglass on Behalf of Horowhenua District Council”, 16 November

[7] Stantec, 2018 “Levin Landfill Annual Compliance Report July 2017 – June 2018,” September.

2.4.2 Surface water

Surface water monitoring locations are shown on Figure 3. Surface water quality data included in the annual compliance reports indicate that:

- Concentrations of ammonia and chloride are elevated in the upstream monitoring locations of the Tatana Drain. Concentrations of ammoniacal-N, Boron, and Chloride in Tatana Drain surface water samples are similar but slightly less than concentrations measured in shallow downgradient bores, suggesting discharge of leachate-impacted groundwater to the Tatana Drain;
- Water quality within Tatana Drain improves at downstream monitoring locations (further from the Original landfill site);
- Tatana Drain flows in a culvert beneath Hokio Beach Road, then discharges to Hokio Stream. Surface water samples collected upstream and downstream the Tatana Drain and Hokio Stream confluence suggest that discharge of Tatana Drain has a minor to negligible impact on water quality in Hokio Stream; and
- Some shallow groundwater is inferred to bypass Tatana Stream and discharge directly to Hokio Stream, however, surface water quality samples within Hokio Stream do not appear to show discernible leachate impacts.

2.4.3 Leachate discharge potential from the Current Landfill

We understand that the Current Landfill was designed and constructed with the following base liner system (from top to bottom)[8]:

- Gravel leachate collection layer;
- Liner protection layer consisting of a 100mm thick sand layer on the landfill base and a protection geotextile on the side slopes;
- 2mm thick HDPE geomembrane, to serve as a primary leachate barrier;
- 6mm thick geosynthetic clay liner (GCL), to serve as a secondary leachate barrier; and
- Prepared subgrade consisting of compacted sand.

Leachate generated at the Current Landfill is collected via the blanket gravel drainage layer and pumped via a rising main to a leachate pond, where it is temporarily stored before being pumped to the Levin Wastewater Treatment Plant. We consider that the base liner and leachate management system adopted in the Current Landfill substantially reduces the risk of leachate discharge to groundwater relative to the unlined Original Landfill.

Groundwater samples downgradient of the Current Landfill and near the leachate pond do not show discernible leachate impacts[6,7]. Based on the design of the Current Landfill and water quality results, we consider that the Current Landfill and leachate pond are not likely to be a significant source of leachate discharge to the environment.

2.4.4 Water quality summary

Groundwater quality is reported to be relatively consistent over time (Stephan Douglass, 2018). Shallow groundwater wells located closest downgradient to the unlined Original Landfill have the highest concentration of analytes associated with leachate. Concentrations of these analytes are an order of magnitude lower in shallow groundwater monitoring wells located hydraulically upgradient. These monitoring data suggest that leachate from the Original Landfill is discharging to shallow

[8] Landmark, P.S., 2016, "Statement of Evidence of Phillip Sverre Landmark (Design/Operations) on Behalf of the Consent Holder", Consent Holder: Horowhenua District Council, 2 September.

groundwater and flowing in a northerly direction, until the groundwater is partially intercepted by Tatana Drain. Surface water quality in the Tatana Drain appears to be impacted with analytes associated with leachate, although we note that there are also other potential sources of contaminants in the Tatana Drain catchment such as grazing in the adjacent pastoral land.

There does not appear to be evidence of significant leachate impact beyond Tatana Drain, including in the Hokio Stream. The improvement in water quality with distance downgradient of the landfill is thought to be due in part to natural processes such as natural attenuation and dilution.

3 Conceptual site model development

We have developed a conceptual site model (CSM) to help inform the leachate BPO assessment. Broadly, the CSM seeks to identify and understand:

- Source – sources of leachate that may potentially impact the site (i.e. the closed, unlined landfill).
- Pathways – migration pathways via which leachate might reach other water bodies.
- Receptor – the shallow and deep water aquifers, the Tatana Drain and Hokio Stream.

The following sections summarise the conceptual understanding of the site. The CSM is presented graphically on Figure 4.

A conceptual side model (CSM) has been developed for the site taking into account the information contained in Sections 2 to 4. A summary of the potential source/pathway/receptor relationships is provided in Table 3.1.

Table 3.1: Summary of CSM

Leachate generation/source	<u>Original landfill</u> · Surface water infiltration from standing water in surface water perimeter drains · Infiltration through cap in Area 1 · Localised ponding at top of cap leading to additional infiltration · Shallow groundwater inflow to base of waste · Upward flow from deep aquifer to shallow aquifer, leading to additional mounding of groundwater levels in waste mass · Infiltration through cap in Area 2
Pathway for migration	Landfill design: The Original Landfill is unlined. Capping quality of top deck varies. Side slopes are capped with sand. Hydrogeology and hydrology: · Elevated leachate levels in waste leading to surface water seeps in downgradient sand dunes · Shallow groundwater discharges to Tatana Drain · Shallow groundwater bypasses Tatana Drain and discharges in Hokio Stream · Leachate discharge to deep groundwater –pathway not likely given upward gradient from deep to shallow groundwater
Receptors	Hydrology: Tatana Drain and Hokio Stream located to the north of the site. Hydrogeology: Shallow aquifer.

3.1 Water balance modelling

Water balance modelling was undertaken to develop the CSM and evaluate the relative benefit of remedial options. Modelling of infiltration through the cap has been undertaken using the Hydrogeological Evaluation of Landfill Performance (HELP) model[9]. The model uses a 50 year synthetic weather file generated from published climate data for Levin[10]. Site specific weather data includes temperature, precipitation, wind speed, humidity and evaporation. The generalised 1D soil profile assumed in the modelling is described in Table 4.2.

Table 3.2: 1D soil profile used for HELP modelling

Layer	Thickness (mm)	Permeability (m/s)	Description/key assumption
Landfill cap	480	1.5ha: k_v = 1.2e-7m/s 1ha: k_v = 1.2e-6m/s 2.3ha (sand slopes): k_v = 1.2e-5m/s	Quality of clay capping is variable with a portion of Area 1 that recorded a permeability of greater than $1x10^{-7}$m/s [11]. Extents of old landfill derived from site knowledge, historical maps and topographical maps [4].
Refuse	1500	k_v = 1.0e-5m/s	
Sand aquifer	10,000	k_h = 1.0e-5m/s	
Gravel aquifer	2500	Modelled as impermeable barrier (upward flow)	

3.2 Model results – leachate generation

The HELP water balance modelling suggests that of precipitation falling on the cap, on average approximately 40% will evapotranspire, approximately 30% will run off the cap surface, and 30% will infiltrate through cap into the refuse, becoming leachate. The amount of infiltration will depend on the quality of the capping material. On the side slopes which have been capped with sand, approximately 35% of precipitation is anticipated to infiltrate through the cap. On the top of the landfill where additional clayey cover soil was placed, approximately 15% of precipitation is expected to infiltrate. Infiltration will be greater than predicted if there is ponding on the cap.

