Fairfield Landfill Ecological Assessment

Prepared for

Waste Management NZ Ltd

March 2025

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Limitations:

Executive Summary

The closed Fairfield Landfill, which ceased waste disposal activities in 2017, continues to generate leachate and gas, requiring ongoing management and resource consents. As part of its reconsenting process, Waste Management NZ Limited (WMNZ) is required to conduct a baseline ecological assessment of the Kaikorai Estuary adjacent to and downgradient of the landfill. This was conducted in late 2024.

The estuary catchment supports a diverse range of bird and fish life. This includes bird species with high conservation values, such as black stilt (Nationally Critical), black-fronted tern (Nationally Endangered), and red-billed gull (Declining). Fish species use the estuary as a migratory pathway into freshwater stream environments, but also as feeding and breeding grounds. Fish species present include shortfin and longfin eel, īnanga, kōaro, banded kōkopu, and pātiki/black flounder. Benthic invertebrates and infauna are less diverse, due in-part to impacts associated with habitat degradation. Overall, the Kaikorai Estuary and its tributaries contain high ecological and cultural values.

The estuary and its tributaries are influenced by an intensively developed catchment. Land use activities include industrial and urban stormwater discharges that are often associated with high contaminant loads, particularly heavy metals. This makes it difficult to ascertain the relative contribution of landfill effects for many water and sediment quality parameters, however low pH levels and high ammoniacal nitrogen concentrations were clearly greater near the landfill site. This suggests that ammonia in landfill leachate is likely having a toxic impact on aquatic communities locally within the estuarine environment.

Ongoing monitoring of the Kaikorai Wetlands and Estuary is essential to understand the long-term impacts of surrounding activities and natural variability, particularly the influence of the lagoon's open and closed states, on water quality and sediment conditions. This monitoring will provide context to the contamination snapshot recorded in this assessment and enable trend analysis over time.

Key monitoring components include:

- Sediment – Annual sampling for nutrients, organic carbon, and metals (iron, lead, zinc).
- Benthic Infauna – Assessed annually alongside sediment monitoring.
- Water Quality – Monthly monitoring when the lagoon is open, and periodic monitoring during closed conditions, with key parameters including nutrients, metals, and oxygen levels.
- Review Period – The programme will be reviewed every two years to assess its effectiveness.

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1.0 Introduction

1.1 Background

The Fairfield Landfill consists of three components: a historical landfill, western landfill and eastern landfill. All are located directly south of Fairfield township and 4 km west of Dunedin City. Fairfield Landfill ceased receiving waste in July 2017 and closure included capping works that were completed in August 2022. It remains closed and is within the "aftercare" phase.

Waste Management NZ (WMNZ), who owns and operates the site, contained resource consents for the:

- discharge of leachate to groundwater,
- take of groundwater containing leachate (which is then discharged into the Dunedin City Council's (DCC) wastewater network for subsequent treatment and disposal),
- discharge of stormwater, and
- discharges to air.

Each resource consent expired in September 2024.

The landfill site is adjacent/upstream of a number of stream, wetland and estuarine environments. These include the tributaries (i.e., Christies Creek, Coal Creek and Kaikorai Stream) that flow into the estuary, the Kaikorai Lagoon Swamp 'Wetland' which is located in the upper estuary, and a medium-sized Kaikorai lagoon estuary. A desktop-based technical effects assessment of landfill effects on groundwater, and surface water and ecology was undertaken by Pattle Delamore Partners (PDP) in 2024 (PDP, 2024). This was for the purpose of informing a resource consent application for the expired take and discharge consents.

The ecological values of the receiving environments were assessed against the matters and attributes outlined in the Environment Institute of Australia and New Zealand Guidelines (Roper-Lindsey *et al*, 2018). The assessment determined the overall ecological values of the stream tributaries as **High,** Kaikorai Lagoon Swamp wetland as **Very High,** and Kaikorai Estuary as **Very High**. No ecological monitoring data has been collected in the surrounding environments to confidently determine surface water and ecological effects emanating from the landfill site. This highlighted the need for targeted ecological surveys to update the assessment with site-specific data.

1.2 Description of activity

A leachate interception drainage system is in place along the southern and eastern boundaries of Fairfield Landfill. This intercepts the outward flow of groundwater leachate from the landfill site and prevents it from directly entering the downstream surface water receiving environment. A series of sumps and a central pump station ensure that leachate intercepted by the drainage system is pumped to the Dunedin City Council (DCC) wastewater network and Green Island treatment plant.

The majority of stormwater at Eastern Landfill (Figure 1) is directed to two unlined stormwater retention ponds. One of these is located on the northern side (‘North Pond’) while the other is in the southwestern corner (‘Weighbridge Pond’). Stormwater overflow from the North and Weighbridge ponds is discharged to the downstream Kaikorai Stream and Kaikorai Lagoon Swamp, respectively. No stormwater management devices exist on the Western Landfill area and stormwater either infiltrates into the landfill or exists as overland flow. The latter discharge into the Kaikorai Lagoon Swamp directly or indirectly via minor waterways.

Surface and groundwater monitoring has been undertaken at several sampling sites in and around Fairfield Landfill at quarterly intervals since 1997[1]. The results of this monitoring is documented in compliance monitoring reports submitted to Otago Regional Council (ORC) in accordance with former Resource Consent requirements.

1.3 Scope and purpose

PDP was engaged by WMNZ (‘the Client’) to undertake baseline ecological and surface water quality monitoring. This was for the purpose of setting an ecological baseline for the surrounding freshwater and estuarine environments in the absence of existing data. Monitoring was undertaken at several pre-determined freshwater tributary and estuarine sampling sites in the Kaikorai Swamp wetland and estuary downgradient of the Fairfield Landfill.

This report details the information collected during baseline monitoring. Its primary objectives are to:

- assess the ecological effects of the leachate and groundwater discharges on the Kaikorai Estuary to supplement the PDP (2024) technical assessment of ecological effects; and
- confirm/identify preferred sampling sites for a long-term monitoring programme.

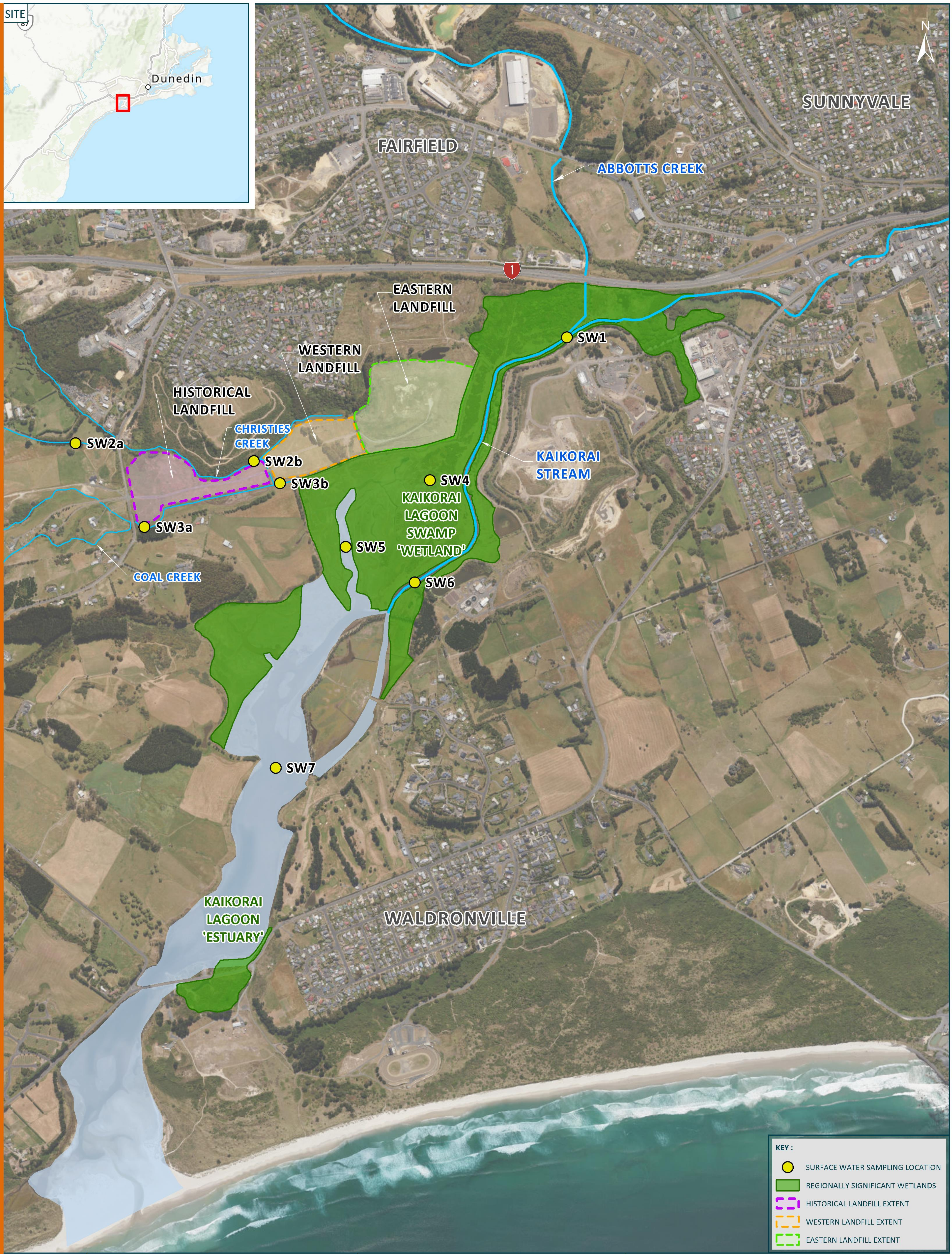
[1] Some datasets provided by the client only trace back to 2001 or 2002.

2.0 Site Description

The Fairfield Landfill is located within the Kaikorai Stream catchment, which is dominated by 'high producing exotic grassland' and 'built-up area' settlements with interspersed 'exotic forest' land cover classes (Manaaki Whenua, 2019). Major land uses include livestock farming, residential housing, and small-scale "light" industrial activities. Kaikorai Stream flows directly west of Eastern Landfill into the Kaikorai Wetland (also known as Kaikorai Lagoon Swamp).

The closed Fairfield Landfill site lies at the head of the Kaikorai Wetland, classified as a 'wetland of regional significance' due to its significant conservation and Kai Tahu values (Figure 1). The wider Kaikorai Estuary located downgradient of the Kaikorai Wetland has been described by Stevens (2018) as an "extensively modified, moderately sized (94 ha), microtidal, shallow (mean depth approx. 1.5 m at high water), tidal lagoon type estuary".

Several tributaries flow into Kaikorai Stream and/or Kaikorai Lagoon Swamp. These include Kaikorai Stream (from the NE), and Christies Creek and Coal Creek (from the NW). These waterways are classified as 'Cool-Dry Low Elevation' streams according to the River Environment Classification (REC) (MfE, 2010).



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SOURCE:
1. AERIAL IMAGERY (FLOWN 2023-2024) SOURCED FROM THE LINZ DATA SERVICE www.linz.govt.nz AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.
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CLIENT

WASTE MANAGEMENT NZ LTD

FIGURE

FIG 1: FAIRFIELD LANDFILL WATERWAYS AND MONITORING SITES

PROJECT

FAIRFIELD LANDFILL RECONSENTING

3.0 Existing Environment

Existing information from PDP (2024) covers key ecological aspects of the Kaikorai Stream and estuary catchment, including water quality, sediment quality, fish, and bird habitat values.

Water quality in Kaikorai Stream (as measured at the ORC monitoring site at Brighton Road) is moderately impacted, with degrading trends in nutrients, clarity, turbidity, and *E. coli* concentrations. Some attributes fall below national bottom lines for ecological health[2]. The ORC 'Kaikorai Stream at Brighton Road' monitoring site is located north-east (1.5 km upstream) of the Fairfield Landfill.

Sediment quality, monitored by ORC for state of the environment reporting, indicates poor conditions in the central estuary (north of the causeway). The site here contains high mud content and elevated nitrogen and zinc levels, while the upper estuary (near the Kaikorai Stream mouth) and lower estuary (near the estuary mouth) show comparatively better conditions (Stevens, 2018).

The estuary has been found to support a range of native fish, including 'at-risk' species such as longfin eel and inanga, and the 'nationally vulnerable' lamprey. Habitat degradation may be affecting the abundance of these species (PDP, 2024). No fish records are present in the New Zealand Freshwater Fish Database (NZFFD) for Coal and Christies creeks.

The Kaikorai Wetland and wider estuary complex is a moderately-sized coastal lagoon with extensive adjacent swamp/marsh area. The area has been found to provide habitat supporting a diverse array of bird species, particularly waterfowl and wading birds. Over eleven bird species with a conservation status of 'at risk' or worse were found to utilise the area. The estuary's saltmarsh habitats provide essential feeding and nesting grounds for the bird species, though habitat quality is impacted by sedimentation and nutrient inputs (PDP, 2024). EBird records, bird species surveyed from January 2024 to January 2025, and LAWA 'commonly observed species' in the estuary area include:

- **Nationally Critical** - Taranui, Caspian Tern, (*Hydroprogne caspia*) and Tara, White-fronted Tern, (*Sterna striata*). **Nationally Vulnerable** - Stewart Island Shag, (*Leucocarbo chalconotus),* Kōtuku-ngutupapa, Royal Spoonbill, (*Platalea regia*), Kawau Tūi, Little Black Cormorant, (*Phalacrocorax sulcirostris*), Kawaupaka, Little Pied Cormorant, (*Microcarbo melanoleucos*), Tōrea, South Island Oystercatcher, (*Haematopus finschi*), Matuku-hūrepo and Australasian Bittern (*Botaurus poiciloptilus*).
- **At – Risk, Naturally Uncommon and Declining** - Kōtuku, White Heron, (*Ardea alba Linnaeus*) and Pūteketeke and Great Crested Grebe,

[2] National bottom lines as per numeric attribute states contained in the National Policy Statement for Freshwater Management (NPS-FM) 2020.

(*Podiceps cristatus*), as well as the declining Tūturiwhatu, Banded Dotterel (*Charadrius bicinctus).*

The eastern edge of the Kaikorai Wetland is bordered by the Green Island Landfill, while the Fairfield Landfill lies along its western edge (Figure 1). The lower reaches of the estuary is intertidal and undergoes intermittent closures to the sea. A range of contaminants enter the lower estuary from multiple sources in the catchment. These include urban stormwater, agricultural and industrial run-off, and leachate from unlined landfills. The estuary is also impacted by an accumulation of muddy sediments resulting from a constricted lagoon mouth, poor flushing, reclamation, and causeways across the lower reaches (Stevens, 2018).

A 2008 State of the Environment (SOE) report (Stewart, 2008) describes the three highest-level pressures on the estuary as nutrient pollution, litter/dumped items, and leachate from landfills. Kaikorai Estuary, in the mid-to-lower zone, is moderately enriched and consists of anoxic sediment patches. Stewart (2008) noted the absence of estuarine macroalgae (e.g., *Gracilaria*, *Enteromorpha*, *Ulva* spp.) in the area. Surveys from Stewart (2008) at two fine-scale sites on low-tidal sand/mud flats, representative of much of the estuary, also found scarce epifauna and almost no macroalgae.

