Boffa Miskell

Green Island Landfill

Ecological Impact Assessment
Prepared for Dunedin City Council

16 March 2023 (Updated October 2024)

TOITŪ NET CARBON ZERO ISO 14064-1 ORGANISATION

Boffa Miskell is proudly a
Toitū net carbonzero certified consultancy

Document Quality Assurance

Bibliographic reference for citation:
Boffa Miskell Limited 2024. *Green Island Landfill: Ecological Impact Assessment*. Report prepared by Boffa Miskell Limited for Dunedin City Council.

Prepared by:	Dr Tanya Blakely (Freshwater) Associate Partner | Ecologist Boffa Miskell Limited	
	Karin Sievwright (Avifauna) Ecologist Boffa Miskell Limited	
	Dr Jaz Morris (Vegetation) Ecologist Boffa Miskell Limited	
Reviewed by:	Dr Sharon De Luca Partner | Ecologist Boffa Miskell Limited	
Status: FINAL	Version 2: to respond to s92 questions	Issue date: 16 September 2024

Template revision: 20230109 0000

File ref: BM210975_001h_Ecological_Impact_Assessment_Report_20241007.docx

Executive Summary

Introduction

The Green Island Landfill is the city's current landfill for the disposal of municipal solid waste and hazardous waste, along with waste diversion, and transfer facilities. The landfill, which is located in the suburb of Green Island, Dunedin requires reconsenting for an extended period of further filling, until the ultimate landfill closure in potentially December 2029. A new landfill has recently been consented at Smooth Hill in southwest Dunedin. However, it is unlikely that Smooth Hill will be ready to accept waste until 2027/2028 and the existing Green Island Landfill resource consents expire on 1 October 2023.

Boffa Miskell Limited has been engaged by DCC to undertake an ecological impact assessment for the extended operation of the landfill. The objective was to assess the effects of the extended operation of the landfill on ecological values (vegetation and habitats, avifauna, freshwater and estuarine) of the receiving environment, to support applications for resource consent following the Environment Institute of Australia and New Zealand guidelines.

Site description

The Green Island landfill is located approximately 10 kms from central Dunedin, within a landscape of undulating coastal hills and basins. It occupies a portion of what was once part of the Kaikorai Lagoon. Abbotts Creek and Kaikorai Stream are the main tributaries of Kaikorai Lagoon. Surface water quality in the catchment has been impacted by past and current land activities. This assessment includes a review of databases and reports which present data from previous ecological information regarding these environments.

Terrestrial habitat within the landfill designation was observed as planted indigenous and exotic vegetation during a site walkover.

Recent avifauna survey data together with other data collated from desktop review identified 32 key species use or may potentially use the landfill site and immediate surrounds. Of these 14 were recorded during recent surveys conducted at Kaikorai Lagoon and the landfill.

The habitat of Abbotts Creek, Kaikorai Stream and Kaikorai Lagoon were assessed and described through both desktop and field investigations. The macroinvertebrate community was predominantly within the range of 'fair to poor' between all sites. Six native fish species were observed during sampling across all sites, including black flounder, common bully, inanga, longfin eel, shortfin eels, and upland bully.

Ecological value

Within the working landfill extent and wider Designation, the terrestrial vegetation has negligible ecological value, avifauna ecological value ranged between low and very high, Kaikorai Stream and Abbotts Creek have moderate ecological value, and Kaikorai Lagoon has high ecological value.

Ecological effects

The potential effects on ecological values associated with the continued operation and multi-stage closure of the landfill have been assessed. Overall, the levels of ecological effects are very low to low for most effects identified, with some positive effects to avifauna. As such these effects do not warrant mitigation or offsetting.

Continued utilisation of the current effective stormwater and leachate treatment is recommended as a key ongoing requirement. However, no additional ecological investigation, monitoring, or management is required at this time. If any significant exceedances are detected and related to landfill activities, additional ecological investigations may be required.

CONTENTS

Appendices

1.0 Introduction

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

To support the implementation of the new kerbside collection service, the DCC is planning to make changes to the use of Green Island landfill site (Figure 1) in coming years.

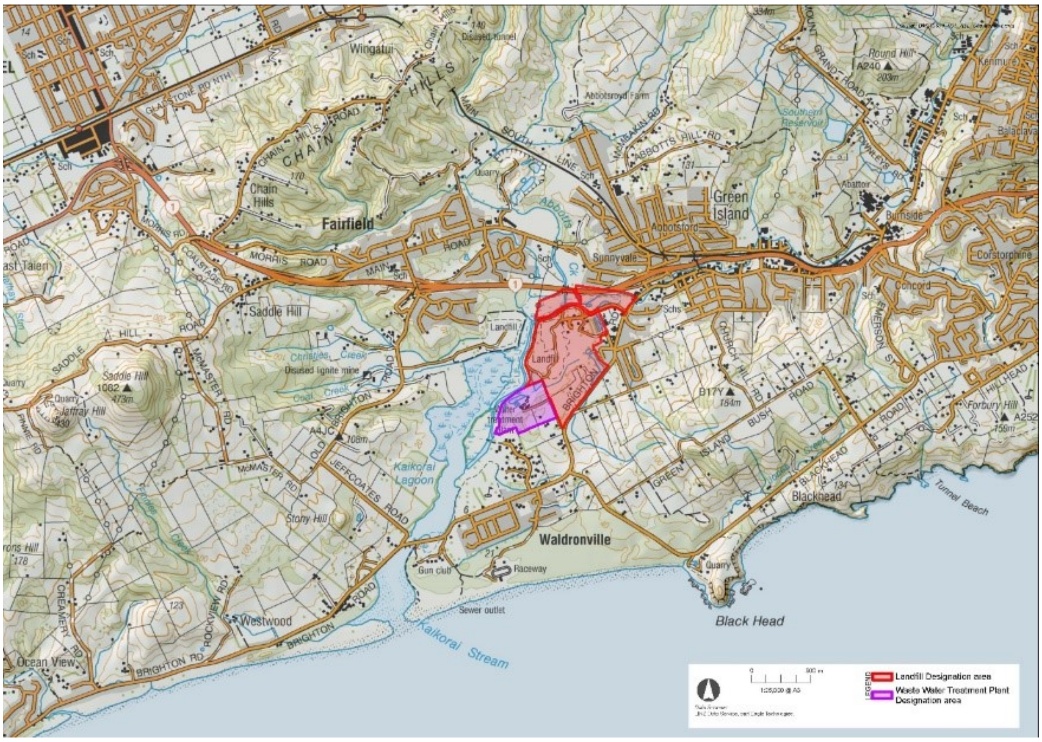


Figure 1. Green Island Landfill site.

The proposed changes include:

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

The resource consents for the new Smooth Hill landfill are subject to appeal. Depending on the outcome of this appeal process, and the time needed to undertake baseline monitoring, preparation of management plans, landfill and supporting infrastructure design and construction, DCC anticipates that the new Class I landfill facility, won't be able to accept waste until 2027/2028, at the earliest.

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

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

The development of the new RRPP and waste transfer facilities at Green Island does not form part of the replacement consent applications. Resource consents for the development and operation of the RRPP will be applied for following the completion of design work and technical assessments later in 2023.

1.1 Ecology scope

Boffa Miskell Limited has been engaged by DCC to undertake an ecological impact assessment (EcIA) for the extended operation of the landfill. The objective was to assess the effects of the extended operation of the landfill and potential post-closure ongoing effects on ecological values (vegetation and habitats, avifauna, freshwater and estuarine) of the site and the surrounding receiving environment, to support applications for resource consent.

This ecological assessment is one of a suite of technical assessments that provide input into the consent for the extended operation of the landfill.

This EcIA provides a detailed assessment of:

- impacts of the proposed extended operation of the landfill on the ecological values within the landfill site and surrounding receiving environment; and
- any ongoing effects of the landfill post-closure on the ecological values within the landfill site and surrounding receiving environment.

1.2 Report structure

This ecological assessment has been divided into the following sections to:

- provide a summary of the proposed works (Section 2.0);
- outline the methodology used to undertake the assessment (Section 3.0);
- describe the existing environment, assess the significance of the vegetation, habitats and ecosystems (Section 5.0), and assess the ecological values (Section 6.0);
- assess the ecological effects of the project (Section 7.0); and
- provide recommendations to avoid, remedy, mitigate or offset effects (Section 8.0).

This report has been updated in September 2024 to include responses to s92 questions from the ORC. This version of the report replaces the original Ecological Impact Assessment issued in March 2023.

1.3 Key technical reports

The following reports are from other organisations within the project team and are reports with key, complementary data and information replied upon for this EcIA, and should be read in conjunction with this report.

- GHD 2024a. *Waste Futures – Green Island Landfill Closure Groundwater Technical Assessment.* Prepared for Dunedin City Council. July 2024
- GHD 2024b. *Waste Futures – Green Island Landfill Closure Surface Water Report.* Prepared for Dunedin City Council. July 2024
- Cawthron Institute 2023. *Green Island Landfill Ecotoxicology of PSD Extracts.* Prepared for Boffa Miskell Limited by Cawthron Institute. December 2023

1.4 Experience and qualifications of report authors

This report has been prepared by suitably qualified experts who declare their relevant qualifications and experience as follows:

Tanya Blakely is an expert freshwater ecologist and Senior Principal at Boffa Miskell, with 18 years' experience as a research and consultant ecologist. Tanya holds a Bachelor of Science with Honours in Zoology and a Doctor of Philosophy in Ecology. She has published eleven peer-reviewed scientific papers, a guidebook on aquatic insects, and numerous technical ecological reports, ecological impact assessments, and other publications in her areas of expertise. Tanya is a Certified Environmental Practitioner – Ecology Specialist, and a full member of the Environment Institute of Australia and New Zealand, the New Zealand Freshwater Sciences Society and the New Zealand Entomological Society; she is the Chair of the New Zealand Fish Passage Advisory Group.

Jaz Morris holds a Bachelor of Science with Honours and a Doctor of Philosophy, both in the field of botany, from the University of Otago. He has over a decade's experience in vegetation and ecological surveying and has been an ecologist at Boffa Miskell since early 2019. He has published a range of peer-reviewed papers in scientific journals, held Tutor and Teaching Fellow roles in Botany and Ecology at the University of Otago. Jaz is a Certified Environmental Practitioner and is a full member of the Environment Institute of Australia and New Zealand. He is also a member of the New Zealand Botanical Society and New Zealand Plant Conservation Network.

Karin Sievwright is an ornithologist and holds a Bachelor of Science degree and a Master of Science degree in Conservation Biology from Massey University. She has seven years of ecological experience working at Boffa Miskell and has conducted bird monitoring and consulted on ornithological aspects for a variety of projects. She has prepared a number of ecological impact assessments and avifauna management plans and has co-authored scientific papers.

2.0 Proposal description

The project is described in the AEE and briefly in Section 1.0. Key aspects of the proposal as they relate to potential ecological effects are summarised below.

2.1 Landfill history

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

The pre-existing landform occupied by the currently active the landfill site was, until the late 1960s / early 1970s, part of the intertidal saltmarsh area (Local Government Geospatial Alliance, n.d.) associated with the upper reaches of the Kaikorai Lagoon. Landfilling commenced at the south-east corner of the landfill site and has continued north and west over the decades. Waste was originally end dumped directly onto the estuarine muds and up against the south-eastern estuary edge. The site has been progressively drained, filled, and capped since that time.

2.2 Landfill leachate management

The following summary on landfill leachate management is taken from that provided in GHD’s groundwater and surface water technical reports (GHD 2024a, 2024b).

In the mid-1990s, a soil bund was constructed that encircles the landfill on the northern and western sides adjacent to Kaikorai Stream. A perimeter leachate collection trench was installed outside of the soil bund in 1994 and the leachate collection system was commissioned in 1995.

The leachate trench is situated in the Upper Kaikorai Estuary Member (UKEM) geological unit or layer, which is comprised of fine sands and silt. The leachate collection system consists of a gravel interception trench (in the UKEM layer) with a HDPE liner on the outer / Kaikorai Stream side, a slotted PVC drainage pipe, and a manhole and pump station configuration (Figure 2). There is also a groundwater monitoring network associated with the perimeter leachate collection system, which includes eight lines of groundwater monitoring wells transecting the trench (Figure 3). The wells include both shallow (wells A, B, and C, located in the UKEM layer) and deep wells (wells D[1], located in the Lower Kaikorai Estuary Member (LKEM) layer) (Figure 4). Pumping from the leachate trench creates a hydraulic barrier for groundwater and leachate migration offsite. The HDPE liner aids in reducing (but does not eliminate) water inflow to the trench from Kaikorai Stream.

Contaminated groundwater (landfill leachate mixed with groundwater) seeping from the site is intercepted and conveyed by gravity to a series of nine pump stations along the leachate collection trench alignment, and ultimately discharged to the Green Island Wastewater Treatment Plant (GIWWTP). Continuous dewatering of the trench is required to maintain the hydraulic barrier to direct contaminated groundwater; pump stations maintain water levels at low levels to create the hydraulic gradient to direct flow to the trench.

As noted above, waste was originally end dumped directly onto the estuarine muds. Historically, there was some placement of waste where the leachate trench is located today (GHD, 2024a). During construction of the leachate collection trench, landfill refuse was recorded in over half of the trench profiles (referenced in GHD 2024a *Groundwater Report*[2]). GHD has identified wells 3C, 4C, 6C, 7C, 8C, and 7D, all of which are outside of the leachate trench (i.e., ‘C’ and ‘D’ wells, see Figure 4 to show the typical locations of A, B, C and D wells in relation to the leachate collection trench), may be within or influenced by historical waste placement. This is important context because the leachate collection system intercepts leachate contaminated groundwater from the landfill as well as drawing groundwater from outside of the leachate collection trench.

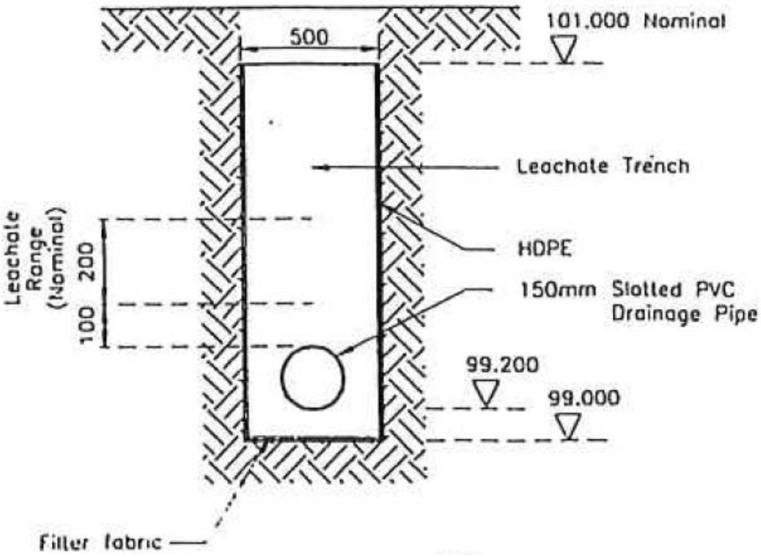


Figure 2. Leachate collection trench schematic (from GHD, 2024a report[3]).

---

[1] Only at Lines 2, 4 & 7 as shown on Figure 2.

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

[3] GHD report cites City Consultants, 1997: Green Island Landfill Leachate Monitoring, Drawing 5526/234.

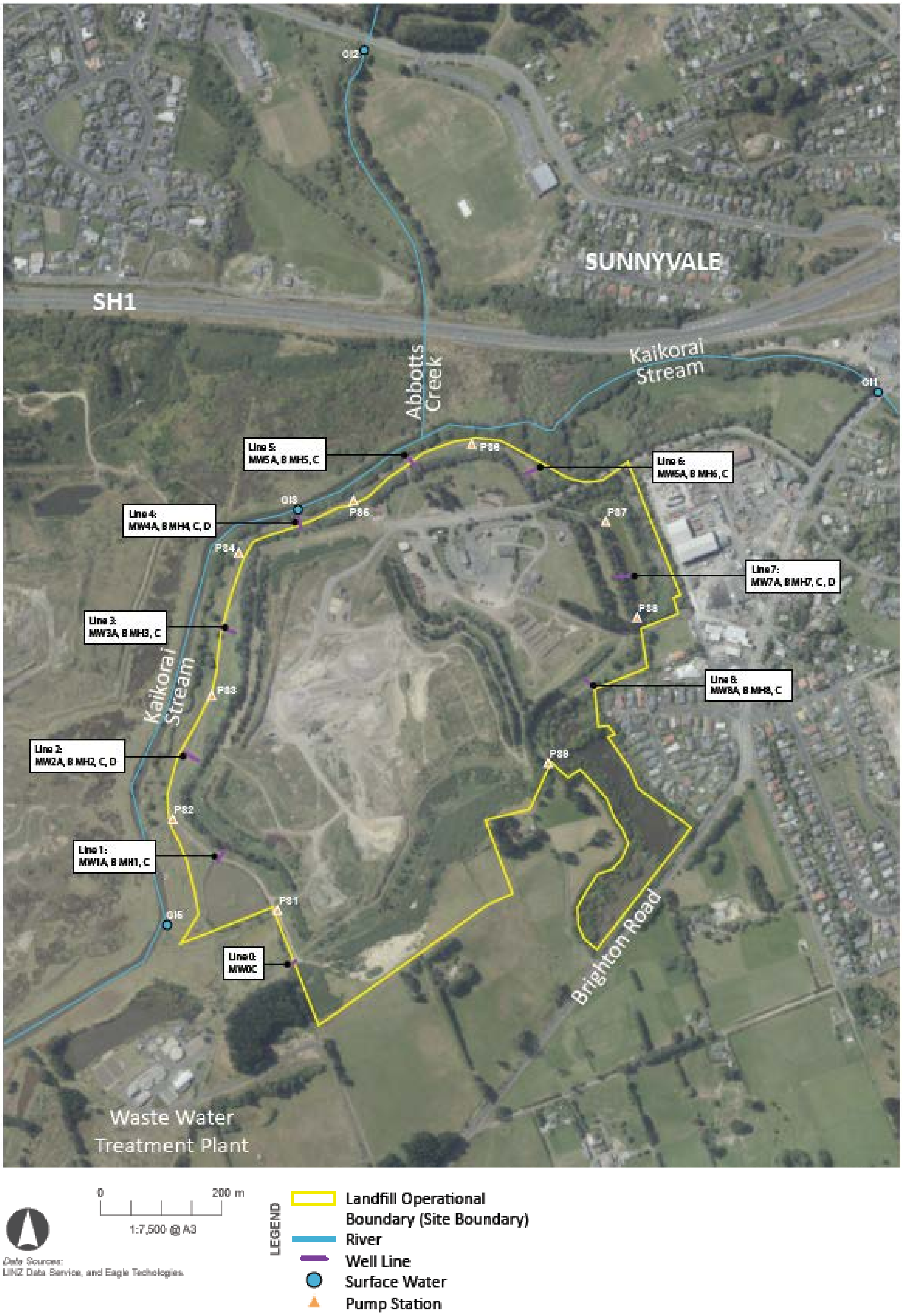


Figure 3. Green Island Landfill groundwater and surface water monitoring locations (from GHD, 2024a).

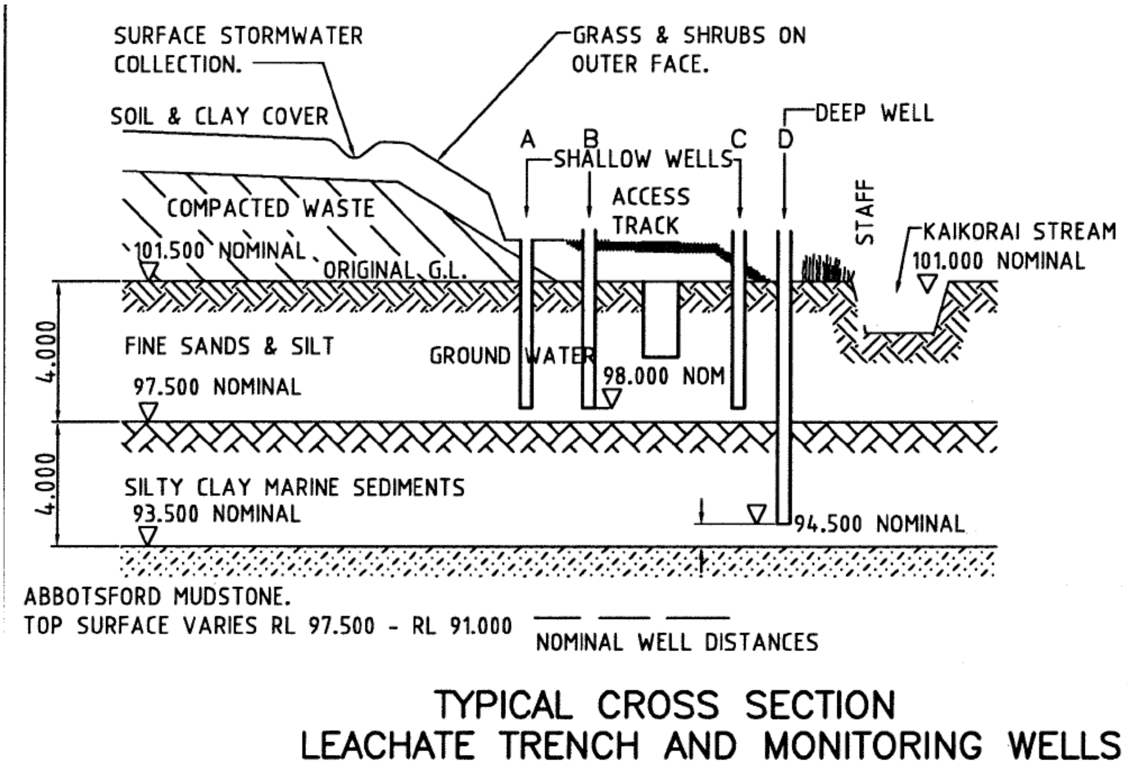


Figure 4. Typical cross section of leachate collection trench (from GHD, 2024a report).

The leachate collection trench is absent along the southern edge of the landfill where waste was placed against the base of the slope that rises to the east. Management of leachate in this area is currently via a shallow surface drain, which conveys the leachate (and any shallow groundwater seepage) to Pump Station 1 (PS1). There is also a 90 m gap in the trench between Manhole 8 (MH8) and PS9, although GHD (2024a) notes that this area of the landfill sits directly on a ridge of Abbottsford Mudstone, which forms an effectively impermeable barrier to flow and, therefore, leachate migration off site is unlikely. A culvert located on the eastern side of the landfill between the south eastern constructed wetlands and the eastern constructed wetland has recently been identified as a pathway for leachate seepage, which has been confirmed from water quality monitoring and a culvert inspection (GHD, 2024b), and remedial measures have been proposed.

Additional leachate drains have been installed over intermediate cover soils in the southern portion of the landfill and in the northern sector of waste placed in 2019-2022, directing leachate to the perimeter leachate collection trench.

Proposed changes to the leachate collection system to address potential risks as part of this consent, include:

- Extension of the leachate collection trench along the 300 m section of the southern side of the landfill where the existing open leachate/surface runoff drain exists;
- Installation of additional internal landfill leachate drains as part of waste placement to manage leachate levels within the waste;
- Provision of infrastructure to deploy submersible air powered pumps in LFG wells to extract leachate in the completed capped sections of the landfill; and

- Remediation of leachate seepage from an existing culvert on the eastern side of the landfill, which transfers surface water between two ponds. The culvert is closely aligned with the leachate collection trench at this location.

Existing consents include a comprehensive regime for the monitoring of groundwater and surface water associated with the Kaikorai Stream and Lagoon receiving environment, to confirm effective operation of the leachate collection system.

2.3 Stormwater management

The existing proposed stormwater management approach is summarised below and described in more detail in the AEE.

- Clean runoff from non-active areas of the landfill and the waste diversion and transfer facilities is conveyed by sheet flow or by swales and pipes to perimeter drains, which either discharge to Kaikorai Stream via sedimentation ponds or, in the case of the western side of the landfill, via culverts directly to the stream.
- Stormwater from exposed earthworks is conveyed by grades on the operational landfill surface and temporary stormwater drains to sedimentation ponds prior to discharge to Kaikorai Stream.
- Stormwater in the active landfilling area that encounters waste or leachate is left to infiltrate the landfill or conveyed to leachate drains and the leachate collection system for discharge to GIWWTP.
- Wastewater from the wheel wash facility is conveyed to a soakage pit, which infiltrates to ground and is intercepted by the leachate collected system.

The existing resource consents require the quarterly monitoring of stormwater quality in the sedimentation ponds to confirm the effectiveness of stormwater measures. The same monitoring regime (with some modifications) is proposed for the continued operation, closure, and aftercare of the landfill.

Surface water quality is also monitored quarterly at four sites within Kaikorai Stream catchment (see Figure 3), including:

- GI1: Kaikorai Stream, upstream of the landfill (a control).
- GI2: Abbotts Creek, upstream of the landfill (a control).
- GI3: adjacent to the landfill, between pumpstations PS5 and PS4 and approximately adjacent groundwater monitoring Line 4.
- GI5: adjacent to the landfill, between pumpstations PS2 and PS1, immediately downstream of groundwater monitoring Line 1, and approximately adjacent to Western Sedimentation Pond.

3.0 Methodology

A combination of desktop assessments (including of relevant databases, published and unpublished reports) and site investigations were undertaken to obtain information regarding the ecological values associated with the landfill site.

Our assessment has considered ecological values within the working landfill extent, within the landfill Designation, and the aquatic habitats in the receiving environment (Figure 5).

3.1 Desktop review

The desktop investigation undertaken to inform this assessment included a review of readily available existing information, reports, published scientific literature, GIS (spatial) databases, and historic and current aerial imagery.

This information was used to assist us in understanding and describing the ecological values within the landfill and of Kaikorai Stream and Kaikorai Lagoon.