An additional leachate source may be inflow of shallow groundwater into the waste mass. The extent of this contribution is unknown; however, we note that free-field shallow groundwater levels in this area would be anticipated to intersect the base of the sand dune deposits (i.e., the base of the waste mass). In a free-field scenario, shallow groundwater wouldn't be significantly elevated above the base of the waste mass and shallow groundwater inflow therefore would not be a significant source of leachate generation. However, shallow groundwater near the landfill may be locally influenced by the topographic effects. Surface water infiltrating to land upgradient of the landfill is no longer able to discharge to the valley between sand dunes, as the inter-dune depressions have been filled with waste. This change in topography due to landfill development may cause a local mounding of groundwater and leachate levels in the waste mass. Poor drainage upgradient of the landfill would exacerbate this condition, as poor drainage leads to an increase in infiltration and consequent increase in the shallow groundwater levels and leachate generation. However, we are

[9] United States Environmental Protection Agency (US EPA), 1997, "Hydrologic Evaluation of Landfill Performance" model version 3.07 (1 November 1997)
[10] The Climate and Weather of the Manuatu-Wanganui, P.R. Chappell, 2015, NIWA.
[11] Levin Landfill Permeability Testing Results, 2012, email communication with Phil Landmark, Stantec, dated 27 August 2019.

not aware of leachate measurements within the waste mass which could help inform this assumption.

Leachate may also be generated from the upward flow of groundwater from the deep aquifer to the shallow aquifer, leading to a further increase in the shallow groundwater levels at the base of the landfill. The likelihood and magnitude of this effect is unknown, as it depends on the thickness and permeability characteristics of the fine-grained soil layer between the sand and gravel aquifers.

3.3 Leachate pathways

Water which has infiltrated through the cap and groundwater which comes in contact with the waste becomes leachate. In the CSM, we have considered the following pathways for leachate:

- Lateral flow of leachate through the sand dunes, emerging as seeps at the base of the sand dunes to the north of the landfill. These seeps would then potentially flow as surface water to the Tatana Drain;
- Discharge to shallow groundwater. Leachate would intermix with the shallow groundwater and flow towards the north-northwest. Leachate-impacted groundwater is then likely to be subject to one of the following:
  - Interception by the Tatana Drain, then surface water flow along the Tatana Drain until discharging at the Hokio Stream; or
  - Bypassing the Tatana Drain and continued groundwater flow towards the north-northwest, followed by groundwater discharge directly to the Hokio Stream.

4 Description of possible remedial options

4.1 Assessment methodology

A best practicable options assessment was undertaken to identify and assess options which will materially reduce the volume and/or effects of the leachate from the Original Landfill. Options considered and assessed are summarised in Table 4.1. A description of each option is provided in the sections below. These options are further described in Appendix A.

Table 4.1: Options considered

Remedial option category	Option considered
Reduce leachate generation	· Additional capping · Cover system surface water drainage improvements · Perimeter drain improvements
Collect leachate	· Leachate interceptor trench with pump and treat capability · Installation of wells in shallow aquifer and pump and treat shallow groundwater · Installation of a leachate collection system
Manage impacts	· Tatana drain improvements (wetland establishment, riparian planting) · Address/repair seeps

4.2 Options to reduce leachate generation

4.2.1 Additional capping

Additional capping was considered in the options assessment. This option would reduce infiltration and therefore reduce leachate generation. Increasing the quality of capping of Area 1 and 2 would reduce leachate flow through to groundwater. However, cap improvements would not have an immediate impact on groundwater quality down gradient due to the time needed for the existing plume to migrate.

Capping options include:

- Option 1 - Improvements to cap top deck in Area 1, in areas where permeability was measured to be less than 1 x 10^{-7}m/s;
- Option 2 - Installation of clay cap on side slopes currently capped with sand in Area 1;
- Option 3 - Installation of clay cap in areas currently capped with sand in Area 2;
- Option 4 - In areas of observed ponding in Area 1, conduct localised repairs by improving cover material and re-profiling

Installation of additional capping material may limit discharge pathways for landfill gas. Capping design would therefore need to consider whether landfill gas control options are warranted, in order to prevent build-up of landfill gas within the waste mass.

4.2.2 Option 5 - Cover system surface water drainage improvements

Drainage improvements on the cap will increase the fraction of precipitation that will runoff rather than infiltrate through the cap. A reduction in infiltration will lead to a decrease in leachate generation and flow to groundwater. These improvements would not have an immediate impact on groundwater down gradient due to the time needed for the existing plume to migrate.

Cap drain improvements considered at the site might include:

- Construction of contour drains above the existing landfill cap. These contour drains would consist of soil bunds which will help to promote radial flow of surface water towards the perimeter of the landfill;
- Lining the invert of the drain channels with compacted clay fill (or similar); and
- Installation of biodegradable jute or coir matting to provide erosion protection until vegetation is established.

For reference, the *Closed Landfill Guidelines*[12] recommends installing stormwater cut-off or contour drains at 6m vertical increments for erosion protection. We have assumed a similar contour drain spacing on the side slopes as a means to promote runoff and reduce infiltration.

4.2.3 Option 6 - Perimeter drain improvements

We have considered a remedial option to improve drainage along the southern perimeter of the Original Landfill. The purpose of these improvements would be to increase the interception of surface water uphill of the landfill, and divert this flow around the landfill. These improvements are anticipated to reduce infiltration upgradient of the landfill, as groundwater generated in this area is expected to flow into the waste and create additional leachate.

[12] Ministry for the Environment, 2001, “A Guide for the Management of Closing and Closed Landfills in New Zealand”, May.

For this remedial option, we have considered the following:

- Minor re-profiling of the existing ground at the southern perimeter of the landfill;
- Construction of a new perimeter drain channel with polypropylene fibre reinforced spray concrete (or similar); and
- The perimeter drain would be approximately 500m long and discharge to the north of the landfill.

