Ōtūkaikino and Cashmere Monitoring 2022

Five-Yearly and Annual Aquatic Ecology Monitoring
Prepared for Christchurch City Council

21 October 2022

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Executive Summary

The Christchurch City Council commissioned Boffa Miskell Limited to conduct an aquatic ecological survey of nine sites within the Ōtūkaikino River catchment, plus two sites in the Cashmere Stream catchment and one site in the Balguerie Stream catchment (desktop only).

These surveys were conducted in March 2022 and form part of the CCC's long-term and annual monitoring of waterways within the Christchurch City limits and are a requirement of its Comprehensive Stormwater Network Discharge Consent (CSNDC).

The purpose of this work is to carry out the annual (Wilsons Drain, Cashmere Stream, and Balguerie Stream) aquatic ecology and five-yearly (Ōtūkaikino River 2022) sediment and aquatic ecology monitoring in accordance with Version 8 of the CSNDC Environmental Monitoring Programme.

Habitat quality in the Ōtūkaikino River catchment is moderate and variable across sites. The riparian habitat is largely comprised of deciduous exotic trees (primarily willows) in the Ōtūkaikino River catchment. There were some sites, however, where noticeable deterioration in riparian conditions had occurred since 2017. At sites in the upper reaches of the catchment, the riparian margin had been planted with *Carex* sedges and other indigenous plantings, but grey willow, hawthorn and other exotic weeds had begun to dominate again. Cashmere Stream catchment sites were largely unchanged.

In-stream conditions were marginally better in the Ōtūkaikino River catchment than the two Cashmere Stream sites. Substrate index was relatively high, indicating a dominance of larger substrates, and embeddedness was generally low in the Ōtūkaikino River catchment. Embeddedness was higher in the two Cashmere Stream sites. Soft sediment depth was generally low across all sites, but there were a few sites (in both catchments) that had higher cover. Macrophyte cover was high at some sites, and higher than recorded in previous years. The toxic cyanobacteria *Phormidium* was found at several sites in the Ōtūkaikino River catchment. This was reported to the CCC when found, as there is a risk to human and domestic animal health especially in sites that are used for recreation.

The macroinvertebrate community was dominated by pollution-tolerant taxa at most sites. But of note was the presence of the mayfly *Coloburiscus humeralis* and caddisflies *Olinga feredayi* and *Helicopsyche albenscens* in the Ōtūkaikino River catchment. These species are considered 'sensitive' to poor water and habitat quality. However, *Coloburiscus humeralis* and *Olinga feredayi* were present at fewer sites and in lower abundances, than in 2017. The stonefly *Zelandobius* was not found in 2022 and hasn't been recorded in the CCC's long-term monitoring of the Ōtūkaikino River catchment since 2012. Although Boffa Miskell has found this taxon in Ōtūkaikino Creek when undertaking other studies for private landowners. A single kēkēwai (freshwater crayfish) was caught in one of the Cashmere Stream sites.

The fish community in both the Ōtūkaikino River and Cashmere Stream catchments were dominated by indigenous species that are commonly found in Christchurch's waterways. Upland bullies and shortfin eels were the most commonly encountered species, but longfin eels, inanga, common bully, and brown trout were also found. There were no marked trends in fish abundance or community composition over time.

Compliance with the consent attribute trigger levels was variable. Sediment quality largely complied with the consent and trigger level guidelines, with only one site having zinc concentrations over the guideline (Wilsons Drain Main North Road – OTUKAI02). Consent attribute target levels for long filamentous algae cover have been met at all monitoring sites over the last 10 years. Around half of the Ōtūkaikino River catchment sites complied with the consent target for total macrophyte cover in 2022, but macrophyte cover was generally higher at all sites than in previous years. A number of sites had soft sediment cover exceeding the CSNDC guidelines of maximum of 20% cover. Consent targets for macroinvertebrate QMCI scores were variable, with one site (Ōtūkaikino Creek at Mcleans Island Road – OTUKAI08) having never met the consent target of QMCI >5, and only 4 of the 9 sites in the Ōtūkaikino River catchment meeting the consent attribute target in 2022. Further, not all sites met the National Policy Statement for Freshwater Management national bottom line value of MCI 90.

Overall, some measures of ecosystem health (e.g., sediment depth, macrophyte cover, MCI, QMCI, and ASPM) at sites in the Ōtūkaikino River and Cashmere Stream catchments are worse than previous years, indicating degradation. Macroinvertebrate indices at the Balguerie Stream site on Banks Peninsula showed increasing or stable trends, indicating no degradation in ecosystem health.

We have made numerous recommendations, including ensuring best practice stormwater management techniques are continued to be employed, especially as greenfield developments continue on the fringes of the city; enhancement riparian planting, with strategic control of problem weeds in the margins, to assist with shading and controlling macrophyte and algal growth and improve riparian and in-stream habitat conditions; introducing meandering sections particularly in highly channelised areas of Ōtūkaikino Creek; more widespread enhancement of waterway habitat across the catchment; and ecological monitoring of waterway enhancements.

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Appendix 1: Site photographs from 2022

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1.0 Introduction

The Christchurch City Council (CCC) monitors sediment quality and aquatic ecology at sites throughout Christchurch and Banks Peninsula. This monitoring is a requirement of the Council's Comprehensive Stormwater Network Discharge Consent (CSNDC) (CRC190445) and in accordance with the CCC's Environmental Monitoring Programme (EMP).