Further studies conducted by Stevens (2018) found that the estuary in a moderate overall state of ecological health. The New Zealand Estuary Trophic Index (ETI) score for Kaikorai Estuary was 0.81 (Band D), reflective of a high degree of eutrophic symptoms. The mud content of sediments was moderate-to-high and no opportunistic macroalgae was present. Phytoplankton concentrations were high in stratified, upper estuary areas. A gross eutrophic zone existed in the central estuary with organic-rich sediments and anoxic muds.

4.0 Field Assessments

4.1 Site Selection

Field assessments were carried out between the 18th and 20th of November 2024 by two PDP and two WMNZ ecologists. The site survey was undertaken during a period of fine weather. Approximately 5.4 mm of rainfall was recorded at NIWA’s Dunedin Musselburgh rain gauge during the four days leading up to the site survey (ORC, 2024).

The mouth of Kaikorai Estuary was open at the time of site assessment.
The Kaikorai Estuary is typically closed to the ocean more often than it is open (Stevens, 2018; Thomas, 2024). In early October 2024, a significant rainfall event, during which 244 mm of rainfall was recorded (ORC, 2024), caused the river mouth to breach. As a result, estuary water levels dropped and the mouth remained open for a prolonged time. This allowed the field assessment to

proceed under conditions suitable for sampling sediment and water quality indicative of upstream sources.

Nine predetermined sampling sites were selected from the technical effects assessment (PDP, 2024) to establish the baseline condition of freshwater and estuarine waterbodies near Fairfield Landfill. The monitoring site locations in relation to the landfill are illustrated in Figure 1 and Appendix A . Field sampling methods are described in detail in the sections to follow.

4.2 Rapid Habitat Assessment

Rapid habitat assessments (RHA) were undertaken and designed to provide habitat quality scores for individual 50 m river reaches only (Table). RHA scores are based on the condition of ten habitat parameters including:

- deposited sediment,
- invertebrate habitat diversity and abundance,
- fish cover diversity and abundance,
- hydraulic heterogeneity,
- bank erosion and vegetation, and
- riparian width and shade availability.

Parameter scores are added together to generate a 'habitat quality score' for a waterway reach, indicating an overall stream habitat condition, the RHA assessment form has been generated by, (Holmes, 2024).

4.3 Water Quality

In-situ measurements of spot water chemistry were undertaken including water temperature, pH, electrical conductivity (EC), dissolved oxygen (DO; mg/L and % saturation), and turbidity (NTU). This was conducted using a calibrated (according to manufacturer’s specifications) handheld water quality probe (YSI Pro Quatro). EC was used as a proxy for salinity to aid in determining freshwater and estuarine environments.

Grab water samples and laboratory analyses were undertaken for contaminants commonly associated with landfill leachate. Parameters included:

- biochemical oxygen demand ($cBOD_5$),
- salinity and alkalinity,
- calcium, sodium, chloride, potassium, sulphate,
- nutrients - nitrate-N, nitrite-N, total ammoniacal-N (TAN), dissolved reactive phosphorus (DRP), total phosphorus (TP) and total nitrogen (TN), and

- total and dissolved metals - magnesium, iron, lead and zinc.

Water quality results were compared to limits or guidelines presented in:

- Resource Consent 93540 – Discharge leachate to groundwater by seepage – Condition 12.
- The ORC amended plan (ORC, 2022), which directs water quality standards within the Dunedin & Coast Freshwater Management Unit (FMU) to align with the National Policy Statement for Freshwater Management (NPS-FM) 2020, as outlined in Section 7 of the Regional Plan[3].
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) Default Guideline Values (DGVs) for physical and chemical stressors.

Results collected from the estuarine environment are compared to saline-specific ANZG (2018) DGVs. The ANZG (2018) toxicant DGVs have been applied with consideration of the high and very high overall ecological values attributed to the stream tributaries, Kaikorai Swamp Wetland, and Kaikorai Estuary (PDP, 2024). Specifically, toxicants in water have been assessed against the 95% species protection level, while the 90% and 80% protection levels are referenced for comparison where appropriate.

4.4 Sediment

Sediment quality

Surface sediment samples were collected into jars from the top 2-3 cm of the estuary or waterbody substrate. This monitoring technique was specifically designed to target the surface sediments that are most representative of recent contamination. Benthic sediments form habitat for the animals and plants living in and on the sediment, and their condition can indicate the drivers of health in benthic aquatic communities.

Sediment samples were collected and stored on ice, before being sent to Hills Laboratories for analysis of nutrients (total recoverable phosphorus and TN), total organic carbon (TOC) and total recoverable iron, lead and zinc.

Results were compared to ANZG (2018) DGVs for toxicants in sediments. Two standards can be used to compare results, DGV and GV-High. The GV-high is used as an indicator of potential high-level toxicity problems, rather than a guideline value to ensure protection of ecosystems.

[3] The NPS-FM attribute bands are designed to be calculated through monthly monitoring over a five-year timeframe and any comparisons to smaller data sets, such as that of this report, are indicative only.

Sediment composition/Particle size distribution

Sediment composition plays an important role in the structure of estuarine communities. Particle size distribution (PSD) analysis was undertaken to determine the proportion of sediments present in each size class.

Samples were collected from three estuarine sites: SW4, SW5 and SW7 (Figure 1), and sent to Hill Laboratories. Pre-treatment of the samples was undertaken at the lab to remove organic material and disperse aggregates. The samples were then dried, weighed and passed through a series of sieves (2mm, 1mm, 0.5mm, 0.25mm and 0.125mm) before each component part being re-weighed. The 'lost' portion (the difference between the total sample dry weight and the sieved sample dry weight) was determined to be the <63 µm fraction.

4.5 Freshwater Macroinvertebrates

Freshwater macroinvertebrate sampling locations were restricted to sites with flowing water and/or low salinity. These were upper and lower Kaikorai Stream (SW1 and SW6), lower Christies Creek (SW2b), and upper Coal Creek (SW3a) (Figure 1). Upper Christies Creek, at the time of the site visit, had no flowing water and was not suitable for macroinvertebrate sampling.

Composite benthic macroinvertebrate samples were collected using a kick-net (500 µm mesh) in accordance with the National Environmental Monitoring Standard (NEMS) semi-quantitative kick-net protocol (MFE, 2020b). This method targets all suitable macroinvertebrate mesohabitats available, in proportions equal to their presence across the monitoring reach. The sampling method involved the disturbance of bank margins and mesohabitats present within the survey reach, sampling a total area of approximately 2 m^2 at each site.

Samples were preserved in 70% isopropyl alcohol in the field and processed in the laboratory by Environmental Impact Assessments Ltd, under appropriate chain of custody. Analysis and taxa identification followed Protocol P200 (200 fixed count with scan for rare taxa).

Biological indices used to assess stream community health included:

- Taxa richness: the number of different taxonomic groups present in a sample. Streams supporting a high number of different taxa generally indicate healthy communities.

- Macroinvertebrate Community Index (MCI-sb): a metric designed for soft-bottomed streams. The MCI allocates macroinvertebrate taxa a tolerance score between 0.1 (pollution tolerant) and 10 (pollution sensitive) depending on each taxon's sensitivity to organic enrichment. It is based on presence/absence data only.
- **Quantitative Macroinvertebrate Community Index (QMCI-sb):** a quantitative variant of the MCI, the QMCI uses the taxa MCI scores and weight them by the relative abundance of each taxon. An overall QMCI score is calculated for each site.

Table 1 below details the relevant macroinvertebrate indices and guideline limits for the river sites investigated.

Table 1: Benthic Macroinvertebrate Indices and Guideline Limits

Source	Classification	Description	MCIsb	QMCI
Stark and Maxted (2007) 'Quality Class'	Excellent	Clean water	>119	>6.00
	Good	Doubtful quality or possible mild pollution	100 - 119	5.00 - 5.99
	Fair	Probable moderate pollution	80 - 99	4.00 - 4.99
	Poor	Probable severe pollution	<80	<4.00
NPS-FM (2020) NOF[1]	Attribute Band A	Pristine conditions with almost no organic pollution or nutrient enrichment	≥130	≥6.5
	Attribute Band B	Mild organic pollution or nutrient enrichment.	≥110 - <130	≥5.5 - <6.5
	Attribute Band C	Moderate organic pollution or nutrient enrichment	≥90 - <110	≥4.5 - <5.5
	Attribute Band D[2]	Severe organic pollution or nutrient enrichment	<90	<4.5

Notes:
1. *NOF refers to the NPS-FM (2020) National Objectives Framework.*
2. *Attribute Band D falls below the National Bottom Line of the MFE (2020a).*
3. *All MCI scores relate to soft bottom waterways.*

4.6 Estuarine Benthic Infauna

Site selection was guided by the broadscale habitat mapping conducted in previous studies by Stewart (2008) and Stevens (2018). The broadscale maps were used to identify the location of key features including:

- extent of low, central and upper estuarine environments (Stevens, 2018), and
- estuarine channels.

The upper and central estuary were targeted as they are downgradient of the Fairfield Landfill. Two sites in the upper estuary (SW4 and SW5), located adjacent to the Fairfield Landfill, were prioristised to focus on potential impacts. Additionally, one site in the central estuary (SW7) was chosen for the assessment to provide broader context around the scale and extent of any potential impacts.

The estuarine sites (Table 12) were assessed according to the *Estuary Monitoring Protocols,* (Robertson, et al., 2002). At each of the three estuarine sites, a grid overlay was used to randomly generate sampling plots. The assessments in each sampling plot included:

- 0.013 m diameter by 0.015 m deep cylindrical core sieved to evaluate benthic macroinvertebrate communities.
- 0.25 m^2 quadrat noting any significant vegetation or features.
- Sediment sample for chemical analysis, 550 ml sample (300 mL and a 250 mL jar) from the top 2 cm of deposited sediment.
- Sediment core to record the sediment profile and redox layers.
- Sediment samples analysed for grain size, as described in section 4.1.4.

4.7 Environmental DNA

Environmental DNA (eDNA) samples were collected to formulate a list of species present near the project site. The eDNA metabarcoding analysis can detect fish, mammals, birds, and invertebrates (including kōura and kākahi), as well as species of plants, algae, fungi, and bacteria[4]. This method has the advantage of detecting rare taxa, or those that have evaded capture following other field survey methods. Samples were analysed in the laboratory by Wilderlab Ltd using appropriate chain of custody protocols.

eDNA sampling is a relatively new method and captures genetic signature data from the upstream catchment rather than just from immediate sampling area. As a result, it may detect organisms from areas far beyond the site, sometimes up to a several kilometres away. This means some data may not be directly relevant to site-specific assessment. However, species that are unlikely to be found within the streams, wetland or estuary environments were disregarded in this assessment.

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[4] The basic multi-species analyte suite was selected for the eDNA analysis. This focuses on the detection of animal DNA.

eDNA syringe and filter kits were used for field sampling. A target volume of 1 L of water was collected from each waterbody and filtered through a 1.2 or 0.5 µm filter. In some cases, the full 1 L could not be filtered due to clogging. Filters gradually accumulated biological material, and were subsequently preserved, labelled, and sent to the laboratory for analysis.

5.0 Results

5.1 Site Summaries

All waterways appeared to be at low flow at the time of the visit. Despite this, adjacent landowners, particularly near Christies Creek US, reported that high rainfall events had caused significant flooding. For example, during the rainfall event in October 2024, high flows lifted and displaced tarseal.

The following describes the survey locations used during this assessment.

- **Christies Creek SW2a** was a tributary that was disconnected from the downstream channel due to a perched culvert and dense rank grasses (Figure 2). It provided some shade and fish cover via an undercut bank, but scored low for habitat provision. Due to stagnant nature of water at this site, water quality results were impacted and not suitable for comparison with other sites (Table 5).

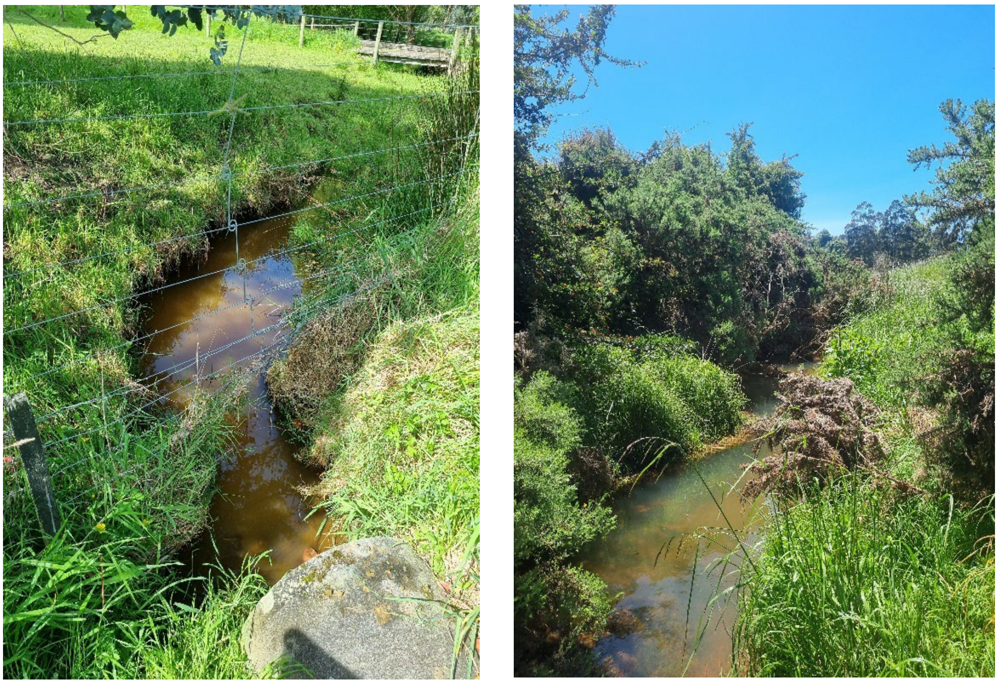

Figure 2: Christies Creek SW2a looking downstream (left) and Christies Creek SW2b looking downstream (right).

- **Christies Creek SW2b**, located downgradient of the Historic Landfill, had a wide riparian buffer with mature vegetation on the true left and rank grass with shrubs on the true right (Figure 2). Abundant fish and invertebrate cover from overhanging vegetation, undercut banks, and woody debris resulted in a high habitat score. Figure 3 shows a culvert that is situated upstream of the confluence with Coal Creek.