4.3 Options to capture leachate

4.3.1 Option 7 - Groundwater interceptor trench

We have considered an option in which a groundwater interceptor trench is installed between the landfill and the Tatana Drain. The purpose of this trench would be to capture leachate-impacted groundwater before it enters the Tatana Drain. We anticipate that it would not be feasible to capture the full lateral and vertical extent of the leachate impacts. Rather, the design intent of this trench is to target extraction at areas of highest leachate concentrations and reduce the overall contaminant load that will continue to flow downgradient to the Tatana Drain or Hokio Stream.

This option might include:

- Construction of an approximately 240m long trench at the base of the sand dunes, to the south of the Tatana Drain;
- Installation of a perforated pipe with drainage gravel surrounds. The surface of the trench would then be reinstated by capping with the excavated soils;
- Design of the trench to allow for flow by gravity to a central leachate collection manhole;
- Periodic pumping of leachate-impacted groundwater to the existing leachate pond. The leachate-impacted groundwater would then be sent off site for treatment and disposal at the Levin Wastewater Treatment Plant;
- Pumping may need to continue in perpetuity, until groundwater quality improves to acceptable levels. We note that the duration of groundwater extraction and treatment will depend on whether other measures to reduce leachate generation are also implemented.

We note that this option may result in significant ongoing operations and maintenance costs, to allow for pumping leachate and provide for treatment. Based on currently available information on site hydrogeology (Douglass, 2018), we anticipate that a groundwater interceptor trench may involve collection and treatment of approximately 5,000 to 15,000m^3 of groundwater per year. We recommend hydrogeologic site investigation to confirm design assumptions if this option proceeds to detailed design.

4.3.2 Option 8 - Pump and treat shallow groundwater

Pumping and treating shallow groundwater is an alternative means of extracting leachate-impacted groundwater for off-site treatment and disposal. We anticipate that the leachate interceptor trench and pump and treat options are mutually exclusive, as they represent two alternative methods for achieving the same purpose of groundwater extraction.

The pump and treat option might involve:

- Installation of extraction wells in the area of potential concern, downgradient of the Original Landfill and south of the Tatana Drain;
- Detailed design of the extraction wells would require confirmation of the site hydrogeology. However, for the purposes of this BPO assessment, we have assumed the wells would be

spaced at approximately 20m intervals (13 No. wells total). The wells are assumed to be approximately 150mm diameter;

- Ongoing pumping of groundwater at each well, for off-site treatment and disposal at the Levin Wastewater Treatment Plant.

As with the leachate interceptor trench, this option may result in lower water levels in the Tatana drain.

4.3.3 Option 9 - Install leachate collection system in Original Landfill

In this option, we have considered the installation of vertical leachate extraction wells in the Original Landfill. The purpose of these wells would be to lower the leachate levels in the waste, which will reduce the amount of leachate which is discharged to the environment. This option would be most effective if the leachate levels in the waste mass are significantly elevated above the base of the landfill. We understand that the leachate levels within the landfill are unknown, therefore the effectiveness of the option is difficult to assess. This option would require ongoing maintenance to pump and treat leachate removed from the waste mass.

4.4 Options to reduce leachate impacts

4.4.1 Option 10 - Constructed wetlands around Tatana Drain

We have considered a remedial option in which a wetland is constructed in the area of Tatana Drain. This option would largely be aesthetic, however, a properly designed wetland can also reduce the contaminant load discharge to Hokio Stream.

No one wetland design can address multiple contaminants. To optimise contaminant extraction the best approach is to design separate wetland bays in series, each bay differently designed to address a specific set of contaminants. Ammonia/ammonium, nitrate, sediment, biological oxygen demand (BOD), and metals all require different wetland conditions to maximise extraction. At the Tatana Drain, the ammonia, chemical oxygen demand (COD), and metals content are the key contaminants of concern, although none seems to be critical in terms of impact on the Hokio Stream.

Ammonia/ammonium reduction requires oxygenated conditions (vertical flow wetland) to promote nitrification. This will generate nitrate (the product of nitrification) which is then best extracted in a low oxygen environment (surface flow wetland). Metals are best extracted by sedimentation (i.e., settling out) for those bound to soil particles and plant uptake (soluble forms). Both require periodic removal from site to ensure net extraction continues to occur (removal of sediment captured in sediment traps and harvest and removal of vegetation).

Based on the above, we have considered that a constructed wetland option might comprise:

- Simple shallow surface flow wetland with an unplanted deeper sediment trap at the downstream end. The surface flow wetland should be flat bottomed, have a mean water depth of 300mm (and not deeper than 500mm) and be fully planted with native sedges and rushes.
- A trench of stoney substrate should be constructed upstream of the wetland, so that groundwater flow is intercepted by the substrate and enter the wetland as a diffuse flow. The stoney substrate will provide a location for nitrification to occur.
- The surface flow wetland will break down the nitrate and trap metals, and the sediment trap will capture sediment and solids containing metals. Net result should be outflow with reduced concentrations of all contaminants.
- The wetland should be designed for a minimum 3 days retention in the wetland. Based on our understanding of the site, we have assumed that the wetland with a surface area of

approximately 3,000m^2 and a depth of 300mm would be required, although these dimensions would need to be verified during detailed design.

- As with any constructed wetland, the proposed system will require periodic maintenance to sustain plant vigour and to remove accumulated metals in the sediment and by trimming the vegetation (and collecting and disposing of the clippings).
- This constructed wetlands is assumed to be implemented on the Tatana's property. The cost of land acquisition has not been included in the indicative costs presented in Appendix A.

4.4.2 Option 11 - Addressing and repairing seeps

This option involves addressing and repairing seeps to limit direct discharges to surface water. Implementation would involve inspections of the landfill perimeter to identify potential seeps, then creating preferential flow paths for leachate seeps to discharge back into the landfill. The seeps would be repaired by reinstating the surface with a good quality cap. This approach could be used to address the aesthetic effects of leachate seeps in isolated area of the site and reduce seepage of leachate to surface water. It is unlikely that the option would significantly reduce the volume of leachate being generated and the benefits will largely be aesthetic.

5 Best practicable options assessment

5.1 Assessment criteria

We have evaluated the potential remedial options described above as part of the BPO assessment. A summary of the BPO assessment is provided in Appendix A.

In the BPO assessment, we have considered the following:

- Likely effects of each option on key risk areas, including leachate generation, discharge to groundwater, and discharge to surface water. These effects were assessed based on the CSM and water balance modelling described in Section 3;
- Potential consent requirements for each remedial option. We note that the potential consent requirements described in Appendix A are related to ground contamination and closed landfill requirements only, and that a full planning assessment for the remedial options has not been carried out;
- Indicative costs to implement each option, and ongoing maintenance costs. Given the conceptual stage of this options assessment, in Appendix A we have provided qualitative cost categories only. These qualitative cost categories are meant to assist in the selection of preferred alternative(s), and anticipate that these costs would be further refined as part of preliminary design; and
- Design considerations or challenges with implementing these options.