We used the following sources of information:

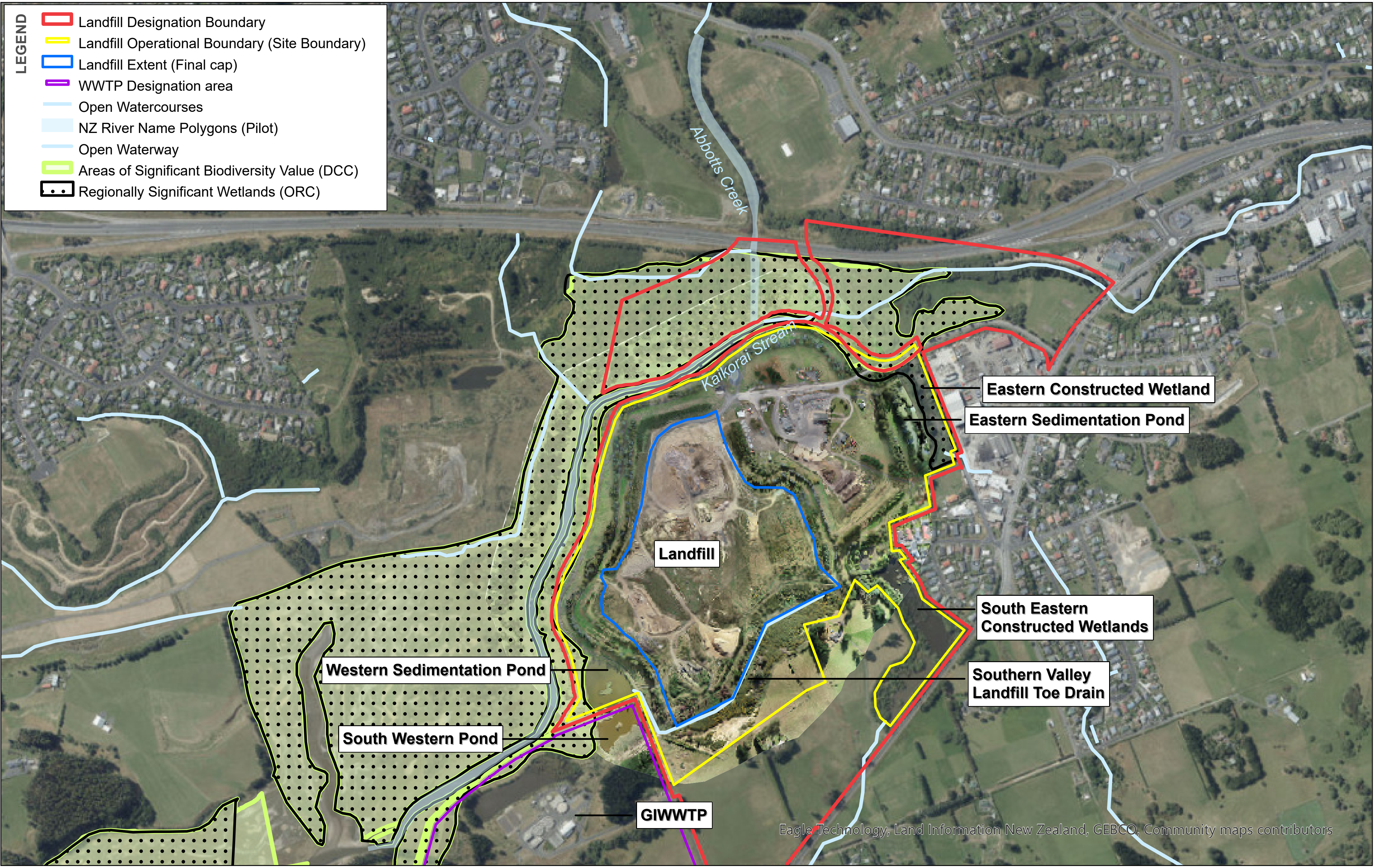
- Ecological region and ecological district GIS layer.
- The NIWA-administered New Zealand Freshwater Fish database (NZFFD): this database holds records of freshwater fish distributions and occurrences based on previous surveys[4]. The conservation status of fish species found in the NZFFD records was assessed based on the most recent conservation threat status for New Zealand's freshwater fish (Dunn et al., 2018).
- Aerial imagery, including current and historical imagery (e.g., Retrolens[5]).
- Land Environments New Zealand (LENZ) Threatened Environments Classification (Walker et al., 2015)[6] – LENZ is a computer modelling process that allows maps to be produced showing layers of landform and class, including aspects of New Zealand's climate, soils, and vegetation. This includes depicting differing levels of remaining indigenous systems and a prediction of historic vegetation cover, and the Threatened Environments Classification includes levels of statutory protection of each land environment.

---

[4] https://nzffdms.niwa.co.nz/search

[5] https://retrolens.co.nz/

[6] https://ourenvironment.scinfo.org.nz/



Boffa Miskell

www.boffamiskell.co.nz

0 240 m
1:10,000 @ A4

Data Sources:
Designations sourced from DCC data service
Waterways sourced from LINZ data service

Projection: NZGD 2000 New Zealand Transverse Mercator

GREEN ISLAND LANDFILL

Constructed waterbodies and landfill boundaries

Date: 29 August 2023 | Revision: 0

Plan prepared for DCC by Boffa Miskell Limited

Project Manager: tanya.blakely@boffamiskell.co.nz | Drawn: BMc | Checked:TBl

Figure 5

Figure 5. Green Island Landfill boundaries and location and naming of constructed waterbodies.

- The Land, Air, Water Aotearoa (LAWA) web database[7], which provides communities with access to up-to-date environmental data from around New Zealand.
- Data from the 10x10 km grid squares of the Ornithological Society of New Zealand's (OSNZ) atlas that encompass the site and immediate surrounds (C. J. R. Robertson et al., 2007).
- Data from appropriate grid squares in the New Zealand Bird Atlas online effort map that shows bird records to date for the data collection process for the new Atlas[8].
- The District Plan[9] and associated Ecological Site information, and relevant websites.

For avifauna, data collected as part of monitoring requirements for the consented Smooth Hill landfill project was also reviewed and relevant aspects were used to inform this assessment, including:

- Seasonal survey data collected for Kaikorai lagoon in May 2021, February 2022, May 2022, August 2023, November 2022 and February 2023. Counts were conducted once per season each year (i.e., once in summer autumn, winter and spring) and involved identifying and counting native species present at different locations along the lagoon.
- Monthly first light count data of black-backed gulls arriving at the landfill conducted between January 2022 and February 2023. During these surveys, the number of black-backed gulls arriving at the landfill at first light were recorded to get an idea of the number of black-backed gulls using the site. The number of red-billed gulls observed at the site were also recorded, as well as incidental observations of other species present.

3.2 Site visits

An initial site visit was undertaken by Boffa Miskell ecologists Drs Tanya Blakely and Tommaso Alestra on Wednesday 11 August 2021, accompanied by Lincoln Coe of DCC, who provided a briefing on the current landfill arrangement and guided them around the landfill site. This site visit did not include any ecological field studies or data collection but provided the opportunity for site familiarisation, including viewing of the working face, the stormwater treatment (sedimentation) ponds, the leachate drainage channels, pump houses, and the adjacent Kaikorai Stream.

This initial site visit was followed up by some specific field investigations and ecological surveys, as outlined in the following sections.

3.2.1 Terrestrial vegetation and habitats for fauna

On 17 October 2022, Dr Jaz Morris conducted a brief site walkover within and surrounding the landfill site to identify vegetation across the site and to view the ponds.

---

[7] https://www.lawa.org.nz/

[8] Atlas Effort Map – New Zealand Bird Atlas (ebird.org). Accessed February 2023.

[9] https://www.dunedin.govt.nz/council/district-plan/2nd-generation-district-plan

3.2.2 Avifauna

Avifauna monitoring has been undertaken at several sites around Dunedin, as part of the Smooth Hill consent conditions.

No specific avifauna surveys were conducted for this assessment. Instead, relevant avifauna survey data collected for the Smooth Hill landfill project was used to inform this assessment (as described above in Section 3.0), together with other information collated from the desktop review.

3.2.3 Aquatic ecology

Dr Tanya Blakely, Jessica Schofield and Kate Hornblow carried out aquatic field sampling on 13 & 14 December 2022.

Existing aquatic ecology values were identified within the landfill site by undertaking field assessments and sampling at four locations in waterways of the immediate receiving environment.

The four sites sampled were at approximately the same locations as GI1, GI2, GI3 and GI5 (i.e., the surface water sites monitored by GHD; Figure 3).

- GI1: Kaikorai Stream, upstream of the landfill.
- GI2: Abbotts Creek, upstream of the landfill.
- GI3: adjacent to the landfill, between pumpstations PS5 and PS4 and approximately adjacent groundwater monitoring Line 4.
- GI5: adjacent to the landfill, between pumpstations PS2 and PS1, immediately downstream of groundwater monitoring Line 1, and approximately adjacent to Western Sedimentation Pond.

3.2.3.1 Water quality

At each site, spot measures of specific conductivity (µS / cm), pH, dissolved oxygen (%), and water temperature (°C) were taken using handheld meters (TPS WP81 and TPS WPS82Y). These parameters were measured immediately before the habitat sampling.

3.2.3.2 Sediment quality

A single composite sample of fine sediments was collected from multiple depositional zones / locations at each of GI1, GI2, GI3 & GI5 survey sites.

Collecting the samples involved collecting sediment from the surface (top 2-3 cm) of the stream bed by scraping along the surface of the waterway bed with a sample container (prepared collection jars were provided by Hills Laboratories). Excess water was drained off the collection sample containers and transferred to a cooler bin before sending (via overnight courier) to Hills Laboratories, an International Accreditation New Zealand (IANZ) laboratory. Hill Laboratories conducted the following analyses (Table 1), all of which are IANZ accredited, except for total organic carbon. All analyses were carried out, separately, for both fine (<63 µm; clay and silt, which are sediment materials most readily resuspended / ingested by organisms) and coarse (<2 mm; sandy sediment grain size).

Table 1. Analyses conducted by Hill Laboratories on sediment samples collected from the five survey sites (GI1, GI2, ECW, GI3, GI5) surveyed in December 2022.

Test	Method description	Reference
Total recoverable arsenic, cadmium, chromium, copper, lead, nickel, zinc	Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	US EPA 200.2
Polycyclic aromatic hydrocarbons (PAHs)	Sonication extraction, GC-MS analysis. Tested on as received sample and as dried sample.	US EPA 8270
Organochlorine Pesticide traces	Sonication extraction, GC-ECD analysis.	US EPA 8081
Total organic carbon	Acid pre-treatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	N/A

3.2.3.3 Riparian and in-stream habitats

Riparian and in-stream habitat was evaluated following standard protocols P1 and P2d (Harding et al., 2009) and the Rapid Habitat Assessment (RHA) tool (Clapcott, 2015).

The RHA involves ranking each of ten parameters between 1 and 10: deposited sediment, macroinvertebrate habitat diversity, macroinvertebrate habitat abundance, fish cover diversity, fish cover abundance, hydraulic heterogeneity, bank erosion, bank vegetation, riparian width, and riparian shade.

Scores for these individual parameters were summed at each site to give a total RHA score ranging from 10 to 100, where higher scores indicate better habitat availability[10].

3.2.3.4 Macroinvertebrate community

Macroinvertebrates (e.g., insects, snails and worms that live on the stream bed) can be extremely abundant in streams and are an important part of aquatic food webs and stream functioning. Macroinvertebrates vary widely in their tolerances to both physical and chemical conditions, and are therefore used regularly in biomonitoring, providing a long-term picture of the health of a waterway.

The macroinvertebrate community was assessed at each site within the same reach where riparian and in-stream habitats were surveyed. The macroinvertebrate community was sampled at each site on the same day that the habitat assessment was conducted (i.e., prior to habitat assessments, but after basic water chemistry and temperature parameters were measured).

Three replicate kick-net (500 µm mesh) samples were collected from each site in accordance with protocols C1 and C2 (Stark et al., 2001). That is, each kick net sampled approximately 0.3 m x 2.0 m of stream bed, including sampling the variety of microhabitats present (e.g., stream margin, mid channel, undercut banks, macrophytes) to maximise the likelihood of collecting all macroinvertebrate taxa present at a site, including rare and habitat-specific taxa.

Macroinvertebrate samples were preserved separately in 70% ethanol prior to sending to Boffa Miskell's independent taxonomy lab, in Tauranga, for identification and counting in accordance with protocol P2 (200 individual fixed count with scan for rare taxa) (Stark et al., 2001),

---

[10] An RHA of 0 indicates poor condition, and 10 indicates optimal condition.

identifying to MCI level, and species level for mayflies, stoneflies and caddisflies (where practical).

3.2.3.4.1 Biotic indices and stream health metrics

GI1 was treated as a hard-bottomed site, while GI2, GI3 and GI5 were all treated as soft-bottomed sites. The following macroinvertebrate metrics were calculated from each kick-net sample, to provide an indication of stream health:

- **Total abundance** – the total number of individuals collected at each site. Macroinvertebrate abundance can be a good indicator of stream health, or ecological condition, because abundance tends to increase in the presence of organic enrichment, particularly for pollution-tolerant taxa (e.g., chironomid midge larvae and oligochaete worms).
- **Taxonomic richness** – the total number of macroinvertebrate taxa collected at each site. Streams supporting high numbers of taxa generally indicate healthy communities, however, the pollution sensitivity / tolerance of each taxon needs to also be considered.
- **%EPT abundance** – the total abundance of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) that belong to the pollution-sensitive EPT orders, relative to the total abundance of all macroinvertebrates, collected at each site. High %EPT richness suggests high water quality.
- **Macroinvertebrate Community Index (MCI)** – this index is based on tolerance scores for individual macroinvertebrate taxa found in hard- or soft-bottomed streams, as appropriate (Stark & Maxted, 2007). These tolerance scores, which indicate a taxon's sensitivity to in-stream environmental conditions, are summed for the taxa present in a sample, and multiplied by 20 to give MCI values ranging from 0-200. Table 2 provides a summary of how MCI scores were used to evaluate stream health.
- **Quantitative Macroinvertebrate Community Index (QMCI)** – this is a variant of the MCI, which instead uses abundance data. The QMCI provides information about the dominance of pollution-sensitive species in hard- or soft-bottomed streams, as appropriate. Table 2 provides a summary of how QMCI scores were used to evaluate stream health.

Table 2. Interpretation of MCI and QMCI scores for hard and soft-bottomed streams (Stark & Maxted, 2007).

Stream health	Water quality descriptions	MCI	QMCI
Excellent	Clean water	>119	>5.99
Good	Doubtful quality or possible mild enrichment	100-119	5.00-5.90
Fair	Probable moderate enrichment	80-99	4.00-4.99
Poor	Probable severe enrichment	<80	<4.00

Note, the MCI and QMCI were developed primarily to assess the health of streams impacted by agricultural activities (e.g., organic enrichment) and should be interpreted with caution in relation to urban systems.

3.2.3.5 Fish community

The fish community was surveyed at three sites (GI1, GI2 and GI3) using a combination of fyke nets and Gee minnow traps. At each site, three fyke nets (baited with tinned cat food) and four Gee minnow traps (baited with marmite) were set within each of the survey reaches late in the afternoon and left overnight. The following morning, all fish captured were identified and measured to the nearest 5 mm before being returned alive to the stream.

Assessments of the fish community were conducted in accordance with Boffa Miskell's research and collection permit from the Department of Conservation (pursuant to section 26ZR of the Conservation Act 1987) and a Special Permit from the Ministry for Primary Industry (pursuant to section 97(1) of the Fisheries Act 1996.

3.3 Assessing ecological significance

Section 6(c) of the RMA requires identification of sites of significant indigenous vegetation and significant habitats of indigenous fauna.

Kaikorai Lagoon is listed as an Area of Significant Biodiversity Value (ASBV) in the DCC 2GP[11]; it is described as of regional significance, with mudflat, saltmarsh, reed swamp, and succulent herb swamp. Kaikorai Lagoon is also listed as a regionally significant wetland by ORC in the Water Plan[12].

There are small areas of overlap between the existing mapped extent of the ASBV and the landfill Designation at the north-eastern edge of the designation and the southwestern corner of the designation. However, the footprint of proposed continued landfilling does not overlap with these areas[13].

There are also constructed waterbodies within and outside the landfill Designation. While these may provide habitats for fauna, we have not assessed the ecological significance of these as they are wholly constructed. The sedimentation ponds are used for managing landfill effects. We describe these constructed waterbodies below, but they are not considered further in the ecological effects assessment.

3.3.1 Constructed waterbodies

Within the landfill Designation there are a number of wholly constructed waterbodies (sedimentation ponds and constructed wetlands). The sedimentation ponds were designed to collect and manage stormwater from the site (Figure 5). In most cases these have sparsely vegetated margins and / or margins of exotic vegetation (e.g., exotic grasses) only. We note that neither the ponds themselves nor any wetland vegetation that has developed or been planted on their margins can be considered a 'natural inland wetland' as they are excluded by Section 3.21 (exclusion c, of the National Policy Statement-Freshwater Management (NPS-FM) (Amended 2022).

3.3.1.1 Eastern Sedimentation Pond

The Eastern Sedimentation Pond has grassy / sparsely vegetated margins, and primarily receives stormwater runoff. A small area between the sediment pond and the access road has

---

[11] Site 106 'Edge of Kaikorai Estuary, Estuary and Lagoon'.

[12] ORC Water Plan 2022. Section F: Regionally Significant Wetlands. Map F57 Kaikorai Lagoon Swamp, Braeside Swamp, Otokia Swamp. https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-policies/water

[13] However, it is worth noting that the landfill was established on what was once mudflats (Beca Stevens, 1992).

had high-quality plantings of native trees and wetland plant species. However, the overall eastern sedimentation pond area is unlikely to provide important habitat for indigenous fauna, although no surveys have been carried out to confirm this.

3.3.1.2 Eastern Constructed Wetland

The Eastern Constructed Wetland is located immediately adjacent (east of) the Eastern Sedimentation Pond. Design drawings from 1993[14] show that it was constructed to convey the catchment waters from above the landfill to Kaikorai Stream. In doing so they receive clean runoff from some landfill surfaces, sediment pond overflow as well as other industrial, residential and rural run-off. The Eastern Constructed Wetland connects, via a culvert under the access road, to Kaikorai Stream. This constructed wetland pond is surrounded by planted indigenous vegetation including pūrei, kōhūhū, and harakeke, and likely provides some habitat for freshwater fauna, and several native and exotic waterfowl species.

3.3.1.3 South-Eastern Constructed Wetlands

A series of ponds described as the South-eastern Constructed Wetlands, located in the south-east of the landfill Designation and of the existing working landfill were constructed in recent decades on an area of former farmland.

These constructed pond areas are surrounded by areas of indigenous plantings, self-established willow trees and occasional weeds. These waterbodies likely provide good habitat for freshwater fauna, native and exotic waterfowl (small numbers of royal spoonbill, an At Risk – Naturally Uncommon species, have been observed at the ponds (L. Coe, *pers. comms*. 2021).

There is a culvert located on the eastern side of the landfill between the south eastern constructed wetlands and the eastern constructed wetlands which has recently been identified as a pathway for leachate seepage, confirmed from water quality monitoring and a culvert inspection (GHD, 2024b); remedial measures have been proposed (GHD, 2024b).

3.3.1.4 Western Sedimentation Pond

The Western Sedimentation Pond has grassy / sparsely vegetated margins and was designed to receive sediment laden stormwater runoff from the landfill. However, the western and southern catchments (from the landfill) are currently precautionarily treated as leachate catchments and all water is directed to Pump Station 1 (PS1). The western sedimentation pond does not, therefore, receive water from the landfill nor does it discharge to Kaikorai Stream or Lagoon, at present.

3.3.1.5 South-Western Pond

The South-western Pond is adjacent to the Western Sedimentation Pond and Kaikorai Lagoon. The pond is surrounded predominantly by exotic tall fescue grass and provides habitat for waterfowl breeding and feeding. It sits outside of the landfill Designation, does not form part of the receiving catchment from the landfill, and has not been considered further.

---

[14] City Consultants Engineers and Surveyors. Green Island Drainage Basin Kaikorai Stream Realignment – Site Plan. Drawing No. 5520/219/3.

3.4 Assessing ecological value and effects

This ecological impact assessment follows the Environment Institute of Australia and New Zealand's (EIANZ) Ecological Impact Assessment (EcIA) guidelines (Roper-Lindsay et al., 2018).

In summary, the EcIA method requires **ecological values** to be assigned, assessed within the zone of influence, (Table 3 to Table 5) and the **magnitude of effects** identified (Table 6) in order to determine the overall **level of effect** of the proposal (Table 7).

The EIANZ guidelines (Roper-Lindsay et al., 2018) note that the level of effect can then be used as a guide to the extent and nature of the ecological management response required (including the need for biodiversity offsetting). For example:

- **'Very high'** represents a level of effect that is unlikely to be acceptable on ecological grounds alone (even with compensation proposals). Activities having very high adverse effects should be avoided.
- **'High' and 'Moderate'** represents a level of effect that requires careful assessment and analysis of the individual case. Such an effect could be managed through avoidance, design, or extensive offset or compensation actions.
- **'Low'** and **'Very low'** should not normally be of concern, although normal design, construction, and operational care should be exercised to minimise adverse effects. If effects are assessed taking impact management measures developed during project shaping into consideration, then it is essential that prescribed impact management is carried out to ensure low or very low-level effects.
- **'Very low'** level effects can generally be classed as 'not more than minor' effects.

When assigning ecological value to species, we used the following threat classifications:

- Plants: de Lange et al. (2018)
- Birds: Robertson et al. (2021)
- Freshwater fish: Dunn et al. (2018)

When assigning magnitude of effect, we used the criteria and descriptions from Roper-Lindsay et al., (2018) (as shown in Table 6). We assessed the magnitude of effect for each component of ecology at the following scales:

- Vegetation and habitats: the ecological district.
- Freshwater: the catchment.
- Avifauna: the ecological district.

Table 3. Matters to be considered when assigning ecological value or importance to terrestrial vegetation / habitats / communities, or a freshwater site or area. From Roper-Lindsay et al., 2018.

MATTERS	ATTRIBUTES TO BE CONSIDERED - TERRESTRIAL	ATTRIBUTES TO BE CONSIDERED - FRESHWATER
Representativeness	Criteria for representative vegetation and aquatic habitats: - Typical structure and composition - Indigenous species dominate - Expected species and tiers are present - Thresholds may need to be lowered where all examples of a type are strongly modified Criteria for representative species and species assemblages: - Species assemblages that are typical of the habitat - Indigenous species that occur in most of the guilds expected for the habitat type	- Extent to which site / catchment is typical or characteristic - Stream order - Permanent, intermittent, or ephemeral waterway - Catchment size - Standing water characteristics
Rarity/distinctiveness	Criteria for rare/distinctive vegetation and habitats: - Naturally uncommon, or induced scarcity - Amount of habitat or vegetation remaining - Distinctive ecological features - National priority for protection Criteria for rare/distinctive species or species assemblages: - Habitat supporting nationally Threatened or At Risk species, or locally uncommon species - Regional or national distribution limits of species or communities - Unusual species or assemblages - Endemism	- Supporting nationally or locally (within relevant Ecological District) Threatened, At Risk or uncommon species - National distribution limits - Endemism - Distinctive ecological features - Type of lake / pond / wetland / spring
Diversity and pattern	- Level of natural diversity, abundance and distribution - Biodiversity reflecting underlying diversity - Biogeographical considerations – pattern, complexity - Temporal considerations, considerations of lifecycles, daily or seasonal cycles of habitat availability and utilisation	- Level of natural diversity - Diversity metrics - Complexity of community - Biogeographical considerations – pattern, complexity, size, shape
Ecological context	- Site history, and local environmental conditions which have influenced the development of habitats and communities - The essential characteristics that determine an ecosystem's integrity, form, functioning, and resilience (from "intrinsic value" as defined in RMA) - Size, shape and buffering - Condition and sensitivity to change - Contribution of the site to ecological networks, linkages, pathways and the protection and exchange of genetic material - Species role in ecosystem functioning – high level, key species identification, habitat as proxy	- Stream order - Instream habitat - Riparian habitat - Local environmental conditions and influences, site history and development - Intactness, health and resilience of populations and communities - Contribution to ecological networks, linkages, pathways - Role in ecosystem functioning – high level, proxies

Table 4. Scoring for sites or areas combining values for four matters in Table 3. From Roper-Lindsay et al., (2018)

VALUE	DESCRIPTION
Very High	Area rates High for 3 or all of the four assessment matters listed in Table 3. Likely to be nationally important and recognised as such.
High	Area rates High for 2 of the assessment matters, Moderate and Low for the remainder; or Area rates High for 1 of the assessment maters, Moderate for the remainder. Likely to be regionally important and recognised as such.
Moderate	Area rates High for one matter, Moderate and Low for the remainder; or Area rates Moderate for 2 or more assessment matters Low or Very Low for the remainder. Likely to be important at the level of the Ecological District.
Low	Area rates Low or Very Low for majority of assessment matters and Moderate for one. Limited ecological value other than as local habitat for tolerant native species.
Very Low / Negligible	Area rates Very Low for 3 matters and Moderate, Low or Very Low for remainder.

Table 5. Assigning ecological value to species. From Roper-Lindsay et al., (2018).

VALUE	SPECIES
Very High	*Nationally Threatened* (Nationally Critical, Nationally Endangered, Nationally Vulnerable, Nationally Increasing[15]) species found in the ZOI[16] either permanently or seasonally.
High	Species listed as *At Risk – Declining* found in the ZOI either permanently or seasonally.
Moderate	Species listed as any other category of *At Risk* (Recovering, Relict, Naturally Uncommon) found in the ZOI either permanently or seasonally; or Locally (ED) uncommon or distinctive species.
Low	Nationally and locally common indigenous species.
Very Low / Negligible	Exotic species, including pests, species having recreational value.

---

[15] Nationally Increasing is category that was devised by DOC (Michel, 2021) in 2021 to resolve a problem that would arise if the population of a taxon assessed as At Risk Recovering A should stabilise. Threatened – Nationally Increasing is assigned to “Small population that has experienced a previous decline (or for which it is uncertain whether it has experienced a previous decline) and that is forecast to increase >10% over the next 10 years or 3 generations, whichever is longer” (Rolfe et al. 2021). Thus, while such a threat category is not identified in Roper-Lindsay et al. (2018), we have included it along with all other *Threatened* classifications in to the Very High ecological value category.

[16] Roper-Lindsay et al. (2018) define the Zone of Influence (ZOI) as “*the areas/resources that may be affected by the biophysical changes caused by the proposed project and associated activities.”*

Table 6. Criteria for describing magnitude of effect. From Roper-Lindsay et al., (2018).