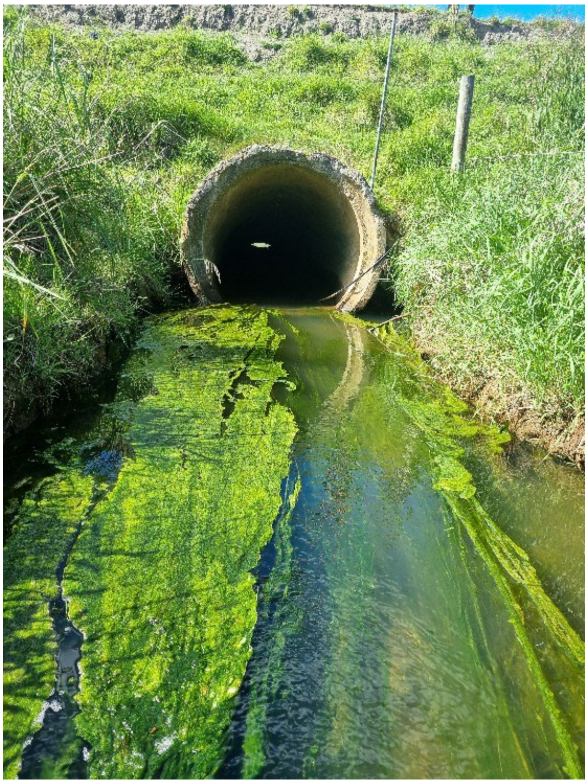

Figure 3: Culvert in between Christies Creek SW2b and Coal Creek SW3b.

- **Coal Creek SW3a** had a dense stand of juvenile willow growing both instream and within the riparian buffer (Figure 4). While the willows appeared to choke the waterway with root mats and debris, it did provide some fish cover. Their invasive nature limited overall habitat quality, however they also contributed positively by offering shade and enhancing bank stability, which are high-scoring habitat features.
- **Coal Creek SW3b,** located in Coal Creek 50 m downstream of the Christies Creek confluence, was at the interface of fresh and estuarine conditions (Figure 4). Salinity measured 0.9 ppt (low-brackish) (ANZECC, 2000). Sites upstream of this location were freshwater. The site had riparian buffers consisting of long rank grass, which provided limited shade but contributed to bank stability. Fish cover included overhanging vegetation and undercut banks, though it was not abundant.

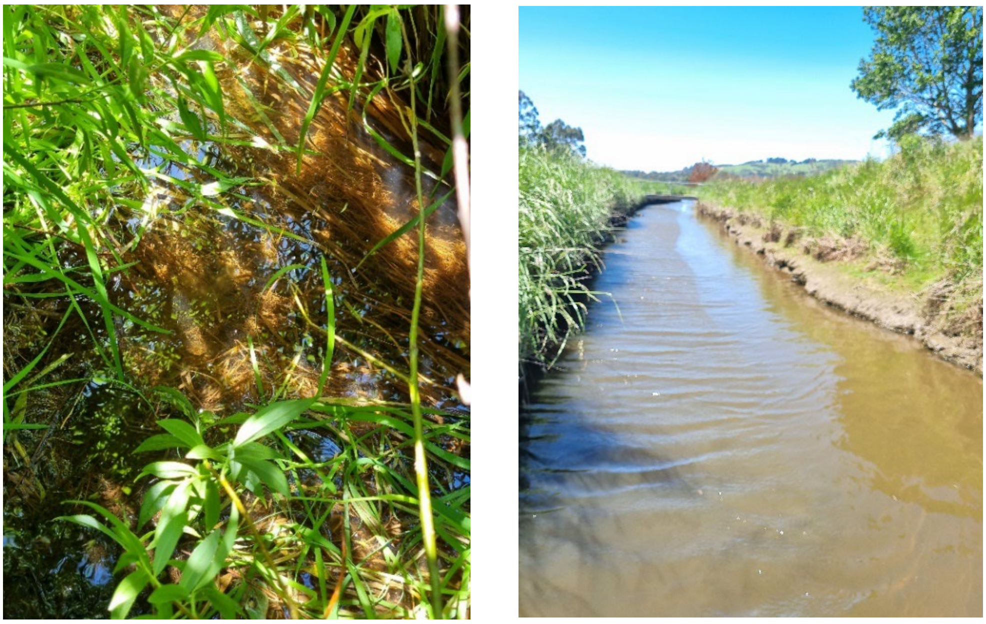

Figure 4: Coal Creek SW3a (left) and Coal Creek SW3b (right).

- **Kaikorai Stream SW1** was located in the Kaikorai Lagoon 'Wetland' (Figure 5). The stream channel featured undercut banks abundant with overhanging vegetation with some woody debris, providing habitat for fish and invertebrates. The site also exhibited a high cover of deposited fine sediment that was readily re-suspended when disturbed. The riparian zone was wide, offering moderate shade from mainly exotic riparian trees and rank grass.

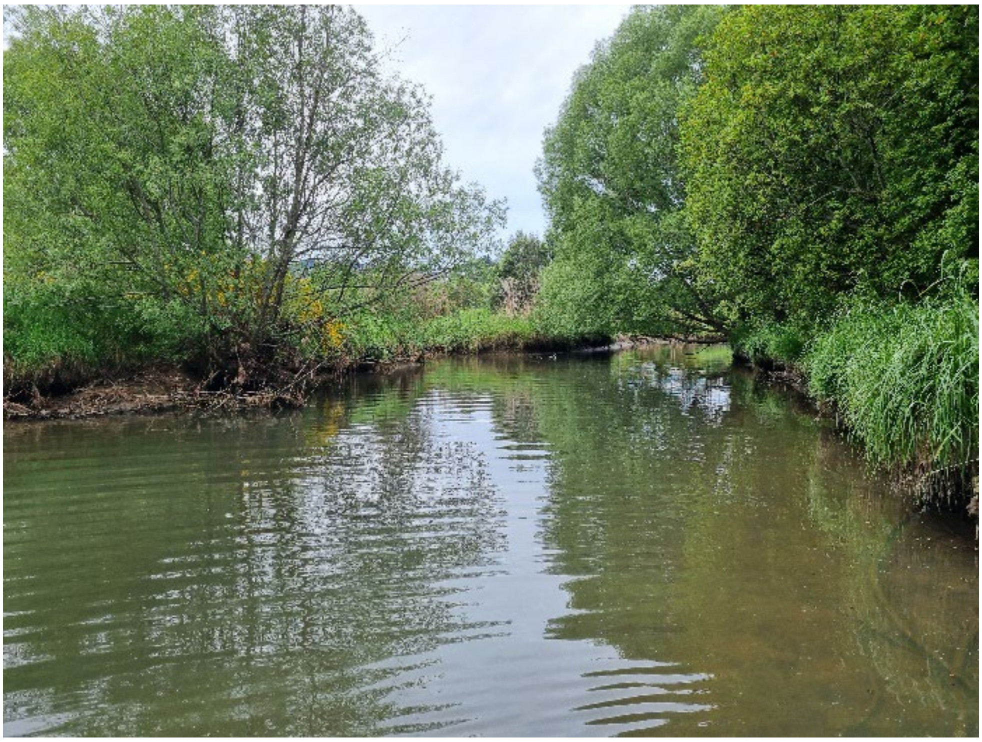

Figure 5: Kaikorai Stream (SW1) looking upstream.

- **Upper estuary SW4** was located in the Kaikorai Lagoon 'Wetland', approximately 150 m west of the main Kaikorai Stream (Figure 6). Unlike SW5, this site lacked a distinct channel, was dry, and did not appear to experience tidal inundation.
- **Upper estuary SW5** was located in the Kaikorai Lagoon 'Wetland' (Figure 6). The estuary channel substrate was predominantly fine sand. Limited fish and invertebrate cover was present with undercut, but eroding banks.

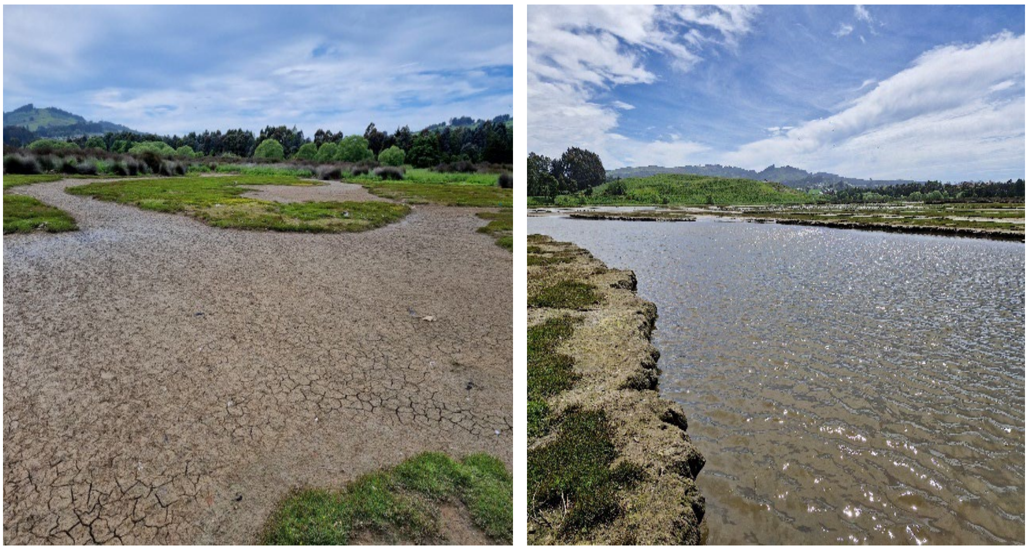

Figure 6: Upper estuary site SW4 looking north (left) and SW5 looking upstream (right).

- **Kaikorai Stream SW6** was located in the upper estuarine reach of Kaikorai Lagoon 'Wetland'. The area contained overhanging rank grasses, providing some fish cover. Over 75% of the stream bank showed signs of erosion. The riparian buffer was wide with short dense rank grass/vegetation and little shade. Some woody debris provided instream habitat. Soft sediment was the dominant stream bed substrate, becoming resuspended when disturbed.

  SW7 was located in the central estuary, this was the most downstream site, where the convergence of all the tributaries forms one main channel. The substrate at this site was notably less compact, softer and more unconsolidated. The wetted channel at low tide was more predominant in the western edge. Little to no native vegetation surrounded the estuary borders at this location.

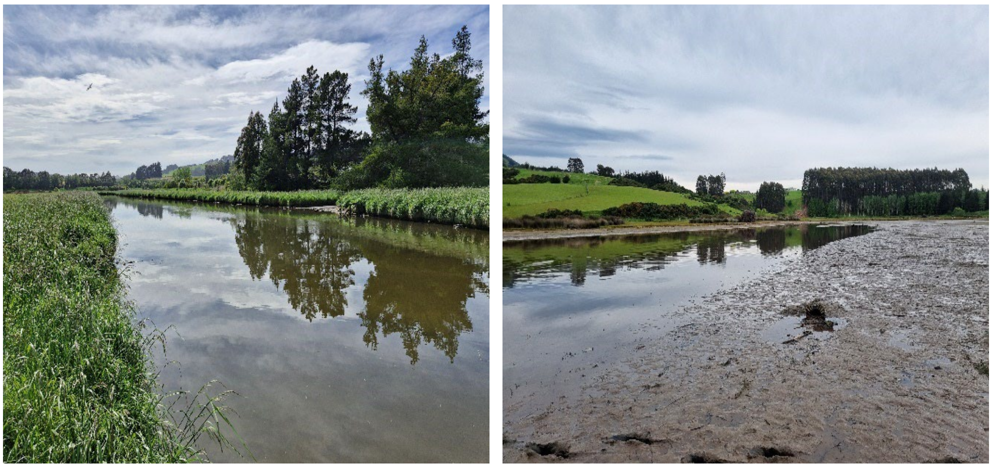

Figure 7: Kaikorai Stream SW6 looking upstream (left) and Central Estuary Site SW7 looking upstream (right).

5.2 Rapid Habitat Assessment

Rapid Habitat Assessments were conducted in stream environments and scores ranged between 27 (SW2a) and 54 (SW2b). Each site typically had low invertebrate habitat diversity, low hydraulic heterogeneity, and high deposited sediment. Fish cover abundance was relatively high at most sites, particularly Kaikorai Stream US, SW3 and SW3b. Fish cover diversity was more variable between sites, with Christies Creek SW2b scoring the highest.

Riparian characteristics varied with Kaikorai Stream at SW1 and SW6, Christies Creek at SW2b, and Coal Creek at SW3a containing high habitat values with wide buffers and densely vegetated banks providing some instream shade. Bank erosion was recorded at SW2b and SW3a.

5.3 Water Quality

Table 2 and Appendix B contains the full suite of results from water quality monitoring conducted in the field. The following sections summarise these results in brief for the most relevant parameters of interest.

5.3.1 pH and Dissolved Oxygen

Water pH at the Christies Creek and Coal Creek sites ranged between 6.14 (Christies Creek SW2b) and 6.64 (Coal Creek SW3b). These were lower than the ANZG (2018) DGV of 7.23 – 7.8. In comparison, sampling at the upper Kaikorai Stream site (SW1), further up catchment from the landfill, was circumneutral (7.06). The lower Kaikorai Stream site had a pH of 6.65. pH levels in the upper estuary (6.65) were lower than those in the lower estuary (7.13). Each were below the ANZG (2018) recommend range (7.23 – 7.8). It is possible that landfill leachate is influencing the pH of localised surface waters given that lower pH was observed at both stream and estuary sites close by.

Dissolved oxygen (DO) levels were extremely low at the upper Christies Creek site (12% saturation). Stream flow was low at this site with extensive pooling and stagnation. Further downstream, DO was higher (54% saturation) but was still below the ANZG (2018) DGV. The upper Coal Creek site was similar. The remaining stream and estuary sampling sites contained DO saturations in excess of 96%. This included sites within close proximity and downgradient of the landfill site, indicating that external factors (i.e., those other than the landfill) are more likely driving these patterns. Indeed, TBOD was low at all sampling sites and generally below the laboratory detection limit (<0.2 mg/L) indicating that little organic enrichment exists.

5.3.2 Metals

The dissolved zinc concentration was higher at the downstream site, compared to the upstream site, in Christies Creek. It exceeded the ANZG (2018) DGV for protecting 80% of species from the effects of chronic toxicity. Downstream data was not obtained for Coal Creek, but the upper site exceeded the 95% species protection threshold. Dissolved zinc in Kaikorai Stream and at all estuary sites all exceeded at least the 90% protection threshold.

Dissolved lead concentrations were below the laboratory detection limit (<0.001 mg/L) at all monitoring sites. There was no discernible pattern in dissolved iron, with the highest concentrations recorded upstream in Christies Creek and Kaikorai Stream. Total iron was similar except for elevated concentrations at the Kaikorai Wetland (SW5). Dissolved magnesium was several orders of magnitude higher at estuary sites than at stream sites, which is expected in more saline waters. Particulate magnesium was a very minor component of the overall total fraction recorded. Potassium and sodium concentrations were also, unsurprisingly, highest at more saline estuarine sites.

Overall, dissolved and total metal concentrations were variable across site locations. The Kaikorai Estuary catchment consists of intensive land uses including those that source metal-enriched urban and industrial stormwater runoff. The estuary likely acts as a sink for these contaminants, as well as any that may be sourced from landfill leachates. However, there were no clear patterns in metal concentrations in respect to proximity to the Fairfield Landfill.