As part of its long-term (five-yearly) monitoring programme, the CCC monitors sediment quality and aquatic ecology at several sites within each of the city's main river catchments every five years. The Ōtūkaikino River catchment was the focus of the 2022 survey. In addition to the five-yearly monitoring, the CCC monitors aquatic ecology at one site in Wilsons Drain (Ōtūkaikino River catchment), two sites in Cashmere Stream (Ōpāwaho / Heathcote River catchment), and Balguerie Stream (Banks Peninsula) each year.

1.1 Scope

The CCC commissioned Boffa Miskell Limited (Boffa Miskell) to conduct the annual aquatic ecology monitoring in Wilsons Drain, Cashmere Stream and Balguerie Stream (desktop only), and the five-yearly in-stream sediment quality and aquatic ecology monitoring in Ōtūkaikino River catchment.

The purpose of this report is to present the findings of these surveys, and:

- Describe the current ecological condition of these waterways, including riparian and in-stream habitat conditions, sediment quality, and the macroinvertebrate and fish communities.
- Compare current conditions against the CSNDC surface water quality objectives; Environment Canterbury's Land and Water Regional Plan (LWRP) water quality standards and freshwater outcome guidelines, and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).
- Compare trends over time by assessing the current conditions against the results of previous surveys (Boffa Miskell Ltd, 2017; EOS Ecology, 2012; InStream Consulting Ltd, 2021).
- Discuss overall ecological health of the sites and recommend how to improve the health, particularly where:
  - Water quality objectives have not been met; and
  - Any significant long-term trends have been observed.

2.0 Methods

2.1 Monitoring sites

The monitoring sites were within the Ōtūkaikino River catchment, Cashmere Stream and Balguerie Stream. These were a combination of sediment quality and aquatic ecology sites, plus a desktop review of macroinvertebrate data collected from Balguerie Stream by Environment Canterbury in June 2022. Two sites (OTUKAI02 and OTUKAI06) are listed as both 'five-yearly' and 'annual ecology' monitoring sites, so they are reported on in both of the respective monitoring subsections in the results.

Ōtūkaikino River is spring-fed, and drains the urban, industrial, and rural land to the north of Christchurch. There were ten monitoring sites within the Ōtūkaikino River catchment, including two sites on Wilsons Drain. Cashmere Stream is also spring-fed and a tributary of Ōpāwaho / Heathcote River. The dominant surrounding land use is rural and residential, and the waterway receives sediment-laden runoff from the Port Hills following rainfall. The two Cashmere Stream monitoring sites are located along Cashmere Road, upstream and downstream of a stormwater outlet. Balguerie Stream is a small, hill-fed stream that drains native bush and pasture and flows into Akaroa Harbour. The Balguerie Stream site is on Settlers Hill Road in the lower catchment and is surrounded by residential properties and native bush.

The co-ordinates (northing and easting) of each site (as provided to Boffa Miskell by the CCC; Table 1) were added to a geo-referenced pdf map using ArcGIS, and sites were located in the field using Avenza maps on an iPad. This enabled monitoring sites to be easily and accurately located and navigated to in the field. The locations of sites are shown in Figures 1-3.

*Table 1. Freshwater ecology survey sites within the Ōtūkaikino River catchment and the Cashmere Stream catchment. *New five-yearly monitoring sites.*

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring	Easting	Northing
OTUKAI01	Ōtūkaikino River	Ōtūkaikino River Groynes Inlet	✓	-	-	2477878	5750484
OTUKAI02	Ōtūkaikino River	Wilsons Drain at Main North Road	✓	✓*	✓	2481242	5752409
OTUKAI03	Ōtūkaikino River	Ōtūkaikino Creek Omaka Scout Camp	✓	✓	-	2475663	5749653
OTUKAI04	Ōtūkaikino River	Ōtūkaikino River upstream of Dickeys Road	-	✓	-	2479660	5752383
OTUKAI05	Ōtūkaikino River	Kaikanui Creek downstream of Clearwater Resort	-	✓	-	2478147	5751998
OTUKAI06	Ōtūkaikino River	Wilsons Drain at Tyrone Street	-	✓*	✓	2480720	5751544
OTUKAI08	Ōtūkaikino River	Ōtūkaikino Creek at Mcleans Island Road	-	✓	-	2472871	5748547
OTUKAI09	Ōtūkaikino River	Ōtūkaikino Creek at Clearwater Resort	-	✓	-	2476944	5751034
OTUKAI10	Ōtūkaikino River	Ōtūkaikino Creek off Coutts Island Road	-	✓	-	2474833	5751369
OTUKAI11	Ōtūkaikino River	Ōtūkaikino Creek Headwaters	-	✓	-	2473541	5751286
HEATH27	Cashmere Stream	Cashmere Stream behind 406 Cashmere Road (downstream of stormwater discharge)	-	-	✓	2477452	5736476
HEATH28	Cashmere Stream	Cashmere Stream behind 420-426 Cashmere Road (upstream of stormwater discharge)	-	-	✓	2477361	5736392
BP03	Balguerie Stream	Downstream of Settlers Hill (road)	-	-	✓	2507759	5711175

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Data Sources: LINZ

Projection: NZGD 2000 New Zealand Transverse Mercator

- Ecology and sediment monitoing site
- Ecology monitoring site
- Sediement monitoring site
- Waterway

Figure 1. Otukaikino ecology monitoring 2022 site locations

Date: 12 May 2022 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: tanya.blakely@boffamiskell.co.nz | Drawn: KHo | Checked: TBI