MAGNITUDE	DESCRIPTION
Very High	Total loss of, or very major alteration, to key elements/ features of the baseline conditions such that the post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether; AND/OR ***Loss of a very high proportion of the known population or range of the element / feature***.
High	Major loss or major alteration to key elements/ features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed; AND/OR ***Loss of a high proportion of the known population or range of the element / feature.***
Moderate	Loss or alteration to one or more key elements/features of the existing baseline conditions, such that post-development character, composition and/or attributes will be partially changed; AND/OR ***Loss of a moderate proportion of the known population or range of the element / feature.***
Low	Minor shift away from baseline conditions. Change arising from the loss/alteration will be discernible, but underlying character, composition and/or attributes of the existing baseline condition will be similar to pre-development circumstances/patterns; AND/OR ***Having a minor effect on the known population or range of the element / feature.***
Negligible	Very slight change from existing baseline condition. Change barely distinguishable, approximating to the "no change" situation; AND/OR ***Having a negligible effect on the known population or range of the element / feature.***

Table 7. Matrix of level of effect modified from Roper-Lindsay et al., (2018).

LEVEL OF EFFECT		Ecological &/or Conservation Value				
		Very High	**High**	**Moderate**	**Low**	**Very Low / Negligible**
Magnitude	**Very High**	Very High	Very High	Very High	Moderate	Low
	High	Very High	Very High	Moderate	Low	Very Low
	Moderate	High	High	Moderate	Low	Very Low
	Low	Moderate	Low	Low	Very Low	Very Low
	Very Low / Negligible	Low	Very Low	Very Low	Very Low	Very Low
	Positive	Net gain	Net gain	Net gain	Net gain	Net gain

4.0 Ecotoxicology

In addition to the ecological desktop and field assessments described above, an ecotoxicology study was carried out by the Cawthron Institute, to assess the toxicity of environmental samples collected from surface and groundwater sites associated with the landfill. The Cawthron Institute deployed passive sample devices (PSD), which accumulate organic chemicals that are partitioned in the water column, at surface water sites: GI1, GI2, GI5 and Kaikorai Lagoon (downstream at Brighton Road Bridge) and at groundwater wells: Line 4C, 4D, 2C and 2D, to collect contaminants from the surface water and groundwater. Cawthron Institute extracted the organic contaminants from these PSDs, and carried out three test models on these, using bioassays in: 1) an algal species; 2) a bacterial species; and 3) blue mussels to provide an assessment of general toxicity of environmental samples collected.

Refer to Appendix 1 for the reports detailing this work.

5.0 Existing environment

5.1 Ecological context and land use history

Kaikorai Valley, including the landfill, is part of the Dunedin Ecological District (ED) in the Otago Coast Ecological Region. The original vegetation of the Dunedin ED included mixed podocarp hardwood forest, with mataī, tōtara, rimu, māhoe and narrow-leaved houhere dominant on coastal hills. Extensive saltmarshes, of which some large remnants are of national importance, are also historic features of the ED (McEwen, 1987).

Prior to European settlement, the Kaikorai Stream catchment would have supported large wetland areas surrounding several defined streams, with hillslopes and elevated areas supporting mixed podocarp hardwood forest. In the lower catchment, freshwater wetland and forest areas would have graded to intertidal / saltmarsh areas. The area occupied by the currently active landfill site was until the late 1960s / early 1970s part of the intertidal saltmarsh area. The site has been progressively drained, filled, and capped since that time.

Deforestation within the catchment began in the 1860s and farming became a dominant land use. The lagoon was also drained, and parts reclaimed for farmland, a golf course, and landfills. There have also been several major industries in the Kaikorai Stream catchment, including a freezing works, cement factory, fertiliser works, steel yards, woollen mills, used oil refinery, and a tannery. These industries disposed wastes directly to the stream and continued to do so until the 1970s (Beca Stevens, 1992).

5.2 The site today

The landfill is located southwest of the suburb of Green Island and approximately 10 kilometres from central Dunedin. It is situated within a landscape of undulating coastal hills and basins and occupies a large portion of what was once part of the Kaikorai Lagoon.

This lagoon is fed by four streams, with the main ones being Abbotts Creek and Kaikorai Stream. Abbotts Creek is a shorter stream, relative to Kaikorai Stream, draining farmland and commercial urban land to the north of the landfill. Kaikorai Stream is a larger waterway, with its catchment extending up into Kaikorai Valley in the hills to the west of Dunedin.

Surface water quality in the Kaikorai Stream catchment has been impacted by past and current land use practices, which include heavy industrial, landfilling, quarrying, and agricultural activities. This long history of heavy industrial activities and the urbanised nature of the catchment, since early to middle of last century, has had a substantial impact on water and sediment quality in the catchment.

The Green Island designation adjoins the Dunedin Southern Motorway to the north and Kaikorai Stream and Lagoon to the west. The GIWWTP is located south of the landfill.

As described in Section 2.2, the landfill is bounded along the north and western edges by a leachate collection trench over a linear distance of 1.7 km, separating the landfill from Kaikorai Stream. The leachate trench was built in 1994 and commissioned in 1995.

There are nine pump stations located along the leachate collection trench to allow for the leachate to be collected and discharged to the Green Island WWTP. There is also an array of monitoring wells to monitor the effectiveness of the leachate collection.

Habitats immediately surrounding the current working landfill extent, but within the landfill Designation (Figure 5) include:

- Wider landfill site: infrastructure (buildings, access roads, compost processing), shelterbelts and previously filled and capped areas of landfill (to the northeast and east); and
- Constructed waterbodies: Eastern Sedimentation Pond, Eastern Constructed Wetland, South-eastern Constructed Wetlands, Western Sedimentation Pond, Southwestern Pond (see Section 3.3.1).

The aquatic habitats of Abbotts Creek, Kaikorai Stream and Kaikorai Lagoon form the receiving environment outside of the landfill designation.

5.3 Terrestrial vegetation and habitats for fauna

Surfaces within the existing working landfill extent are highly modified and do not support ecologically important indigenous vegetation or habitats for indigenous fauna (except for black-backed gulls and red-billed gulls; further discussed in Section 5.4).

Where vegetation occurs on recently worked areas of the landfill, it comprises exotic grassland and weedy exotic herbs and shrubs (e.g., gorse, scotch broom). Sparse indigenous plant species (common early successional species e.g., fireweed) that have self-established may be present.

Immediately surrounding the current working landfill, to the southeast within the broader landfill Designation, areas of indigenous vegetation (e.g., toetoe, pūrei, kōhūhū, and other indigenous species) have been deliberately planted on bunds and some previously filled and capped areas of the landfill (Appendix 3: Figure 24). These planted areas, along with the shelterbelts planted around the landfill site and rank exotic grass and gorse scrub, provide habitat for native and exotic bird species and may also provide poor-quality habitat for indigenous lizards. However, we note that the landfill and surrounding residential and commercial areas may support a reasonably large population of predators (e.g., rodents), which may be attracted by waste and because of the history of extensive land-use modification in the wider area. A large predator population may also limit lizard presence and population sizes.

5.4 Avifauna

Habitats available for avifauna assemblages at the project site and immediate surrounds include the landfill itself and associated infrastructure, areas of planted indigenous vegetation on previously filled and capped areas of the landfill, shelterbelts, rank exotic grass, weedy exotic herbs and shrubs, constructed ponds and wetlands, and Kaikorai Stream and Lagoon.

The broad desktop review provided a base list of 68 bird species (Appendix 2) that have been recorded in the 10x10 km OSNZ squares that encompass the project site, in the data currently being collated for an updated version of the Bird Atlas that overlaps the site and from data collected for the Smooth Hill Landfill project. These data include habitats, and species, not present within the landfill project site and immediate surrounds. As such, by excluding species with primary habitats that are not present within the project site and surrounds, excluding species that are likely to be rare visitors to the site, and / or excluding exotic species, the base list was filtered to 32 (of 63) key species. These 32 species use or may potentially use, the landfill site and immediate surrounds; 14 of these 32 species were recorded during surveys conducted at Kaikorai Lagoon and the landfill for the Smooth Hill Landfill project (Table 8).

Of the 32 species, three are classified as nationally Threatened (black-fronted tern, Otago shag and Caspian tern), 12 as At Risk (white-fronted tern, black-billed gull, New Zealand pied oystercatcher, red-billed gull, New Zealand pipit, eastern bar-tailed godwit, banded dotterel, little shag, variable oystercatcher, pied shag, black shag and royal spoonbill) and 17 classified as Not Threatened (Table 8).

All three Threatened species and the majority of the 12 At-Risk species listed, do not use the landfill site itself, but instead use Kaikorai Lagoon (the downstream receiving environment of the landfill), primarily as part of their foraging habitat network in the wider area. The lagoon hosts large numbers of birds and is an important feeding and breeding ground for a wide range of coastal, oceanic and wetland bird species, including gulls, terns, swans, ducks, shags, stilts and oystercatchers (Miller, 1993; Otago Regional Council, 2021).

Excluding Kaikorai Lagoon, At-Risk species recorded at the site itself and surrounds include New Zealand pipit (grassland / shrub areas), royal spoonbill (ponds), shags (waterways) and red-billed gulls (roosting on infrastructure).

Of note is that up to 9000 black-backed gulls (Not Threatened) have been observed using the landfill site itself, primarily as foraging habitat. The black-backed gulls commute to and from the landfill site daily from colonies or roosting grounds, and it appears that the active landfill is a main food source for these birds. Black-backed gulls have also nested on the site, and they regularly fly between Kaikorai Lagoon and the landfill during the day. Black-backed gulls are native to New Zealand but are not protected under the Wildlife Act 1953. At times colony control and other management methods are implemented by DOC to control their numbers; such control is required at the landfill prior to closure as part of the Smooth Hill landfill project consent conditions.

Table 8. Avifauna species with primary habitat within the project site and immediate surrounds. Data from the eBird Atlas squares DY31 & 32 and species noted during surveys conducted in 2022 and 2023 for the Smooth Hill landfill project. The dark green cells indicate the primary habitat used by each species and the light green cells represent secondary habitat/s used by the species.

SPECIES Common and scientific names		**CONSERVATION STATUS – Robertson et al. 2021**	**HABITAT**								**SOURCE**	
			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	eBird (DY31, DY32)	Observed during 2022/2023 surveys for Smooth Hill Landfill project
White-fronted tern	*Sterna s. striata*	**At Risk - Declining**						🟩			x	
Little shag	*Phalacrocorax melanoleucos brevirostris*	**At Risk - Relict**					🟩	▨			x	
Welcome swallow	*Hirundo n. neoxena*	Not Threatened				🟩	▒				x	
Black-billed gull	*Larus bulleri*	**At Risk - Declining**				▨	🟩	▨			x	
Silvereye	*Zosterops lateralis lateralis*	Not Threatened	▨	▨	🟩					▨	x	x
Otago shag	Leucocarbo chalconotus	**Threatened - Increasing**									x	
Variable oystercatcher	*Haematopus unicolor*	**At Risk - Recovering**				▨	▨	🟩			x	x
Pied shag	*Phalacrocorax varius varius*	**At Risk - Recovering**					🟩	▨			x	
NZ pied oystercatcher	*Haematopus finschi*	**At Risk - Declining**				▨	🟩	▨			x	
Royal spoonbill	*Platalea regia*	**At Risk – Naturally Uncommon**					▨	🟩			x	x
Black shag	*Phalacrocorax carbo novaehollandiae*	**At Risk - Relict**					🟩	▨			x	x
Black-backed gull	*Larus d. dominicanus*	Not Threatened				▨		🟩			x	x
Red-billed gull	*Larus novaehollandiae scopulinus*	**At Risk - Declining**				▨	▨	🟩			x	x
White-faced heron	*Egretta novaehollandiae*	Not Threatened				▨	▨	🟩			x	
South Island fantail	*Rhipidura f. fuliginosa*	Not Threatened	🟩	▨	▨					▨	x	x
Spur-winged plover	*Vanellus miles novaehollandiae*	Not Threatened				🟩	▨				x	

SPECIES Common and scientific names		**CONSERVATION STATUS – Robertson et al. 2021**	**HABITAT**								**SOURCE**	
			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	eBird (DY31, DY32)	Observed during 2022/2023 surveys for Smooth Hill Landfill project
Kingfisher	*Todiramphus sanctus vagans*	Not Threatened	■		▨	▨	■				x	
Pied stilt	*Himantopus h. leucocephalus*	Not Threatened				▨	■	▨			x	x
Paradise shelduck	*Tadorna variegata*	Not Threatened				▨	■				x	x
Morepork	*Ninox n. novaeseelandiae*	Not Threatened	■	▨	▨	▨					x	
Grey teal	*Anas gracilis*	Not Threatened				▨	■	▨			x	
Black-fronted tern	*Chlidonias albostriatus*	**Threatened – Nationally Endangered**					■	▨			x	
Pukeko	*Porphyrio m. melanotus*	Not Threatened				▨	■				x	x
Grey warbler	*Gerygone igata*	Not Threatened	▨	▨	■					▨	x	x
Black swan	*Cygnus atratus*	Not Threatened				▨	■	▨			x	x
Bellbird	*Anthornis m. melanura*	Not Threatened	■	▨	▨					▨	x	x
Tui	*Prosthemadera n. novaeseelandiae*	Not Threatened	■	▨	▨					▨	x	x
Australian shoveler	*Anas rhynchotis*	Not Threatened					■	▨			x	
Caspian tern	*Hydroprogne caspia*	**Threatened – Nationally Vulnerable**					▨	■			x	
NZ pipit	*Anthus n. novaeseelandiae*	**At Risk - Declining**				■	▨	▨			x	
Eastern bar-tailed godwit	*Limosa lapponica baueri*	**At Risk - Declining**						■			x	
Banded dotterel	*Charadrius bicinctus bicinctus*	**At Risk - Declining**					▨	■			x	

5.5 Aquatic ecology

The following sections summarise existing information about the aquatic habitats of the receiving environment, then provide descriptions of the ecological conditions at the four survey sites. As discussed in Section 5.2, the landfill occupies what was once part of the Kaikorai Lagoon. Kaikorai Lagoon is fed by four streams, with the main ones being Abbotts Creek and Kaikorai Stream.

The margins of Kaikorai Stream bordering the landfill to the north and west are identified as a Regionally Significant Wetland in the Regional Plan: Water[17], and an Area of Significant Biodiversity Value and a Wāhi Tupuna of cultural significance to mana whenua in the 2GP[18].

5.5.1 Kaikorai Stream

Kaikorai Stream drains a catchment of c.50 km^2, extending up into Kaikorai Valley in the hills to the west of Dunedin. The stream flows through a variety of land uses, including agriculture, industry, and residential housing. The land cover in the catchment is mainly exotic grassland with some mānuka and kānuka (Otago Regional Council, 2008). The Kaikorai Valley, adjacent to Kaikorai Stream, has a long history of heavy industrialisation dating back over 100 years. Untreated discharges from industries such as freezing works, cement factories, fertilizer works, steel yards, woollen mills, oil refineries and tanneries were directed into the Kaikorai Stream until at least the 1970s (Beca Stevens, 1992). Today, Kaikorai Stream still receives discharges from a multitude of stormwater outfalls and monitoring results show that water quality is degraded (GHD, 2024b; LAWA, n.d.; Otago Regional Council, 2008). Most of the pollutants that enter Kaikorai Stream are likely to reach Kaikorai Lagoon (Beca Stevens, 1992). Fraser’s Stream is a major tributary of Kaikorai Stream, which receives discharges from the Mt Grand Water Treatment Plant. Discharges from this water treatment plant occur only when the reservoir of the treatment plant is full and significantly improve water quality in Kaikorai Stream (Otago Regional Council, 2008).

The macroinvertebrate health in Kaikorai Stream is poor, reflecting poor water quality (Otago Regional Council, 2008; LAWA, n.d.). Historic fish records (1989) from Kaikorai Stream in the NZFFD (accessed August 2020) include īnanga and longfin eel (both At Risk - Declining species), black flounder, common bully, and redfin bully (Not Threatened species; Dunn et al., 2018). More recent records (2007) include upland bully, shortfin eel (both Not Threatened), and Kēkēwai / freshwater crayfish (At Risk – Declining) was found in 2007, and kanakana / lamprey (Threatened - Nationally Vulnerable) in 2008. The introduced species brown trout is also present in Kaikorai Stream.

5.5.2 Abbotts Creek

Abbotts Creek is a tributary of Kaikorai Stream, draining farmland and commercial urban land to the north of the landfill. The Fairfield Quarry is within the upstream catchment of Abbotts Creek. Land-use upstream of the quarry is predominantly farmland, residential properties, and

---

[17] https://www.orc.govt.nz/managing-our-environment/water/wetlands-and-estuaries/dunedin-district/kaikorai-lagoon-swamp

[18] http://dunedin.maps.arcgis.com/apps/webappviewer/index.html?id=f7fc69e07dba4db589ffe2ddcac4acc7

fragmented forested areas. Much of the forested area in the upstream catchment is classified by ORC[19] as broadleaved species scrub / forest or kahikatea, tōtara, mātai forest.

Abbotts Creek also has poor water quality and has historically recorded low dissolved oxygen levels (Otago Regional Council, 2008). Historic fish records show īnanga, common bully, and banded kōkopu were recorded in Abbotts Creek in 1999.

5.5.3 Kaikorai Lagoon

As a moderately large coastal wetland / lagoon, Kaikorai Lagoon is of ecological importance and is a naturally uncommon ecosystem (Williams et al., 2007). The estuary as a whole has an area of approximately 0.64 km^2 and a tidal range of 1.7 m (NIWA, 2016).

Kaikorai Lagoon is listed as an Area of Significant Conservation Value in the DCC 2GP[20] where it is described as being of regional significance, with mudflat, saltmarsh, reed swamp, and succulent herb swamp. It is also listed as a regionally significant wetland by ORC[21] (Figure 5). There are small areas of overlap between ORC's existing mapped extent of the significant wetland and the designated landfill extent at the north-eastern edge of the designation, inclusive of the Eastern Sedimentation Pond and Eastern Constructed Wetland. However, the footprint of proposed continued landfilling does not overlap with this area[22].

The indigenous vegetation of the lagoon is largely saltmarsh ribbonwood, pūrei and oioi rush. However, much of the former indigenous vegetation such as the succulent herb swamp has been replaced by weedy exotic species, particularly cocksfoot, gorse and crack willow. Freshwater-influenced swamp areas border the brackish mudflats in some places; swamps are historically reduced in the wider area, and less than 15% of original swamps remain in the Otago Region (Ausseil et al., 2008) making the presence of the swamp more important.

The lagoon is shallow (0.5 m - 2 m deep) and is frequently cut off from the Pacific Ocean by the periodic formation of a sandbar at its mouth. This results in reduced tidal flushing and large fluctuations in salinity and water oxygenation. Reduced water oxygenation is known to cause hypoxic (low oxygen) events in the lagoon (Larkin, 2006).

Information about benthic invertebrate and fish communities in the lagoon is limited. Benthic invertebrates living on or in proximity of the lagoon bed include a mix of marine and freshwater species, with species composition shifting depending on whether the lagoon is isolated from or connected to the ocean. Large numbers of benthic invertebrates are flushed out of the lagoon during breaching events, which also expose the benthic communities to large fluctuations in salinity and significant habitat loss (Lill et al., 2012). Fish diversity is considered low and the main fish species inhabiting the lagoon are common bully, estuarine triplefin, smelt, flounder, eels, whitebait (possibly īnanga) and trout (Beca Stevens, 1992; Taddese et al., 2018). A recent fish kill event (affecting smelt, flounder, giant bully, trout and whitebait) in February 2021 may have been linked to warm water temperatures and hypoxic conditions; opening of the lagoon mouth was not considered a cause[23].

---

[19] ORC Otago Ecosystems and Habitat Mapping GIS Layer https://maps.orc.govt.nz/OtagoViewer232/?map=f11442f65b1b454ba3f3ade3e8a4ade8#

[20] Site 106 'Edge of Kaikorai Estuary, Estuary and Lagoon'.

[21] ORC Water Plan 2022. Section F: Regionally Significant Wetlands. Map F57Kaikorai Lagoon Swamp, Braeside Swamp, Otokia Swamp. https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-policies/water

[22] However, it is worth noting that the landfill was established on what was once mudflats (BECA Stevens, 1992).

[23] https://www.orc.govt.nz/media/9667/ryderenv-orc-kaikorai-lagoon-memo.pdf

The lagoon hosts large numbers of birds and is an important feeding and breeding ground for a wide range of coastal, oceanic and wetland bird species, including gulls, terns, swans, ducks, shags, stilts and oystercatchers (Miller, 1993; Otago Regional Council, 2021). Historic records from the lagoon include threatened species such as Australasian bittern and banded dotterel. The lagoon is close to the landfill and it is highly likely that birds interchange between these sites (Boffa Miskell Ltd & Avisure, 2021).

5.5.4 Aquatic ecology site descriptions

The following information provides a summary of the findings from the December 2022 surveys, and any additional information found during the desktop review.

Refer to Appendix 3 for images of the survey sites.

5.5.4.1 GI1: Kaikorai Stream, upstream of the landfill

GI1, Kaikorai Stream upstream of the landfill, is located approx. 460 m upstream of the landfill operational boundary and 9 km downstream of the headwaters near the Kaikorai Hill and Mount Grand Road. Here, the stream is within an urban and industrial area. On the day of sampling, the water appeared clear, slightly discoloured from possible tannins.

The average water depth across the survey reach was 0.24 m with a wetted channel width of approximately 6.2 m. The site is dominated by run habitat and a small riffle section. Stream bed substrates were comprised of 60% silt / sand, 15% large cobbles, 10% small cobbles, 9% gravels, 5% pebbles, and 1% boulders. Of these, around 65% of substrates were embedded and c.75% compacted. Embeddedness and compactness are measures of the degree to which larger substrates are surrounded by fine particles and, therefore, are an indication of the clogging of interstitial spaces. Greater levels of embeddedness and compactness reduce the habitat quality and availability for freshwater flora and fauna (e.g., macroinvertebrates), therefore reducing overall stream health and resilience.

The riparian area provides partial shading. The true left bank has an upper bank height of 0.6 m and was dominated by exotic mature canopy trees with exotic grasses below. Beyond the immediate riparian margin, the area is short (maintained) grass in the dog exercise area. The true right riparian area has an upper bank height of around 2 m, which is steep, retained by brick and stone and the channel appears straightened. There was some exotic rank grass and shrubs beyond the retained wall, but otherwise the area is a fenced industrial area.

The RHA score was 42 out of a possible 100 (Table 9), which was predominantly influenced by the minimal bank erosion and relatively heterogeneous in-stream habitats (boulders, cobbles, gravels) for invertebrates and fish. However, the abundance of invertebrate and fish habitats scored lower due to influences from the urban and modified catchment, sediment coverage in the stream, and embedded and compacted substrates.

Table 9: General habitat conditions, based on the Rapid Habitat Assessment, at GI1, upstream Kaikorai Stream.

Habitat parameter	Description	Score
Deposited sediment	Deposits of fine sediment spread between hard bottomed cobbles/gravels, large sections of deposited sediment near stream edges in slow-flow edge areas.	3/10
Invertebrate habitat diversity	Multiple notable substrate types considered invertebrate habitat, including cobbles, gravel, sand, and periphyton. No interstitial spaces present.	7/10
Invertebrate habitat abundance	Approximately 25% of the visible substrate was favourable for EPT colonisation, including an absence of macrophytes and filamentous algae.	3/10
Fish cover diversity	Substrate types which may be utilised as fish cover included cobbles, undercut banks, and overhanging/encroaching vegetation, with substrates providing some spatial complexity.	6/10
Fish cover abundance	Approximately 30% of the active river channel provided fish cover opportunities.	5/10
Hydraulic heterogeneity	Hydraulic components included riffles and fast runs.	3/10
Bank erosion	Minimal erosion. On both sides of the stream around 5% of the riverbank was exhibiting signs of recent / active erosion at the water line.	8/10
Bank vegetation	The riparian margin includes mature exotic trees with exotic grass below on true left, true right is limited to a few shrubs and rank exotic grass on a steep slope.	4/10
Riparian width	The riparian width which is constrained by vegetation is approximately 5 m wide on average on the true left, and approximately 3 m on the true right.	4/10
Riparian shade	Typically, 10% of the river channel is shaded from the riparian margin (including vegetation, banks, or other structures).	2/10
Total score		**42/100**

5.5.4.2 GI2: Abbotts Creek, upstream of the landfill

GI2, within Abbotts Creek upstream of the landfill, is located approx. 600 m upstream of the landfill and 4 km downstream of the headwaters. Here, the stream is within an urban area with Sunnyvale Park along the true left of the creek.

Average water depth across the reach was 0.30 m with a wetted channel width of approximately 4.8 m, with a weakly sinuous channel shape comprising of only run habitat. There was a large sediment accumulation of approximately 0.6 m depth within the reach. Stream bed substrate was comprised of entirely silt / sand and mud.

The riparian area provides partial shading. The true left has a shallow upper bank height of approximately 0.35 m and was dominated by exotic mature canopy with native plantings and exotic grasses below, beyond which is a large mown park. The true right riparian area has an upper bank height of around 0.65 m, dominated by exotic rank grass, shrubs, and occasional mature trees beyond which is an unmanaged area of rank grass. Species observed within the riparian area include eucalyptus, harakeke / flax, pines, willow, gorse, and the aquatic macrophyte *Ranunculus*. There were some native plantings along the true left bank under willows.

The RHA score was 41 out of a possible 100 (Table 10) with highest scoring components the minimal erosion (largely because of the shallow bank slope), reasonable size of the riparian buffer width, and lowest scoring components the large percentage of deposited sediment and very low hydraulic heterogeneity.

Table 10: General habitat conditions, based on the Rapid Habitat Assessment, at GI2, upstream Abbotts Creek.