5.3.3 Nutrients

Total nitrogen (TN) concentrations were most elevated at the most-downstream sampling sites in stream tributaries. Conversely, the upper estuary at SW5 contained the highest TN of the estuary sites. Patterns in elevated TN were largely driven by correspondingly high total ammoniacal nitrogen (TAN) concentrations. TAN concentrations at lower Christies Creek SW2a (0.75 mg/L or

0.26 mg/L $_{\text{pH8 converted}}$), Coal Creek SW3b (3 mg/L or 1.11 mg/L $_{\text{pH8 converted}}$) and SW5 (1.3 mg/L or 0.501 mg/L $_{\text{pH8 converted}}$), the sites closest to the downgradient end of the landfill, far exceeded toxicity ANZG (2018) and NPS-FM 2020 toxicity standards. Comparatively, nitrate-N concentrations were all less than 0.5 mg/L. At this level, nitrate-N is unlikely to be causing toxic effects on aquatic biota but are sufficient to potentially cause eutrophication of waterbodies.

Total phosphorus (TP) mostly showed the opposite pattern to TN with more elevated concentrations measured at the uppermost sampling sites in Christies and Coal creeks. TP in Kaikorai Stream and the estuary were variable, but most elevated at SW5 neat the lagoon wetland. Dissolved reactive phosphorus (DRP) was a small proportion of the TP make-up. There was no discernible pattern in DRP concentrations with many sites recording below the laboratory detection limit of <0.004 mg/L.

Of all the water quality parameters sampled, the elevated concentrations of TAN at near-field sampling sites downgradient of the landfill is the strongest indicator that the landfill leachate is impacting surface water quality. At elevated pH levels, the ratio of TAN represented as toxic ammonia, rather than relatively harmless ammonium, is greater. pH levels measured at these sites were slightly acidic. Despite this, TAN concentrations are severe enough to be causing chronic toxicity impacts (at least in localised areas) in the upper estuary or in downstream reaches of small stream tributaries.

5.3.4 Other parameters

A range of other parameters were also sampled as part of the monitoring programmes. Like that of other salts (e.g., potassium and sodium), chloride concentrations were highest in more saline estuary waters. Calcium and sulphate concentrations were variable, but typically highest at the estuary sites. These parameters did not provide any insight into potential leachate contamination.

5.4 Sediment Quality

Total recoverable zinc concentrations at Coal Creek SW3a (55 mg/kg dry wt) was lower than at Coal Creek SW3b (550 mg/kg dry wt). The latter exceeded ANZG (2018) DGV and GV-High thresholds, indicating chronic toxicity effects could be occurring on benthic taxa. The zinc DGV was exceeded at both upstream sites in Coal Creek and Christies Creek, but only the SW4 site in the estuary.

Total recoverable lead concentrations only exceeded the ANZG (2018) DGV at the upper estuary site SW4 (70 mg/kg dry wt). Other stream and estuary sites had concentrations that were comparatively low. Total recoverable iron was highest at sites in close proximity to the landfill site. In particular, the upper Coal Creek site (SW3a) had the greatest recorded total recoverable iron concentration of

150,000 mg/kg dry wt. It is uncertain whether this pattern relates to the influence of landfill leachate or other catchment-based factors.

Total recoverable phosphorus concentrations in sediment were variable across stream and estuary sampling sites with no discernible patterns. Sediment TN was similar, although highest concentrations were typically recorded in Christies Creek, Coal Creek and upper estuary sites (SW4 and SW5). Total organic carbon content was highest in sediment were notably higher at upper Coal Creek SW3a compared to SW3b, reaching 1,680 mg/kg and 0.87 g/100g, respectively. Other sites Coal Creek, Christies Creek and SW5 showed phosphorus concentrations ranging from 380 to 930 mg/kg, and nitrogen concentrations between 0.05 and 0.81 g/100g.

Total organic carbon (TOC) was highest in the sediments sampled from downstream sampling sites in Christies Creek and Coal Creek, and the upper estuary site SW4 (range: 5.1 - 10.5 g/100g dry wt). Comparatively moderate TOC concentrations were recorded at other stream and estuary sites near the landfill (e.g., 2.3 g/100 g dry wt at SW5).

Table 2: Water Quality Field Measurements

Parameter	SW1	SW2a	SW2b	SW3a	SW3b	SW5	SW6	SW7	NES-FM & ORC WQ target Attribute State	ANZG DGV [4]
Waterbody	Kaikorai Stream US	Christies Creek US	Christies Creek DS	Coal Creek US	Coal Creek DS (and Christies Creek)	Coal / Christies Creek (Upper Estuary)	Kaikorai Stream	Kaikorai Stream		
Environment	Freshwater	Freshwater	Freshwater	Freshwater	Freshwater/Estuarine	Estuarine	Estuarine	Estuarine		
Catchment Size (km^2)	39.03	0.95	2.34	1.80	4.40	5.69	40.75	46.69		
DO (mg/L) [3]	9.84	**1.2**	**5.79**	**5.30**	9.40	8.88	9.59	9.33	**5.0[2]**	-
DO % Saturation (%)	96.6	12	54.1	53.2	104.3	101.1	96.4	103	-	(81 – 101)
Temperature (°C) [3]	14.4	13.3	11.8	14.8	20.3	19.1	14.8	18.2	-	-
Electrical Conductivity (µS/cm)[3]	600	739	583	563	1,847	15316	5575	12396	-	116
pH [3]	7.06	6.39	6.14	6.23	6.64	6.84	6.65	7.13	-	7.23 – 7.8
Turbidity (NTU)	25.3	17.6	2.63	5.53	11.2	53.5	6.46	14.0	-	1.3
Periphyton (thick mats >3mm thick)	-	-	40%	-	-	-	-	-		
Periphyton (long filaments >2cm long)	-	5%	35%	-	<5%	-	-	-		
Macrophtyes (total emerged and submerged)	-	5% Submerged	10% emergent	100% submerged	-	-	-	-		
Epiphytic Periphyton	-	-	-	-	-	-	<5%	<5%		

Notes:

1. *Site are arranged form most upstream to downstream.*
2. *National Policy Statement - Freshwater Management. National Bottom lines or the lowest available Attribute Band for median values only. <5 National Bottom line NPSFM (2020)*
3. *Parameters relate to consent condition requirement.*
4. *ANZG (2018) Default Guideline Values for Cool, Dry, Low Elevation Values refer to the 80th percentile reference values. pH and dissolved oxygen (% saturation) values refer to the 20th and 80th percentile values - https://www.waterquality.gov.au/anz-guidelines/your-location/new-zealand*

5.5 Sediment Grain Size

The bioavailability and toxicity of contaminants in sediments is influenced by sediment grain size. This is because the contaminant binding capacity of sediments decreases with increasing grain size with the concentration of contaminants typically being greater in the finer sediment fractions. The dominant grain sizes among the three estuary sampling sites were mud/silt (SW4 and SW5) and very fine sand (SW7) Table 4. A high level of mud/silt content in esturaies is often resultant from terrestrial sediment inputs from the surrounding catchment. Sediment characteristics, and their contaminant retention capacity, can drive ecological health in benthic communities.

The upper estuary at SW4 was drier than other sites at the time of sampling and is subject to less tidal inudation (i.e., when the lagoon is open). Despite its high proportion of mud/silt, it exhibited a diverse range of sediment types across various size fractions with the notable presence of very fine to coarse sands. It also contained low amounts of coarser particles, including gravel and very coarse sand, indicating a mix of finer and coarser sediments overall.

Site SW5, also located in the upper estuary and down-gradient of Coal and Christies Creek, was dominated by mud/silt with much lower levels of coarser materials. This suggests that SW5 may represent an area where finer sediments settle and accumulate. SW7 is characterised by a sediment composition that was more sand-dominated compared to other sites. It had high proportions of very fine and fine sands, and a moderate amount of mud/silt.

Table 3: Seven Grain Sizes Profile

Sample Name		SW4 19-Nov-2024	SW7 19-Nov-2024	SW5 19-Nov-2024	Wentworth Grain Size Classification Wentworth, (1922).
Lab Number:		3723191.1	3723191.2	3723191.3	
Dry Matter of Sieved Sample	g/100g as rcvd	39	64	45	
Fraction >/= 2 mm	g/100g dry wt	1.4	0.4	< 0.1	Gravel
Fraction < 2 mm, >/= 1 mm	g/100g dry wt	1.6	0.6	< 0.1	Very Coarse Sand
Fraction < 1 mm, >/= 500 µm	g/100g dry wt	6.1	1	0.1	Coarse Sand
Fraction < 500 µm, >/= 250 µm	g/100g dry wt	6	2.8	1.7	Medium Sand
Fraction < 250 µm, >/= 125 µm	g/100g dry wt	5.9	41	2.6	Fine Sand
Fraction < 125 µm, >/= 63 µm	g/100g dry wt	9.6	29.7	6	Very Fine Sand
Fraction < 63 µm	g/100g dry wt	69.4	24.5	89.5	Mud/Silt

5.6 Sediment Profile

Sediment cores were cut and pulled from each estuarine site. Observations and measurements were undertaken to assess the redox layer and sediment profile. The following details results on a site-by-site basis.

SW4

SW4 sediment cores indicate low sedimentation rates in the upper estuary. Roots penetrated down to 0.150 m bgl indicating a stable presence of vegetation, characteristic of a well-drained or slightly elevated site. Profile characteristics were:

- 0 – 0.002 m: Depositied fine sediment on the surface.
- 0.002 – 0.020 m: Black anoxic clay showing the redox layer.
- 0.02 – 0.150 m: Grey gleyed clay with mottle iron, fibrous root system extending to 0.150 m bgl and no obvious odour. No water was present in the sediment core hole.
- 0.150 m: Grey, white and black, sandy clay, moderately coarse.

SW5

SW5 sediment cores showed an accumulation of fine sediments suggesting ongoing sedimentation. The presence of water at 0.120 m bgl indicated a shallow groundwater influence, which may contribute to anoxic conditions. Profile characteristics were:

- 0 – 0.01 m: Deposited fines, light brown.
- 0 – 0.04 m: Black anoxic clay layer.
- 0.04 – 0.150 m: Grey, gleyed clay with red oxide iron mottled, some fibrous matter, no odour. Water was present at 0.120 m bgl.

SW7

SW7 had a thicker fine sediment layer suggesting higher rates of recent deposition. The presence of a black anoxic layer at shallow depths indicates organic matter decomposition and potential hypoxic conditions. Profile characteristics were:

- 0 – 0.030 m: deposition fines, brown, silty clay
- 0.030 – 0.150 m: black anoxic layer. Water was present at 0.13 m

5.7 Macroinvertebrate Survey

Macroinvertebrate results are compared to NPS-FM 2020 Attribute Bands and the quality classes contained in Table 3 (Stark and Maxted, 2007). The taxa list and counts obtained at sites can be found in Appendix D. Christies Creek SW2a was not sampled due to the absence of flowing water.

Kaikorai Stream sites (US & DS) contained overhanging vegetation and instream woody debris that provided some habitat and instream cover for macroinvertebrates. The streambed at upper Kaikorai Stream SW1 was dominated by soft sediments and the site recorded the lowest MCI score (55) of any site sampled. It had communities dominated by midge larvae (*Chironomus* spp.) and worms (Oligochaetes). Kaikorai Stream SW6 recorded the highest MCI and QMCI scores of the sites assessed, with higher-scoring damesfly (*Xanthocnemis* spp.) and midges (*Tanytarsini* spp.) present. This was resultant in a classification of 'fair' quality using the Stark and Maxted (2007) criteria.

Christies Creek SW2b was the only sampling site that contained any pollution-sensitive EPT (mayfly, caddisfly or stonefly) taxa. Despite this, the MCI and QMCI scores at the site were still 'poor' and indicative of a degraded community. Coal Creek SW3a had a similar macroinvertebrate community, but with the absence of any EPT species.

Overall, macroinvertebrate communities sampled in streams were indicative of poor aquatic ecosystem health. This may be driven, in-part, by degraded water quality in the catchments. However, physical habitat conditions, particularly sediment smothered streambeds, are likely a major driver of macroinvertebrate community structure.

Table 4: Benthic Macroinvertebrate Community Indices

Site	MCI-sb	QMCI-sb	(MCI/QMCI) NPS-FM (2020) Attribute Band[1]	Stark and Maxted (2007) 'Quality Class'
Kaikorai Stream SW1	**54.92**	**3.20**	D/D	Poor/Poor
Christies Creek SW2b	**69.0**	**2.87**	D/D	Poor/Poor
Coal Creek SW3a	**68.18**	**2.40**	D/D	Poor/Poor
Kaikorai Stream SW6	**84.36**	5.31	D/C	Fair/Good

Notes:
***BOLD** denotes the results in Attribute Band D, that fall below the National Bottom Line of the MFE (2020a)*

5.9 Infauna Sediment Cores

Upper Estuary

Benthic infauna were sampled at the freshwater/estuarine interface at Coal Creek DS, in the upper estuary at sites SW4 and SW5, and in the central estuary at site SW7. Results were reflective the upper lagoon's predominantly freshwater conditions, likely due to its closed state for long and frequent periods. Raw data from the infauna sediment cores is displayed in Appendix E. Results are summarised below.

Coal Creek SW3b showed a high diversity of taxa but with a lower overall abundance. The site was dominated by dipteran fly larvae (*Chironomus* spp.) commonly found in areas of moderate organic enrichment. The larvae, known as "blood worms", are a tolerant taxa and found in low-oxygen environments (Manaki Whenua, 2025).

Site SW4, in the upper estuary, is one of the closet sites to the Fairfield Landfill. Similar to Coal Creek DS, this site was dominated by dipteran species, which are highly tolerant of pollution and environmental stress. Limited tidal flushing appears to restrict the dispersal of crustaceans and gastropods, resulting in minimal presence of these taxa groups.

SW5 had the lowest species abundance, with only 17 species recorded across five different taxon groups. This is suggestive of a stressed and limited community. Amphipods (*Paracorophium* and *Paracalliope*) were recorded indicating a greater estuarine influence. These species are tolerant of a range of estuarine conditions and can serve as indicators of disturbance and low salinity levels. *Paracalliope* spp., a shrimp-like amphipod, is particularly important in estuarine ecosystems playing a key role in breakdown of organic matter. It serves as a food source for fauna at higher trophic levels.

Central Estuary

SW7 recorded an abundance of gastropods and amphipods. This site was the only to have the marine specialist polychaeta *Scolecolepides benhami*. Sensitive species such as *Paracalliope spp.* were the most abundant at the site, and it also recorded the highest number of *Potamopyrgus spp.* The latter is an endemic mudsnail found in both fresh and brackish waters. It is tolerant of habitat degradation and organically enriched environments.