File Ref: BM211177_site_locations_20220512.mxd

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Data Sources: LINZ

Projection: NZGD 2000 New Zealand Transverse Mercator

Ecology monitoring site

Waterway

Figure 2. Cashmere Stream ecology monitoring 2022 site locations

Date: 12 May 2022 | Revision: 0

Plan prepared by Boffa Miskell Limited

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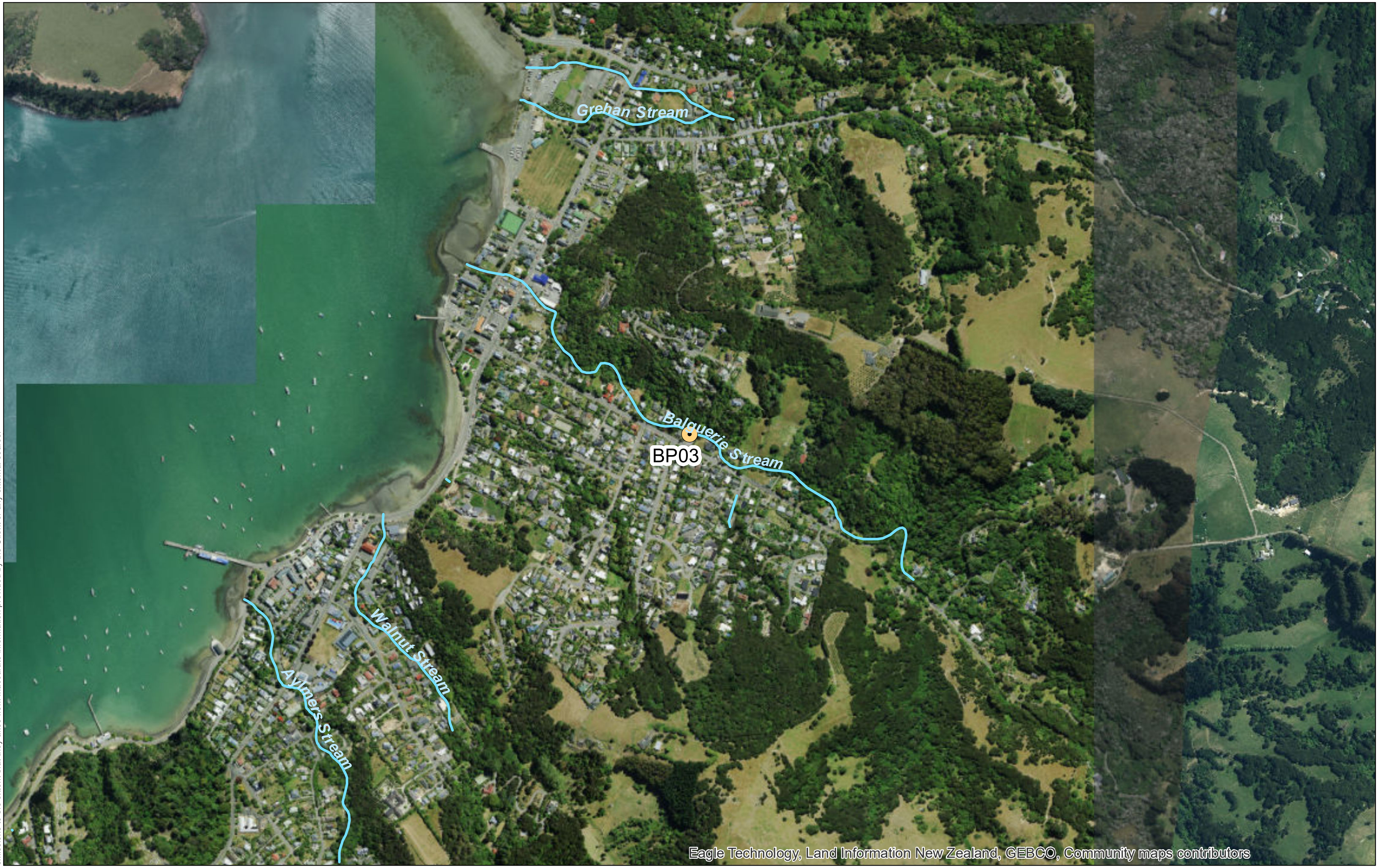

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Data Sources: Waterways sourced from CCC and ECan

Projection: NZGD 2000 New Zealand Transverse Mercator

LEGEND

- Annual Aquatic Ecology
- Five-Yearly Aquatic Ecology
- Waterway

CCC FRESHWATER MONITORING

Banks Peninsula Site Locations 2022

Date: 04 August 2022 | Revision: 0

Plan prepared for CCC by Boffa Miskell Limited

Project Manager: tanya.blakey@boffamiskell.co.nz | Drawn: BMc | Checked: KHo

Figure 3

At each site, shown in Figures 1-3, assessments of riparian and in-stream habitat conditions, and the macroinvertebrate and fish communities were conducted during base-flow conditions (i.e., no less than 5-7 days after a flood peak) between 24 March and 1 April 2022. Monitoring methods were in line with the CCC Waterway Ecology Standard Sampling Methodology as detailed below.

2.2 Water quality

Spot measures of specific conductivity, pH, dissolved oxygen, and water temperature were taken at each site using a handheld TPS multi-parameter water quality meter.

2.3 Riparian and in-stream habitat

The percent composition of different flow habitats (i.e., riffle, run or pool) was estimated for each site. At each site, three equally spaced transects, spaced at 10 m intervals, were established across the waterway, where the downstream most transect was located at the co-ordinates provided in Table 1. Transects two and three were located 10 m and 20 m upstream of the first (transect one).