Habitat parameter	Description	Score
Deposited sediment	Stream bed entirely covered by fine sediment (90%+).	1/10
Invertebrate habitat diversity	Some substrate types considered invertebrate habitat, including wood, leaves, and macrophytes. No interstitial spaces present.	4/10
Invertebrate habitat abundance	Approximately 15% of the visible substrate was favourable for EPT colonisation.	2/10
Fish cover diversity	Limited diversity. Substrate types which may be utilised as fish cover included woody debris, root mats, and overhanging/encroaching vegetation.	3/10
Fish cover abundance	Limited. Approximately 10% of the active river channel provided fish cover opportunities.	3/10
Hydraulic heterogeneity	Hydraulic components slow run habitat only.	1/10
Bank erosion	Minimal erosion. On both sides of the stream around 5% of the riverbank was exhibiting signs of recent/active erosion at the water line.	9/10
Bank vegetation	The riparian margin includes mature exotic trees with exotic grass and native plantings below on true left, true right is limited to a few trees and rank exotic grass.	5/10
Riparian width	The riparian width which is constrained by vegetation is more than 5 m wide on average on the true left, and more than 10 m wide on average on the true right.	8/10
Riparian shade	Typically, 40% of the river channel is shaded from the riparian margin (including vegetation, banks, or other structures).	5/10
Total score		**41/100**

5.5.4.3 GI3: adjacent to the landfill and Line 4

GI3 is within Kaikorai Stream, located approximately 900 m downstream of GI1 and 200 m downstream of the confluence with Abbotts Creek, and is adjacent to Line 4 of the groundwater monitoring sites along the leachate collection trench, and within the receiving environment of the landfill.

The stream is deep and non-wadeable at this site, being well over chest depth in parts. The wetted channel width was approximately 10 m, and with a weakly sinuous channel shape comprised entirely of run habitat. Stream bed substrates were comprised of entirely silt / sand and mud.

The riparian area provides partial shading. The true left has an upper bank height of 1.5 m, covered by rank grass (tall fescue) with some mature deciduous exotic trees, including willow, and harakeke, ti kouka / cabbage tree. The true right riparian area has an upper bank height of around 1 m and vegetation is dominated by tall rank grass and exotic herbs with some oioi, pūrei and saltmarsh ribbonwood within a broader upper lagoon area. While trees on the true left bank provided some shading capacity, the stream at this site was mostly unshaded.

The RHA score was 34 out of a possible 100 (Table 11), predominantly influenced by having minimal hydraulic heterogeneity and limited diversity of invertebrate and fish habitats, mostly due to the dominance of fine substrates (silt, sand, muds) and absence of woody material.

Table 11: General habitat conditions, based on the Rapid Habitat Assessment, at GI3 Kaikorai Stream.

Habitat parameter	Description	Score
Deposited sediment	Stream bed entirely covered by fine sediment (90%+).	1/10
Invertebrate habitat diversity	Limited substrate types considered invertebrate habitat, including sand and root mats. No interstitial spaces present.	2/10
Invertebrate habitat abundance	Approximately 15% of the visible substrate was favourable for EPT colonisation.	2/10
Fish cover diversity	Limited substrate types which may be utilised as fish cover included undercut banks and overhanging/encroaching vegetation, with substrates providing some spatial complexity.	3/10
Fish cover abundance	Approximately 30% of the active river channel provided fish cover opportunities.	3/10
Hydraulic heterogeneity	Hydraulic components included slow run habitat only.	1/10
Bank erosion	Minimal erosion. On both sides of the stream around 5% of the riverbank was exhibiting signs of recent/active erosion at the water line.	8/10
Bank vegetation	The riparian margin was cover mostly by long, rank exotic grass continuous along the reach on both banks.	3/10
Riparian width	The riparian width which is constrained by vegetation is approximately 5 m wide on average on the true left, and more than 30 m on the true right.	8/10
Riparian shade	Typically, 15% of the river channel is shaded from the riparian margin (including vegetation, banks, or other structures).	3/10
Total score		**34/100**

5.5.4.4 GI5: adjacent to the landfill and downstream of Line 1

GI5 is within Kaikorai Stream, located approx. 800 m downstream of GI3 and c.250 m downstream of Line 2 of the groundwater monitoring sites along the leachate collection trench, and within the receiving environment of the landfill. This site is the most downstream of the four surface water monitoring sites, but upstream of the GIWWTP.

Again, the stream was too deep (and non-wadeable), being well over chest depth, so water depth was not measured.

The wetted channel width was approximately 15 m, with a weakly sinuous channel shape comprised entirely of run habitat. Stream bed substrates were comprised of entirely silt / sand and mud.

The riparian vegetation is similar to that at GI3, with tall rank grass and exotic herbs with some oioi, pūrei and saltmarsh ribbonwood within the broader upper lagoon area. The stream at this site was mostly unshaded.

The RHA score was 33 out of a possible 100 (Table 12), predominantly influenced by having minimal hydraulic heterogeneity, low shading due to the wide channel and absence of trees, and minimal habitat diversity for invertebrates and fish mostly due to the high cover of fine sediment across the stream bed.

Table 12: General habitat conditions, based on the Rapid Habitat Assessment, at GI5 in Kaikorai Stream.

Habitat parameter	**Description**	**Score**
Deposited sediment	Stream bed entirely covered by fine sediment (90%+).	1/10
Invertebrate habitat diversity	Limited substrate types considered invertebrate habitat, including sand and some leaves. No interstitial spaces present.	1/10
Invertebrate habitat abundance	Approximately 5% of the visible substrate was favourable for EPT colonisation.	1/10
Fish cover diversity	Limited substrate types which may be utilised as fish cover included some overhanging/encroaching vegetation and root mats at the edges.	2/10
Fish cover abundance	Approximately 5% of the active river channel provided fish cover opportunities.	2/10
Hydraulic heterogeneity	Hydraulic components included slow run habitat only.	1/10
Bank erosion	Minimal erosion. On both sides of the stream less than 5% of the riverbank was exhibiting signs of recent/active erosion at the water line.	9/10
Bank vegetation	The riparian margin was cover mostly by long, rank exotic tall fescue grass continuous along the reach on both banks with some mature trees and shrubs on the true left, and saltmarsh herbs on the true right.	5/10
Riparian width	The riparian width which is constrained by vegetation is more than 50 m wide on both banks as this is within the broader lagoon area.	10/10
Riparian shade	Typically, <5% of the river channel is shaded from the riparian margin (including vegetation, banks, or other structures).	1/10
Total score		**33/100**

5.6 Water quality

The Otago Regional Council monitors water quality at one site in Kaikorai Stream: Kaikorai Stream at Brighton Road (a freshwater site, approximately 200 m upstream of GI1). The water quality monitoring is summarised by LAWA and is presented in Table 13.

Table 13: Five-year median water quality parameter values, and the associated attribute bands in the National Policy Statement for Freshwater Management 2020 (where available), from LAWA at Kaikorai Stream[24] (located upstream of GI1).

Parameter	**Value**	**NPS-FM attribute band**
E. coli (n/100 mL)	925	E
Clarity (metres)	1.22	A
Turbidity (NTU)	3.05	-
Total Nitrogen (mg/L)	0.735	-
Total Oxidised Nitrogen (mg/L)	0.415	-
Dissolved Inorganic Nitrogen (mg/L)	0.444	-
Ammoniacal Nitrogen (mg/L)	0.011	C
Nitrate Nitrogen (mg/L)	0.415	A
Dissolved Reactive Phosphorus (mg/L)	0.008	B
Total Phosphorus (mg/L)	0.026	-

Boffa Miskell also collected spot measures of water quality parameters in December 2022 (Table 14).

Table 14: Spot measurements of basic water quality parameters collected at each of the four survey sites within Kaikorai Stream and Abbotts Creek, December 2022. Time of day is presented in paratheses.

Parameter	**GI1 - Control (1:45 pm)**	**GI2 - Control (12:45 pm)**	**GI3 - Landfill (10:30 am)**	**GI5 - Landfill (09:45 am)**
Dissolved Oxygen (% saturation)	112.6	79	107.10	79.3
Temperature (°C)	17.8	16.4	14.2	14.4
pH	7.86	7.11	7.65	7.55
Conductivity (µs/cm)	57.9	461.2	1210	1852

5.7 Sediment quality

The Otago Regional Council also monitors sediment quality at three estuary sites in Kaikorai Lagoon: Kaikorai-D, Kaikorai-B and Kaikorai-A[25], all downstream of GI5.

The LAWA estuary sampling site Kaikorai-D is approximately 1 km downstream of GI5, where sediment quality samples were collected in December 2022.

---

[24] https://www.lawa.org.nz/explore-data/otago-region/river-quality/kaikorai-stream/kaikorai-stream-at-brighton-road/

[25] https://www.lawa.org.nz/explore-data/otago-region/estuaries/kaikorai-estuary/

The contaminants reported by LAWA show acceptable concentrations below (not exceeding) the Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) default guideline value (DGV) for sediment quality[26] (Table 15).

Table 15: Annual mean concentration of key contaminants in bed sediments, and comparison to the Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) sediment quality default guideline value (DGV), from LAWA at Kaikorai-D approximately 1 km downstream of GI5.

Parameter	Value	ANZG sediment quality DGV
Mud Content (%)	36.7	-
Zinc (mg/L)	160	200
Copper (mg/L)	13.0	65
Lead (mg/L)	25.7	50
Arsenic (mg/L)	7.1	20
Mercury (mg/L)	0.04	0.15
Cadmium (mg/L)	0.12	1.5
Chromium (mg/L)	24.3	80
Nickel (mg/L)	13.7	21

Boffa Miskell also collected sediment samples in December 2022 and the concentration of metal, metalloid, and organic toxicants in these surface sediments was compared to default guideline values provided in the ANZG for sediment quality[26]. These guideline values include the DGVs, which indicate concentrations below which there is a low risk of adverse effects on aquatic ecosystems, and upper guideline values (GV-high), which provide an indication of high toxicity.

Concentrations of common metal stormwater contaminants (lead and zinc) were above the DGVs at GI3 and GI5 (either in the <63 µm fraction[27] or in both), while the concentration of nickel at these sites was just below the DGV (Figure 6). However, the upstream control sites in Kaikorai Stream (GI1) and / or Abbotts Creek (GI2) had higher concentrations of lead, nickel, and zinc than GI3 and GI5 located further downstream, suggesting contaminants are entering the catchment from other sources further up-catchment.

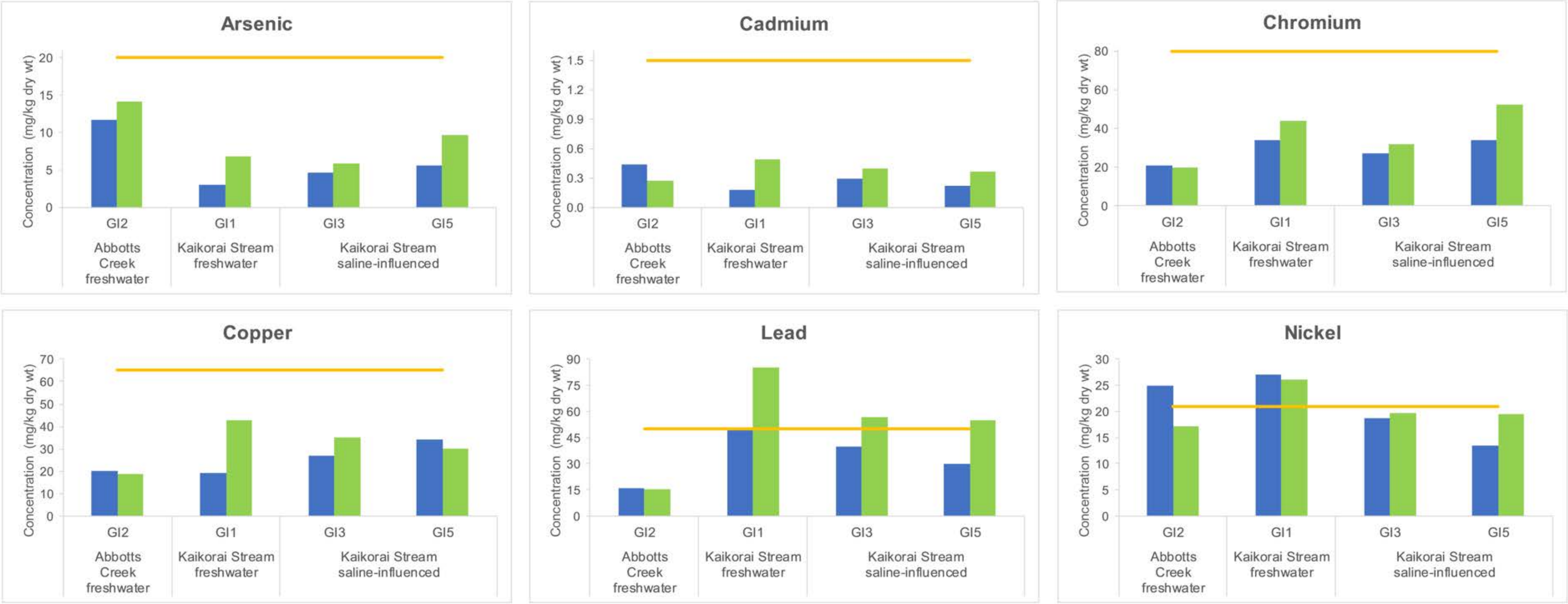
Zinc concentrations were particularly high at GI1, exceeding the upper guideline values (GV-high) in the <63 µm fraction. GI2 (Abbotts Creek) control site had lower levels of contamination from metals and metalloids than the Kaikorai sites, with only nickel exceeding DGV in the coarser <2 mm fraction (Figure 6).

Further, concentrations of polycyclic aromatic hydrocarbons (PAHs) and of the organochlorine pesticide dieldrin were above DGV in the <2 mm sediment fraction at site GI1 (upstream of the landfill) and below DGV elsewhere (including at sites adjacent to the landfill) (Figure 6). Contamination from other organochlorine pesticides (i.e., DDT and its DDD / DDE metabolites) was widespread in the Kaikorai Stream (Figure 6). DDT levels were above GV-high and DDD / DDE concentrations above DGV in both grain size fractions at all Kaikorai Stream sites. DDD concentrations were also above GV-high at GI1 and GI3 (Figure 6). GI1 had higher concentrations of DDT / DDD / DDE relative to the other Kaikorai Stream sites. In particular, DDT levels in the <63 µm fraction at GI1 were almost ten times higher than the GV-high (Figure 6). GI2 (Abbotts Creek) had lower levels of contamination from DDT and its derivates than the Kaikorai Stream sites, with DDT concentrations just above DGV and DDD / DDE below guideline levels (Figure 6).

---

[26] ANZG DGV for sediment quality. https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/sediment-quality-toxicants

[27] <63 µm fraction represents clay and silt, which are sediment materials most readily resuspended / ingested by organisms.


Arsenic
Cadmium
Chromium
Copper
Lead
Nickel
Concentration (mg/kg dry wt)
0
5
10
15
20
0.0
0.3
0.6
0.9
1.2
1.5
0
20
40
60
80
0
10
20
30
40
50
60
70
0
15
30
45
60
75
90
0
5
10
15
20
25
30
GI2
GI1
GI3
GI5
Abbotts Creek freshwater
Kaikorai Stream freshwater
Kaikorai Stream saline-influenced

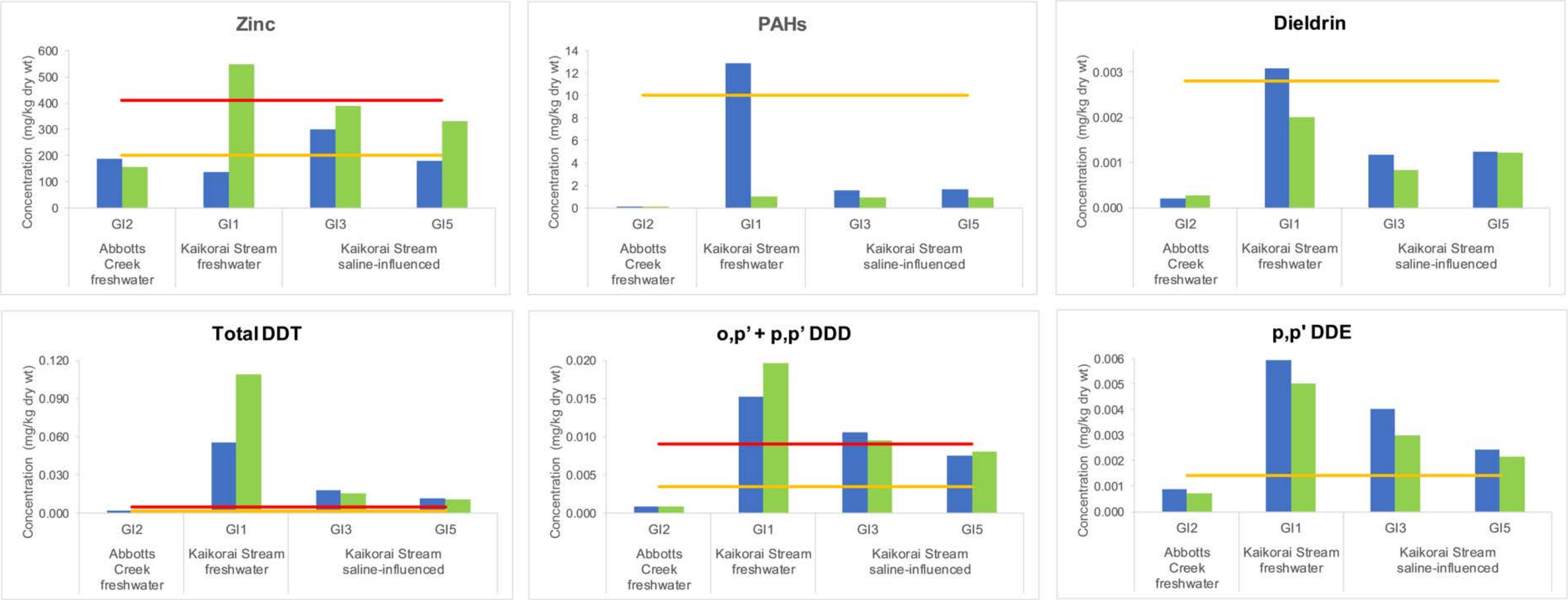


Figure 6. (This page and previous page). Toxicant concentrations in the <2 mm (blue bars) and <63 µm (green bars) particle size fraction of surface sediment samples (top 2-3 cm) collected at Kaikorai Stream and Abbotts Creek monitoring sites, GI1, GI2, GI3, and GI5. Default guideline values (DGV) are included in each panel, shown by the orange line. Upper guideline values (GV-High) are also included when exceeded, shown by the red line. The concentration of hydrophobic organic contaminants (PAHs, Dieldrin, Total DDT, o,p’ + p,p’ DDD, and p,p’ DDE) was normalised to 1% of the total content of organic carbon.

5.8 Macroinvertebrate community

Freshwater habitats: At the Otago Regional Council long-term monitoring site, just upstream of GI1[24], the five-year median of the macroinvertebrate community indices suggest stream health is very degraded as scores fall within the attribute band 'D' (Table 16).

The NPS-FM attribute band of D for macroinvertebrate community indices suggest severe organic pollution or nutrient enrichment. The macroinvertebrate communities are largely comprised of taxa tolerant of pollution / nutrient enrichment. This band is below the NPS-FM national bottom line. The MCI score has been within a similar range for the previous 10 years. However, the water quality parameters collected for this report showed variable attribute band status between A (excellent) to E (poor, below national bottom line) (Table 13 in Section 5.6).

Table 16: Five-year median macroinvertebrate community indices, and the associated attribute bands in the National Policy Statement for Freshwater Management 2020 (where available), from LAWA at Kaikorai Stream (located upstream of GI1). MCI = Macroinvertebrate Community Composition; QMCI = quantitative variant of MCI; ASPM = macroinvertebrate Average Score Per Metric; EPT = Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies).

Parameter	Value	NPS-FM attribute band
MCI	69.4	D
QMCI	2.13	D
ASPM	0.142	D
Taxonomic richness	18	-
Percent EPT* richness	11	-

Lagoon habitats: LAWA also reports on overall estuarine health based on the macrofauna monitoring by Otago Regional Council (at three sites within the lagoon[25]). Scoring is based on the national Benthic Health Models (BHM), where the BHM provides a score between 1 (least impacted) and 5 (most impacted), which indicates health of macrofaunal communities relative to sediment mud content compared. Table 17 compares the three long-term Kaikorai Lagoon sites (Figure 7).

Table 17: The latest annual mean estuary macrofauna BHM score (2019) for three locations within the Kaikorai lagoon, compared to other similar estuaries in Otago, from LAWA. Kaikorai Lagoon sites are listed from furthest to closest to the coast / lagoon mouth.

Site	Estuarine macrofauna BHM score	State Category
Kaikorai-D	4.28	Poor
Kaikorai-B	3.68	Fair
Kaikorai-A	4.24	Poor

Figure 7. Site locations, (upstream to downstream) Kaikorai-D, Kaikorai-B, Kaikorai-A monitored by Otago Regional Council and reported by LAWA.

Based on the long-term monitoring presented on LAWA, the dominant macrofauna species within the lagoon (between 2018-2020) were crustacea (*Paracropophium excavatum*) and polychaeta (*Scolecolepides benhami* and *Perinereis vallata*). There were a few taxa observed that may be sensitive to mud and organic enrichment, including *Perinereis vallata* and *Austrovenus stutchburyi*[28]*,* and certain Diptera, Amphipod, and Nematoda taxa. The first two taxa mentioned are sensitive to increases in fine sediments. No species with the lowest, highly sensitive AMBI[29] score of 1 were recorded in the Otago Regional Council's long-term monitoring data set.

5.8.1 December 2022 findings

Both sites GI3 and GI5, adjacent to the landfill, were brackish (note the high conductivity in Table 14) compared with GI1 and GI2 (Kaikorai Stream and Abbotts Creek upstream of the landfill), which showed taxa more commonly found in freshwater systems Some of the macroinvertebrate fauna found are not observed in freshwater environments, so were excluded from the freshwater macroinvertebrate community indices (e.g., MCI, QMCI). These included the amphipod *Paracorophium* and mysid shrimp *Tenagomysis* spp. both of which are found in brackish or estuarine waters, and *Potamopyrgus kaitunuparaoa* (a species of mud snail found in brackish waters).

The most abundant macroinvertebrate groups comprised mostly tolerant taxa (Figure 8). GI1 was dominated by oligochaetes (aquatic worms) and true-fly larvae (Diptera), mostly 'blood worm' larvae of the non-biting midge *Chironomus*. GI2 was dominated by oligochaetes and crustaceans, especially water fleas. Sites GI3 and GI5 were dominated by the crustaceans mysid shrimps.

---

[28] https://www.waikatoregion.govt.nz/environment/coast/ecosystem-health/regional-estuary-monitoring-programme/organisms/bivalves/

[29] AZTI (AZTITecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI)

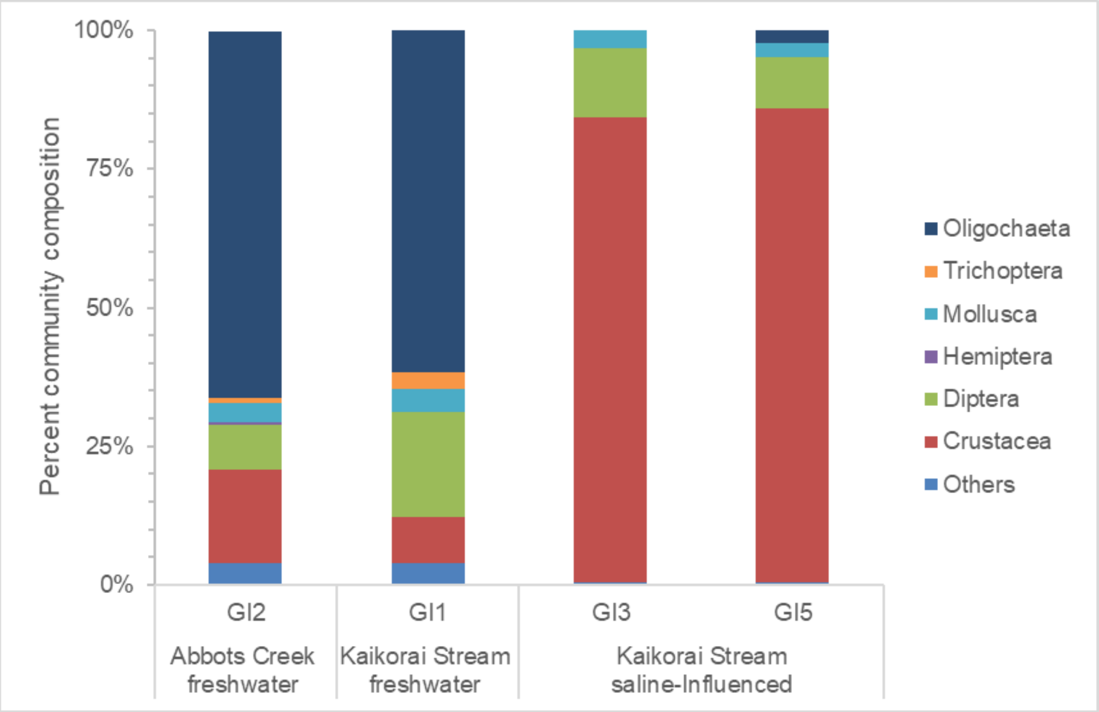


Figure 8: Community composition of benthic macroinvertebrates at GI1 and GI2 upstream reference sites alongside GI3 and GI5 sites adjacent to the landfill.

The percentage of the pollution-sensitive freshwater insects mayflies, stoneflies and caddisflies (the EPT taxa) was low at GI1 (3%) and GI2 (1%), and represented by caddisflies only, the stick-cased *Triplectides* and algal-piercing *Oxyethira*. No EPT taxa were found at GI3 and GI5 likely due to the saline influence and silt / sand substrates. No kākahi / freshwater mussels or kēkēwai (freshwater crayfish) were found.

The MCI scores indicated all sites surveyed have probable mild-severe enrichment, with all sites assessed within “fair” or “poor” water quality categories of Stark & Maxted (2007), while the QMCI (which is considered a better indicator of “health” as it also takes into account abundance of macroinvertebrate taxa) showed GI3 and GI5 meet the “good” water quality category of Stark & Maxted (2007) (Table 18).

Table 18. Macroinvertebrate community index (MCI) and the quantitative variant (QMCI) results for each of the sites surveyed in December 2022.

Site	MCI	Water quality category	QMCI	Water quality category
GI1	61.9	Poor	1.6	Poor
GI2	64.7	Poor	3.2	Poor
GI3	77.2	Poor	5.6	Good
GI5	87.6	Fair	5.6	Good

It is important to note that these indices were not developed for brackish / saline-influenced waters so the results should be treated with caution. Mysid shrimp, which have moderate MCI tolerance scores, were very abundant so potentially strongly influenced the QMCI at GI3 and GI5.

The full macroinvertebrate community found at the four sites is presented in Appendix 4.

5.9 Fish community

The fish community was assessed at three of the four survey sites: GI2 – Abbotts Creek upstream; GI1 – Kaikorai Stream upstream; and GI3 – Kaikorai Stream within the landfill.