5.2 Effectiveness of the remedial options

The water balance model described in Section 3 was run under various soil parameter and site characteristics scenarios to evaluate the approximate impact of the remedial options. A summary of model outputs for each remedial option is provided in Table 5.1.

Table 5.1: Remedial options and model outputs

Option No.	Remedial option	Leachate reduction potential (indicative only)
Additional capping		
1	· Improve ~1ha portion of the top deck where k>1e-7m/s was measured	· ~15% reduction in total infiltration
2	· Install clay cap alongside slopes (k=1e-7m/s):	· ~45% reduction in total infiltration
1 & 2	· Improve top deck and side slopes so that all portions of cap have k=1e-7m/s	· ~60% reduction in total infiltration
3	· Cap Area 2 with low permeability material	· ~45% reduction in infiltration in Area 2. However, it is unclear whether Area 2 is a significant source of leachate
4	· Repair cap where ponding is observed	· Would reduce infiltration, but magnitude of reduction depends on extent of repairs
Drainage improvements		
5	· Construct contour drains at ~30m intervals, to reduce infiltration by increasing the amount of run off.	· Construction of lined drains is estimated to increase runoff by ~20 to 30%[1]. Infiltration is expected to decrease by a similar amount.
6	· Perimeter drain improvements	· Expected to reduce shallow groundwater levels upgradient of the landfill and therefore reduce leachate generate. Magnitude of leachate reduction depends on condition of existing drain and frequency of ponding in this area.
Extract leachate		
7	· Leachate interceptor collection trench	· Would not reduce leachate generation but would seek to capture a significant fraction of leachate-impacted groundwater prior to discharge to Tatana Drain
8	· Pump and treat shallow groundwater	· Would not reduce leachate generation but would seek to capture a significant fraction of leachate-impacted groundwater prior to discharge to Tatana Drain
9	· Install leachate collection system in old landfill	· Would not reduce leachate generation but would seek to capture a significant fraction of leachate-impacted groundwater prior to discharge to shallow groundwater
Mitigate leachate impacts		
10	· Constructed wetlands around Tatana Drain	· Would not reduce leachate generation or discharge to Tatana Drain, but would seek to improve quality of drain and reduce contaminant load discharged to Hokio Stream
11	· Repair seeps	· Would not reduce leachate, but would seek to limit discharge to surface water

Notes:

1 Influence of adding contour drains is based on runoff coefficients in the Rational Method, not from the HELP model. Values are indicative only.

5.3 BPO outcomes

Key outcomes of the assessments include:

- A number of options were identified that were evaluated to likely have desired effect in reducing leachate generation, discharges to groundwater, and discharges to surface water. We have not identified a single "best" option, as selection of an appropriate option will depend on effectiveness, cost, and community acceptance.
- We anticipate that a remedial design may include selection of a suite of options that may be complementary. As an example, a preferred remedial plan may involve improving drainage on and around the cap, repair of seeps and damaged areas of the existing cap, and construction of a wetland around Tatana Drain.
- Remedial options ranged from low cost (<$100k) to very high cost (>$1000k). Some of the most expensive options such as large scale recapping may be the most effective at reducing leachate generation. However, these large scale improvements may not be warranted given the observed level of environmental impact;
- Operational and maintenance costs were considered for each option. Installation of a leachate collection system, pumping and treating shallow groundwater and construction of a wetland will require continuous maintenance and/or operational costs.
- Certain remedial options may have other impacts that should also be considered. For instance, groundwater extraction using a leachate interceptor trench or by pumping from extraction wells may reduce water levels in the Tatana Drain and therefore limit the habitat potential of this drain.
- We recommend that a preferred alternative, or set of alternatives, be selected in consultation with HDC, local residents, and other s274 parties as identified in the *Landfill Agreement*. The aim of this process would be to develop a remedial plan that has broad acceptance by the community and other interested parties.

6 Applicability

This report has been prepared for the exclusive use of our client Horowhenua District Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Pty Ltd

Environmental and Engineering Consultants

Report prepared by:

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David Umberg
Civil Engineer

Authorised for Tonkin & Taylor Pty Ltd by:

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Chris Purchas
Project Director

Technical review by Simonne Eldridge, Technical Director - Environmental Engineering

DAUM
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LEGEND

Property Boundary

A3 SCALE: 1:5,000

0 50 100 150 200 250 (m)