Water velocity was measured at each of the three transects, using a Seba Current Meter c/w counter and wading rods, where:

*Velocity = (S * r.p.s) + C,*

S = slope specific to the propeller used; *r.p.s* = revolutions per second as determined by the count meter; and *C* = constant.

Total wetted width (m) was also recorded at each of the three transects. An average wetted width was calculated from these three measures for each site.

Canopy cover (%), bank erosion (%), extent of undercut bank (cm) and overhanging vegetation (cm) (if present), percent of bank with vegetation cover, bank slope (degrees), bank height (cm), type of bank material, types of riparian vegetation, and the surrounding land use were separately recorded on the true left and true right banks along each of the three transects at each site.

At each of five locations (true left (TL) bank, 25%, 50%, 75%, and true right (TR) bank) along each of the three transects (at each site) the following parameters were also measured:

- Water depth (cm)
- Soft sediment depth (cm)
- Embeddedness (%)
- Substrate composition (%)
- Macrophyte depth (cm), percent cover, type (submerged or emergent), and dominant species present
- Percent cover and type of organic material (leaves, moss, coarse woody debris)
- Percent cover and type of periphyton.

Where parameters were measured at five locations across each of the transects (i.e., water depth, sediment depth, embeddedness, and macrophyte and periphyton cover), these were averaged to give a mean value for each transect.

Embeddedness is a measure of the degree to which larger substrates are surrounded by fine particles, and therefore, an indication of the clogging of interstitial spaces.

Soft sediment depth was determined by gently pushing a metal wading rod (10 mm diameter) into the substrate until it hit the harder substrates underneath.

Substrate composition was measured within an approximately 20 x 20 cm quadrat at each of the five locations along the three transects. Within each quadrat, the percent composition of the following sized substrates was estimated: silt / sand (< 2 mm); gravels (2 – 16 mm); pebbles (16 – 64 mm); small cobbles (64 – 128 mm), large cobbles (128 – 256 mm), boulders (256 – 4000 mm), and bedrock / concrete / artificial hard surfaces (> 4000 mm) (modified from Harding et al. 2009).

A substrate index (SI) was calculated from the five replicate substrate composition measures taken along each transect. These values were then averaged, to give a mean SI for each transect.

The SI was calculated using the formula (modified from Harding et al. 2009):

SI = (0.03 x %silt / sand) + (0.04 x %gravel) + (0.05 x %pebble) + (0.06 x (%small cobble + %large cobble)) + (0.07 x %boulder)

The calculated SI can range between 3 and 7, where an SI of 3 indicated 100% silt / sand and an SI of 7 indicated 100% boulders. That is, the larger the SI, the coarser the substrate and the better the habitat for macroinvertebrate and fish communities. Finer substrates generally provide poor, and often unstable, in-stream habitat, and smother food (algal) resources and macroinvertebrates inhabiting the waterway.

Each of these measures were averaged, to give one measure at each site.

Photographs were also taken at each site.

2.4 Sediment quality

Sediment samples were collected from multiple locations at each of the sediment quality monitoring sites (Table 1), within the same reach as the habitat conditions and macroinvertebrate community was assessed.

Surface sediment (approximately top 3 cm) was collected by scraping along the surface of the waterway bed with a sample container (prepared collection jar provided by Hills Laboratory) attached to a mighty gripper. Water was drained directly off the collected samples and transferred to a cooler bin before transporting to Hill Laboratories, an International Accreditation New Zealand (IANZ) laboratory. Hill Laboratories conducted the following analyses (Table 2), all of which are IANZ accredited, except for total organic carbon (TOC).

Table 2 Analyses conducted by Hill Laboratories on sediment samples collected from the three survey sites in March 2022.

Test	Method description	Reference
7 grain sizes profile	Wet sieving, gravimetric analysis	N/A
Total recoverable copper, lead, and zinc	Air dried at 35°C and sieved, <2 mm fraction. Nitric / hydrochloric acid digestion, ICP-MS, screen level.	US EPA 200.2
Total organic carbon (TOC)	Air dried at 35°C and sieved, <2 mm fraction. Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	N/A
Total recoverable phosphorus (TP)	Air dried at 35°C and sieved, <2 mm fraction. Nitric / hydrochloric acid digestion, ICP-MS, screen level.	US EPA 200.2
Polycyclic aromatic hydrocarbons (PAHs)	Air dried at 35°C and sieved, <2 mm fraction. Dried at 103°C for 4-22 hr, sonication extraction, SPE cleanup, GC-MS SIM analysis.	US EPA 3540, 3550 & 3630.
Semi-volatile organic compounds (SVOCs)	Air dried at 35°C and sieved, <2 mm fraction. Sonication extraction, SPE cleanup, GC-MS full scan analysis.	US EPA 3540, 3550, 3640 & 8270

Comparisons of the sediment analysis results were made to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).

Total PAHs were calculated by summing the 18 PAHs analysed, which include the PAHs listed as priority pollutants by the USEPA (1982). Total PAHs were normalised to 1% TOC, as recommended in ANZECC (2000), before comparison to the guidelines. Where one or more PAH compound was below the detection limit, half the detection limit was used in the calculation. This method is consistent with the approach used in many reports of sediment quality in Christchurch's waterways (e.g., NIWA, 2015).

Sediment quality data from the three sites sampled in 2022 were summarised for comparison against consent attribute target levels and ANZG (2018) upper guideline values (Table 3), and compared to data from 2017.