Six species of freshwater fish were caught (Table 19). Black flounder (a freshwater species of flounder) was only recorded at GI3, and upland bully was only found at GI1 where cobbles were present. No eels were caught at GI2. Inanga were found at all sites and were particularly abundant at GI2 and GI3.

Table 19. Fish species caught at GI1, GI2, and GI3 during 13-14 December 2022 survey. Conservation status assigned by Dunn et al., (2018).

Site	Common name	Scientific name	Conservation status	Number recorded	Size Range (mm)
GI3	Black Flounder	*Rhombosolea retiaria*	Not Threatened	1	25
GI1	Common bully	*Gobiomorphus cotidianus*	Not Threatened	189	20-60
GI2				270	20-60
GI3				1261	20-80
GI1	īnanga	*Galaxias maculatus*	At Risk – Declining	2	40-60
GI2				158	20-120
GI3				478	40-100
GI1	Longfin eel	*Anguilla dieffenbachii*	At Risk – Declining	3	500-650
GI3				27	150-1200
GI3	Shortfin eel	*Anguilla australis*	Not Threatened	12	300-900
GI1	Upland bully	*Gobiomorphus breviceps*	Not Threatened	25	45-50

Similar species were caught at GI1 and GI2 as have been previously recorded in the NZFFD. In addition to the species found in the December 2022 survey, the NZFFD has recorded banded kokopu near GI2, and shortfin eel and kēkēwai[30] near GI1.

Downstream of the landfill, within Kaikorai Lagoon, there are previous records of shortfin eel, common bully, īnanga, common smelt, yellow-eye mullet, black flounder, and estuarine triplefin.

5.10 Ecotoxicology

The outcomes of the ecotoxicology assays conducted by Cawthron Institute are detailed in Appendix 1. The following sections provide a summary of the findings by Cawthron Institute.

5.10.1 Bacterial bioluminescence

Cawthron Institute’s ecotoxicology testing found the bioluminescent bacteria responds to general toxicity of the broad range of organic contaminants collected by the PSDs from groundwater and surface water (Figure 9).

---

[30] Although kēkēwai / freshwater crayfish is a macroinvertebrate it is often captured during fish surveys and can be reported in the NZFFD.

The results from testing of the extracts from the groundwater PSDs (from Line 4C (shallow well only) and Line 2 shallow (C) and deep (D) wells) are significantly different from the field blank. This indicates the potential presence of organic contaminants (e.g., pesticides, phenols and industrial alkylphenols, personal care chemicals, biocides, steroid hormones, pharmaceuticals and PFOS/PFOA) in the groundwater outside of the leachate collection trench, which can be toxic to the bacteria.

The results from testing of the extracts from the surface water PSDs showed there was a significant reduction of bacterial luminescence at site GI5 relative to the field blank (near groundwater monitoring Line 2), which was not observed at the upstream Kaikorai Stream (GI1) and Abbotts Creek (GI2) sites. This again indicates the potential presence of organic contaminants in the surface water of Kaikorai Stream, which can be toxic to the bacteria. The same toxicity effect was seen from the groundwater sample nearby to GI5 (Line 2), in both the shallow and deep wells. This suggests that organic contaminants may be present in Kaikorai Stream at GI5.

5.10.2 Algal growth

The marine algae responds to general toxicity and / or influences growth rates to the broad range of organic contaminants collected by the PSDs from groundwater and surface water (Figure 9).

The results from testing of the extracts from the groundwater PSDs showed a significant increase in algal density relative to the field blank, suggesting that there is likely general organic enrichment within the groundwater at Line 4C and 4D (both shallow and deep wells) and Line 2C (shallow only).

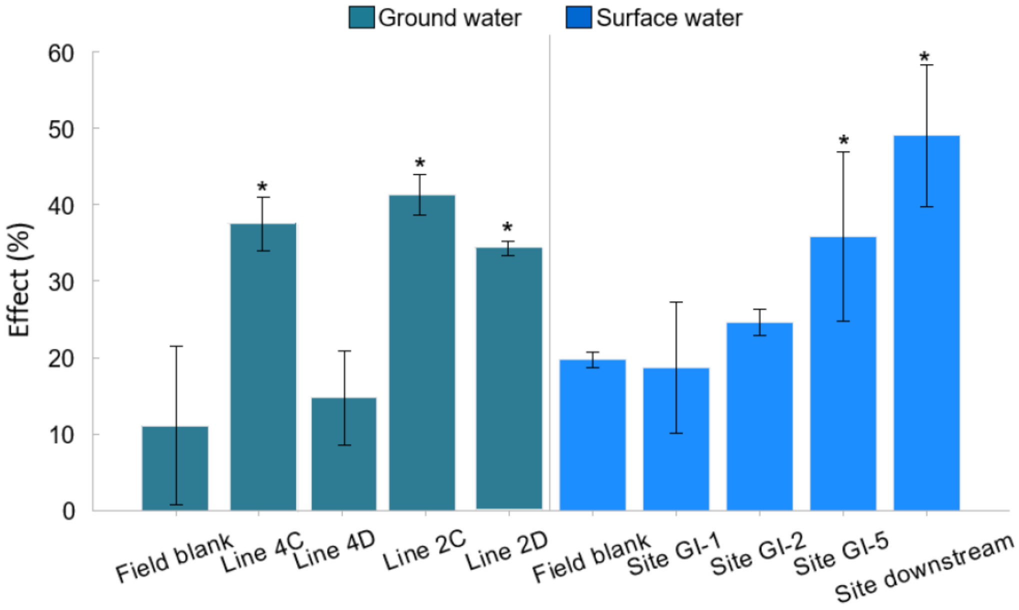
The results from testing of the extracts from the surface water PSDs showed there was no significant effect on algal growth (inhibited or accelerated) at any of the surface water sites, relative to the field blank.

5.10.3 Blue mussel embryo-larval development

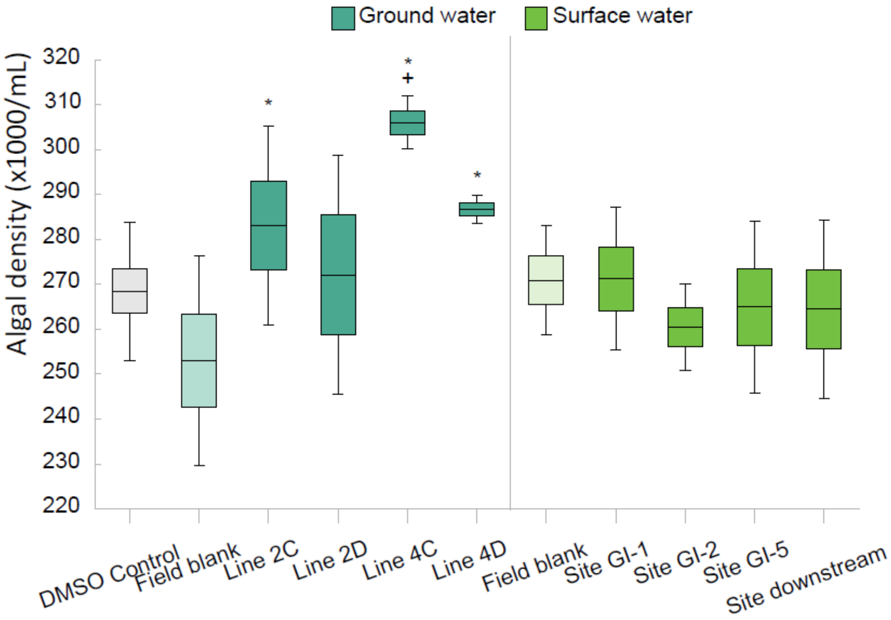
The blue mussels respond to acute toxicity through a test to indicate embryo toxicity in early life stage development from the broad range of organic contaminants collected by the PSDs from groundwater and surface water.

The results from testing of the extracts from the groundwater PSDs showed there was no significant difference in blue mussel embryo survival rates between field blanks and the groundwater sites, suggesting no or low toxicity of the extracts to blue mussels.

The results from testing of the extracts from the surface water PSDs showed there was no significant difference in blue mussel embryo survival rates between field blanks and the surface water sites, suggesting no or low toxicity of the extracts to blue mussels.



Ground water
Surface water
Effect (%)
60
50
40
30
20
10
0
Field blank
Line 4C
Line 4D
Line 2C
Line 2D
Field blank
Site GI-1
Site GI-2
Site GI-5
Site downstream
*



Ground water
Surface water
Algal density (x1000/mL)
320
310
300
290
280
270
260
250
240
230
220
DMSO Control
Field blank
Line 2C
Line 2D
Line 4C
Line 4D
Field blank
Site GI-1
Site GI-2
Site GI-5
Site downstream
*
+

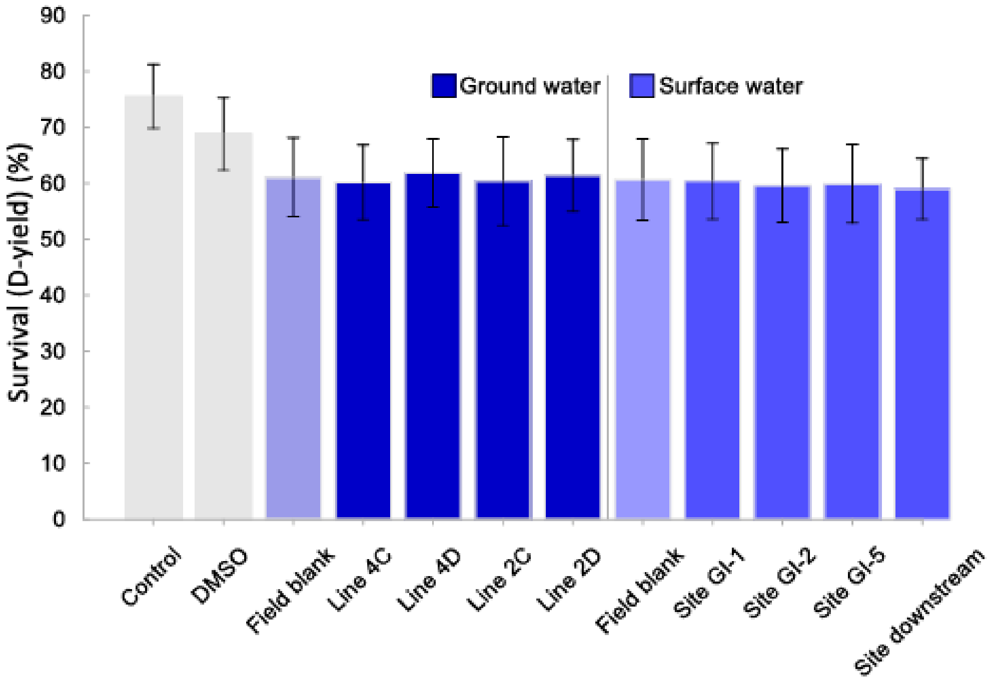


Figure 9: Copy of Cawthron Institute's ecotoxicology bioassays on (top) bacterial bioluminescence and (middle) algal density and (bottom) blue mussel bioassays from groundwater and surface water sites. From Cawthron Institute (2023). See Appendix 1 for full results.

As discussed by Cawthron Institute (Appendix 1), the PSDs used in the ecotoxicology study absorbed organic compounds present in the surface and groundwater, but did not absorb metals or highly hydrophobic molecules, which would partition mainly in suspended solids and sediment. The results indicated that there may be leachate seeping out from the landfill, however, the study was not designed to be able to determine what contaminants were driving the toxicity findings.

Further, it is important to note that the leachate collection trench is operating in such a way that leachate contaminated groundwater should not be able to enter Kaikorai Stream; but surface water from Kaikorai Stream can be drawn into the leachate collection system (as reported by GHD).

It is also important to understand the broader context and landscape or catchment effects, and the ecotoxicology results also found a non-significant but increased reduction of bacterial luminescence in the surface water well downstream of the landfill, in Kaikorai Lagoon. Cawthron concluded that this toxicity effect from the surface water sample collected at the Brighton Road Bridge suggests that there are likely additional sources of stressors, not directly associated with the landfill leachate affecting the lagoon.

6.0 Ecological value

6.1 Terrestrial vegetation and habitats for fauna

Surfaces within the existing working landfill extent are highly modified. Where vegetation occurs on recently worked areas of the landfill, it comprises exotic grassland and weedy exotic herbs and shrubs (e.g., gorse, scotch broom).

Other areas of the landfill site comprised exotic shelterbelts, rank grass, and gorse scrub. This vegetation is not representative or rare, has very low indigenous species diversity, and is not expected to provide important habitat for any indigenous species.

The areas of deliberately planted indigenous species (immediately surrounding the working landfill extent), comprise widespread and locally common readily growing tree / shrub species. and are not representative of intact vegetation types in the ED; the area of planting is small and has very low species diversity and habitat pattern. In terms of ecological context, these planted areas are of low to moderate importance as they may provide some bird habitat.

Terrestrial vegetation within the landfill designation is considered to have **Negligible** ecological value.

6.2 Avifauna

As per the EIANZ guidelines (Table 5), the key avifauna species that use the site and immediate surrounds range from **Low** to **Very High** ecological value (Table 20), based on their current threat statuses (Robertson et al., 2021).

Table 20. Ecological value of avifauna species that use, or potentially use the project site and immediate surrounds.

Species	Threat Status	Ecological Value
Otago shag, black-fronted tern, Caspian tern	Threatened – Nationally Endangered, Vulnerable or Increasing	Very High
White-fronted tern, black-billed gull, NZ pied oystercatcher, red-billed gull, NZ pipit, eastern bar-tailed godwit, banded dotterel	At Risk – Declining	High
Little shag, variable oystercatcher, pied shag, royal spoonbill, black shag	At Risk – Recovering, Naturally Uncommon or Relict	Moderate
Welcome swallow, silvereye, black-backed gull, white-faced heron, South Island fantail, spur-winged plover, kingfisher, pied stilt, paradise shelduck, morepork, grey teal, pukeko, grey warbler, black swan, bellbird, tui, Australian shoveler	Not Threatened	Low

6.3 Kaikorai Stream

Kaikorai Stream is of moderate representativeness at the site (GI1); whilst the lower reaches are listed as part of the Areas of Significant Biodiversity Value, the stream has modified habitat and water quality conditions, the banks are modified and artificial in certain sections, and the riparian area is highly modified. Rarity and distinctiveness is low: there is a small range of native and migratory fish species present including ‘At Risk’ species (longfin eel). However, the macroinvertebrate fauna in the site upstream of the landfill is depauperate and considered “pollution tolerant”, including ubiquitous species taxa typically found in urban waterways and slow-flowing, modified watercourses. There is an absence of mayflies and stoneflies. Diversity and pattern is moderate: the aquatic habitats present are typically modified and degraded due to poor water quality and surrounding land-use pressures. There is low to moderately diverse aquatic habitat available for fish and macroinvertebrates. Ecological context is low, as the stream is within an urban-industrial environment with a history of industrial activity surrounding the stream impacting its function. Despite this, the stream forms a notable connection to the Kaikorai Lagoon, supporting migratory fish species. However, the lagoon is not always open to the marine environment which limits the ecological connectivity and habitat availability for some migratory fish species.

Considering the above, Kaikorai Stream is determined to have **Moderate** ecological value.

6.4 Abbotts Creek

Abbotts Creek is of low representativeness at the site (GI2). The site surveyed had limited habitat heterogeneity comprising only a slow flowing run and high cover of filamentous algae and soft sediments on the stream bed. Up-gradient the stream may have a greater range of habitat types (e.g., riffle, run) being represented but ecological connectivity may be compromised due to road crossings throughout the catchment. Rarity is moderate: īnanga, including juveniles, were numerous at the site indicating potential good habitat for this species. However, the macroinvertebrate fauna in the site surveyed was depauperate and considered “pollution tolerant”, including ubiquitous species taxa typically found in urban waterways and slow-flowing, modified watercourses. There is an absence of mayflies and stoneflies. Diversity and pattern is low: the aquatic habitats present at the site were dominated by a slow flowing, soft-bottomed run; diversity and pattern are typically modified and degraded due to poor water quality and surrounding land-use pressures. Ecological context is low, as the stream is within an urban environment with a history of industrial activity surrounding the stream impacting its function. Although the waterway and catchment support some migratory freshwater fish species and forms part of the downstream Kaikorai Lagoon catchment, the lagoon is not always open to the marine environment, which limits the ecological connectivity and habitat availability for some migratory fish species. Human-made barriers to fish passage also likely exist due to numerous road crossings over Abbotts Creek.

Considering the above, Abbotts Creek is determined to have **Moderate** ecological value.

6.5 Kaikorai Lagoon

Kaikorai Lagoon is of moderate representativeness, as it presents a moderate degree of wetland naturalness[31,32] despite habitat and water quality degradation. The lagoon is listed as an Area of Significant Conservation Value in the DCC 2GP and is classified as a regionally significant wetland by ORC. Rarity is high, as brackish systems with extensive swamp / marsh areas are historically reduced in the Otago Region[31]. Diversity and pattern is moderate, as the lagoon presents a variety of habitat types, including river-like wide channel sections, mudflats

---

[31] Otago Regional Council (2004) Regional Plan: Water for Otago. Published by the Otago Regional Council, Dunedin.

[32] Ausseil, A.G., Newsome, P., Johnson, P, (2008) Wetland Mapping in the Otago Region. Landcare Research Contract Report prepared for the Otago Regional Council.

and a wide range of marsh types adapted to different levels of salinity. However, extensive habitat degradation has occurred due to the replacement of native vegetation by exotic species and surrounding land-use pressures. Ecological context is high, as the lagoon provides critical habitat for the life cycle of indigenous bird species, which are dependent on wetlands[30]. The lagoon is also used by migratory freshwater fish. However, the lagoon is not always open to the marine environment, which limits the ecological connectivity and habitat availability for some migratory fish species.

Considering the above, Kaikorai Lagoon is determined to have **High** ecological value.

6.6 Aquatic fauna

As per the EIANZ guidelines, the ecological value of the key fish species present within the receiving environment surrounding the landfill range from **Low** to **High** (Table 21).

Table 21. Ecological value of avifauna species that use, or potentially use the project site and immediate surrounds.

Species	Threat Status	Ecological Value
Longfin eel, īnanga	At Risk – Declining	High
Common bully, upland bully, shortfin eel, black flounder	Not Threatened	Low

6.7 Summary of ecological value

Overall, using the EIANZ Guidelines (Roper-Lindsay et al., 2018), values are summarised as follows:

- Terrestrial vegetation has **Negligible** ecological value
- The ecological value for avifauna ranged between **Low – Very High**
- Kaikorai Stream has **Moderate** ecological value
- Abbotts Creek has **Moderate** ecological value
- Kaikorai Lagoon has **High** ecological value
- The ecological value for aquatic fauna ranged between **Low – High**

7.0 Assessment of effects

The following assessment of effects on the ecological values within the the landfill site, and of the receiving aquatic habitats, is in accordance with the EIANZ EcIA guidelines (Roper-Lindsay et al., 2018).

We determine the magnitude of the potential effects of the proposed activities and then the likely level of effect without mitigation. The assessment has been limited to the potential effects of activities on the ecological values within the landfill designation, and the downstream freshwater and lagoon habitats.

A typical scale of magnitude ranges from very high to negligible.

The level of effect (without mitigation) ranges from “very high” to “very low” or “net gain” for positive effects.

The level of effect provides guidance on the extent and nature of the ecological management response required.

7.1 Terrestrial vegetation and habitats for fauna

Vegetation clearance:

- No vegetation clearance within the existing landfill footprint is of ecological concern, as the areas that are proposed to receive landfill have already been cleared of their original vegetation, and any vegetation that may be cleared is generally comprised largely of exotic species (or deliberately planted indigenous species) and is of negligible ecological value. We also understand that clearance there will be no indigenous vegetation clearance associated with the proposal outside the landfill footprint. The magnitude of effect is assessed as negligible. A negligible magnitude of effect on negligible ecological value results in a very low level of effect.

7.2 Aquatic habitats and fauna

Groundwater drawdown of Kaikorai Stream:

- The GHD 2024a *Groundwater Report* notes that it is likely that the groundwater drawn into the leachate collection system is hydraulically connected with surface water in the Kaikorai Stream, with the potential for groundwater abstraction to have a stream depletion effect. A modelling assessment completed by GHD indicated that approximately 30% of the water pumped from the leachate trench is derived from groundwater or connected surface water outside of the trench in areas where the trench is close to Kaikorai Stream. Whilst stream depletion could pose a risk to aquatic habitat within Kaikorai Stream, the volume is estimated to be approximately 0.5 l / s for the entire trench length. The mean annual low flow (MALF) in Kaikorai Stream downstream of the Abbotts Creek confluence is 81 l / s (GHD, 2024b) and there is a clear tidal flushing influence on water levels in Kaikorai Lagoon with an amplitude of generally over half a meter between low and high tides. This volume (of 0.5 l / s) is very small relative to stream flows *even* during low flow conditions, therefore, the magnitude of effect is assessed as negligible. A negligible magnitude of effect on high ecological value results in a very low level of effect.

Sediment discharge to Kaikorai Stream and Kaikorai Lagoon:

- Ongoing earthworks associated with the active landfilling zone may result in sediment discharges to Kaikorai Stream and Kaikorai Lagoon. This could result in sediment runoff into the estuary, which could lead to sedimentation of habitats in Kaikorai Stream and an increase in mud content within the estuary. The sediment particle size in Kaikorai Lagoon from Feb 2019 and Nov 2021 (undertaken by Salt Ecology[33]) shows sand is the predominant substrate type and mud content is not high at 26.2%. Further, the continued operation of the landfill will not alter or increase the footprint, however, ongoing stormwater management will be needed to avoid or minimise sediment discharge to and sedimentation of Kaikorai Stream and the downstream lagoon. Current stormwater management includes collection of clean stormwater run-off in the perimeter drains before being discharged to Kaikorai Stream. Any potentially sediment laden waters are directed to flow through sedimentation ponds, before being discharged to the stream. Given this stormwater management will continue to be in place, the ongoing operation of the landfill is likely to result in a no-change situation, which is considered a negligible magnitude of effect. A negligible magnitude of effect on species of low to high ecological value results in a very low overall level of effect.
- The construction of the final landfill cap (completed in stages) has the potential to result in a substantial sediment source that may be entrained in runoff. This will occur only on completion of filling within each active landfill zone and is relatively short-term activity. A specific erosion and sediment control plan is to be established for this work, which controls for sediment discharged into the receiving environment (GHD, 2024b). Additionally, the establishment of vegetation cover as part of the final stages of landscaping after installation of the impermeable cap is expected, over the longer-term, to provide effective prevention of sediment runoff. With appropriate erosion and sediment controls and vegetation cover in place, sediment discharge to the stream and lagoon should be avoided or minimised, and the magnitude of effect is considered negligible. A negligible magnitude of effect on the high ecological value Kaikorai Lagoon results in a very low level of effect.

Continued leachate loss to Kaikorai Stream and Kaikorai Lagoon:

- Although no substantive evidence has been observed from GHD monitoring and Boffa Miskell's ecological surveys, ongoing landfilling within the existing footprint may result in leachate contaminants entering Kaikorai Stream and Kaikorai Lagoon. This could occur through stormwater run-off coming into contact with landfill material or from contaminated groundwater collected by the leachate collection system moving into surface water. Any stormwater in the active landfilling area that encounters waste or leachate is left to infiltrate the landfill or directed to leachate drains, to enter the leachate collection system and discharge to the Green Island WWTP. The groundwater assessment (GHD, 2024a) has shown the leachate collection system to be effective at creating the hydraulic barrier needed to intercept leachate from the landfill. Given the current effective functioning of the leachate collection system and that this will continue to be in place during ongoing landfilling and will continue to operate post closure, the ongoing operation of the landfill is likely to result in a no-change situation.

---

[33] https://www.lawa.org.nz/media/5261396/kaikorai-estuary-summary-report-2021-22.pdf

- GHD (2024b) suggests that sites adjacent to and downstream of the landfill do not exhibit any significant changes in dissolved metals concentrations, which indicates there is not a strong indicator of leachate discharge to the environment. GHD (2024b) also notes that the historical data set for dissolved metals does not indicate persistent and significant levels of contamination of the pond water from landfill activities, with dissolved metal results from 2023 all below the trigger concentrations set by existing conditions for the landfill. This also applies to the nutrient concentrations, with Ammoniacal-Nitrogen concentrations measured in the 2023 below the trigger level set in the existing conditions.

- The ecological data collected in this study indicate stream health, both up- and downstream of the landfill, is compromised by a long history of land-use change. The ecotoxicology study conducted by Cawthron Institute (2023) indicates the potential presence of organic contaminants in the surface water of Kaikorai Stream; the same toxicity effect was seen from the groundwater sample nearby to GI5 (Line 2), in both the shallow and deep wells. However, no or low toxicity in the ecotoxicology test on blue mussel embryos of the extracts taken from groundwater and surface water were observed. There was also a greater toxicity effect from surface water much further downstream of the landfill, in Kaikorai Lagoon. This suggests that there are likely additional sources of stressors, not directly associated with the landfill leachate affecting the lagoon.

- Overall, the GHD (2024a) *Groundwater Report* states that with the continuing operation of the leachate collection system, and maintenance of the groundwater hydraulic barrier, no discernible effect on surface water quality is expected and there has not been an indication of leachate discharge to the environment in surface water sampling. Based on this assumption, the magnitude of effect on ecology of Kaikorai Stream and Lagoon is expected to be negligible. A negligible magnitude of effect on a high ecological value results in a very low level of effect.

7.3 Avifauna

Impacts on food supply for black-backed gull:

- Organic food waste deposited at the landfill is an important food source for thousands of black-backed gulls in Dunedin. In the short-term (up until July 2024) continued operation of the landfill will continue to provide food for this species and help sustain the population; this is considered a positive effect for this species.
- From July 2024, DCC is introducing kerbside collection of food and organic waste. This will result in a significant reduction in organic waste entering the landfill resulting in considerably less food being available to black-backed gulls. Furthermore, it is intended to implement the Southern Black-Backed Gull Management Plan required by the resource consent conditions for the Smooth Hill Landfill. This will have the effect of managing the food availability at the landfill and the breeding success of the black-backed gull population at Dunedin breeding sites where access is available. These actions are a result of decisions made that are external to this project (i.e., construction of the new Smooth Hill Landfill and change to waste management in Dunedin), but all of these projects are intertwined therefore it is difficult to tease out effects. We conclude however that these actions will result in a high magnitude of effect on black-backed gulls by significantly reducing their food supply and reducing their numbers. A high

magnitude of effect on a low value species results in a low overall level of effect. While having a negative ecological effect, it is important to note that black-backed gulls are a Not Threatened species that are not protected under the Wildlife Act. They are sometimes considered a nuisance species, and at times DOC conducts colony control at braided river habitats in New Zealand to manage their numbers.