N

1. Property Boundary,Titles,Street Name,Street Number sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 3.0 New Zealand licence.
2. World Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Created On:	23/09/2019
Created By:	DUmberg
Approved By:	
TT Proj Ref: 1011583	
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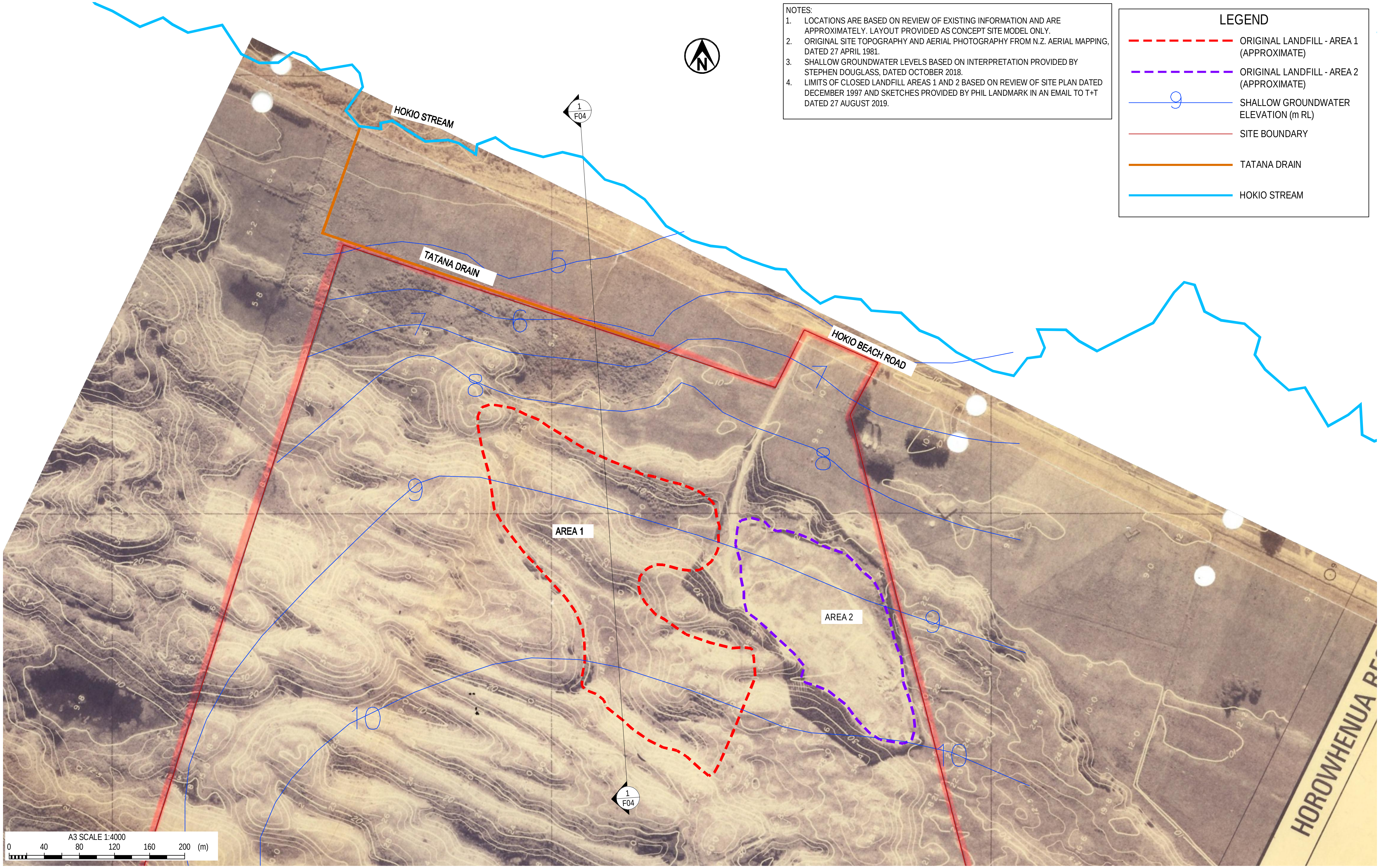
HOROWHENUA DISTRICT COUNCIL
LEVIN LANDFILL
Site Location

FIGURE No.
1

NOTES:
1. LOCATIONS ARE BASED ON REVIEW OF EXISTING INFORMATION AND ARE APPROXIMATELY. LAYOUT PROVIDED AS CONCEPT SITE MODEL ONLY.
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.
4. LIMITS OF CLOSED LANDFILL AREAS 1 AND 2 BASED ON REVIEW OF SITE PLAN DATED DECEMBER 1997 AND SKETCHES PROVIDED BY PHIL LANDMARK IN AN EMAIL TO T+T DATED 27 AUGUST 2019.

LEGEND
- ORIGINAL LANDFILL - AREA 1 (APPROXIMATE)
- ORIGINAL LANDFILL - AREA 2 (APPROXIMATE)
- 9 SHALLOW GROUNDWATER ELEVATION (m RL)
- SITE BOUNDARY
- TATANA DRAIN
- HOKIO STREAM



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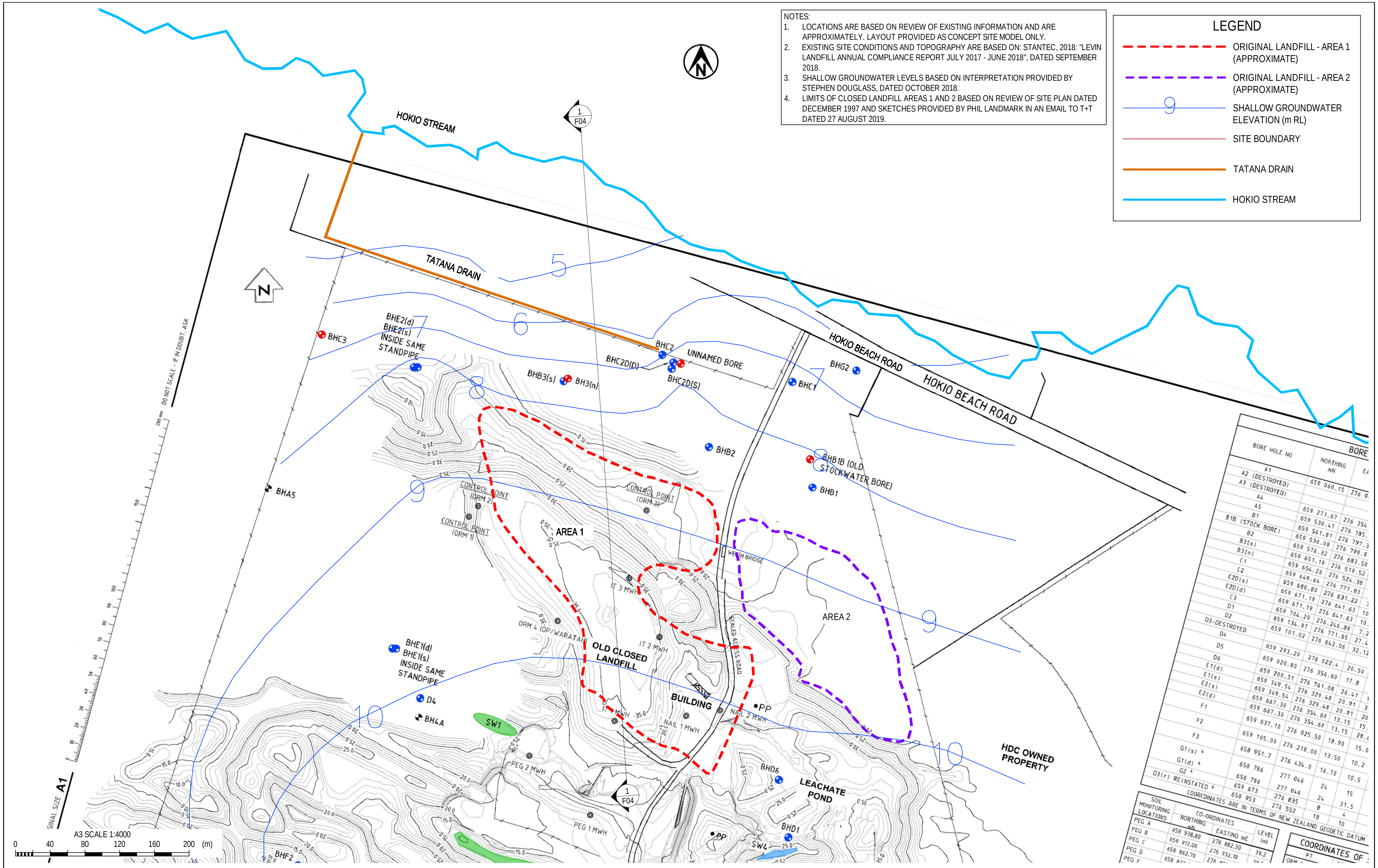
0	DRAFT FOR DISCUSSION	DAUM	SEPT 2019