Summary

The infauna communities align with the estuary's predominantly freshwater conditions during the times when it is frequently closed to the sea. Species compositions and abundancies reflected varying levels of tidal influence and habitat conditions, with SW7 being the most marine-influenced site. The benthic infauna data from the upper estuary (SW4 and SW5) may highlight some influence of the Fairfield Landfill with the dominance of pollution-tolerant species such as dipteran larvae being present. However, it is noted that habitat degradation and contamination in the upper estuary is likely driven by multiple sources in the wider catchment, including urban and industrial stormwater runoff. The low species diversity and abundance upper estuary sites, alongside the limited presence of more sensitive organisms, indicative of a degraded community and poor ecosystem health.

5.10 Vegetation Plots

A vegetation plot survey was undertaken in the upper estuary at SW4. The site was mostly void of vegetation, is at least occasionally dry, and has limited tidal flushing.

The SW5 vegetation assessment was conducted adjacent to the main outflow channel. The site was dominated by brass button (*Cotula coronopifolia*) growing above the estuarine channel. This is an invasive plant species, known to thrive in disturbed habitats. Its growth as dense mats outcompetes native vegetative species (D'Antonio, 1991). SW5 was more densely vegetated than any other estuary site surveyed.

Downstream, in the central estuary at site SW7, the survey plot recorded a low cover of sea grass (less than 5%), with the remaining area being bare sand. The low percentage of seagrass at this site may indicate environmental stress or degradation. Its absence could be having flow-on effects on the overall health of the estuary.

5.11 Fish and Bird Fauna

5.11.1 eDNA Fish Species

A total of eleven estuarine and freshwater fish species were detected across all sites using eDNA (Table 5). Banded kokopu (*Galaxias fasciatus*) and kōaro (*Galaxias brevipinnis*) were detected, but are absent in NZFFD records. These species are likely to inhabit locations in the upper catchment. They migrate seasonally from the sea, therefore using the estuary and lower river reaches as habitat and/or migratory pathways. Taonga species that are present (as per NIWA, 2024) include shortfin eel (*Anguilla australis*), longfin eel (*Anguilla dieffenbachii*), īnanga (*Galaxias maculatus*), kōaro, banded kōkopu, yelloweye mullet (*Aldrichetta forsteri*), and black flounder (*Rhombosolea retiaria*).

The marine species Bluenose Warehou, Tarakihi, Blue Cod, and Barracouta (not included in Table 5) were also detected using eDNA at the brackish sites at Coal Creek SW3b and SW7. These are deep sea species and would not be living within the estuary environment. It is possible that DNA signatures were obtained from contamination via, for example, the droppings of birds.

Table 5: Fish species eDNA results

Scientific name	Common name	NZTC Status[1]	Sample Site		
			Kaikorai Stream US	Coal Creek DS	SW7
Anguilla australis	Shortfin eel; tuna; hao; aopori; hikumutu	Not Threatened	✓	✓	✓
Anguilla dieffenbachii	Longfin eel; tuna; kūwharuwharu; reherehe; kirirua	At Risk - Declining	✓	✓	✓
Aldrichetta forsteri	Yelloweye mullet; kātaha; aua; kātaka	Not Threatened	✓	✓	✓
Galaxias brevipinnis	Kōaro; maehe	At Risk - Declining	✓		✓
Galaxias fasciatus	Banded kōkopu	Not Threatened	✓	✓	✓
Galaxias maculatus	Īnanga	At Risk - Declining	✓	✓	✓
Gobiomorphus cotidianus	Common bully; tīpokopoko; toitoi	Not threatened	✓	✓	✓
Gobiomorphus huttoni	Redfin bully	Not Threatened	✓	✓	✓
Gobiomorphus breviceps	Upland bully	Not Threatened	✓	✓	✓
Rhombosolea retiaria	Black Flounder; freshwater flounder	Not Threatened			✓
Salmo trutta	Brown trout; taraute; tarauta	Introduced and Naturalised	✓	✓	✓

Notes:
1. *New Zealand Threat Classification System (NZTCS): https://nztcs.org.nz/* (Dunn, 2017)
2. *Wilderlab reports can be accessed via these links*

SW! https://s3.ap-southeast-2.amazonaws.com/wilderlab.openwaters/reports/cc7f92c3b2bce265.html
SW3b https://s3.ap-southeast-2.amazonaws.com/wilderlab.openwaters/reports/093475357c575869.html
SW7 https://s3.ap-southeast-2.amazonaws.com/wilderlab.openwaters/reports/26701f7a17d92d37.html

5.11.2 Bird Species

The genetic eDNA signatures of 14 bird species were detected (Table 6). Four of these were found at all sites: mallard duck, pūkeko, black teal, and black swan. Kaikorai Stream SW1 had the highest bird species diversity, with nine species detected, an abundance that may be influenced by people observed feeding them. Coal Creek SW3b had the second-most diverse community detected, with eight species recorded. SW7 had seven species detected.

Kaikorai Stream SW1 had five avian species unique to this site: muscovy duck, house sparrow, common starling, pigeon, and greylag goose. Each was detected with a low abundance sequence counts indicating that they were unlikely to be recently present in large numbers. Paradise shelduck was only detected at site Coal Creek SW3b with a high number of sequence counts. Brown teal, grey teal and little shag were detected at both Kaikorai Stream SW1 and Coal Creek SW3b. The Southern black-backed gull was only observed at SW7. Only two species identified have a conservation status which include the red billed gull which is 'Native-Declining' and little Shag 'At Risk-Relict'.

From the eDNA results and 5MBC (Table 7) only two species were identified to have an endangered or threatened conservation status which included the red billed gull, 'Native-Declining' and little shag 'At Risk-Relict'. This is a small contribution to the list of endangered and threatened birds recorded on eBird and associated with the area from LAWA discussed in Section 3.0

Table 6: Results of eDNA samples of bird species from Fairfield Landfill

Scientific name	Common name	NZTC Status[1]	Kaikorai Stream US	Coal Creek DS	SW7
Anas platyrhynchos	Mallard duck; rakiraki	Introduced and Naturalised	✓	✓	✓
Porphyrio melanotus	pūkeko	Not Threatened	✓	✓	✓
Tadorna variegata	Paradise Shelduck; pūtangitangi	Not Threatened		✓	
Anas chlorotis or gracilis	Brown or grey teal; pāteke	Nationally increasing	✓	✓	
Aythya novaeseelandiae	New Zealand scaup; black teal; papango;	Not Threatened	✓	✓	✓
Cygnus atratus	Black swan; wāna;	Not Threatened	✓	✓	✓
Branta canadensis	Canada goose; kuihi	Introduced and Naturalised		✓	✓
Microcarbo melanoleucos	Little shag; kawaupaka	At risk(relict)	✓	✓	
Cairina moschata	Muscovy duck	-	✓		
Passer domesticus	House sparrow; tiu	Introduced and Naturalised	✓		
Sturnus vulgaris	Common starling; tāringi	Introduced and Naturalised	✓		
Columba livia	Pigeon	Introduced and Naturalised	✓		
Anser anser	Greylag goose	Introduced and Naturalised	✓		
Larus dominicanus	Southern black-backed gull; karoro	Not Threatened			✓

Notes:

1. *NZTC Conservation status. New Zealand threat Classification system* https://nztcs.org.nz/ (DOC, 2024)

Table 7: 5 Minute Bird Counts (5MBC), all birds seen or heard within 100m radius of each site.

Scientific name	Common name	Conservation status[1]	SW4	SW5	SW7
Larus dominicanus	Kelp gull or Southern black-backed gull	Native-Not threatened	340	450	44
Onychoprion lunatus	Grey-backed tern	Native-Vagrant	3		
Tadorna variegata	Paradise shelduck, Pūtangitangi	Endemic-Not Threatened	40	23	
Chroicocephalus novaehollandiae	Red-billed Gull Tarāpunga, silver gull	Native-Declining	60		
Himantopus himantopus	Pied stilt-Poaka	Native-Not Threatened	6	3	2
Cygnus atratus	Black swan-Kakīānau	Native-Not Threatened	3	6	17
Porphyrio melanotus	Pūkeko	Native-Not Threatened	1	2	
Branta canadensis	Canada goose or Kuihi	Introduced and Naturalised	3	3	6
Anser anser	Greylag goose	Introduced and Naturalised	1		
Aythya novaeseelandiae	New Zealand scaup or Pāpango	Endemic-Not Threatened		43	

Notes:

1. New Zealand Birds Online. The digital encyclopaedia of New Zealand Birds. (New Zealand Birds Online, 2024)

6.0 Potential Effects

It is difficult to determine the effects of the Fairfield Landfill on receiving environments. This is because the catchment of the Kaikorai Estuary and Wetland Complex is highly developed, with multiple activities contributing to its water quality and ecological condition. These activities include those that generate contaminant laden (e.g., heavy metal) industrial and urban stormwater runoff, as well as agricultural land uses. Additionally, the hydrological state of the estuary is highly-dynamic changing between an open and closed status. This results in periodic changes to the salinity profile of the estuary and the lower reaches of the waterways that feed it. The changing gradient in salinity concentrations will influence the baseline chemistry of the receiving waterbodies, including the chemical composition of any contaminants that may be entering them.

High nutrient concentrations in waterbodies near the landfill suggest that eutrophication effects could be occurring. The potential effects of eutrophication include the promotion of algal blooms and fine sediment retention, more-so at times when the lagoon is closed and/or during time of prolonged low flows. Despite this, estuarine assessments undertaken by Stewart (2008 & 2018) found that there is an absence of estuarine macroalgae (e.g., *Gracilaria*, *Enteromorpha*, and *Ulva* spp.) and scarce epifauna. This suggests that that at least some parts of the estuary are either well flushed, don't have eutrophication issues, or lacks the intertidal space for these flora and fauna to live and grow.

The most prominent indicator that suggests leachate from the Fairfield Landfill is impacting surface waterbody ecology is the presence of ammoniacal nitrogen. Total ammoniacal nitrogen (TAN) concentrations were noticeably higher in the upper estuary and in the lower reaches of Christies Creek and Coal Creek. pH levels were also more acidic at sites nearer the landfill, another potential indicator of leachate effects. The lower pH levels moderate, to some extent, the magnitude of aquatic toxicity effects exhibited by the high TAN. This is because the ratio of toxic ammonia to non-toxic ammonium is higher when waters are more alkaline. However, even in consideration of the low pH levels, TAN concentrations exceeded ANZG (2018) and NPS-FM 2020 toxicity thresholds for aquatic fauna with chronic exposure.

Total and dissolved metal concentrations in water and sediments were more variable across sampling sites. Given the influence of industrial and urban stormwater on streams and Kaikorai Estuary, it is difficult to ascertain the relative contribution of the landfill to elevated metal concentrations. Iron concentrations in water and sediment tended to be highest nearer the landfill, but there were no distinct upstream-downstream patterns that clearly indicated a discrete effect.

Ecological monitoring, and desktop analyses, found that an array of 'at risk' and 'threatened' bird and fish species inhabit the waterways near the landfill. Notable bird species include black stilt (Nationally Critical), black-fronted tern (Nationally Endangered), and red-billed gull (Declining). Fish species identified included shortfin and longfin eel, īnanga, kōaro, banded kōkopu, and pātiki/black flounder. The presence of diverse bird and fish species highlight the estuary's role in supporting habitat for high conservation species, including as feeding, rearing and breeding grounds. Some are also considered as taonga, illustrating the cultural significance of the environment.

Benthic macroinvertebrate and estuary infauna surveys indicated that the health of aquatic communities is being negatively impacted by catchment land uses. Macroinvertebrate indices reflected communities indicative of 'probable severe pollution', however it is likely that habitat degradation (particularly deposited sediment) is having a major influence on community health. The benthic infauna results indicate a gradient of ecological conditions in the estuary influenced by both freshwater and tidal influences, and sediment composition. The upper estuarine sites were dominated by species tolerant of degraded water quality, whereas the central estuary had a greater saline influence and supported a higher diversity of estuarine and marine species. The presence of pollution-tolerant species at upper estuary sites suggest environmental stress likely linked to sediment-bound contaminants.

Overall, the patterns seen in ecological communities in the vicinity of Fairfield Landfill are heavily influenced by a range of catchment land uses. Teasing apart the relative contribution of landfill leachates to driving poor ecosystem health, compared to other activities (e.g., particularly stormwater discharges), is difficult to determine. Heavy metal and other contaminant concentrations are variable, however high ammonia levels measured at monitoring sites are indicative of landfill-based leachates entering the environment. Ammonia is highly toxic to aquatic biota and therefore the landfill is likely having at least a localised detrimental effect on stream and estuary ecosystems.

7.0 Recommended Monitoring

The Kaikorai Wetland and Estuary Complex is influenced by multiple catchment activities. Monitoring indicates that some waterbody areas experience more pronounced ecosystem impacts from catchment land uses than others. Additionally, the estuary's natural variability, particularly the changes in salinity gradients when the lagoon is open versus closed, periodically affect its water chemistry.

To capture these dynamics, sampling should prioritise periods when the mouth is open, but also consider changes to water quality and sediment conditions when the lagoon is closed. Ongoing monitoring will provide additional context to the snapshot of contamination recorded during this assessment. It will enable us to examine longer-term trends in environmental conditions. This will help us understand how the influence of different catchment factors, particularly the Fairfield Landfill, condition evolve over time.

Based on the findings of this ecological assessment, the following is recommended for ongoing monitoring. It accounts for the shifting conditions during open and closed states of the lagoon.

- Monitoring sites:
  - Lower Christies Creek at SW2b
  - Lower Coal Creek at SW3b
  - Upper Kaikorai Estuary at SW4
  - Kaikorai Lagoon Wetland at SW5
  - Centre of Kaikorai Estuary at SW7
- Sediment sampling:
  - Frequency - annually when the lagoon is open (or when it is closed if sites are accessible)
  - Parameters - nutrients (total phosphorus and total nitrogen), Total Organic Carbon and total recoverable iron, lead and zinc.
- Benthic infauna - annually (collected at the same time as sediment samples)
- Water quality:
  - Frequency (when lagoon mouth is open) - monthly
  - Frequency (when estuary mouth is closed) - three rounds of monitoring at least one month apart. This data will be reviewed after this period to examine the usefulness of monitoring programme.
  - Parameters - in situ measurements: conductivity, pH, temperature, and dissolved oxygen; laboratory measurements: BOD5, salinity, alkalinity, calcium, sodium, chloride, potassium, sulphate, nutrients (nitrate-N, nitrite-N, total ammoniacal-N, dissolved reactive phosphorus, total phosphorus and total nitrogen), and total and dissolved magnesium, iron, lead and zinc.
- Review period - the monitoring programme will be reviewed every two years to assess its relevance and effectiveness.