Construction-related disturbance:

- Construction works associated with the extension of the leachate collection trench along the southern side of the landfill and installation of additional internal leachate drains may result in disturbance to avifauna foraging and roosting at the landfill (primarily black-backed gulls). Given that these works are of a temporary nature (i.e. short-term) and that species that may be disturbed by these works are highly mobile and can disperse to alternative areas if disturbed, we consider that construction-related disturbance will have a negligible magnitude of effect on avifauna. A negligible magnitude of effect on low to high value[34] species results in a very low overall level of effect.

Operational disturbance:

- Continued operation of the landfill will result in continued operational disturbance to avifauna using the site (i.e., disturbance from people, truck movements, excavator use, etc). Given that this disturbance already exists at the site, the level of disturbance is unlikely to change with continued operation of the landfill, and birds currently present at the site are already habituated to this disturbance. We consider that continued operational disturbance will have a negligible magnitude of effect on avifauna. A negligible magnitude of effect on low to high[35] value species results in a very low overall level of effect.

Operational impacts on food supply:

- Whilst there is a leachate collection trench at the edge of the landfill nearest Kaikorai Stream, there is still a risk that some leachate may infiltrate into Kaikorai Stream and the Kaikorai Lagoon receiving environment, during continued operation of the landfill. This, combined with the impacted water quality within the lagoon, has the potential to adversely impact the amount and quality of the food supply for avifauna foraging at the lagoon. This risk already exists with the current operation of the landfill. Given that with the continuing operation of the leachate collection system, and maintenance of the groundwater hydraulic barrier, no additional discernible effect on water quality is expected (as stated in Section 7.2), we expect that adverse effects on avifauna food supplies will not be discernibly greater than those currently experienced by avifauna foraging in Kaikorai lagoon. As such, we consider that continued operational impacts on avifauna food supplies will have a negligible magnitude of effect on avifauna. A negligible magnitude of effect on low to very high value species results in very low to low overall levels of effect.

Operational impacts on foraging ability:

- Continued operation of the landfill may result in continued sediment discharge into Kaikorai Lagoon as a result of ongoing earthworks associated with the active landfilling zone. Prior to settlement, suspended sediment in the water column may reduce visual

---

[34] Very high value species are not considered as such species only utilise Kaikorai lagoon not the GIL itself, therefore will not be impacted by construction-induced disturbance.

[35] Very high value species are not considered as such species only utilise Kaikorai lagoon not the GIL itself, therefore will not be impacted by operational disturbance.

acuity and thus foraging ability of avifauna using the lagoon. As stated in Section 7.2, given that stormwater management will continue to be in place, ongoing earthworks and associated sediment discharge into Kaikorai Lagoon is likely to result in a no-change situation which is considered a negligible magnitude of effect. Accordingly, potential negative impacts on foraging ability are not expected to increase relative to the current situation. As such, we consider that continued operational impacts on foraging ability will have a negligible magnitude of effect on avifauna. A negligible magnitude of effect on low to very high value species results in very low to low overall levels of effect.

Closure impacts on food supply:

- Closure of the landfill is unlikely to result in a discernible change in water quality in the Kaikorai Stream and Kaikorai Lagoon. Leachate is currently managed and removed via the leachate treatment system, and this will continue after closure. As such, the quality of the food supply (fish and benthic invertebrates) for avifauna foraging at the lagoon is unlikely to change with landfill closure (i.e., a negligible magnitude of effect). A negligible magnitude of effect on low to very high value species results in very low to low overall levels of effect.

Closure impacts on foraging ability:

- Closure of the landfill is likely to reduce sediment inputs into Kaikorai Lagoon, however as the current operational inputs are not that high, (because of the stormwater management systems in place), a discernible reduction in sediment loading is not expected. As such, visual acuity and thus foraging ability of avifauna using the lagoon is unlikely to change with landfill closure (i.e., a negligible magnitude of effect). A negligible magnitude of effect on low to very high value species results in very low to low overall levels of effect.

Closure disturbance impacts:

- Landfill closure activities such as capping and removing infrastructure no longer required will temporarily disturb birds using the area and immediate surrounds, however once complete, disturbance will be greatly reduced at the site, as a result of the cessation of operation of the landfill. We expect this will have a positive effect on avifauna and depending on what restoration is done at the site may provide new habitat opportunities for some species of avifauna.

Closure habitat loss:

- At the time of closure, it is expected that the number of black-backed gulls present at the landfill will be greatly reduced (relative to current numbers). This is because kerbside collection of organic waste (which will commence in Dunedin in July 2024) will result in very little food being present at the landfill for birds to forage on, and because of black-backed gull management actions implemented to fulfil consent conditions for the Smooth Hill landfill. Accordingly, at closure, the landfill is likely to provide very little habitat for black-backed gulls, and as such we consider that closure will have a negligible magnitude of effect on black-backed gulls. A negligible magnitude of effect on species of low ecological species results in a very low overall level of effect.

- Red-billed gulls currently roost on the rooves of some buildings on site. As part of closure activities, some of these buildings will be removed and as such there will be a loss of roosting habitat for this species. Given, that some buildings will remain and that there are ample alternative structures, rooves and natural habitats for red-billed gulls to roost on nearby and in the wider area, we consider that loss of this roosting habitat will have a negligible magnitude of effect on red-billed gulls. A negligible magnitude of effect on species of high ecological value results in a very low overall level of effect.

7.4 Overall summary of ecological effects

A summary of the overall levels of ecological effects is provided in Table 22 below.

Table 22. Summary of the overall levels of ecological effects assessed.

Ecological effect	Ecosystem Component	Ecological Value	Magnitude of Effect	Level of Effect
Terrestrial environment				
Extension: vegetation clearance	Non-native, weedy exotic herbs and shrubs	Negligible	Negligible	Very Low
Aquatic environment and fauna				
Extension: Groundwater drawdown	Kaikorai Stream and Kaikorai Lagoon	Moderate – High	Negligible	Very Low
Extension: Sediment discharge	Kaikorai Stream and Kaikorai Lagoon	Moderate – High	Negligible	Very Low
Closure: Sediment discharge	Kaikorai Stream and Kaikorai Lagoon	Moderate – High	Negligible	Very Low
Extension/closure: Continued leachate loss	Kaikorai Stream and Kaikorai Lagoon	Moderate – High	Negligible	Very Low
Avifauna				
Extension: impacts on food supply for black-backed gulls (short-term)	Black-backed gulls	Low	N/A	Positive
Extensions: impacts on food supply for black-backed gulls (long-term)	Black-backed gulls	Low	High	Low
Extension: construction-related disturbance	Avifauna utilising the landfill	Low - High	Negligible	Very Low
Extension: operational disturbance	Avifauna utilising the landfill	Low - High	Negligible	Very Low
Extension: operational impacts on food supply	Avifauna utilising the landfill and Kaikorai Lagoon	Low – Very High	Negligible	Very Low – Low
Extension: operational impacts on foraging ability	Avifauna utilising the landfill and Kaikorai Lagoon	Low – Very High	Negligible	Very Low – Low
Closure: impacts on food supply	Avifauna utilising the landfill and Kaikorai Lagoon	Low – Very High	Negligible	Very Low – Low

Ecological effect	Ecosystem Component	Ecological Value	Magnitude of Effect	Level of Effect
Closure: impacts on foraging ability	Avifauna utilising the landfill and Kaikorai Lagoon	Low – Very High	Negligible	Very Low - Low
Closure: disturbance impacts	Avifauna utilising the landfill	Low - High	N/A	Positive
Closure: avifauna habitat loss	Black-backed gulls Red-billed gulls	Low - High	Negligible	Very Low

8.0 Recommendations

The overall levels of ecological effects of landfill extension / operation and closure assessed for vegetation and habitats, avifauna, freshwater and estuarine habitats all very low to low (as well as some potential positive effects) and as such do not warrant mitigation or offsetting.

With regards to the aquatic habitats in the receiving environment, the level of effects are assessed as very low due to the effective functioning of the leachate collection system, which must continue.

The minimisation measures, which are recommended to be undertaken and / or continued are detailed below.

8.1 Minimise

Continue to treat stormwater and avoid / minimise stormwater-derived contaminants and sediment entering the waterways:

- GHD has shown the eastern and western sedimentation ponds are functioning as intended in terms of contaminants and sediment, and meeting their existing condition requirements regarding trigger concentrations (GHD, 2024b).
- After closure, landfill surfaces will have vegetation established and an impermeable cap intact, which will reduce or remove the ability for stormwater run-off to come into contact with landfill material and leachate.

8.2 Monitor

- Continued utilisation of the current effective stormwater and leachate treatment and ongoing monitoring of groundwater and surface water quality is recommended by GHD (2024a, b). However, no additional ecological investigation, monitoring, or management is required at this time. If any significant exceedances are detected and related to landfill activities, additional ecological investigations may be required.

9.0 References

Ausseil, A.-G., Newsome, P., & Johnson, P. (2008). *Wetland mapping in the Otago Region* [Landcare Research Contract Report]. Prepared by Landcare Research for Otago Regional Council.

Beca Stevens. (1992). *Environmental impact assessment of the existing Green Island landfill*. Prepared by Beca Stevens for Dunedin City Council.

Boffa Miskell Ltd, & Avisure. (2021). *Smooth Hill Landfill—Bird management: Draft management plan* (Report BM200252; pp. 1–90). Prepared by Boffa Miskell Ltd and Avisure for Dunedin City Council.

Clapcott, J. (2015). *National rapid habitat assessment protocol development for streams and rivers* (Cawthron Report 2649). Prepared by Cawthron Institute for Northland Regional Council.

de Lange, P. J., Rolfe, J. R., Barkla, J. W., Courtney, S. P., Champion, P. D., Perrie, L. R., Beadel, S. M., Ford, K. A., Breitwieser, I., Schönberger, I., Hindmarsh-Walls, P. B., Heenan, P. B., & Ladley, K. (2018). *Conservation status of New Zealand indigenous vascular plants, 2017* (New Zealand Threat Classification Series 22). Department of Conservation.

Dunn, N. R., Allibone, R. M., Closs, G. P., Crow, S. K., David, B. O., Goodman, J. M., Griffiths, M., Jack, D. C., Ling, N., Waters, J. M., & Rolfe, J. R. (2018). *Conservation status of New Zealand freshwater fishes, 2017* (New Zealand Threat Classification Series 24). Department of Conservation.

GHD. (2021). *Green Island Landfill 2019-2020 annual monitoring report*. Prepared by GHD for Dunedin City Council.

GHD. (2024a). *Water Futures—Green Island Landfill Closure Groundwater Technical Assessment*. Prepared by GHD for Dunedin City Council. Updated July 2024

GHD. (2024b). *Water Futures—Green Island Landfill Closure Surface Water Report*. Prepared by GHD for Dunedin City Council. Updated July 2024.

Harding, J. S., Clapcott, J., Quinn, J., Hayes, J. W., Joy, M. K., Storey, R. G., Greig, H., Hay, J., James, T., Beech, M., Ozane, R., Meredith, A., & Boothroyd, I. (2009). *Stream habitat: Assessment protocols for wadeable rivers and streams of New Zealand*. School of Biological Sciences, University of Canterbury.

Larkin, G. J. A. (2006). *Hypoxia: Dynamics, causes and biological impacts in the Kaikorai Estuary, Dunedin* [Unpublished Master of Science in Environmental Science thesis]. University of Otago.

LAWA. (n.d.). *Factsheet: Coastal and freshwater recreation monitoring*. Land, Air, Water Aotearoa (LAWA). https://www.lawa.org.nz/learn/factsheets/coastal-and-freshwater-recreation-monitoring/

Lill, A. W. T., Closs, G. P., Schallenberg, M., & Savage, C. (2012). Impact of berm breaching on hyperbenthic macroinvertebrate communities in intermittently closed estuaries. *Estuaries and Coasts*, *35*(1), 155–168.

Local Government Geospatial Alliance. (n.d.). *Retrolens historical image resource*. https://retrolens.nz/

McEwen, W. M. (Ed.). (1987a). *Ecological regions and districts of New Zealand. Booklet to accompany Sheet 1: Descriptions of districts in the northern North Island, from Kermadec to Mayor* (3rd rev. ed. in four 1:500 000 maps). Department of Conservation.

McEwen, W. M. (Ed.). (1987b). *Ecological regions and districts of New Zealand. Booklet to accompany Sheet 4: Descriptions of districts in the southern South Island from Browning to Snares, also southern islands not shown on map* (3rd rev. ed. in four 1:500 000 maps). Department of Conservation.

Michel, P. (2021). *Amendment to the New Zealand Threat Classification System manual 2008: Revised categories 2021*. Department of Conservation.

Miller, M. A. (1993). A survey of birds on the Kaikorai Estuary. *Notornis*, *40*(4), 273–284.

NIWA. (2016). *A classification of New Zealand's coastal hydrosystems*. Prepared for the Ministry for the Environment.

Otago Regional Council. (2008). *Surface water quality: The water of Leith and Lindsay's Creek, Kaikorai Stream, Waitati River and Carey's Creek*. Otago Regional Council.

Otago Regional Council. (2021). *Regional Plan: Water for Otago*. Otago Regional Council.

Robertson, C. J. R., Hyvonen, P., Fraser, M. J., & Pickard, C. J. (2007). *Atlas of bird distribution in New Zealand: 1999-2004*. Ornithological Society of New Zealand.

Robertson, H. A., Baird, K. A., Elliott, G. P., Hitchmough, R. A., McArthur, N., Makan, T. D., Miskelly, C. M., Sagar, P. M., Scofield, R. P., Taylor, G. A., & Michel, P. (2021). *Conservation status of birds in Aotearoa New Zealand, 2021* (New Zealand Threat Classification Series 36). Department of Conservation.

Roper-Lindsay, J., Fuller, S. A., Hooson, S., Sanders, M. D., & Ussher, G. T. (2018). *Ecological impact assessment (EcIA). EIANZ guidelines for use in New Zealand: Terrestrial and freshwater ecosystems* (2nd ed.). Environment Institute of Australia and New Zealand.

Stark, J. D., Boothroyd, I. K. G., Harding, J. S., Maxted, J. R., & Scarsbrook, M. R. (2001). *Protocols for sampling macroinvertebrates in wadeable streams* (p. 65). Prepared for the Ministry for the Environment.

Stark, J. D., & Maxted, J. R. (2007). *A user guide for the Macroinvertebrate Community Index* (Cawthron Report 1166). Prepared by Cawthron Institute for the Ministry for the Environment.

Taddese, F., Schallenberg, M., Mikheev, P., Jarvis, M. G., & Closs, G. P. (2018). Ichthyofaunal assemblages in shallow littoral habitats of permanently open estuaries and intermittently closed and open lakes or lagoons in Otago, New Zealand. *Marine and Freshwater Research*, *69*(8), 1222–1230.

Walker, S., Cieraad, E., & Barringer, J. (2015). *The Threatened Environment Classification for New Zealand 2012: A guide for users* (Landcare Research Contract Report LC2184). Landcare Research.

Williams, P. A., Wiser, S. K., Clarkson, B. R., & Stanley, M. C. (2007). New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. *New Zealand Journal of Ecology*, *31*(2), 119–128.

Appendix 1: Cawthron Ecotoxicology Report

CAWTHRON

REPORT NO. 3895

PRELIMINARY ASSESSMENT OF THE IMPACTS OF THE GREEN ISLAND LANDFILL LEACHATE ON THE RECEIVING ENVIRONMENT USING PASSIVE SAMPLERS AND TOXICITY TESTING


World-class science
for a better future.

PRELIMINARY ASSESSMENT OF THE IMPACTS OF THE GREEN ISLAND LANDFILL LEACHATE ON THE RECEIVING ENVIRONMENT USING PASSIVE SAMPLERS AND TOXICITY TESTING

OLIVIER CHAMPEAU,[1] GRANT L NORTHCOTT,[2] LOUIS A TREMBLAY[1]

[1] CAWTHRON INSTITUTE
[2] NORTHCOTT RESEARCH CONSULTANTS LTD

Prepared for Boffa Miskell Ltd
Attention: Tanya Blakely

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Carlos Campos

APPROVED FOR RELEASE BY:
Roger Young

ISSUE DATE: 13 March 2023

RECOMMENDED CITATION: Champeau O, Northcott GL, Tremblay LA 2023. Preliminary assessment of the impacts of the Green Island landfill leachate on the receiving environment using passive samplers and toxicity testing. Prepared for Boffa Miskell Limited. Cawthron Report No. 3895. 13 p. plus appendices.

1. INTRODUCTION

This study investigated the potential impacts from the leachate of the Green Island landfill on ground and surface waters. An effect-directed analysis was used to assess the toxicity of surface and groundwater samples collected using passive sampling devices (PSDs) deployed at a range of sites in the catchment surrounding the landfill. The PSDs used concentrate hydrophilic organic chemicals, so the resulting extracts do not contain all contaminants present in the leachate, e.g. trace metals. The toxicity of the PSD extracts was assessed using tests on an algal and bacterial test species. If toxicity is detected using this method, it triggers further investigations, which can involve the use of sophisticated chemical fractionation and analysis to identify the chemical(s) responsible for the effects.

2. MATERIALS AND METHODS

2.1. Passive sampling devices

Hydrophilic–lipophilic balance (HLB) polar organic chemical integrative sampler (POCIS) PSDs were obtained from Affinisep (Le Houlme, France). This type of PSD was selected for this application because it adsorbs and concentrates primarily polar hydrophilic organic contaminants that are mobile and transported in aquatic environments. The Affinisep POCIS provides a ring-type PSD for deployment in surface-water sites and a rectangular-shaped PSD geometry designed for deployment in groundwater wells of reduced diameter (< 100 mm). Therefore, the same HLB sorbent can be used to sample both surface-water and groundwater well sites.

The HLB adsorbent phase in the Affinisep PSD exhibits an affinity and capacity to concentrate a broad range of semi-polar to polar organic contaminants, including pesticides, phenols and industrial alkylphenols, personal care chemicals, biocides, steroid hormones and pharmaceuticals.

2.2. Deployment sites

Figure 1 is an aerial photo of the Green Island landfill and its surroundings. On Thursday, 28 April 2022, PSDs were deployed at four surface-water sites (GI-1, Kaikorai Stream upstream of landfill; GI-2, Abbotts Creek upstream of landfill; GI-5, downstream of the landfill; and ‘Site downstream’, on the Kaikorai Stream close to the receiving estuary, to provide an insight into stressors from other sources) and then retrieved by staff of Boffa Miskell Ltd on Friday, 20 May 2022. The deployment was for a duration of 22 days as longer periods in surface water typically result in biofouling of the membrane, which can ultimately inhibit the uptake of contaminants (Stewart et al. 2016).

PSDs were also deployed at two groundwater well monitoring sites outside the leachate trench (Lines 2 and 4) within the Green Island landfill. A single groundwater PSD was deployed into a shallow well (C) and into a deep well (D). A duplicate set of each type of PSD (surface water and groundwater) was used as field blanks, and another single PSD of each type was used as a laboratory blank (Table 1). The groundwater PSDs were deployed on Friday, 29 April 2022 and retrieved on Friday, 20 May 2022, corresponding to a 21-day deployment period.

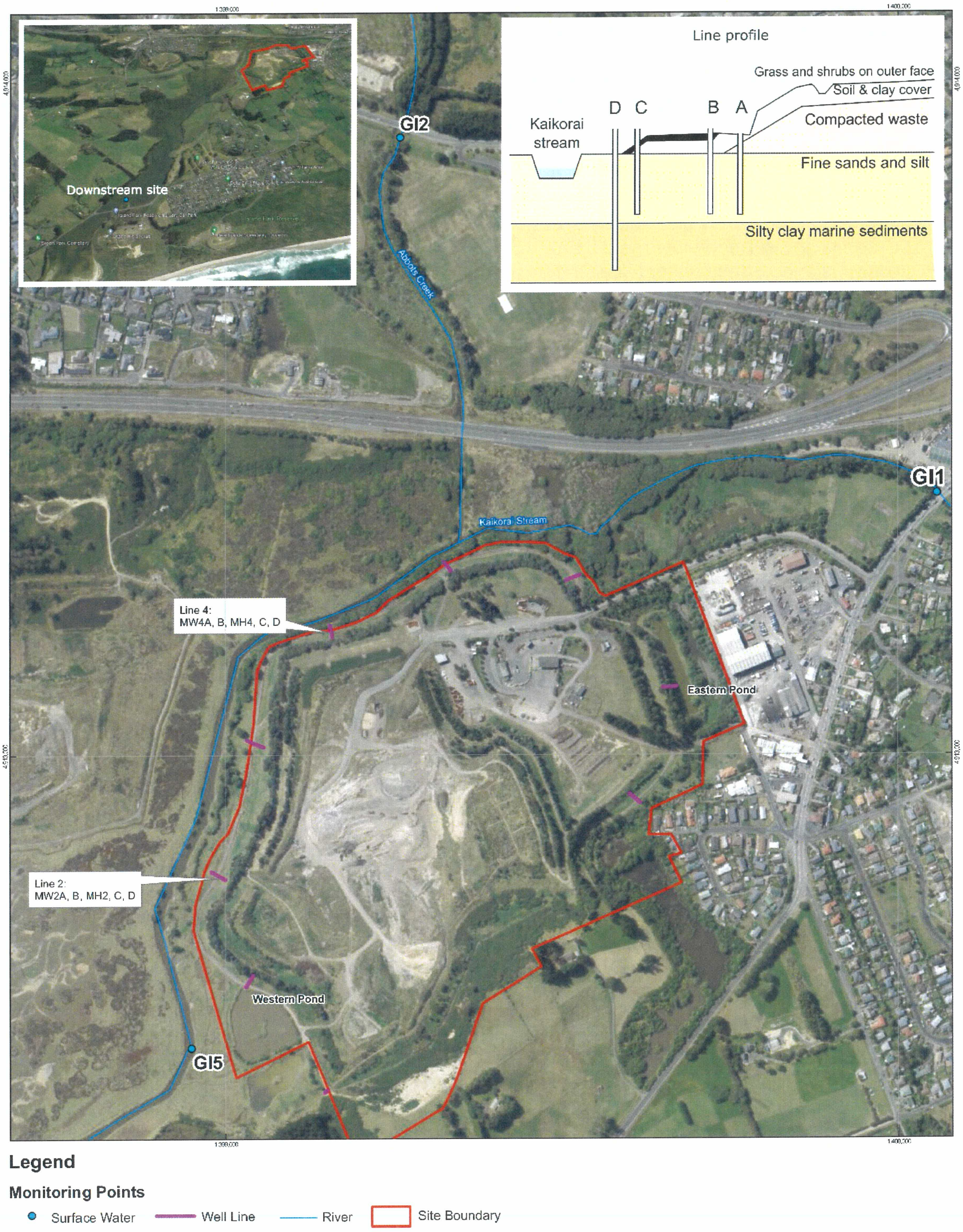


Figure 1. Map of Green Island landfill and surroundings, including the locations where passive sampling devices were deployed and groundwater-line well bore profiles near Kaikorai Stream. Source: GHD and Dunedin City Council.

Table 1. Details of sampling sites and where the PSDs were deployed, along with deployment durations.

Sampling site	Deployment period (days)
Green Island groundwater field blank	Not applicable
Green Island groundwater, Line 2C, shallow well	21
Green Island groundwater, Line 2D, deep well	21
Green Island groundwater, Line 4C, shallow well	21
Green Island groundwater, Line 4D, deep well	21
Green Island surface-water field blank	Not applicable
Green Island surface water, Site GI-1	22
Green Island surface water, Site GI-2	22
Green Island surface water, Site GI-5	22
Green Island surface water, Site downstream	22

The surface water PSDs were mounted within plastic burley cages to protect them from debris in the stream water (Figure 2). The burley cages were attached to a deployment rope with plastic cable ties, and a 0.5 kg lead diving weight was attached to the end of the rope approximately 1 m from the burley cage.

At the GI-2 and GI-5 sites and Site downstream near the estuary, the PSD units and weights were placed in water at a depth > 1 m, with the lead weight placed downstream so that the burley cage was positioned parallel to the flow of water. At the downstream estuary site, where the burley cage would not be exposed to potentially high flow rates, the unit was placed perpendicular to the edge of the estuary bank. A steel waratah (1.6 m long) was driven firmly into the side of the bank and the rope end of the deployment unit was securely tied off to it.

Special care was taken to ensure the deployment system was not in plain sight unless stumbled upon. Sampling site GI-1 on the Kaikorai Stream is located within the suburb of Green Island where the Brighton Road bridge crosses the stream. The stream banks at this site were too steep to secure a waratah and were easily seen from the adjacent footpath. At this site, the deployment rope was secured to utility piping fixtures within the concrete-box bridge culvert passing under the roadway. The burley cage containing the PSDs was submerged in water within the culvert and was visible only if a person physically walked down the stream and halfway into the culvert.

Prior to deployment of the groundwater PSDs, a lead weight was attached to fishing line and run to the base of the well, and the depth from the top of the well casing to the well base was recorded. The height of the water column in the well was determined by deploying a moisture probe attached to a tape measure and lowered into the well.

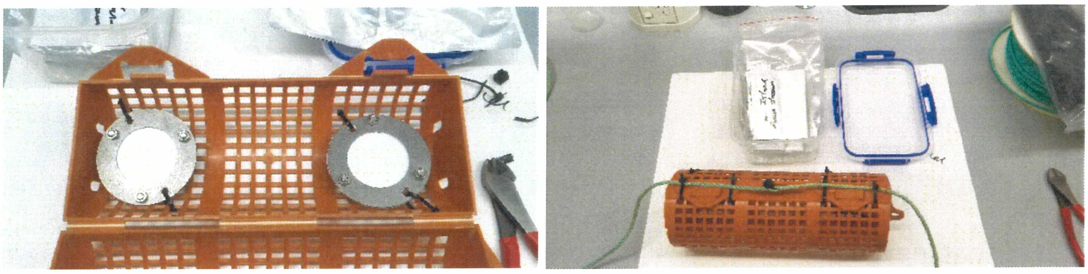


Figure 2. Preparation of surface water passive sampler devices.