PROJECT No.
DESIGNED DAUM Apr.19
DRAWN
CHECKED
APPROVED DATE

CLIENT HOROWHENUA DISTRICT COUNCIL
PROJECT LEVIN LANDFILL
TITLE LEACHATE BEST PRACTICABLE OPTION ASSESSMENT
ORIGINAL TOPOGRAPHY

UNDER REVISION

SCALE (A3) 1:4000   FIG No. 1011583-002   REV 0



NOTES:

1. LOCATIONS ARE BASED ON REVIEW OF EXISTING INFORMATION AND ARE APPROXIMATELY. LAYOUT PROVIDED AS CONCEPT SITE MODEL ONLY.
2. EXISTING SITE CONDITIONS AND TOPOGRAPHY ARE BASED ON: STANTEC, 2018: "LEVIN LANDFILL ANNUAL COMPLIANCE REPORT JULY 2017 - JUNE 2018", DATED SEPTEMBER 2018.
3. SHALLOW GROUNDWATER LEVELS BASED ON INTERPRETATION PROVIDED BY STEPHEN DOUGLASS, DATED OCTOBER 2018.
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LEGEND

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PROJECT No.			
DESIGNED	DAUM	SEPT 19	
DRAWN			
CHECKED			
0	DRAFT FOR DISCUSSION	DAUM	SEPT 2019
APPROVED	DATE		

CLIENT HOROWHENUA DISTRICT COUNCIL
PROJECT LEVIN LANDFILL
TITLE LEACHATE BEST PRACTICABLE OPTION ASSESSMENT
EXISTING SITE CONDITIONS

UNDER REVISION

SCALE (A3) 1:4000   FIG No. 1011583-002   REV 0

NOTES:
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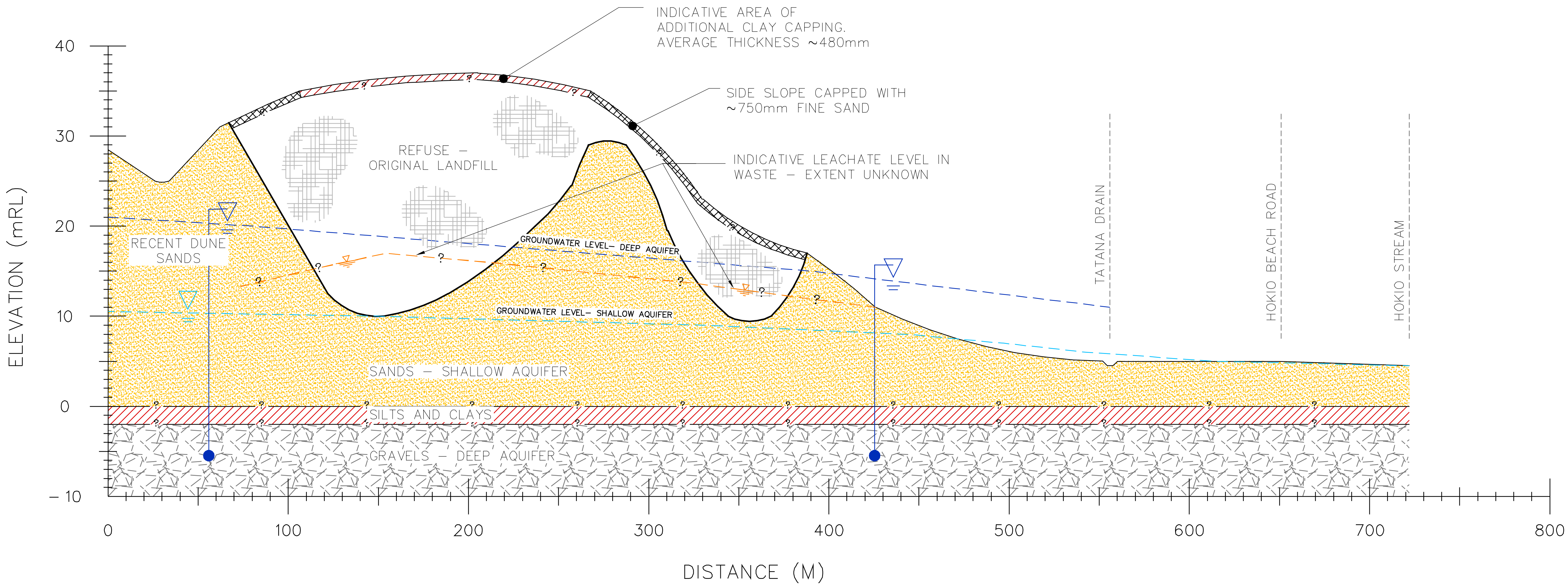

5: 1 VERTICAL EXAGGERATION

SCALE 1: 4000 (H)

0 40 80 120 160 200 (m)

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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) FIG No. 1011583-002 REV 0

Appendix A: Best practicable options assessment

Levin Landfill – Leachate best practicalble option (BPO) assessment with indicative costs