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Appendix A: Site Location and Sampling

Table 8: Sampling sites in relation to the Kaikorai Estuary and their corresponding assessments

Site Name	Environmental Setting	Assessments	GPS
SW1	Kaikorai Stream SW1 freshwater tributary Referred to as upper estuary	Spot and laboratory water quality measurements	-45.904815° 170.412154°
		Rapid Habitat Assessment (RHA)	
		Sediment chemical analysis	
		MCI	
		eDNA active sampling	
SW2a	Christies Creek SW2a freshwater tributary	Spot and laboratory water quality measurements	-45.907316 ° 170.386410 °
		RHA	
		Sediment chemical analysis	
SW2b	Christies Creek SW2b freshwater tributary	Spot and laboratory water quality measurements	-45.908510° 170.397463°
		RHA	
		Sediment chemical analysis	
		MCI	
SW3a	Coal Creek SW3a freshwater tributary	Spot and laboratory water quality measurements	-45.910408 ° 170.392822 °
		RHA	
		Sediment chemical analysis	
		MCI	

Table 8: Sampling sites in relation to the Kaikorai Estuary and their corresponding assessments

Site Name	Environmental Setting	Assessments	GPS
SW3b	Coal Creek SW3b freshwater/estuarine interface	Spot and laboratory water quality measurements	-45.909287° 170.398553°
		RHA	
		Sediment chemical analysis	
		Infauna	
		eDNA	
SW4	Kaikorai Wetland estuarine Referred to as upper estuary	Infauna + Vegetation Plot	-45.909341° 170.405519°
		Sediment chemical analysis and particle size distribution (PSD)	
		Bird count	
SW5	Kaikorai Wetland estuarine Referred to as upper estuary	Saline Water Quality + YSI	-45.911431° 170.401472°
		RHA	
		Sediment chemical analysis and PSD	
		Infauna + Vegetation Plot	
		Bird count	
SW6	Kaikorai Stream SW6 estuarine Referred to as upper estuary	Saline Water Quality and YSI	-45.912667° 170.404652°
		RHA	
		Sediment chemical analysis	
		MCI	
SW7	Kaikorai Estuary estuarine Referred to as central estuary	Saline Water Quality + YSI	-45.918584° 170.397853°
		RHA	
		Sediment chemical analysis and PSD	
		Infauna + Vegetation Plot	
		eDNA	
		Bird count	

Appendix B: Water and Sediment Quality Results

Fairfield

Table 1: Water quality results for freshwater sites

Sample Name:	SW1	SW 2a	SW 2b	SW 3a	SW3b	ANZG 95% Species Protection Level unless	ANZG 90% Species Protection Level [5]	ANZG 80% Species Protection Level [5]	NPS-FM (2020) [3] Bottom Line/Attribute Band	
Environment type:	Freshwater									
Sample Date:	19/11/2024	18/11/2024	18/11/2024	18/11/2024	18/11/2024					
Lab Report Number:	3720231.8	3718872.1	3718872.4	3718872.2	3718872.3					
Dissolved Metals										
Magnesium	16.9	29	18.4	22	40	-	-	-	-	
Iron	0.35	1.76	0.16	0.16	0.21	-	-	-	-	
Lead	< 0.00010	< 0.00010	< 0.00010	< 0.00010	<0.0010	0.0034 [5]	0.0056	0.0094	-	
Zinc	0.017	0.0018	0.055 [1]	0.0093 [1]	-	0.008 [5]	0.015	0.031	-	
Total Metals										
Magnesium	17.1	30	18.9	23	43	-	-	-	-	
Potassium	3.9	2.2	6.9	2.6	26	-	-	-	-	
Sodium	60	50	43	42	220	-	-	-	-	
Iron [4]	2	5.1	0.81	1.49	1.19	-	-	-	-	
Lead [4]	0.0003	< 0.00011	< 0.00011	< 0.00011	<0.0011	0.0034 [5]	0.0056	0.0094	-	
Zinc [4]	0.021	0.0023	0.050 [1]	0.0080 [1]	0.026	0.008 [5]	0.015	0.031	-	
Calcium	26	38	40	33	56	-	-	-	-	
Nutrients and Aggregates										
Total Alkalinity	48	174	78	23	125	-	-	-	-	
Salinity [10]	0.3	0.3	0.3	0.3	0.9	-	-	-	-	
Chloride [4]	91	60	44	47	370	-	-	-	-	
Total Nitrogen	0.86	1.2	1.43	0.44	4	0.913 [6]	-	-	0.75 [9]	D
Total Phosphrous	0.028	0.123	0.005	0.039	0.05	0.014 [6]	-	-	0.05 [9]	D
Sulphate	89	63	135	171	185	-	-	-	-	
Total Biochemical Oxygen Demand (TBOD5) [4]	<2	< 2	< 2	2	3	-	-	-	-	
Nutrient Profile										
Total Ammoniacal-N [4]	0.195	0.039	0.75	0.019	3	0.01 [6]	-	-	0.24	C
Total Ammoniacal-N converted pH 8	0.08	0.013	0.264	0.006	1.111	0.01 [6]	-	-	0.24	C
Nitrite	0.0076	0.002	0.002	0.002	0.026	-	-	-	-	
Nitrate [4]	0.36	0.005	0.33	0.146	0.45	0.265 [6]	-	-	2.4	C
Nitrate-N + Nitrite-N	0.37	0.007	0.33	0.148	0.47	-	-	-	-	
Dissolved Reactive Phosphorus	0.001	0.029	< 0.004	< 0.004	0.006	0.008 [6]	-	-	0.018	D

Table 2: Water quality results for saline environment sites

Sample Name:	SW5	SW6	SW7	ANZG 95% Species Protection Level [5,6]	ANZG 90% Species Protection Level [5]	ANZG 80% Species Protection Level [5]	NPS-FM (2020) [3] Attribute Band	
Environment type:	Saline							
Sample Date:	19/11/2024	19/11/2024	19/11/2024					
Lab Report Number:	3720231.3	3720231.1	3720231.6					
Dissolved Metals								
Magnesium	350 [1]	119 #1	240	-	-	-	-	
Iron	0.02	0.15	0.04	-	-	-	-	
Lead	< 0.0010	< 0.0010	< 0.0010	0.0044 [5]	0.0066	0.012	-	
Zinc	0.017	0.017	0.021	0.008 [5]	0.012	0.021	-	
Total Metals								
Magnesium	320 [1]	114 #1	270				-	
Potassium	107	36	81	-	-	-	-	
Sodium	2,700	890	2,200	-	-	-	-	
Iron	3	0.69	1.06	-	-	-	-	
Lead	0.0048	< 0.0011	0.0015	0.0044 [5]	0.0066	0.012	-	
Zinc	0.04	0.0182	0.024	0.008 [5]	0.012	0.021	-	
Calcium	138	59	107	-	-	-	-	
Nutrients and Aggregates								
Total Alkalinity	110	65	74	-	-	-	-	
Salinity [10]	9	3.1	7.1	-	-	-	-	
Chloride	4,900	1,630	4,100		-	-	-	
Total Nitrogen	2.8	0.94	1.09	0.913 [6]	-		0.75 [9]	D
Total Phosphrous	0.26	0.035	0.051	0.014 [6]	-		0.05 [9]	D
Sulphate	740	260	570		-	-	-	
Total Biochemical Oxygen Demand (TBOD5)	3	< 2	< 2	-	-	-	-	
Nutrient Profile								
Total Ammoniacal-N	1.3	0.174	0.24	0.01 [6]	-	-	-	
Total Ammoniacal-N converted pH 8	0.501	0.064	0.103	0.01 [6]	-	-	0.24	C
Nitrite	0.039	0.0124	0.0147	-	-	-	-	
Nitrate	0.29	0.35	0.32	0.265 [6]	-	-	2.4	C
Nitrate-N + Nitrite-N	0.33	0.36	0.33	-	-	-	-	
Dissolved Reactive Phosphorus	0.004	0.008	0.0079	0.008 [6]	-	-	0.018	D

Notes:

1 The result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

3. National Policy Statement - Freshwater Management. National Bottomline or the lowest available Attribute Band for median values only.

4 Parameters to be tested as per consent 93540

5. ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Toxicity Protection Levels

6. Refers to River Environment Classification 'Cool dry, low elevation'. ANZG DGV for Physical and Chemical Stressors 80th percentile (ANZG, 2018)

7. Value in mg/L unless otherwise stated

9. Refers to NPS-FM ecosystem Health - Trophic State for Lakes

10. Values in part per thousand (ppt) (<0.5 ppt freshwater),(0.5 - 5 ppt low-brackish), 5 - 18 ppt moderate-brackish), ANZECC (2000)

-	
Underline	

Table 3: Sediment quality results for freshwater environment sites							
Sample Name:		**SW1**	**SW 2a**	**SW 2b**	**SW 3a**	ANZG DVG[1]	ANZG DVG[1]
Sample date:		**19-Nov-24**	**18-Nov-24**	**18-Nov-24**	**18-Nov-24**		
Lab Number:		**3720231.9**	**3718872.5**	**3718872.8**	**3718872.6**	**DGV**	**GV-high**
Total Recoverable Iron	mg/kg dry wt	19,600	51,000	90,000	150,000		
Total Recoverable Lead	mg/kg dry wt	44	7.9	11	14.6	50	220
Total Recoverable Phosphorus	mg/kg dry wt	540	380	660	1,680		
Total Recoverable Zinc	mg/kg dry wt	310	55	520	260	200	410
Total Nitrogen	g/100g dry wt	0.11	< 0.05	0.33	0.87		
Total Organic Carbon	g/100g dry wt	2	0.51	5.1	10.5		

Table 4: Sediment quality results for saline environment sites								
Sample Name:		**SW 3b**	**SW4**	**SW5**	**SW6**	**SW7**	ANZG DGV [1]	ANZG DGV [2]
Sample date:		**18-Nov-24**	**19-Nov-24**	**19-Nov-24**	**19-Nov-24**	**19-Nov-24**		
Lab Number:		**3718872.7**	**3720231.5**	**3720231.4**	**3720231.2**	**3720231.7**	**DGV**	**GV-high**
Total Recoverable Iron	mg/kg dry wt	24,000	33,000	26,000	13,700	17,000		
Total Recoverable Lead	mg/kg dry wt	34	70	35	28	21	50	220
Total Recoverable Phosphorus	mg/kg dry wt	500	2,400	930	470	650		
Total Recoverable Zinc	mg/kg dry wt	300	320	182	164	132	200	410
Total Nitrogen	g/100g dry wt	0.25	0.81	0.22	0.06	0.1		
Total Organic Carbon	g/100g dry wt	2.7	7.1	2.3	1.09	1.13		

Notes

1. Default Guideline values for sediment quality. ANZG 2018. Australian and New Zealand Guidelines for Sediment Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

Appendix C: Rapid Habitat Assessment

Table 9: RHA assessment

Assessment Parameter	Kaikorai Stream SW1	Christies Creek SW2a	Christies Creek SW2b	Coal Creek SW3a	Coal Creek SW3b	Kaikorai Stream SW6
Deposited Sediment	1	5	1	1	1	1
Invertebrate Habitat Diversity	2	3	7	3	2	3
Invertebrate Habitat Abundance	4	1	1	1	1	1
Fish Cover Diversity	2	2	8	4	4	1
Fish Cover Abundance	10	4	8	7	7	9
Hydraulic Heterogeneity	1	1	2	2	1	1
Bank Erosion	1	3	8	8	6	1
Riparian Vegetation	7	2	5	4	3	3
Riparian Width	9	2	8	5	8	10
Riparian Shade	7	4	6	10	3	4
Total	**44**	**27**	**54**	**45**	**36**	**34**

Notes:

1. *Cawthron* Institute, (2015)

Appendix D: Macroinvertebrate Community Index Results

Table 10: Macroinvertebrate community Index Results - Fairfield landfill monitoring

Taxa	Kaikorai Stream SW1	Christies Creek SW2B	Coal Creek SW3A	Kaikorai Stream SW6
Caddisfly Oxyethira	2	-	-	-
Caddisfly Paroxyethira	-	-	1	-
Caddisfly Triplectides	-	3	-	-
Damselfly Austrolestes	1	2	-	-
Damselfly Ischnura	-	1	-	-
Damselfly Xanthocnemis	2	7	2	1
Dragonfly Procordulia	-	1	-	-
Bug Sigara	1	-		1
True Fly Austrosimulium	-	-	2	-
True Fly Ceratopogonidae	-	3	-	-
True Fly Chironomus	150	-	-	3
True Fly Empididae	-	1	-	-
True Fly Hexatomini	-	-	1	-
True Fly Muscidae	-	-	2	-
True Fly Orthocladiinae	16	-	-	1
True Fly Tanypodinae	-	-	-	2
True Fly Tanytarsini	-	-	-	29
Crustacea Copepoda	1	-	-	-
Crustacea Corophium	-	-	-	35
Crustacea Isopoda	-	3	5	-
Crustacea Mysid shrimps	2	-	-	37
Crustacea Ostracoda	2	12	35	-

Table 10: Macroinvertebrate community Index Results - Fairfield landfill monitoring

Taxa	Kaikorai Stream SW1	Christies Creek SW2B	Coal Creek SW3A	Kaikorai Stream SW6
Crustacea Paracalliope	-	45	120	77
Crustacea Talitridae	-	-	-	26
MITES (Acari)	1	1	2	-
Spiders Dolomedes	-	-	-	1
Mollusc Potamopyrgus	4	60	27	1
Mollusc Sphaeriidae	-	3	2	-
OLIGOCHAETES	4	55	3	-
NEMERTEA	16	6	-	-
Number of Taxa	13	15	12	12
EPT Value	0	1	0	0
Number of Individuals	202	203	202	214
% EPT	0.0	1.48	0.00	0.00
% EPT Taxa	0.0	6.67	0.00	0.00
Sum of recorded scores	42.00	57.00	44.00	45.00
Count of recorded scores	12.00	14.00	12.00	11.00
Sum of recorded scores	200.00	202.00	202.00	142.00
Count of recorded scores	70.00	81.43	73.33	81.82
Sum of individuals with scores	291.00	683.00	886.00	811.00
MCI Value	1.46	3.38	4.39	5.71
Sum of abundance load	35.70	48.30	37.50	46.40
QMCI Value	13.00	14.00	11.00	11.00

Table 10: Macroinvertebrate community Index Results - Fairfield landfill monitoring

Taxa	Kaikorai Stream SW1	Christies Creek SW2B	Coal Creek SW3A	Kaikorai Stream SW6
Sum of individuals with scores	202.00	158.00	82.00	137.00
SBMCI Value	**54.92**	**69.00**	**68.18**	**84.36**
Sum of abundance load	645.70	453.80	197.10	728.10
QMCI-sb Value	**3.20**	**2.87**	**2.40**	**5.31**
Fraction Examined for VA Taxa	1/4	1/4	1/8	1/16

Appendix E: Infauna Sediment Cores

Infauna Raw Data				
Sample Name:	**SW3b**	**SW 4**	**SW 5**	**SW 7**
Sample date:	**19-Nov-24**	**19-Nov-24**	**19-Nov-24**	**19-Nov-24**
Sample Type	**Infauna**	**Infauna**	**Infauna**	**Infauna**
Taxa				
Oligochaeta	2	6		
Paracorophium excavatum	9		3	101
Paracalliope sp.	5	3	6	54
Daphnia				1
Mysidacea	2			
Ostracoda				18
Collembola		1		
Potamopyrgus sp.	6		1	123
Scolecolepides benhami				2
Chironomus	52	15	3	9
Tanypodinae	14	1		9
Dolichopodidae		3	4	
Total	90	29	17	317