After establishing the height of the water column above the base of the well, the PSD unit was attached to stainless-steel wire with an aluminium crimp (Figure 3A and B) and a length of wire measured off so that the PSD unit could be sited at the midpoint of the water column. The top end of the measured length of stainless-steel wire was fixed to the top well with another aluminium crimp (Figure 3C). The PSD was then deployed into the body of the well by hand.

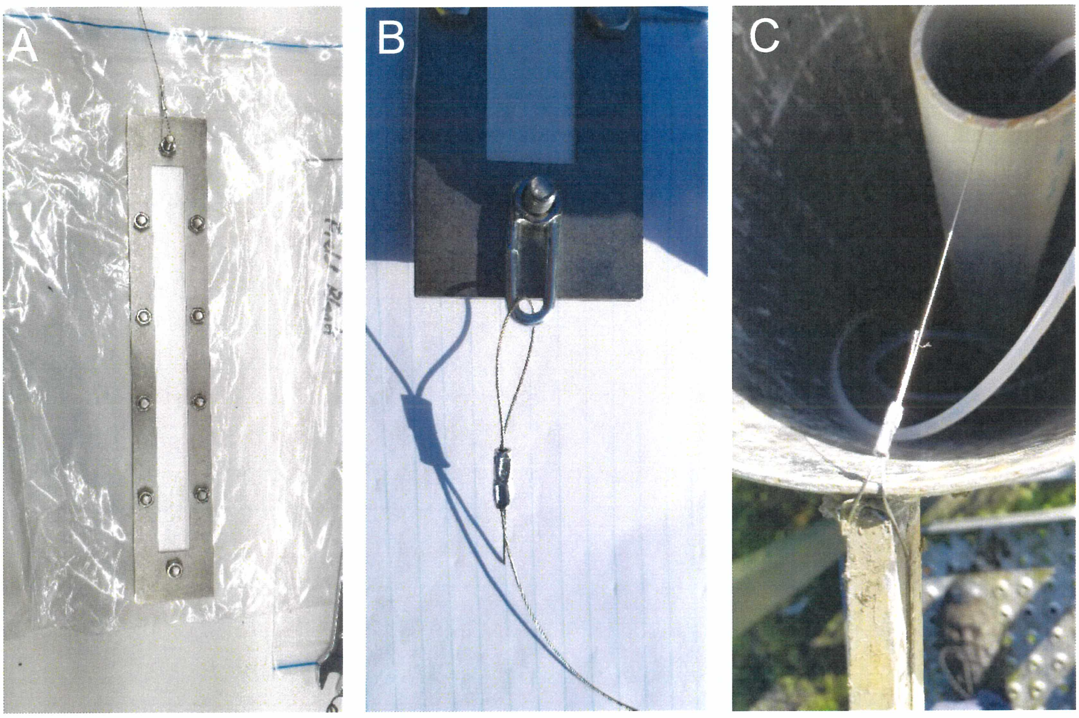


Figure 3. Securing ground water passive sampling devices with attachment to the frame (A and B), and to the body of the well (C).

The duplicate PSDs used as field blanks were removed from their packaging and exposed to the air for the duration of time that the sample PSDs were being prepared and deployed. In this way the field blank PSDs were exposed to the same sources of any potential background environmental contaminants as the deployed PSDs would have been during their preparation and deployment at a sampling site.

2.3. Extraction of passive samplers and preparation for biological testing

The retrieved and quality assurance field and laboratory blank PSD samples were disassembled at the Plant and Food Research Ruakura laboratories in Hamilton. The outer membranes were washed with purified water to remove adhering particulate material before the PSDs were opened. The adsorbent media were then transferred into empty 6 mL solid-phase extraction (SPE) cartridges. A porous polypropylene frit was inserted into the barrel of the SPE cartridge and pushed down to compress the adsorbent media. The organic contaminants accumulated by the adsorbent media were eluted with acetone, methanol and ethylacetate, which was collected in a glass flask.

The raw sample extracts were concentrated by evaporation under a stream of nitrogen gas and the concentrated solutions were filtered through a small bed of Hyperflo-Supercell celite filtration aid into tapered glass gas chromatography (GC) vials. The extracts were evaporated to dryness under a stream of nitrogen gas and reconstituted in dimethyl sulfoxide (DMSO) for bioassay testing.

The prepared extracts were shipped to the Cawthron Institute Ecotoxicology Laboratories for toxicity assessment.

2.4. Bioassays

Two bioassays were used in standardised test species. A bacteria-based bioluminescence test was used to detect general toxicity in the PSD extract samples. This test also provides insights into the presence of contaminants with antimicrobial activities. The algal-based assay was used to indicate the presence of herbicidal toxicity in the PSD extracts.

Both tests were carried out with a reference toxicant[1] to ensure consistency of the response observed. Summary of the test's conditions are reported in Table 2.

2.4.1. Luminescence inhibition assay

Microtox™ (ISO 11348-3) is an *in vitro* testing system that uses a strain of naturally occurring luminescent marine bacteria (*Aliivibrio fischeri*, syn. *Vibrio fischeri*) sensitive to a range of toxicants to determine the acute toxicity in an aqueous suspension

---

[1] Chemical used to assess the constancy of response of a given species of test organisms to that chemical. It is assumed that any change in sensitivity to the reference substance will indicate the existence of some similar change in degree of sensitivity to other chemicals / effluents whose toxicity is to be determined.

(Environment Canada 1992; ISO 2007). Briefly defined, the test measures light changes produced naturally by the luminescent bacteria when they are exposed to the samples under standard conditions over 15 minutes. Zinc as Zn^{2+} was used as the reference toxicant.

The testing of the PSD extracts at 1:100 (maximum concentration of carrier solvent) resulted in a total extinction of the bacterial luminescence, likely due to the colour of the extracts (Figure 4). Extracts from the groundwater Line 2D and Line 4C had dark brown colour. Extracts from surface-water site GI-1 had a slightly lighter brown colour, while groundwater Lines 2C and 4D, surface-water sites GI-2 and GI-5, and Site downstream extracts had the lightest brown colour. Groundwater field blank and surface-water field blank extracts were transparent. The Line 2D sample extract was used to determine the dilution required to achieve a suitable colouring of the solution for the test. A further dilution of the extracts 1:32 in DMSO was carried out to reduce colour-quenching impact during measurement.

For the assay, a final concentration of DMSO in the test tube was 1:100, with the final extract dilution being 1:3,200 (0.0313%).

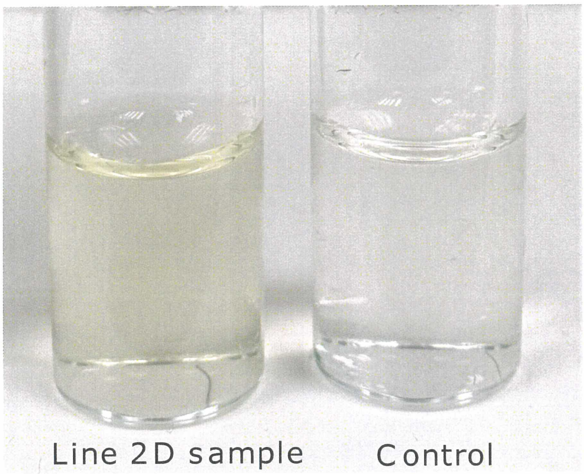


Figure 4. Example of a sample of passive sampling device extract at 1% in test tubes before dilution.

2.4.2. Algal growth inhibition assay

The 96-hour chronic toxicity test uses the green microalga *Dunaliella tertiolecta* according to the American Society for Testing and Materials standard (ASTM 2012) and is recommended by the Ministry for the Environment as a method for direct toxicity assessment (DTA) testing (Hall & Golding 1998). During their exponential growth phase, the algae are exposed to dilutions of a test solution under static conditions (i.e. no renewal of the test solutions) and at constant temperature and salinity over a period of 96 hours. Over that period, the algae can produce several generations and their growth while exposed to the test solution is compared to the growth of the control. A test solution is considered toxic when statistically significant dose-dependent inhibition of algal growth occurs. Potential effects from the solvent DMSO were assessed by testing solutions with and without the carrier solvent. Copper was used as the reference toxicant.

2.5. Statistical analysis

Comparison in toxicity between PSD sample extracts (level of statistical significance of $P < 0.05$) and calculation of the EC_{50} (the concentration that produces an effect on 50% of the test organisms) with associated 95% confidence intervals (CI) followed Hall and Golding (1998) using CETIS™ (Tidepool Scientific, LLC, USA) and Statistica™ (TIBCO software, California, USA).

Table 2. Summary of the test conditions.

	Microtox™	**Green microalgae**
Test start to end dates	11/01/2023	19/01/2023 to 23/01/2023
Standard	ISO 11348-3 (2007)	ASTM E1218-04 (2012)
Test species	*Aliivibrio fischeri*	*Dunaliella tertiolecta*
Source	BioLight Aqua-Science (Lot 10641121)	Laboratory culture (CS3/7)
Density, number per test container	n/a	10.6 ± 3 × 10^3p/mL
Type of test container	5 mL glass tube	96-well plate round bottom
Exposure time (h)	0.25	96
Concentrations (%)	0, 0.03%	0, 0.03%
Replicates	2	10 for controls, 5 for treatments
Light	n/a	Continuous 200 µmol/m^2/sec
Temperature (°C)	15	18.3 ± 1.4
Dissolved oxygen (at the beginning of the test) (mg/L)	n/m	n/m
pH	n/m	7.8
Dilution water	Brackish water	Artificial seawater
Aeration	None	None
Salinity (at the beginning of the test, PSU)	20	26
Endpoint	Luminescence	Growth inhibition
Sensitivity (EC_{50} with 95% CI)	1.43 (1.14–1.79) mg Zn^{2+}/L	0.141 (0.132–0.150) mg Cu^{2+}/L
Control quality for sensitivity (mean±2 standard deviation)	1.33 (1.06–1.6) mg Zn^{2+}/L ($n = 2$)	0.128 (0.041–0.215) mg Cu^{2+}/L ($n = 47$)
Test acceptability (in controls)	Yes	CV < 20%, 16-fold increase
Note	–	Age of culture: 6 days

Abbreviations: n/m = not measured, CI = confidence interval, CV = coefficient of variation, h = hour.

3. RESULTS

3.1. Luminescence inhibition assay

The results of the luminescence inhibition test with the bacterium *Aliivibrio fischeri* are presented in Figure 5. The results are relative to the control (DMSO and diluent water). The groundwater and surface-water field blanks were not statistically different from each other. The groundwater sample extracts from Line 4C and Lines 2C and 2D were significantly different from their field blank (*P* < 0.05). The surface-water sample extracts from site GI-5 and Site downstream are significantly different from the field blank (*P* < 0.05).

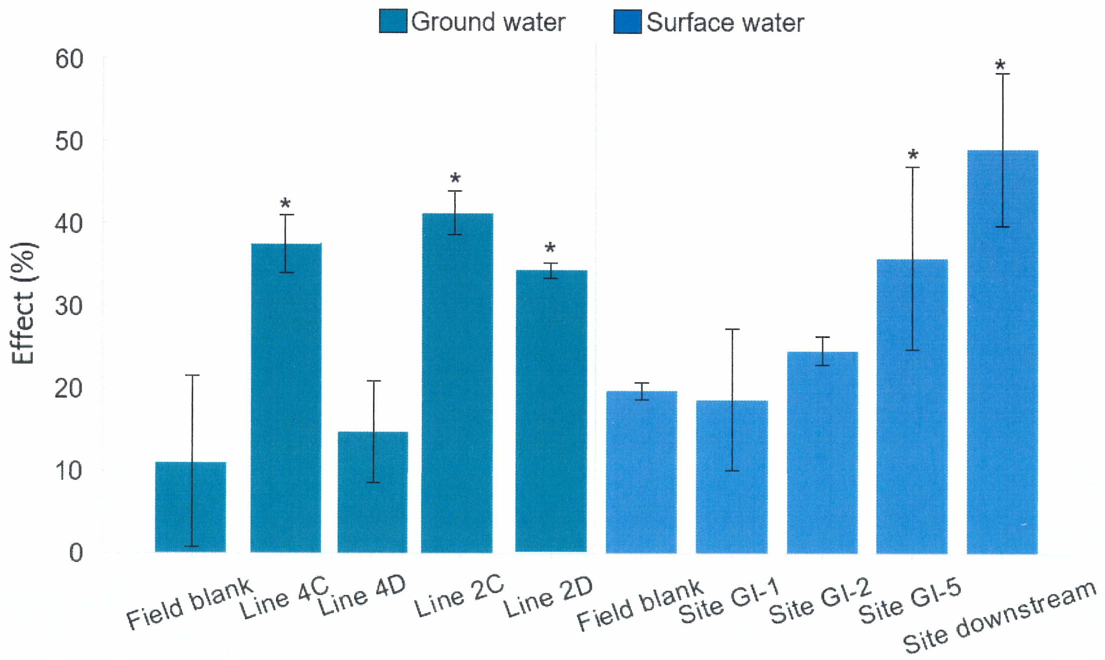


Figure 5. Acute toxicity effect (reduction of bacterial luminescence expressed as %) after a 15-minute exposure to passive sampling device extracts (0.0313%). Asterisks (*) indicate a significant difference (*P* < 0.05) from the related field blank.

3.2. Algal growth inhibition assay

No statistical difference was found between the field blanks and DMSO control (Table 3), indicating no effect of the solvent used with the PSD extracts. The results of the algal growth inhibition test with the marine green microalgae are presented in Figure 6. Field blanks (groundwater and surface water) were not significantly different from the DMSO control. A significant difference from the related field blank was found only for groundwater samples from Line 2C, Line 4C and Line 4D ($P < 0.05$). The sample from Line 4C was also significantly different from the DMSO control ($P < 0.05$). No statistical difference was observed between surface-water samples and their respective DMSO control or field blank.

Table 3. Average algal density (×1,000/mL) in DMSO and artificial seawater (ASW).

Controls	*n*	Average	Standard deviation	Coefficient of variation
DMSO control	15	250.1	16	6%
ASW (control)	15	257.6	14	5%

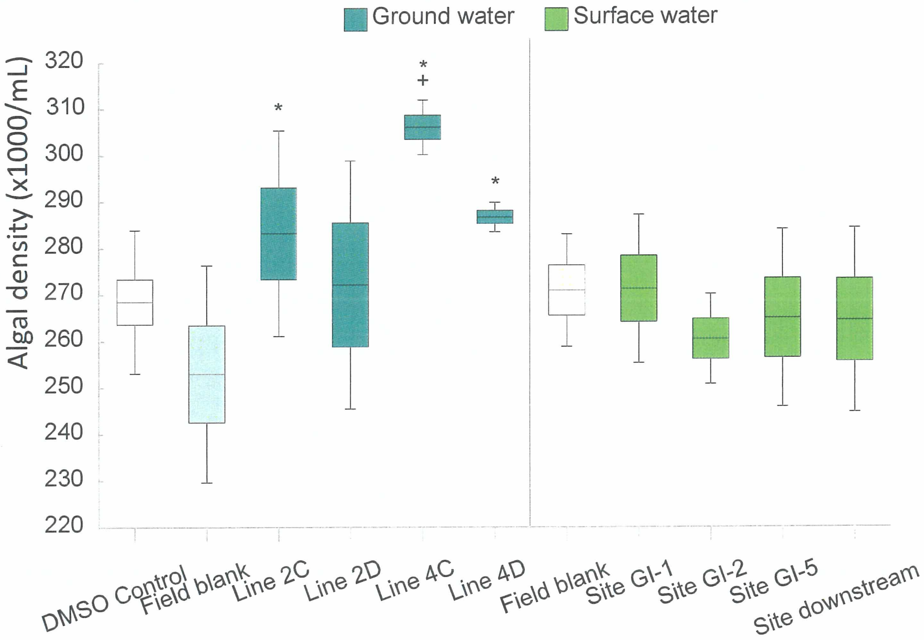


Figure 6. Box plots showing effects of passive sampling device extracts (0.0313%) on algal growth density after a 96-hour exposure. Asterisks (*) indicate a significant difference from the related field blank and the plus sign (+) a significant difference from the control ($P < 0.05$).

4. DISCUSSION

Environmental samples are often complex mixtures containing a range of molecules. The PSDs used in this study absorb organic compounds present in the water column, so the extracts tested did not contain metals or highly hydrophobic molecules, which would partition mainly in suspended solids and sediment. The PSD extracts from Lines 2C and 4C had some impact on the populations of the two test model organisms used.

The Microtox™ results show a pattern of increasing toxicity from the surface sample sites upstream of the landfill (GI-1, GI-2) to the GI-5 site and Site downstream. The higher inhibition at Site downstream compared to GI-5 suggests that there are sources other than the landfill contributing to the toxicity. The bacterial luminescence results of the groundwater samples indicate a potential pattern of transport and distribution of the leachate from the landfill site. The sample from Line 4C, closer to the top of the landfill, had higher toxicity than the Line 4D sample, suggesting that the leachate is present in the fine sand and silt portion at this location but has not yet migrated into the deeper silty clay marine sediment portion. The toxicity results from the Lines 2C and 2D samples, further downstream from the site, indicate that the leachate plume has now migrated across both these environmental compartments.

The bacterial luminescence data from the surface-water samples show toxicity at the sites downstream of the landfill, suggesting that toxic leachate is seeping out. The extract from Site downstream was more toxic than that at GI-5. Although the difference is not significant, this suggests that some of the toxicity is from sources other than the landfill.

Some of the groundwater extracts tested showed a stimulation of algal growth instead of the expected inhibition. This indicates that some organic compounds present in the extract samples can be used by the algae as a source of nutrient and can stimulate their growth (Yu et al. 2015). This suggests that it is unlikely that the extracts contain herbicidal activity.

The interpretation of the results of this study warrants some caution as they use data from a one-off sampling event. The results suggest that there is leachate seeping out from the landfill, but this conclusion is based solely on PSDs that concentrated hydrophilic organic chemicals. The toxicity at the site is likely to be higher when accounting for other contaminants such as trace metals, which were not captured by the type of PSD used. It would be advisable to gain a better understanding of the dynamics and composition of the leachate from the landfill to assess any long-term impacts. It would also be advisable to adopt an approach for capturing both the spatial and temporal variations of landfill leachate (Butt et al. 2008) to account for factors such as seasonality and the increase in the occurrence of extreme rain events.

5. RECOMMENDATIONS

- Establishing the chemical characterisation of the leachate would be valuable to identify the more toxic components and inform whether remedial actions are required to reduce the risk to exposed biota.
- Ongoing monitoring of the biota in the aquatic environment would provide valuable information on the ecological impacts of the leachate.
- Establishing the complementary characterisation of other sources of stressors in the catchment would assist in more effective management and protection of this area.

6. REFERENCES

[ASTM] American Society for Testing and Materials. 2012. E1218-04 – standard guide for conducting static toxicity tests with microalgae. West Conshohocken, PA: ASTM International. 14 p.

Butt TE, Lockley E, Oduyemi KOK. 2008. Risk assessment of landfill disposal sites – state of the art. Waste Management 28(6): 952–964.

Environment Canada. 1992. Biological test method: toxicity test using luminescent bacteria EPS 1/RM/24. Environmental Protection Series. Ottawa: Environment Canada. 53 p.

Hall JA, Golding LA. 1998. Standard Methods for Whole Effluent Toxicity Testing: development and application. Report no. MfE80205. NIWA report for the Ministry for the Environment (TR 84). 53 p.

[ISO] International Organization for Standardization. 2007. ISO 11348-3. Water quality – Determination of the inhibitory effect of water samples on the light emission of *Vibrio fischeri* (luminescent bacteria test) – Part 3: Method using freeze-dried bacteria. 15 p.

Stewart M, Cameron M, McMurtry M, Sander SG, Benedict B, Graham L, Hosie M, Green T. 2016. Development of passive sampling devices for bioavailable contaminants of current and emerging concern: Waitemata Harbour case study. New Zealand Journal of Marine and Freshwater Research 50(4): 526–548.

Yu X, Chen L, Zhang W. 2015. Chemicals to enhance microalgal growth and accumulation of high-value bioproducts. Frontiers in Microbiology 6: 10.

Appendix 1. Complete datasets for both bioassays

A1.1 Microtox^{TM}

Table A1.1. Luminescence, gamma values and effect (as % of control) per replicate after a 15-minute exposure to the PSD extracts.

Extract samples	**Luminescence (relative unit)** t0	t15min.	**Gamma**	**Effect (%)**
Control diluent	87	71	–	–
Control diluent	91	90	–	–
Control DMSO 1	90	88	–	–
Control DMSO 1	103	101	–	–
Control DMSO 2	95	81	–	–
Control DMSO 2	101	93	–	–
Groundwater field blank	76	61	0.395	3.80
Groundwater field blank	94	64	0.226	18.40
Groundwater Line 2C, shallow well	87	44	0.650	39.39
Groundwater Line 2C, shallow well	95	45	0.761	43.23
Groundwater, Line 2D, deep well	92	51	0.505	33.56
Groundwater, Line 2D, deep well	94	51	0.539	34.97
Groundwater, Line 4C, shallow well	83	45	0.538	35.02
Groundwater, Line 4C, shallow well	98	49	0.669	40.07
Groundwater, Line 4D, deep well	79	59	0.118	10.49
Groundwater, Line 4D, deep well	89	60	0.238	19.20
Surface water field blank	87	68	0.257	20.44
Surface water, Site GI-1	93	74	0.235	19.01
Surface water, Site GI-1	78	67	0.144	12.57
Surface water, Site GI-1	96	71	0.328	24.72
Surface water, Site GI-2	85	64	0.305	23.36
Surface water, Site GI-2	92	67	0.349	25.87
Surface water, Site GI-5	82	58	0.389	28.01
Surface water, Site GI-5	94	52	0.776	43.69
Surface water, Site downstream	92	52	0.738	42.47
Surface water, Site downstream	94	41	1.252	55.60

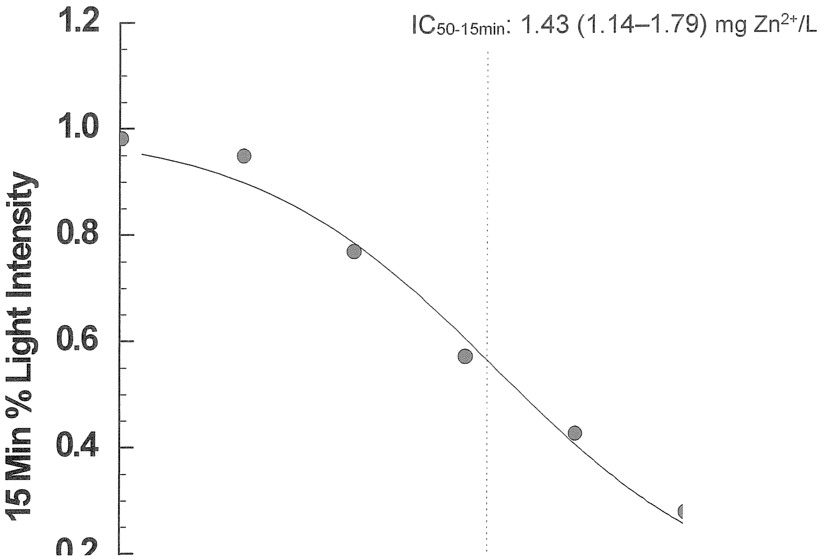


Figure A1.1. Average (red dots) light intensity after a 15-minute exposure, with 95% confidence interval (dashed line) for the dose response to the reference toxicant (zinc as Zn^{2+}).

A1.2 Algal growth

Table A1.2.Algal density (×1,000/mL) per replicate after a 96-hour exposure to PSD extracts. Abbreviations: nm = not measured.

Control	Groundwater					Surface water				
DMSO	Field blank	Line 2C	Line 2D	Line 4C	Line 4D	Field blank	GI-1	GI-2	GI-5	Down-stream
247.2	240.7	265.9	290.7	301.3	289.3	267.7	263.1	252.1	243.2	230.4
245.0	284.6	284.6	298.7	304.3	290.9	260.0	288.2	267.7	295.0	269.7
261.2	266.6	265.4	243.7	300.2	284.6	291.6	288.1	273.8	259.0	277.4
265.6	248.8	280.4	255.4	310.7	284.1	265.7	263.5	254.1	259.1	265.8
266.3	224.3	319.7	n/m	313.6	284.5	269.6	253.4	254.5	268.5	279.1
287.5										
273.9										
281.6										
265.9										
290.8										

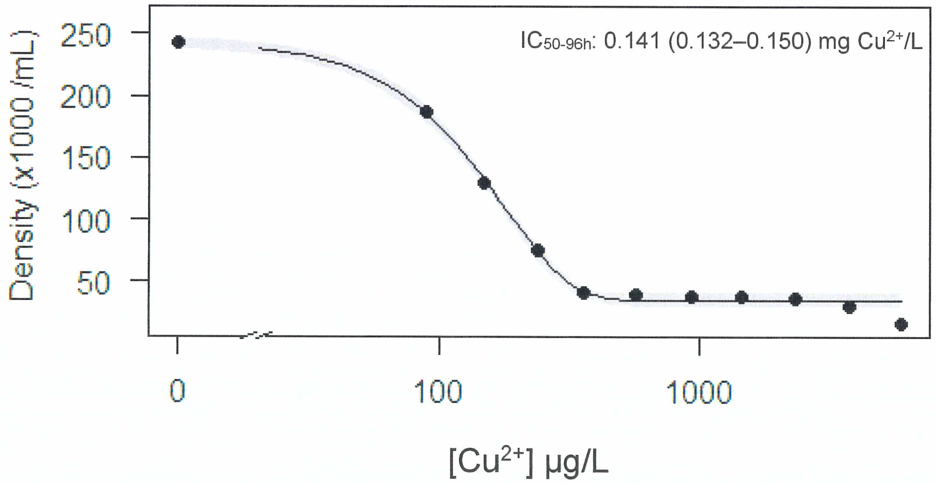


Figure A1.2. Average (black dots) algal density with 95% confidence interval (greyed surface) for the dose response to the reference toxicant (copper).