2.5 Macroinvertebrate community

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

The macroinvertebrate community was assessed at each site within the same 20 m reach where riparian and in-stream habitat was surveyed. The macroinvertebrate community was sampled at each site on the same day that the habitat assessment was conducted (i.e., prior to habitat assessments, but after basic water chemistry and temperature parameters were measured).

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

Macroinvertebrate samples were preserved separately in 70% ethanol prior to sending to Boffa Miskell's independent taxonomy lab, in Tauranga, for identification and counting in accordance with Protocol P2 (200 Individual Fixed Count with scan for rare taxa) of Stark et al (2001), identifying to species level where practical.

2.5.1 Biotic indices and stream health metrics

The following macroinvertebrate metrics were calculated from each kick-net sample, to provide an indication of stream health:

- **Total abundance** – the total number of individuals collected at each site. Macroinvertebrate abundance can be a good indicator of stream health, or ecological condition, because abundance tends to increase in the presence of organic enrichment, particularly for pollution-tolerant taxa (e.g., chironomid midge larvae and oligochaete worms).
- **Taxonomic richness** – the total number of macroinvertebrate taxa collected at each site. Streams supporting high numbers of taxa generally indicate healthy communities, however, the pollution sensitivity / tolerance of each taxon needs to also be considered.
- **EPT taxonomic richness** – the total number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) collected at each site. These three insect orders (EPT) are generally sensitive to pollution and habitat degradation and therefore diversity of these insects provides a useful indicator of degradation. High EPT richness suggests high water quality, while low richness indicates low water or habitat quality.
- **EPT taxonomic richness (excl. hydroptilids)** – the total number of EPT taxa excluding the family Hydroptilidae. The algal piercing caddisflies belonging to the family Hydroptilidae are generally considered more tolerant of degraded conditions than other EPT taxa. Excluding hydroptilid caddis from the EPT metric is a more conservative approach and more accurately represents the 'clean-water' EPT taxa.

- **%EPT abundance** – the total abundance of macroinvertebrates that belong to the pollution-sensitive EPT orders, relative to the total abundance of all macroinvertebrates, collected at each site. High %EPT richness suggests high water quality.
- **%EPT abundance (excl. hydroptilids)** – the percentage abundance of EPT taxa, excluding the more pollution-tolerant hydroptilid caddisflies, collected at each site.
- **Macroinvertebrate Community Index (MCI)** – this index is based on tolerance scores for individual macroinvertebrate taxa found in hard- or soft-bottomed streams, as appropriate (Stark and Maxted 2007). These tolerance scores, which indicate a taxon's sensitivity to in-stream environmental conditions, are summed for the taxa present in a sample, and multiplied by 20 to give MCI values ranging from 0-200. Table 3 provides a summary of how MCI scores were used to evaluate stream health.
- **Quantitative Macroinvertebrate Community Index (QMCI)** – this is a variant of the MCI, which instead uses abundance data. The QMCI provides information about the dominance of pollution-sensitive species in hard- or soft-bottomed streams, as appropriate. Table 3 provides a summary of how QMCI scores were used to evaluate stream health.
- **Average Score Per Metric (ASPM)** – this combines: %EPT, EPT taxa richness, and MCI indices into a single metric (Collier 2008). Following recommendations of the NPS-FM, the ASPM was calculated as the average of the following: %EPT / 100, EPT taxa richness / 29, and MCI / 200.

Table 3. Interpretation of MCI and QMCI scores for hard and soft-bottomed streams (Stark & Maxted 2007).

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

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

2.6 Fish community

The fish community was surveyed within a (minimum) reach of 30 m in length and 30m^2 in area. This area overlapped with the 20 m reach where the macroinvertebrate community and habitat assessments were made. The fish community assessments were conducted on 28-29 March and 1 April 2022, at least three days after the habitat and macroinvertebrate assessments had been carried out.

Several factors, including soft sediment depth, macrophyte cover, water velocity and water depth were taken into consideration when determining the most appropriate fish surveying technique (i.e., electric fishing or trapping and netting) to use.

Electric fishing: the fish community at Sites OTUKAI03, OTUKAI05, OTUKAI06, OTUKAI08, OTUKAI09, OTUKAI10, HEATH27 and HEATH28 was assessed using a single pass with a Kainga EFM 300 backpack mounted electric-fishing machine (NIWA Instrument Systems, Christchurch). Fish were captured in a downstream push net or in a hand (dip) net and temporarily held in buckets. All fish were then identified, counted and measured (length, mm) before being returned alive to the stream.

Trapping and netting: OTUKAI02 and OTUKAI04 (two lower catchment sites) were too deep and, OTUKAI11 (the headwater site) was too restricted by low hanging vegetation for electric fishing techniques to be safe, or an appropriate method for sampling. At these sites, two[1] fyke nets[2] (baited with tinned cat food) and five[3] Gee minnow traps[4] (baited with marmite) were set late in the afternoon and left overnight. The following morning, all fish captured were identified and measured to the nearest 5 mm before being returned alive to the stream.

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

2.6.1 Catch per unit effort

In order to account for the inevitable differences in areas sampled at each site, fish catches were converted into catch per unit effort (CPUE). Electric fishing data were converted to number of fish captured per 100 m^2 of stream surveyed; trapping data were presented as number of fish captured per trap, per night.