Appendix F: Lab Methods

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Certificate of Analysis

Client:	Pattle Delamore Partners Limited	**Lab No:**	3718872 SUPv1
Contact:	Gemma Scott C/- Pattle Delamore Partners Limited Level 3, 36-40 Kelvin Street Invercargill 9810	**Date Received:**	19-Nov-2024
		Date Reported:	09-Dec-2024
		Quote No:	126015
		Order No:	
		Client Reference:	C021870002
		Submitted By:	Gemma Scott

Sample Type: Saline

Sample Name:		Sw 3b 18-Nov-2024 1:20 pm
Lab Number:		3718872.3
Individual Tests		
Total Alkalinity*	g/m³ as $CaCO_3$	124.5 ± 5.1
Salinity*		0.920 ± 0.074
Total Calcium	g/m³	56.0 ± 2.4
Dissolved Iron	g/m³	0.207 ± 0.025
Total Iron	g/m³	1.19 ± 0.15
Dissolved Lead	g/m³	< 0.0010 ± 0.00067
Total Lead	g/m³	< 0.0011 ± 0.00074
Dissolved Magnesium	g/m³	40.3 ± 3.6
Total Magnesium	g/m³	42.5 ± 4.3
Total Potassium	g/m³	25.6 ± 1.3
Total Sodium	g/m³	222 ± 23
Total Zinc	g/m³	0.0259 ± 0.0050
Chloride	g/m³	366 ± 18
Total Nitrogen	g/m³	4.02 ± 0.24
Total Ammoniacal-N	g/m³	2.98 ± 0.50
Nitrite-N	g/m³	0.0260 ± 0.0043
Nitrate-N	g/m³	0.445 ± 0.063
Nitrate-N + Nitrite-N*	g/m³	0.471 ± 0.063
Dissolved Reactive Phosphorus	g/m³	0.00602 ± 0.00084
Total Phosphorus	g/m³	0.0496 ± 0.0024
Sulphate	g/m³	185 ± 13
Total Biochemical Oxygen Demand ($TBOD_5$)	g O_2/m³	2.9 ± 1.5

Sample Type: Sediment

Sample Name:		SW 2a 18-Nov-2024 3:30 pm	SW 3a 18-Nov-2024 2:02 pm	Sw 3b 18-Nov-2024 1:20 pm	SW 2b 18-Nov-2024 12:39 pm
Lab Number:		3718872.5	3718872.6	3718872.7	3718872.8
Individual Tests					
Total Recoverable Iron	mg/kg dry wt	50,700 ± 5,100	150,000 ± 15,000	24,400 ± 2,500	89,700 ± 9,000
Total Recoverable Lead	mg/kg dry wt	7.9 ± 1.3	14.6 ± 2.2	34.4 ± 5.2	11.0 ± 1.7
Total Recoverable Phosphorus	mg/kg dry wt	382 ± 47	1,680 ± 180	499 ± 57	661 ± 72
Total Recoverable Zinc	mg/kg dry wt	54.7 ± 4.7	263 ± 19	302 ± 22	521 ± 37
Total Nitrogen*	g/100g dry wt	< 0.05 ± 0.041	0.869 ± 0.066	0.247 ± 0.043	0.334 ± 0.045
Total Organic Carbon*	g/100g dry wt	0.512 ± 0.058	10.49 ± 0.84	2.70 ± 0.22	5.10 ± 0.41

Sample Type: Aqueous

Sample Type: Aqueous				
Sample Name:		SW 2a 18-Nov-2024 3:30 pm	SW 3a 18-Nov-2024 2:02 pm	SW 2b 18-Nov-2024 12:39 pm
Lab Number:		3718872.1	3718872.2	3718872.4
Individual Tests				
Total Alkalinity	g/m³ as $CaCO_3$	173.6 ± 7.0	23.1 ± 1.2	78.3 ± 3.3
Salinity*		0.328 ± 0.027	0.280 ± 0.023	0.286 ± 0.023
Total Calcium	g/m³	37.6 ± 1.6	32.8 ± 1.4	40.4 ± 1.7
Dissolved Iron	g/m³	1.76 ± 0.13	0.162 ± 0.018	0.159 ± 0.018
Total Iron	g/m³	5.13 ± 0.72	1.49 ± 0.21	0.81 ± 0.12
Dissolved Lead	g/m³	< 0.00010 ± 0.000067	< 0.00010 ± 0.000067	< 0.00010 ± 0.000067
Total Lead	g/m³	< 0.00011 ± 0.000074	< 0.00011 ± 0.000074	< 0.00011 ± 0.000074
Dissolved Magnesium	g/m³	28.6 ± 2.0	22.2 ± 1.5	18.4 ± 1.3
Total Magnesium	g/m³	30.2 ± 2.5	22.7 ± 1.9	18.9 ± 1.6
Total Potassium	g/m³	2.23 ± 0.14	2.63 ± 0.17	6.95 ± 0.42
Total Sodium	g/m³	49.6 ± 3.0	41.6 ± 2.5	42.7 ± 2.6
Dissolved Zinc	g/m³	0.00176 ± 0.00069	0.0093 ± 0.0011 [#1]	0.0549 ± 0.0052 [#1]
Total Zinc	g/m³	0.00233 ± 0.00076	0.00800 ± 0.00097 [#1]	0.0502 ± 0.0041 [#1]
Chloride	g/m³	59.9 ± 2.9	46.9 ± 2.3	43.9 ± 2.2
Total Nitrogen	g/m³	1.201 ± 0.071	0.440 ± 0.027	1.433 ± 0.085
Total Phosphorus	g/m³	0.123 ± 0.015	0.0386 ± 0.0048	0.0046 ± 0.0014
Sulphate	g/m³	62.7 ± 4.2	171 ± 12	134.6 ± 9.0
Total Biochemical Oxygen Demand ($TBOD_5$)	g O_2/m³	< 2 ± 1.4	2.2 ± 1.4	< 2 ± 1.4
Nutrient Profile				
Total Ammoniacal-N	g/m³	0.0392 ± 0.0075	0.0194 ± 0.0069	0.754 ± 0.067
Nitrite-N	g/m³	0.0023 ± 0.0014	0.0020 ± 0.0014	0.0021 ± 0.0014
Nitrate-N	g/m³	0.0046 ± 0.0021	0.146 ± 0.018	0.330 ± 0.040
Nitrate-N + Nitrite-N	g/m³	0.0069 ± 0.0016	0.148 ± 0.018	0.332 ± 0.040
Dissolved Reactive Phosphorus	g/m³	0.0286 ± 0.0031	< 0.004 ± 0.0027	< 0.004 ± 0.0027

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/Intro_To_UOM.pdf, or contact the laboratory.

Analyst's Comments

[#1] It has been noted that the result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

Summary of Methods

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

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Individual Tests			
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E (modified) : Online Edition.	-	3
Total Alkalinity*	Saline water, titration to pH 4.5. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch.	1.0 g/m³ as $CaCO_3$	3
Filtration for dissolved metals analysis - Ultratrace	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	3
Total Calcium	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B : Online Edition.	1.1 g/m³	3
Dissolved Iron	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B : Online Edition.	0.02 g/m³	3
Total Iron	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B : Online Edition.	0.021 g/m³	3
Dissolved Lead	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B : Online Edition.	0.0010 g/m³	3
Total Lead	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B : Online Edition.	0.0011 g/m³	3

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Dissolved Magnesium	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B : Online Edition.	0.4 g/m³	3
Total Magnesium	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B : Online Edition.	0.42 g/m³	3
Total Potassium	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B : Online Edition.	1.1 g/m³	3
Total Sodium	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B : Online Edition.	0.42 g/m³	3
Total Zinc	Nitric acid digestion, ICP-MS, ultratrace. APHA 3125 B : Online Edition.	0.0042 g/m³	3
Total Ammoniacal-N	Filtered saline sample from Christchurch. Phenol/hypochlorite colorimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H : Online Edition.	0.005 g/m³	3
Nitrite-N	Filtered saline sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.0010 g/m³	3
Nitrate-N + Nitrite-N*	Filtered saline sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser.	0.0010 g/m³	3
Dissolved Reactive Phosphorus	Filtered saline sample from Christchurch. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G : Online Edition.	0.0010 g/m³	3
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H (modified) : Online Edition.	0.004 g/m³	3

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%. (Free water removed before analysis, non-soil objects such as sticks, leaves, grass and stones also removed).	-	5-8
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation May contain a residual moisture content of 2-5%. (Free water removed before analysis, non-soil objects such as sticks, leaves, grass and stones also removed).	-	5-8
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	5-8
Total Recoverable Iron	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	5-8
Total Recoverable Lead	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	0.4 mg/kg dry wt	5-8
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	5-8
Total Recoverable Zinc	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	4 mg/kg dry wt	5-8
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	5-8
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	5-8

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Total Nitrogen Digestion	Caustic persulphate digestion. APHA 4500-N C : Online Edition.	-	1-4
Filtration, Unpreserved	Sample filtration through 0.45 µm membrane filter. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch.	-	1-4
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) : Online Edition.	-	1-2, 4
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2320 B (modified for Alkalinity <20) : Online Edition.	1.0 g/m³ as $CaCO_3$	1-2, 4

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Salinity*	Conductivity Meter (Eutec CON 2700 with linear temperature compensation according to EN 27 888). Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 2520 B : Online Edition.	0.2	1-4
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	1-2, 4
Total Calcium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.053 g/m³	1-2, 4
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-2, 4
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.021 g/m³	1-2, 4
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00010 g/m³	1-2, 4
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition / US EPA 200.8.	0.00011 g/m³	1-2, 4
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m³	1-2, 4
Total Magnesium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.021 g/m³	1-2, 4
Total Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.053 g/m³	1-2, 4
Total Sodium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.021 g/m³	1-2, 4
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m³	1-2, 4
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B : Online Edition / US EPA 200.8.	0.0011 g/m³	1-2, 4
Chloride	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	1-4
Total Nitrogen	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500-$NO3^-$ I (modified) : Online Edition.	0.010 g/m³	1-4
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) : Online Edition.	0.010 g/m³	1-2, 4
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.002 g/m³	1-2, 4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N. In-House.	0.0010 g/m³	1-4
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) : Online Edition.	0.002 g/m³	1-2, 4
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) : Online Edition.	0.004 g/m³	1-2, 4
Total Phosphorus	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H (modified) : Online Edition.	0.002 g/m³	1-2, 4
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m³	1-4
Total Biochemical Oxygen Demand ($TBOD_5$)	Incubation 5 days, DO meter, no nitrification inhibitor added, seeded. Analysed at Hill Laboratories - Chemistry; Unit 1, 17 Print Place, Middleton, Christchurch. APHA 5210 B (modified) : Online Edition.	2 g O_2/m³	1-4
Nutrient Profile		0.0010 - 0.010 g/m³	1-2, 4

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

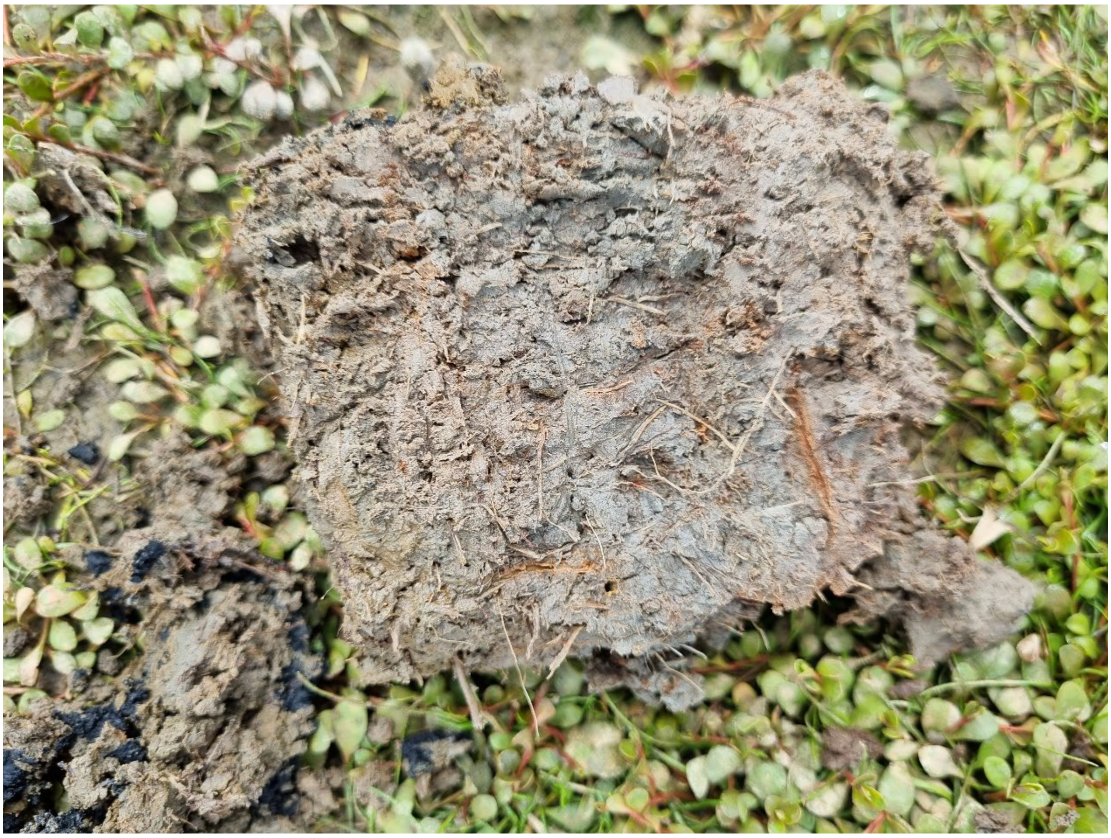
Testing was completed between 19-Nov-2024 and 06-Dec-2024. For completion dates of individual analyses please contact the laboratory.