Tonkin & Taylor Ltd
T+T Project No. 1011583
December 2019

Table 1: Potentially viable remedial options at Levin Landfill

No.	Remedial action/ task[3]	Description	Effects on key risk areas				Consent requirements for implementation[1]	Rough order indicative capital & OM costs[5]	Design considerations and cost assumptions	Overall effectiveness with consideration of results of water balance modelling
			Leachate generation	Discharge to groundwater	Discharge to surface water	Other impacts				
Reduce leachate generation through additional capping										
1	Capping improvements on top of landfill where permeability $>10^{-7}$ m/s was measured	Scrapping back topsoil and importing and constructing new capping material to a higher standard, where testing has indicated $k > 10^{-7}$ m/s	Will reduce infiltration and therefore reduce leachate generation.	Reduced leachate generation will reduce leachate discharge to groundwater.	May increase discharge (of clean water) to surface water, particularly during heavy rainfall events.	Will reduce ability for landfill gas to discharge passively to atmosphere and therefore may increase risk of lateral migration.	Consent likely to be required under NES Soil due to the volume of soil disturbance involved.	High Similar operational costs	· Cost will dependant on how extensive the cap improvements need to be · Assume approximately 1 ha (~1/3) of the top deck does not achieve a permeability of 10^{-7} m/s or less · LFG impacts may not be significant if no changes are proposed to the landfill side slopes	Modelling indicates will only moderately reduce leachate generation. Will increase truck movements as material will need to be brought to site. Will not have an immediate impact on groundwater downgradient as existing leachate plume continues to migrate.
2	Capping improvements to side slopes of landfill which were originally capped with sandy material	Scrapping back topsoil and importing and constructing new capping material to a higher standard.	Will reduce infiltration and therefore reduce leachate generation.	Reduced leachate generation will reduce leachate discharge to groundwater.	May increase discharge (of clean water) to surface water, particularly during heavy rainfall events.	Will reduce ability for landfill gas to discharge passively to atmosphere and therefore may increase risk of lateral migration.	Consent likely to be required under NES Soil due to the volume of soil disturbance involved.	Very High Similar operational costs	· Cost will dependant on how extensive the cap improvements need to be · LFG controls may need to be incorporated into cap.	Modelling indicates will reduce leachate generation. Will increase truck movements as material will need to be brought to site. Will not have an immediate impact on groundwater downgradient as existing leachate plume continues to migrate.
3	Cap Area 2 with low permeability material	Scrapping back topsoil and importing and constructing new capping material to a higher standard.	Extent of potential contamination unknown – if Area 2 is a significant source of leachate, capping will reduce infiltration and therefore reduce leachate generation.	If Area 2 is a significant source of leachate, reduced leachate generation will reduce leachate discharge to groundwater.	May increase discharge (of clean water) to surface water, particularly during heavy rainfall events.	Will reduce ability for landfill gas to discharge passively to atmosphere and therefore may increase risk of lateral migration.	Consent likely to be required under NES Soil due to the volume of soil disturbance involved.	Very High Similar operational costs	· Cost will dependant on how extensive the cap improvements need to be · LFG controls may need to be incorporated into cap. · Unclear how much Area 2 is contributing to leachate issues. Additional water quality testing and field investigation to evaluate extent of waste would be required to evaluate effectiveness of remedial option	Difficult to measure environmental benefit as current monitoring of impacts downgradient of Area 2 is not conclusive. Modelling indicates will reduce leachate generation, depending on the quality and extent of the cap. Will increase truck movements as material will need to be brought to site. Will not have an immediate impact on groundwater downgradient as existing leachate plume continues to migrate.

Table 1 (continued): Potentially viable remedial options at Levin Landfill

No.	Remedial action/ task[3]	Description	Effects on key risk areas				Consent requirements for implementation[1]	Rough order indicative capital & OM costs[5]	Design considerations and cost assumptions	Overall effectiveness with consideration of results of water balance modelling
			Leachate generation	Discharge to groundwater	Discharge to surface water	Other impacts				
4	Improve cover material and site contour in the portions of the site where ponding is observed on the cap	Improve the cover thickness and quality in areas where ponding is observed to reduce infiltration.	Will reduce infiltration and therefore reduce leachate generation.	Reduced leachate generation will reduce leachate discharge to groundwater.	May slightly increase discharge of clean water to surface water	Minimal impact.	Localised repairs on cap may not require additional consents, depending on existing consent conditions. Consent may be required under NES Soil if a large volume of soil disturbance is proposed.	Low to Medium Similar operational costs	· Repair depressions in cap by placing fill to achieve positive drainage and prevent ponding · Ongoing maintenance costs to carry out regular inspections of cap and repair depressions in cap as they occur	Will reduce infiltration and therefore leachate generation at areas of ponding. Current information is insufficient to determine how beneficial this would be.
Reduce leachate generation through drainage improvements										
5	Cap drainage improvements	Clay lined contour drains along top of landfill to increase runoff and reduce infiltration. Minor recontouring/cap repairs where ponding has been observed	Will reduce infiltration and therefore reduce leachate generation.	Reduced leachate generation will reduce leachate discharge to groundwater.	May increase discharge (of clean water) to surface water, particularly during heavy rainfall events.	Minimal impact.	Depends on existing consent conditions for the closed landfill. Consent may be required under NES Soil if large volume of soil disturbance is proposed.	Medium to High Similar operational costs	· Assumes up to 1500 m of lined contour drains to be constructed on cap of original landfill. · Drains to be formed as an earth bund. Where drains are placed over sand cap, over excavate and replace with low permeability fill. · Cost of local improvements to reduce ponding will be dependent on how extensive the drainage improvements are. Lower cost to target 1 or 2 key areas, higher cost to target more areas. · Aim to work with existing site contours to improve runoff in areas of identified ponding. · Assume earthworks would occur outside limits of waste and no excavation into waste will be required.	Will reduce infiltration through the cap and increase the amount of runoff thereby reducing leachate generation and associated discharge to groundwater.
6	Perimeter drain improvement	Lined drain at southwestern perimeter of original landfill to reduce ponding and infiltration into the landfill	Will reduce infiltration and therefore reduce leachate generation.	Reduced leachate generation will reduce leachate discharge to groundwater.	May increase discharge (of clean water) to surface water, particularly during heavy rainfall events.	Minimal impact.	Depends on existing consent conditions for the closed landfill. Consent may be required under NES Soil if large volume of soil disturbance is proposed.	Medium Similar operational costs	· Assumes 500 m long polypropylene fibre reinforced spray concrete lined channel · Earthworks to form channel section · Discharge at base of sand dune	Will reduce infiltration into shallow groundwater above the landfill, which is expected to reduce groundwater inflow to the closed landfill. Will not have an immediate impact on groundwater downgradient as existing leachate plume continues to migrate.