2.7 Consent target levels and guidelines

Water quality, sediment quality, habitat, and macroinvertebrate data were compared against the relevant CSNDC attribute target levels, the 'Freshwater Outcomes for Canterbury Rivers' set out in the Canterbury Land and Water Regional Plan (LWRP, Environment Canterbury 2015); and the ANZG guideline value (GV-high) (Table 3). The monitoring sites in the Ōtūkaikino River catchment are classified as "Spring-fed – plains" under the LWRP, while the two Cashmere Stream and Balguerie Stream monitoring sites are classified as "Banks Peninsula".

[1] Three fyke nets were mistakenly set at OTUKAI02 and OTUKAI04.

[2] Fyke net mesh size: 4 mm; net dimensions were in line with recommendations of Joy et al. (2013).

[3] Six Gee minnow traps were mistakenly set at OTUKAI11.

[4] Gee minnow traps mesh size: 1/8 inch or 3.175 mm.

Table 4: Consent attributes target levels and guidelines for relevant stream attributes in the Ōtūkaikino River catchment, Cashmere Stream catchment, and Banks Peninsula in 2022. SP= "Spring-fed – plains, BP= "Banks Peninsula" under the LWRP.

Parameter	Consent Attribute Target Level	LWRP[1]	NPS-FM 2020[2]	ANZG (2018)[3]
Water quality				
Dissolved oxygen		≥70%	4 mg/L	
Temperature (°C)		<20		
pH		6.5–8.5		
Fine sediment cover (%)	SP: 20 BP: 20		21-29	
Sediment quality				
Copper (mg/kg)	65			270
Lead (mg/kg)	50			220
Zinc (mg/kg)	200			410
Total PAHs (mg/kg)	10			50
Emergent macrophyte cover (%)		SP: 30		
Total macrophyte cover (%)	SP: 50 BP: 30			
Long filamentous algae (>2 cm long) cover (%)	SP: 30 BP: 20			
Macroinvertebrates				
QMCI	SP: 5 BP: 5		4.5	
MCI			90	
ASPM[4]			0.3	

[1]Land and Water Regional Plan Receiving Water Standards for dissolved oxygen and temperature, and Freshwater Outcome for pH. [2]National Policy Statement for Freshwater Management 2020 national bottom line values. [3]Australia New Zealand Water Quality Guidelines (2018) for sediment quality are GV-high. [4]Average Score per Metric

2.8 Changes over time

<u>Habitat conditions</u>

Comparisons in habitat conditions were made of variables measured at the monitoring sites over various studies (InStream Consulting 2021; Boffa Miskell Limited 2017; EOS Ecology 2012) and this study. For those parameters where field methods were generally comparable across the two surveys, two-way analyses of variance (ANOVA) were used to test for differences over time. Where necessary, response variables were log transformed to meet assumptions of normality and homogeneity of variances. ANOVAs were performed in R version 4.1.2 (RStudio Team, 2020).

Macroinvertebrate community

Visual comparisons were made between taxonomic richness, EPT richness, and QMCI values calculated for 2017 (Boffa Miskell Ltd, 2017), 2021 (InStream Consulting Ltd, 2021) and 2022 (this study); a two-way (ANOVA) was not conducted due to a lack of replication.

Spearman rank correlation was used to explore relationships between habitat variables and invertebrate metrics at the 11 ecology sites sampled in 2022. Due to a small sample size, no correlations were undertaken between invertebrate metrics and sediment quality or council monthly water quality monitoring data. Macroinvertebrate data was instead qualitatively compared to the sediment quality data and the most recent analysis of monthly water quality monitoring data in the district (Margetts and Marshall 2021).

Fish community

Qualitative comparisons were made between the fish communities found in the Ōtūkaikino River catchment sites: comparing this study (2022) with the findings from previous surveys conducted in 2017 (Boffa Miskell Ltd, 2017) and 2021 (InStream Consulting Ltd, 2021). Comparisons in the fish community at OTUKAI11 between years was not possible due to different sampling methods used – the sites was electro-fished in 2017 (Boffa Miskell Ltd, 2017), but trapped in this survey. The two sites in the Cashmere Stream catchment were not fished in the previous survey (InStream Consulting Ltd, 2021), so no temporal comparisons were made.

3.0 Results

3.1 Water quality

Dissolved oxygen (DO) was variable across all sites, with greater than 100% saturation DO recorded at OTUKAI06 Wilsons Drain at Tyrone Street (Table 5). All sites except OTUKAI04, OTUKAI05 and OTUKAI06 had moderate-to-low DO and did not meet the LWRP guideline of >70% saturation. The lowest DO recorded was 43.3% recorded in Cashmere Stream at HEATH28.

DO was measured only once during the daytime, and at different times of the day across the monitoring sites. It's important to note that DO can vary diurnally and seasonally, and macrophyte and algal abundances at a site can greatly influence DO concentrations.

Water temperature was variable across sites, but generally low (i.e., cool) with temperatures at all sites below the LWRP guideline of 20°C for Canterbury Rivers (Table 5). The coolest water temperature of 13.8°C was recorded in OTUKAI02: Wilsons Drain at Main North Road, while OTUKAI10: Ōtūkaikino Creek off Coutts Island Road had the highest water temperature (17.1°C). Again, it is important to note, however, that temperature was measured only once during the daytime, and at different times of the day across the five sites; water temperature can vary diurnally and seasonally.

pH was similar across sites, with circum-neutral pH recorded in all monitoring sites surveyed (Table 5). These spot measures (i.e., a single measurement on one occasion) of pH also met the LWRP water quality standard for receiving waters of pH between 6.5 and 8.5. However, it's important to note that pH can fluctuate both daily and seasonally.