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

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

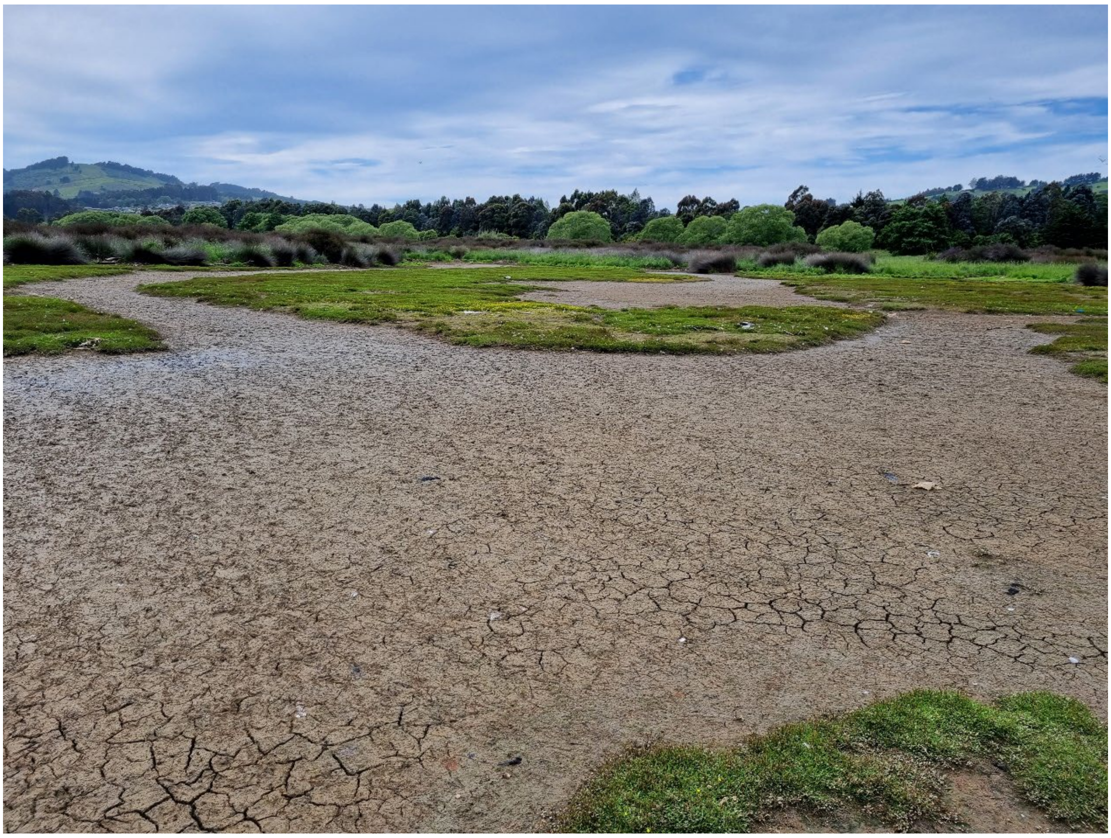
Kim Harrison MSc
Client Services Manager - Environmental

Appendix G: Photolog



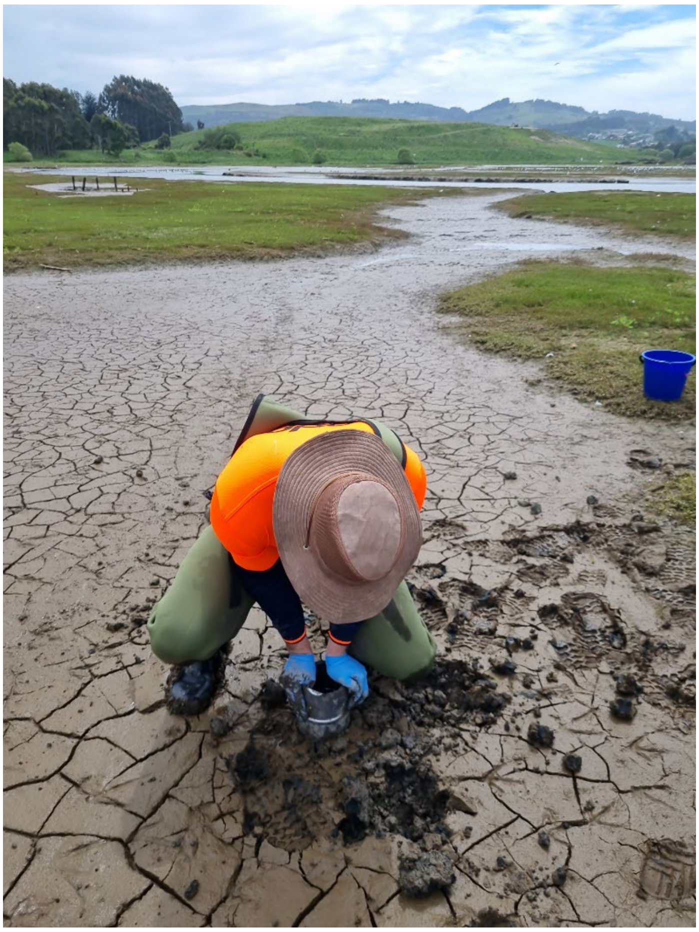
Photograph 1: (Sediment core from Upper estuary SW4)

Photograph 2: (Sediment grain size from SW4)



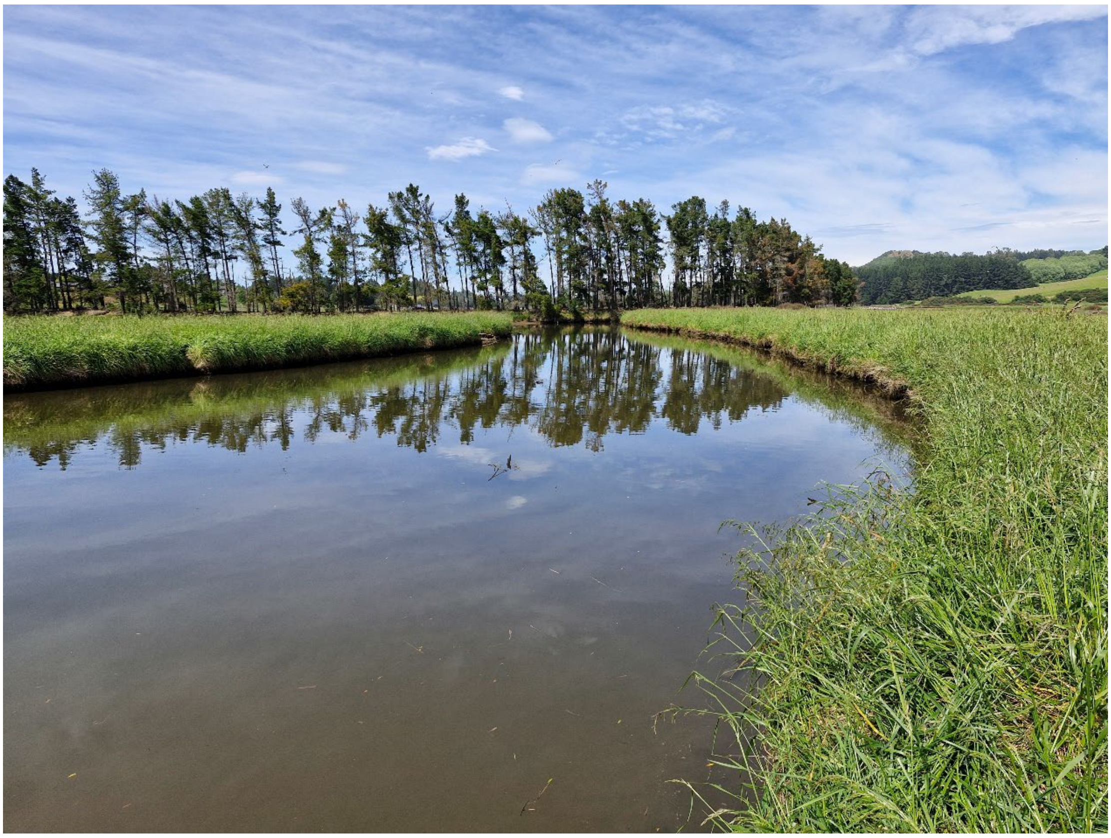
Photograph 3: (SW4 looking north-east towards Kaikorai Stream)

Photograph 4: (SW7 Vegetation Plot)

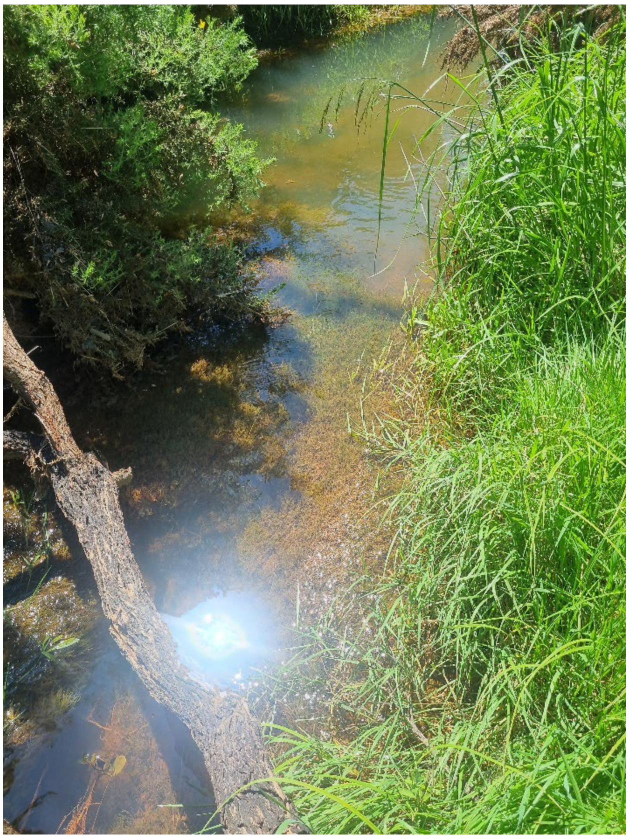


Photograph 5: (Sediment core in upper estuary at SW5, adjacent to the estuarine channel shown in Figure 9 of report)

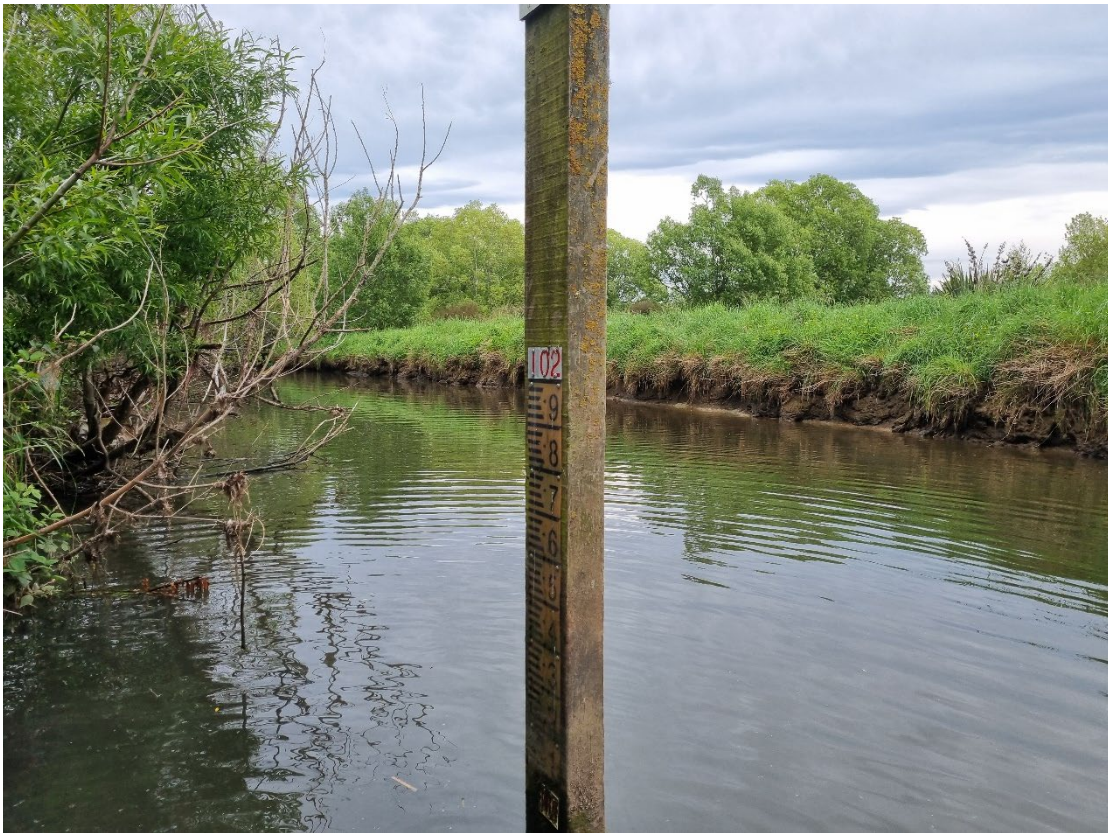
Photograph 9: (SW5 estuarine channel, sampled channel full of water in the background)



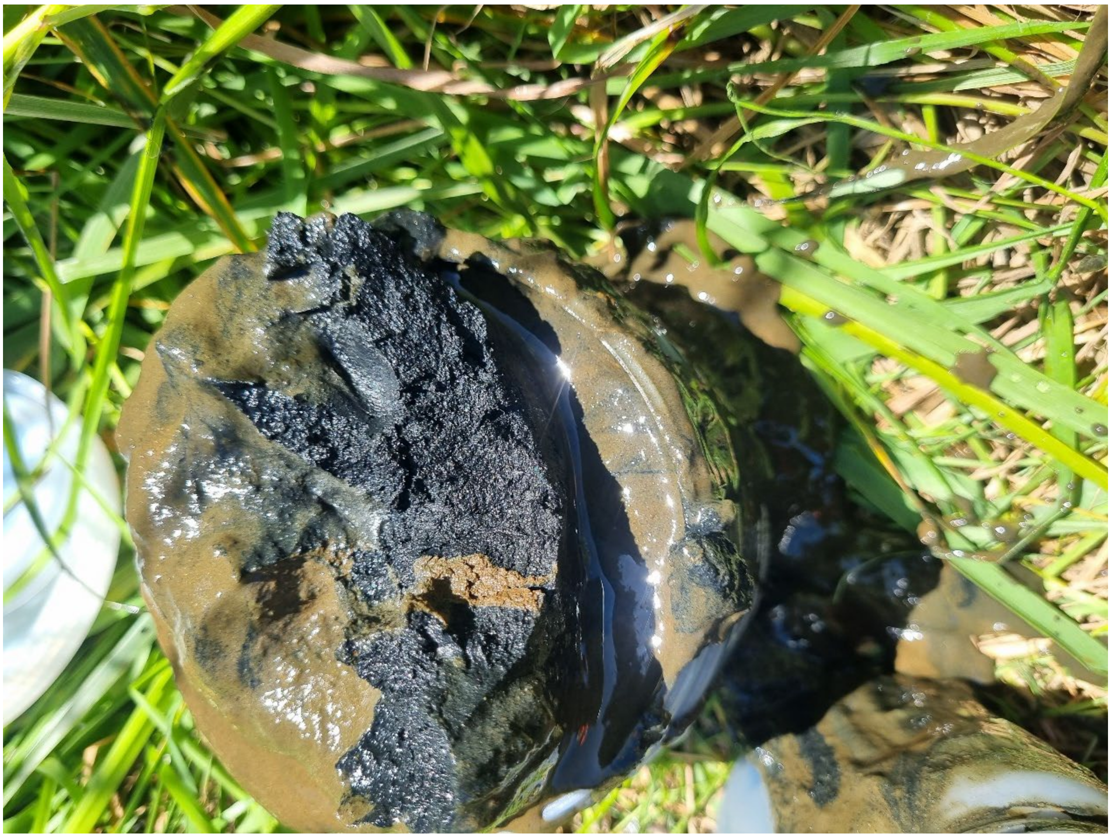
Photograph 10: (SW6, looking downstream)



Photograph 11: (SW2, looking downstream)



Photograph 12: (SW1, looking downstream)



Photograph 13: (SW3b, sediment sample)