Table 1 (continued): Potentially viable remedial options at Levin Landfill

No.	Remedial action/ task[3]	Description	Effects on key risk areas				Consent requirements for implementation[1]	Rough order indicative capital & OM costs[5]	Design considerations and cost assumptions	Overall effectiveness with consideration of results of water balance modelling
			Leachate generation	Discharge to groundwater	Discharge to surface water	Other impacts				
Extract leachate										
7	Install leachate interceptor collection system along north perimeter[4]	Leachate collection trench to intercept shallow groundwater downgradient of Area 1 (approx. 240 m long).	No impact on leachate generation but will increase the volume of leachate being collected.	Will intercept leachate thereby reducing discharge to groundwater.	Will reduce leachate seeps discharging to surface water in this area.	Will likely reduce flow in Tatana Drain	Consent may be required under NES Soil as a large volume of soil disturbance is proposed.	Medium to High Ongoing maintenance of pumping system	· Assumes 240 m long gravity fed drainage trench discharging into manhole · Filled with drainage aggregate and lined on downgradient side to direct flow towards perforated pipe. · Trench to be located at base of sand dunes. · Collection efficiency will depend on depth of trench. · Likely additional cost to allow for pumping as required to achieve discharge to the existing leachate storage system. · Increased quantity of leachate to be treated	Will reduce leachate entering surface water at Tatana Drain and Hokio Stream. Will result in a significant increase in leachate volume to be managed which may be beyond the capacity of the current system.
8	Pump and treat shallow groundwater[4]	Install wells in shallow aquifer downgradient of the landfill. Pump groundwater and treat to reduce contaminant load	No impact on leachate generation.	Groundwater quality improvement downgradient of the landfill	No impact	Groundwater drawdown may lower water levels in Tatana Drain	Consents likely needed for installation of wells	Medium to High Ongoing maintenance of treatment system	· Cost would depend on number and location of treatment wells – to be informed by hydrogeologic review · From high-level review of sand aquifer permeability and thickness, preliminary cost estimate has assumed 150 mm diameter wells at 20 m spacing, across 240 m total length (13 No. wells total) · Costs will depend on the level of treatment required · Design would need to consider how treated groundwater is discharged	Secondary impacts are possible depending on where the treated groundwater is discharged (e.g., surface water dilution with treated leachate). This approach will result in a significant increase in contaminated water volume to be managed which may be beyond the capacity of the current system.
9	Install leachate collection system in old landfill	Install vertical collection wells in old landfill and pump leachate to draw down leachate levels in the waste.	No impact on leachate generation.	Groundwater quality improvements downgradient of the landfill	Will reduce leachate seeps discharging to surface water	Minimal impact	Depends on existing consent conditions for the closed landfill. Consents may be needed for installation of wells	Medium to High Ongoing maintenance of leachate pumping system	· Cost would depend on number and location of extraction wells · Would only be a viable option if the leachate level is significantly elevated above the base of the landfill · Risk is that leachate in the waste mass may not travel efficiently towards the vertical extraction wells	Will not affect leachate generation but will reduce leachate discharge to groundwater Will not have an immediate impact on groundwater downgradient as existing leachate plume continues to migrate

Table 1 (continued): Potentially viable remedial options at Levin Landfill

No.	Remedial action/ task[3]	Description	Effects on key risk areas				Consent requirements for implementation[1]	Rough order indicative capital & OM costs[5]	Design considerations and cost assumptions	Overall effectiveness with consideration of results of water balance modelling
			Leachate generation	Discharge to groundwater	Discharge to surface water	Other impacts				
Mitigate leachate impacts										
10	Constructed wetlands around Tatana drain	Shallow surface flow wetland with unplanted deeper sediment trap at downstream end. Excavate ~3,000 m^2 wetland area to north of Tatana drain to intercept shallow groundwater and achieve average water depth of ~300 mm. Wetlands to be planted with native sedges and rushes Add fencing to exclude stock from drains.	No impact on leachate generation.	No reduction in discharge as drain is outside the landfill footprint.	Will not change volume of discharge but will aim to improve water quality in drains by reducing stock impacts	Potential reduction in contaminants in Tatana drain due to biological treatment and sedimentation	Consent potentially needed for works in a watercourse.	Medium to high Medium cost to implement plus cost of land acquisition Ongoing maintenance of riparian plants, particularly in first 3-5 years following planting	· Assume drain improvements includes excavation to expand Tatana Drain to form a shallow constructed wetland · Install stony substrate where groundwater enters the wetland · Riparian planting will improve quality of habitat and provide aesthetic benefits · Tatana drain is on private land – would need to secure access to perform the work · Biological treatment (e.g., nitrogen and ammonia removal) may be possible, depending on the design of the planting scheme · Sedimentation and biological treatment may improve quality at the discharge to Hokio Stream · Wetland system will require periodic maintenance to sustain plant vigour and remove accumulated metals in the sediment. Maintenance to include clipping of vegetation disposal of clipping.	Difficult to differentiate water quality issues from leachate versus other sources, but may lead to better water quality in the drain regardless of the source Works will aim to improve habitat which should improve the quality of water and the aesthetic appearance of the drains. Will not reduce the volume of leachate being generated. Stony substrate will provide a location for nitrification, while the surface flow wetland will break down nitrates and trap metals To optimise contaminant extraction, the wetland will need be designed as separate wetland bays in series, each designed differently to address a specific set of contaminants.
11	Carry out localised works in areas where seepage has been observed.	Create preferential flow paths for leachate seeps to discharge back into the landfill, and reinstate the surface with good quality cap.	Minimal impact on leachate generation.	May slightly increase discharges to groundwater as leachate is being redirected into the landfill.	Will reduce direct discharges to the perimeter drains.	Minimal impact.	Depends on existing consent conditions for the closed landfill. Consent may be required under NES Soil if a large volume of soil disturbance is proposed.	Low Similar operational costs	· Costs based construction of a subsoil drain to address seepage. · Only considers repair of a few locations · Costs assume leachate can be directed back into the landfill with no connection to the leachate collection system. · Individual design for each seepage situation would be required.	Will address the aesthetic effects of leachate seeps in isolated area of the site and reduce seepage of leachate to perimeter drains. Is unlikely to significantly reduce the volume of leachate being generated and the benefits will largely be aesthetic.

Notes:

1. Consent requirements are limited to consents related to ground contamination and closed landfills. A planning assessment for the remedial options has not been carried out.
2. Indicative capital costs are qualitative and provided for comparative purposes only. These costs should not be relied on for budgeting purposes. No proof of concept or detailed design has been carried out for any of the options. Costs will be dependent on the remedial objective for each action, site conditions, detailed design, and local rates for labour and materials.
3. Within each table, remedial options have been organised from simplest to most complex
4. :These two options are considered mutually exclusive.
5. For the purposes of this qualitative cost estimate, we have applied the following categories:

Category	Indicative cost
Low	<$100k
Medium	$100k-350k
High	$350k-$1000k
Very High	>$1,000k