Conductivity, which is often used to indicate the level of pollutants in the water column, was relatively similar at sites within catchments, but dissimilar between the two catchments (Table 5). Conductivity in the Ōtūkaikino River catchment ranged between 85 µS / cm at OTUKAI10: Ōtūkaikino Creek off Coutts Island Road to 148 µS / cm at OTUKAI06: Wilsons Drain at Tyrone Street. At site OTUKAI06, a pipe that transected the waterway approx. 30 cm above the water level was covered in toilet paper and sanitary products. It was difficult to ascertain is this was due to a flood event, where it was washed from an upstream source, or if it had entered the waterway from a nearby overflow event.

Conductivity in Cashmere Stream was twice as high as sites in the Ōtūkaikino River catchment, reaching 233 µS / cm at HEATH27 and 249 µS / cm at HEATH28. The conductivity measures across all sites were relatively similar than those recorded in many urban systems such as the Halswell River (InStream Consulting Ltd, 2021) and Avon River (InStream Consulting Ltd, 2019) catchments. All field-measured water quality results, except DO, were similar to previous measurements in 2021 and 2017.

Table 5. Field-measured water quality in 2022, at sites in the Ōtūkaikino River catchment and Cashmere Stream catchment. Values in red do not comply with the relevant LWRP Freshwater Outcomes for Receiving Environment standards.

Site ID	Site name	Dissolved oxygen (%)	Temperature (°C)	pH	Conductivity (µS / cm)
OTUKAI02	Wilsons Drain at Main North Road	66.3	13.8	7.04	136
OTUKAI03	Ōtūkaikino Creek Omaka Scout Camp	49.9	15.6	7.36	105
OTUKAI04	Ōtūkaikino River upstream of Dickeys Road	81.8	14.8	7.90	104
OTUKAI05	Kaikanui Creek downstream of Clearwater Resort	77.4	14.0	7.03	108
OTUKAI06	Wilsons Drain at Tyrone Street	134.3	16.5	6.63	148
OTUKAI08	Ōtūkaikino Creek at Mcleans Island Road	69.5	15.6	7.11	107
OTUKAI09	Ōtūkaikino Creek at Clearwater Resort	67.2	14.5	6.75	94
OTUKAI10	Ōtūkaikino Creek off Coutts Island Road	48.9	17.1	6.99	85

Site ID	Site name	Dissolved oxygen (%)	Temperature (°C)	pH	Conductivity (µS / cm)
OTUKAI11	Ōtūkaikino Creek Headwaters	52.8	16.4	7.01	88
HEATH27	Cashmere Stream behind 406 Cashmere Road	69.1	14.6	7.14	233
HEATH28	Cashmere Stream behind 420-426 Cashmere Road	43.3	15.0	6.77	249

3.2 Riparian and in-stream habitat

A brief summary of the general habitat conditions encountered at each site is given in Table 6; further site descriptions are provided below. Photographs of all aquatic ecology sites monitored in this survey are in Appendix 1.

There was little change in riparian conditions between 2017 and 2022 at OTUKAI03, OTUKAI05, and OTUKAI08; and between 2021 and 2022 at OTUKAI02 and HEATH28. However, riparian conditions had improved at OTUKAI04 (Figure 4) and OTUKAI10 (Figure 5) since 2017. At OTUKAI04 in 2017 the riparian margin was dominated by overhanging deciduous exotic trees (primarily willows). In 2022, the presence of willows was minimal, likely due to mechanical removal. The true right bank has also been planted in native *Carex* sedges, shrubs, and trees, which will in time provide shading and fish cover. Similarly, in 2022, OTUKAI10 had native plantings of native *Carex* sedges, shrubs, and trees on both banks. In 2017, the riparian vegetation at OTUKAI10 comprised of pasture grass and weeds.

Riparian conditions had declined at OTUKAI09, OTUKAI11 and HEATH 27 since they were last sampled. At OTUKAI09 in 2017 the riparian margin on both banks was dominated by exotic vegetation, with some native *Carex* sedges and trees; in 2022 the true right bank was dominated by sprayed grass (Figure 6). While the removal of exotic vegetation provides ecological benefits, such as reduced leaf litter inputs, the removal of *all* vegetation and leaving banks bare can have adverse effects on stream health. At OTUKAI11 in 2017 the true left bank was dominated by grey willow, while the true right bank was dominated by exotic grasses and native *Carex* sedges. In 2022, the grey willow had encroached in the stream, and the true right bank also had patches of broom and gorse. The cover of riparian vegetation on the true right bank at HEATH27 had declined from 2021 to 2022, and there was an increased cover of impervious surfaces due to new terraced courtyards (Figure 8).

Table 6. Summary of the riparian and in-stream habitat conditions at each of the monitoring sites surveyed between 24 and 28 March 2022. TLB = true left bank; TRB = true right bank.