Appendix 2. Acronyms and definitions

Acronym	Definition
ASTM	American Society for Testing and Materials
ASW	Artificial seawater
CETIS™	Comprehensive Environmental Toxicology Information System™
CI	Confidence interval
Cu^{2+}	Ion of copper with a double positive charge
CV	Coefficient of variation
DMSO	Dimethyl sulfoxide
DO	Dissolved oxygen
DTA	Direct toxicity assessment
$EC_{x\text{-}t}$	**Effective concentration** is the generic term for a concentration of a substance or material that is estimated to cause some defined effect on a proportion (x%) of the test organisms after a defined period of exposure (t). This kind of end point allows the classification and the comparison of the toxic potency or intensity of different chemicals. More terms can be derived to describe specific effects (e.g. lethality, inhibition): • **$LC_{x\text{-}t}$ (lethal concentration)** is the concentration of a substance or material that is estimated to be lethal to a proportion (x%) of the test organisms after a defined period of exposure (t). This is an acute toxicity indicator. • **$IC_{x\text{-}t}$ (inhibitory concentration)** is the concentration of a substance or material that is estimated to have an inhibitory effect (e.g. algal growth) on a proportion (x%) of the test organisms after a defined period of exposure (t). This is a chronic toxicity indicator.
GC	Gas chromatography
LOEC	**Lowest observed effect concentration** is the lowest concentration of a test substance or material that is observed to have a statistically significant adverse effect on the test organisms after a defined time of exposure and under the test conditions, relative to the control.
NOEC	**No observed effect concentration** is the highest concentration of a test substance or material that is observed not to have a statistically significant adverse effect on the test organisms after a defined time of exposure and under the test conditions, relative to the control.
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
POCIS	Polar organic chemical integrative sampler
PSD	Passive sampling device
PSU	Practical salinity unit. A unit based on the properties of seawater conductivity to measure salinity. It is equivalent to parts per thousand (‰), or to g/kg.
SD	Standard deviation
SPE	Solid-phase extraction
Zn^{2+}	Ion of zinc with a double positive charge

CAWTHRON

18 December 2023

Tanya Blakeley
Boffa Miskell Ltd
141 Cambridge Terrace
Christchurch 8013

ID: 2392

Dear Tanya,

ADDENDUM TO CAWTHRON REPORT 3895: ‘PRELIMINARY ASSESSMENT OF THE IMPACTS OF THE GREEN ISLAND LANDFILL LEACHATE ON THE RECEIVING ENVIRONMENT USING PASSIVE SAMPLERS AND TOXICITY TESTING’

Please find herewith the results for the blue mussel embryo-larval development test conducted on extracts.

Embryo-larval development assay

The blue mussel (*Mytilus galloprovincialis*) 48-hour embryo-larval development (survival) acute test is a widely used and well-validated test (ASTM 2021). Briefly, freshly fertilised eggs are exposed to dilutions of the test solution under static conditions (no renewal of the test solution) for a fixed period of 48 hours. At the end of the test, larvae are fixed in a solution of formalin and D-larvae are numbered. The number of abnormal D-larvae in the test solution gives an indication of embryo toxicity in early life stage development. A test solution is considered toxic when a statistically significant, dose-dependent increasing percentage of abnormalities occurs. The test is conducted during the mussel’s early life stages, which are highly sensitive. The test parameters and sensitivity control are reported in Table 1.

Table 1. Exposure parameters for the embryo-larval development assay

	Bivalve – embryo-larval development
Test start–end dates	29 November 2023–1 December 2023
Standard	ASTM E724-21 (2021)
Cawthron SOP	ETX 4
Test species	*Mytilus galloprovincialis*
Source	Duncan Bay
Density (no. per container)	~ 400
Test containers	6-well plate (10 mL/well)
Exposure time (hr)	48
Sample pre-treatment	None
Replicates	5
Light	None
Temperature (°C)	16.3 ± 0.8
Dissolved oxygen (at beginning) (mg/L)	8.7 (108%)
pH	8.4
Dilution water	Reconstituted seawater
Aeration	None
Salinity (beginning; PSU)	33.4
End point	Survival
Sensitivity (EC_{50} with 95% CI)	0.230 (0.224–0.236) mg Zn^{2+}/L
Control quality for sensitivity (mean with 2SD)	0.183 (0.118–0.247) mg Zn^{2+}/L (n = 10)
Test acceptability (in controls)	> 60% development
Test compliance to procedure	Yes
Notes	Collection date: 28 November 2023 Spawning method: thermal stimulation

Results and discussion

Mussel embryo survival rates (as larvae D-yield) for the tested extracts are presented in Figure 1 (raw data are reported in Appendix 1, Table A.1). The assay did not show any significant difference between the reconstituted seawater control (Control) and the extracts resuspension solvent (DMSO [dimethyl sulfoxide] control). Nor was any difference detected between the DMSO control and the extracts for the tested sites. Only the difference between the Control (without DMSO) and the sites was significant ($P < 0.05$). A previous trial showed the same trend (results not shown as the standard deviations were too wide to be used). As no difference was detected between field blanks and tested sites, this could indicate a low toxicity, if any, of extracts towards the tested organism.

Water used for the test with the mussel embryos was saltier (33.4 PSU) than media used with the other tested organisms (20 PSU and 26 PSU for the marine bacterium *Aliivibrio fischeri* and the green microalga *Dunaliella tertiolecta*, respectively). This may have buffered the impact on the embryo-larval development of the blue mussel, by reducing the bioavailability of the different compounds (Heugens et al. 2021).[1]

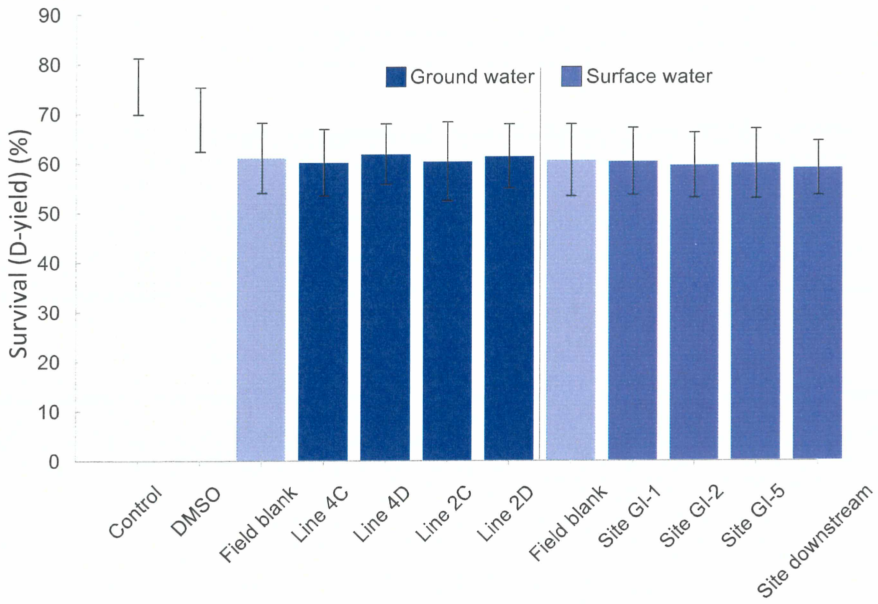


Figure 1. Blue mussel larvae survival (% D-yield) (average ± standard deviation).

Yours sincerely

Scientist

Olivier Champeau
Ecotoxicologist
Cawthron Institute

Reviewed by

Louis Tremblay
Environmental Toxicologist
Cawthron Institute

---

[1] Heugens E, Hendriks A, Dekker T, Straalen N, Admiraal W. 2001. A review of the effects of multiple stressors on aquatic organisms and analysis of uncertainty factors for use in risk assessment. Critical Reviews in Toxicology. 31:247–284. https://doi.org/10.1080/20014091111695

Appendix 1

Table A.1 Blue mussel embryo survival (% D-yield larvae) after a 48-hour exposure to extracts from test sites

Seawater control	GI.1 DMSO control	GI.2 Field blank GW	GI.5 Line 4C	GI.6 Line 4D	GI.3 Line 2C	GI.4 Line 2D	GI.7 Field blank S	GI.8 Site GI-1	GI.9 Site GI-2	GI.10 Site GI-5	GI.11 Site downstream
71.2	64.2	53.5	55.5	57.8	60.8	61.1	65.3	61.0	56.5	60.5	53.4
69.0	60.9	54.3	52.5	53.7	51.9	56.8	57.2	50.5	50.0	49.1	54.8
77.2	70.6	62.2	59.8	65.3	61.2	53.6	57.9	58.5	61.9	61.5	64.8
78.7	77.6	69.4	69.4	69.0	72.8	68.2	70.6	69.2	67.1	68.6	64.9
79.6	70.8	66.1	63.8	63.8	55.3	67.6	52.3	62.7	62.6	60.0	57.2
67.5											
71.2											
69.4											
81.7											
73.5											

Appendix 2: Avifauna Species List

Table 23: Complete list of avifauna species within DY31 and DY32 grid squares encompassing the landfill and Kaikorai Lagoon from the online eBird atlas. The dark green cells indicate the primary habitat used by each species and the light green cells represent secondary habitat/s used by the species.

SPECIES - Robertson et al. 2012		CONSERVATION STATUS - Robertson et al. 2021		HABITAT								SOURCE	
				Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	eBird (DY31, DY32)	2022-23 project site surveys
White-fronted tern	*Sterna s. striata*	At Risk	Declining$^{CI\ CR\ DPT}$						■			x	
Little shag	*Phalacrocorax melanoleucos brevirostris*	At Risk	Relict$^{CR\ DPT}$					■	▨			x	
Welcome swallow	*Hirundo n. neoxena*	Not Threatened	Not Threatened$^{SO\ ST}$				■	░				x	
Black-billed gull	*Larus bulleri*	At Risk	Declining$^{CI\ CR\ RF}$				▨	■	▨			x	
Greenfinch	*Carduelis chloris*	Introduced	Introduced & Naturalised^{SO}		▨	▨	■				▨	x	
Silvereye	*Zosterops lateralis lateralis*	Not Threatened	Not Threatened^{SO}	▨	▨	■					▨	x	
Redpoll	*Carduelis flammea*	Introduced	Introduced & Naturalised^{SO}			▨	■				▨	x	
Australasian gannet	*Morus serrator*	Not Threatened	Not Threatened^{CI} De* Inc SO						▨	■		x	
Otago shag	Leucocarbo chalconotus	Threatened	Recovereing									x	
Fairy prion	*Pachyptila turtur*	At Risk	Relict$^{CDB\ RR\ SO}$							■		x	
Variable oystercatcher	*Haematopus unicolor*	At Risk	Recovering$^{CI\ Inc}$				▨	▨	■			x	x
Shining cuckoo	*Chrysococcyx l. lucidus*	Not Threatened	Not Threatened	■		▨						x	
Grey duck x mallard hybrid	*Anas superciliosa x platyrhynchos*	Not Threatened	Not Threatened				▨	■				x	
Pied shag	*Phalacrocorax varius varius*	At Risk	Recovering^{CD}					■	▨			x	
Sooty shearwater	*Puffinus griseus*	At Risk	Declining$^{CD\ CI\ SO}$							■		x	
NZ pied oystercatcher	*Haematopus finschi*	At Risk	Declining^{CI}				▨	■	▨			x	x

SPECIES - Robertson et al. 2012		CONSERVATION STATUS - Robertson et al. 2021		HABITAT								SOURCE	
				Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	eBird (DY31, DY32)	2022-23 project site surveys
Mallard	*Anas platyrhynchos*	Introduced	Introduced & Naturalised^{SO}				▨	🟩				x	
Royal spoonbill	*Platalea regia*	At Risk	Naturally Uncommon$^{\text{Inc RR SO Sp}}$					▨	🟩			x	
Brown creeper	*Mohoua novaeseelandiae*	Not Threatened	Not Threatened	🟩	▨	▨						x	
Southern blue penguin	*Eudyptula minor minor*	At Risk	Declining$^{\text{CI CR DPS DPT}}$						▨	🟩		x	
Black shag	*Phalacrocorax carbo novaehollandiae*	At Risk	Relict$^{\text{CR DPS DPT SO Sp}}$					🟩	▨			x	
Black-backed gull	*Larus d. dominicanus*	Not Threatened	Not Threatened^{SO}				▨		🟩			x	
Red-billed gull	*Larus novaehollandiae scopulinus*	At Risk	Declining^{CI}				▨	▨	🟩			x	
White-faced heron	*Egretta novaehollandiae*	Not Threatened	Not Threatened^{SO}				▨	▨	🟩			x	
Canada goose	*Branta canadensis*	Introduced	Introduced & Naturalised^{SO}				🟩	▨	▨			x	
Magpie	*Gymnorhina tibicen*	Introduced	Introduced & Naturalised^{SO}		▨		🟩				▨	x	
South Island fantail	*Rhipidura f. fuliginosa*	Not Threatened	Not Threatened^{EF}	🟩	▨	▨					▨	x	
Eastern falcon	*Falco n. novaeseelandiae*	Threatened	Nationally Vulnerable$^{\text{CR DPS CPT}}$	▨		▨	🟩					x	
Southern giant petrel	*Macronectes giganteus*	Migrant	Migrant^{SO}							🟩		x	
Spur-winged plover	*Vanellus miles novaehollandiae*	Not Threatened	Not Threatened^{SO}				🟩	▨				x	
Little owl	*Athene noctua*	Introduced	Introduced & Naturalised^{SO}				🟩				▨	x	

SPECIES - Robertson et al. 2012		CONSERVATION STATUS - Robertson et al. 2021		HABITAT								SOURCE	
				Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	eBird (DY31, DY32)	2022-23 project site surveys
Kingfisher	*Todiramphus sanctus vagans*	Not Threatened	Not Threatened	▓		░	░	▓				x	
White heron	*Ardea modesta*	Threatened	Nationally Critical$^{CR\ OL\ SO\ St}$					▓	░			x	
Southern Buller's mollymawk	*Thalassarche b. bulleri*	At Risk	Declining$^{CD\ CR\ RR}$							▓		x	
NZ white-capped mollymawk	*Thalassarche cauta steadi*	At Risk	Declining$^{CD\ CI\ CR}$ $_{EF\ RR}$							▓		x	
Northern giant petrel	*Macronectes halli*	At Risk	Recovering$^{RR\ Inc}$ $_{SO}$							▓		x	
Swamp harrier	*Circus approximans*	Not Threatened	Not Threatened^{SO}				▓					x	
Pied stilt	*Himantopus h. leucocephalus*	Not Threatened	Not Threatened^{SO}				░	▓	░			x	x
Tui	*Prosthemadera n. novaeseelandiae*	Not Threatened	Not Threatened^{Inc}	▓		░						x	
Blackbird	*Turdus merula*	Introduced	Introduced & Naturalised^{SO}	░	░	▓	░				░	x	
Paradise shelduck	*Tadorna variegata*	Not Threatened	Not Threatened				░	▓				x	
Morepork	*Ninox n. novaeseelandiae*	Not Threatened	Not Threatened	▓	░	░	░					x	
Grey teal	*Anas gracilis*	Not Threatened	Not Threatened$^{Inc\ SO}$				░	▓	░			x	
Eastern rosella	*Platycercus eximius*	Introduced	Introduced & Naturalised^{SO}	░	░	▓						x	
Black-fronted tern	*Chlidonias albostriatus*	Threatened	Nationally Endangered^{CI} $_{CD,\ PD,\ RF,\ Sp}$					▓	░			x	
Pukeko	*Porphyrio m. melanotus*	Not Threatened	Not Threatened$^{Inc\ SO}$				░	▓				x	
Grey warbler	*Gerygone igata*	Not Threatened	Not Threatened	░	░	▓					░	x	

SPECIES - Robertson et al. 2012		CONSERVATION STATUS - Robertson et al. 2021		HABITAT								SOURCE	
				Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	eBird (DY31, DY32)	2022-23 project site surveys
Dunnock	*Prunella modularis*	Introduced	Introduced & Naturalised^{SO}	░	░	░	▓				░	x	
Skylark	*Alauda arvensis*	Introduced	Introduced & Naturalised^{SO}				▓					x	
South Island tomtit	*Petroica macrocephala macrocephala*	Not Threatened	Not Threatened	▓	░	░						x	
Starling	*Sturnus vulgaris*	Introduced	Introduced & Naturalised^{SO}				▓				░	x	
Black swan	*Cygnus atratus*	Not Threatened	Not Threatened^{SO}				░	▓	░			x	
Yellowhammer	*Emberiza citrinella*	Introduced	Introduced & Naturalised^{SO}			░	▓					x	
Rock pigeon	*Columba livia*	Introduced	Introduced & Naturalised^{SO}				░				▓	x	
Song thrush	*Turdus philomelos*	Introduced	Introduced & Naturalised^{SO}	░	░	░	▓				░	x	
Chaffinch	*Fringilla coelebs*	Introduced	Introduced & Naturalised^{SO}	░	░	░	▓				░	x	
House sparrow	*Passer domesticus*	Introduced	Introduced & Naturalised^{SO}				▓				░	x	
Bellbird	*Anthornis m. melanura*	Not Threatened	Not Threatened	▓	░	░					░	x	
Kereru	*Hemiphaga novaeseelandiae*	Not Threatened	Not Threatened^{CD} Inc	▓		░						x	
Goldfinch	*Carduelis carduelis*	Introduced	Introduced & Naturalised^{SO}			░	▓				░	x	
Australian shoveler	*Anas rhynchotis*	Not Threatened	Not Threatened^{SO}					▓	░			x	
Caspian tern	*Hydroprogne caspia*	Threatened	Nationally Vulnerable$^{CI\ SO}$ Sp					░	▓			x	
NZ pipit	*Anthus n. novaeseelandiae*	At Risk	Declining$^{CI\ CR}$				▓	░	░			x	

SPECIES - Robertson et al. 2012		CONSERVATION STATUS - Robertson et al. 2021		HABITAT								SOURCE	
				Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	eBird (DY31, DY32)	2022-23 project site surveys
Feral goose	*Anser anser*	Introduced	Introduced & Naturalised^{SO}				▨	🟩	▨			x	
Eastern bar-tailed godwit	*Limosa lapponica baueri*	At Risk	Declining$^{CI\ TO}$						🟩			x	
North Island fernbird	*Bowdleria punctata vealeae*	At Risk	Declining$^{CI\ CR\ DPS\ DPT}$					🟩	▨			x	
NZ scaup	*Aythya novaeseelandiae*	Endemic	Not Threatened^{Inc}					🟩	▨				x
Banded dotterel	*Charadrius bicinctus bicinctus*	At Risk	Declining$^{CD\ CI\ CR\ DPS\ PD}$					▨	🟩			x	

Appendix 3: Site Visit Photographs

Figure 10: GI1 aquatic sampling site looking upstream. Image taken 13th December 2022.

Figure 11: GI1 aquatic sampling site looking downstream. Image taken 13th December 2022.

Figure 12: GI2 aquatic sampling site looking upstream. Image taken 13th December 2022.

Figure 13: GI2 aquatic sampling site looking downstream. Image taken 13th December 2022.

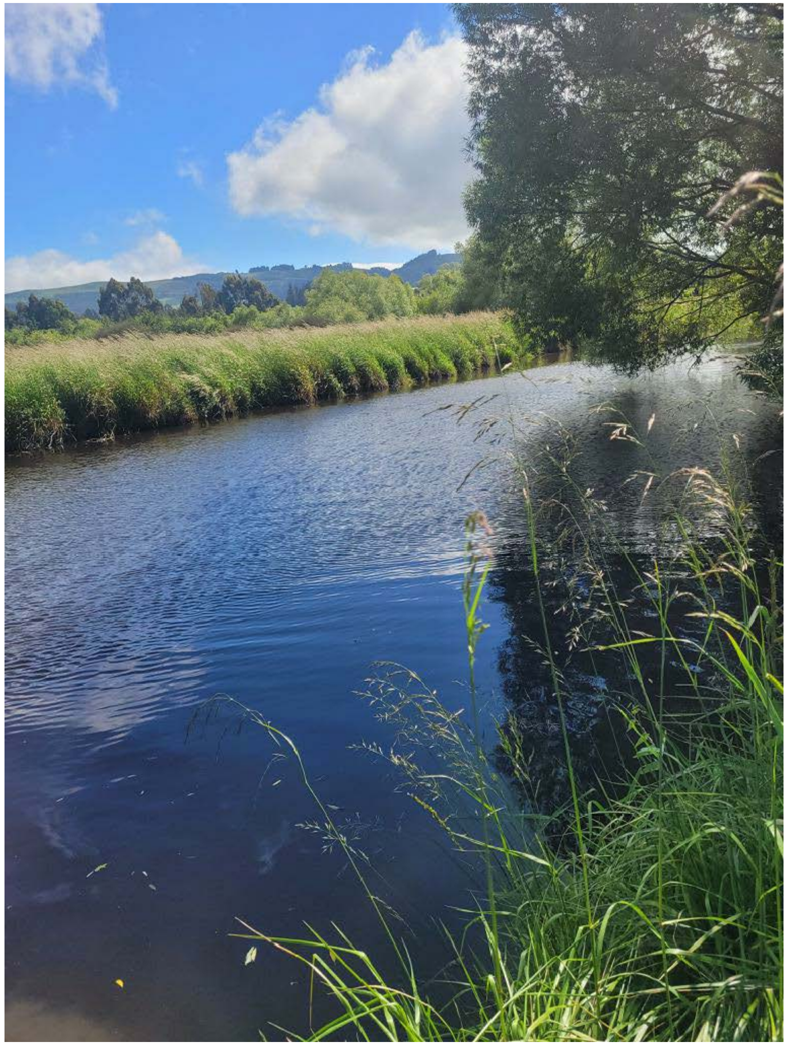


Figure 14: GI3 aquatic sampling site. Image taken 13th December 2022.

Figure 15: Additional aquatic sampling site in Kaikorai Stream near culvert outlet from Eastern Sedimentation Pond. Image taken 13th December 2022.

Figure 16: GI5 aquatic sampling site looking upstream. Image taken 13th December 2022.

Figure 17: GI5 aquatic sampling site looking downstream. Image taken 13th December 2022.

Figure 18: South-eastern constructed wetlands. Image taken 17 October 2022.

Figure 19: Western Sedimentation Pond. Image taken 17 October 2022.

Figure 20: Large numbers of southern black backed gulls within the landfill. Image taken 11 August 2021.

Figure 21: Western Sedimentation Pond. Image taken 11 August 2021.

Figure 22: Kaikorai Lagoon at bridge downstream of the landfill. Image taken 11 August 2021.

Figure 23: Kaikorai Lagoon at bridge downstream of the landfill. Image taken 11 August 2021

Figure 24: Example of planted vegetation on the landfill site. Image taken 11 August 2021.

Figure 25: South-western pond south of the landfill site. Image taken 17 October 2022.

Figure 26: Constructed wetland adjacent to eastern sediment pond. Image taken 11th August 2021.

Figure 27: Culvert inflow to the constructed wetland from Taylor Street. Image taken 11th August 2021.

Appendix 4: Macroinvertebrate Community Data

Table 24: Macroinvertebrate community data for all aquatic survey sites. Three replicate samples (a – c) were collected per sampling site. Zeros are shown as blanks.

Group	Species	GI 1 a	GI 1 b	GI 1 c	GI 2 a	GI 2 b	GI 2 c	GI 3 a	GI 3 b	GI 3 c	GI 5 a	GI 5 b	GI 5 c
Metrics	**Total abundance**	1771	2292	1399	323	65	1408	3300	1045	2490	840	2160	844
	Number of taxa	13	16	12	19	14	14	5	11	4	5	6	6
	Number of EPT taxa	1	1	1	2	0	1	0	0	0	0	0	0
	MCI score	61.5	67.5	56.7	64.4	57.9	71.7	70	90	71.5	72.4	82.7	107.7
	QMCI	1.6	1.3	1.9	2.8	3.3	3.4	6	5	5.8	5.8	5.6	5.6
Acarina	Acarina	13	6		3	1	6						
Annelida	Oligochaeta	1086	1740	566	146	29	1013		20		16	10	60
Annelida	Polychaeta								10			10	4
Bryozoa	Bryozoa			26									
Cnidaria	Hydra	86	33	20	15		20						
Collembola	Collembola		6		1		6						
Crustacea	Amphipoda								15				16
Crustacea	Cladocera	20			53		66						
Crustacea	Copepoda		6		3	1		140	10	20	8	280	
Crustacea	Mysidae							2910	540	2080	692	1690	600
Crustacea	Ostracoda	160	93	80	40	6	133						
Crustacea	*Paracalliope*	13	1	73					20				
Diptera	*Austrosimulium*					1							
Diptera	*Chironomus*	120	180	153	13	4	80	220	310	270	64	130	160
Diptera	Culicidae					1							
Diptera	*Maoridiamesa*			13									
Diptera	Muscidae					1							
Diptera	Orthocladiinae, excl. Corynoneura	106	120	320	11	3	1	10	5				
Diptera	Tanypodinae		26		1		6		25				4
Diptera	Tanytarsini		6		8		13		5				
Hemiptera	*Microvelia*				1	7							

Group	**Species**	**GI 1 a**	**GI 1 b**	**GI 1 c**	**GI 2 a**	**GI 2 b**	**GI 2 c**	**GI 3 a**	**GI 3 b**	**GI 3 c**	**GI 5 a**	**GI 5 b**	**GI 5 c**
Mollusca	*Physa* **=** *Physella*	6	1										
Mollusca	*Potamopyrgus*	60	13	53	6	2	20	20	85	120	60	40	
Mollusca	Sphaeriidae	20	40	33	1	4	33						
Nematoda	Nematoda	1	1	2	10	1	5						
Nemertea	Nemertea				1								
Odonata	*Xanthocnemis*				3	4							
Trichoptera	*Oxyethira*	80	20	60	6								
Trichoptera	*Triplectides*				1		6						

Together. Shaping Better Places.

Boffa Miskell is a leading New Zealand environmental consultancy with nine offices throughout Aotearoa. We work with a wide range of local, international private and public sector clients in the areas of planning, urban design, landscape architecture, landscape planning, ecology, biosecurity, Te Hīhiri (cultural advisory), engagement, transport advisory, climate change, graphics, and mapping. Over the past five decades we have built a reputation for creativity, professionalism, innovation, and excellence by understanding each project's interconnections with the wider environmental, social, cultural, and economic context.

www.boffamiskell.co.nz

Whangarei	**Auckland**	**Hamilton**	**Tauranga**	**Wellington**	**Nelson**	**Christchurch**	**Queenstown**	**Dunedin**
09 358 2526	09 358 2526	07 960 0006	07 571 5511	04 385 9315	03 548 8551	03 366 8891	03 441 1670	03 470 0460