Site ID	Site name	Surrounding land use	Bank material	Canopy cover	Horizontal bank undercut	Overhanging vegetation	Ground cover vegetation (%)	Flow habitat type (%still: backwater: pool: run: riffle)
OTUKAI02	Wilsons Drain at Main North Road	TLB: Rural, farming TRB: Reserve / park	TLB: Earth TRB: Earth	TLB: 22% TRB: 23%	TLB: 5 cm TRB: 3 cm	TLB: 46 cm TRB: 28 cm	TLB: 97% TRB: 43%	5: 5: 0: 90: 0
OTUKAI03	Ōtūkaikino Creek Omaka Scout Camp	TLB: Lawn/ park TRB: Lawn/ park	TLB: Earth TRB: Earth, concrete	TLB: 25% TRB: 20%	TLB: 5 cm TRB: 7 cm	TLB: 0 cm TRB: 0 cm	TLB: 70% TRB: 46%	5: 1: 0: 94: 0
OTUKAI04	Ōtūkaikino River upstream of Dickeys Road	TLB: Rural, farming TRB: Reserve / park	TLB: Earth TRB: Earth	TLB: 5% TRB: 21%	TLB: 0 cm TRB: 25 cm	TLB: 0 cm TRB: 0 cm	TLB: 100% TRB: 83%	2: 0: 0: 98: 0
OTUKAI05	Kaikanui Creek downstream of Clearwater Resort	TLB: Rural, farming TRB: Rural, farming	TLB: Earth TRB: Earth	TLB: 0% TRB: 0%	TLB: 3 cm TRB: 8 cm	TLB: 0 cm TRB: 0 cm	TLB: 98% TRB: 95%	5: 0: 0: 95: 0
OTUKAI06	Wilsons Drain at Tyrone Street	TLB: Semi-urban, road TRB: Residential/ garden	TLB: Earth TRB: Earth	TLB: 95% TRB: 100%	TLB: 0 cm TRB: 0 cm	TLB: 0 cm TRB: 0 cm	TLB: 50% TRB: 50%	0: 0: 0: 100: 0
OTUKAI08	Ōtūkaikino Creek at Mcleans Island Road	TLB: Rural, crops TRB: Rural, road	TLB: Earth TRB: Earth	TLB: 0% TRB: 0%	TLB: 0 cm TRB: 0 cm	TLB: 0 cm TRB: 0 cm	TLB: 100% TRB: 100%	0: 0: 0: 98: 2
OTUKAI09	Ōtūkaikino Creek at Clearwater Resort	TLB: Rural, farming TRB: Golf course	TLB: Earth TRB: Earth	TLB: 80% TRB: 17%	TLB: 0 cm TRB: 18 cm	TLB: 0 cm TRB: 0 cm	TLB: 100% TRB: 60%	0: 0: 0: 95: 5
OTUKAI10	Ōtūkaikino Creek off Coutts Island Road	TLB: Rural, farming TRB: Rural, farming	TLB: Earth TRB: Earth	TLB: 0% TRB: 0%	TLB: 0 cm TRB: 0 cm	TLB: 0 cm TRB: 0 cm	TLB: 100% TRB: 100%	10: 0: 0: 90: 0

Site ID	Site name	Surrounding land use	Bank material	Canopy cover	Horizontal bank undercut	Overhanging vegetation	Ground cover vegetation (%)	Flow habitat type (%still: backwater: pool: run: riffle)
OTUKAI11	Ōtūkaikino Creek Headwaters	TLB: Rural, farming TRB: Rural, farming	TLB: Earth TRB: Earth	TLB: 77% TRB: 50%	TLB: 0 cm TRB: 0 cm	TLB: 10 cm TRB: 0 cm	TLB: 78% TRB: 100%	45: 10: 0: 45: 0
HEATH27	Cashmere Stream behind 406 Cashmere Road	TLB: Rural, farming TRB: Residential/ garden	TLB: Earth TRB: Earth	TLB: 0% TRB: 0%	TLB: 0 cm TRB: 4 cm	TLB: 0 cm TRB: 22 cm	TLB: 100% TRB: 53%	0: 0: 0: 100: 0
HEATH28	Cashmere Stream behind 420-426 Cashmere Road	TLB: Rural, farming TRB: Residential/ garden	TLB: Earth TRB: Earth	TLB: 30% TRB: 42%	TLB: 0 cm TRB: 20 cm	TLB: 0 cm TRB: 15 cm	TLB: 92% TRB: 100%	5: 0: 0: 95: 0

Figure 4. Site OTUKAI04 in 2017 (left) and 2022 (right)

Figure 5. Site OTUKAI10 in 2017 (left) and 2022 (right)

Figure 6. Site OTUKAI09 in 2017 (left) and 2022 (right)

Figure 7. Site OTUKAI11 in 2017 (left) and 2022 (right)

Figure 8. Site HEATH27 in 2021 (left) and 2022 (right)

Figure 9. Site OTUKAI06 surveyed in 2021 (left) and surveyed site 30 downstream in 2022 (right)

3.3 Wetted width and water depth

Five-yearly monitoring

Wetted width in 2022 was greatest at OTUKAI04 and narrowest in the channelized Wilsons Drain at Tyrone Street (OTUKAI06) (Figure 10). The narrowest site (OTUKAI06) had the shallowest water depth, the widest site OTUKAI04 was also the deepest (unwedable at two transects).

Wetted width was significantly different among sites (ANOVA: $F_{8,459} = 11.04$; $P < 0.001$), and significantly different between years (ANOVA: $F_{2,459} = 3.96$; $P = 0.02$) (Figure 10). Sites OTUKAI03, OTUKAI04, and OTUKAI05 were generally wider in 2022 compared to 2012 and 2017. All other sites were generally a similar width between years.

Water depth was significantly different among sites (ANOVA: $F_{10,459} = 61.1$; $P < 0.001$), and significantly different between years (ANOVA: $F_{2,459} = 5.26$; $P < 0.001$) (Figure 10). Water depth has fluctuated at sites in the Ōtūkaikino River catchment over time. Notably OTUKAI03 was approx. 20 cm deeper in 2022, and OTUKAI04 approx. 20 cm shallower in 2022 compared to 2012 and 2017.

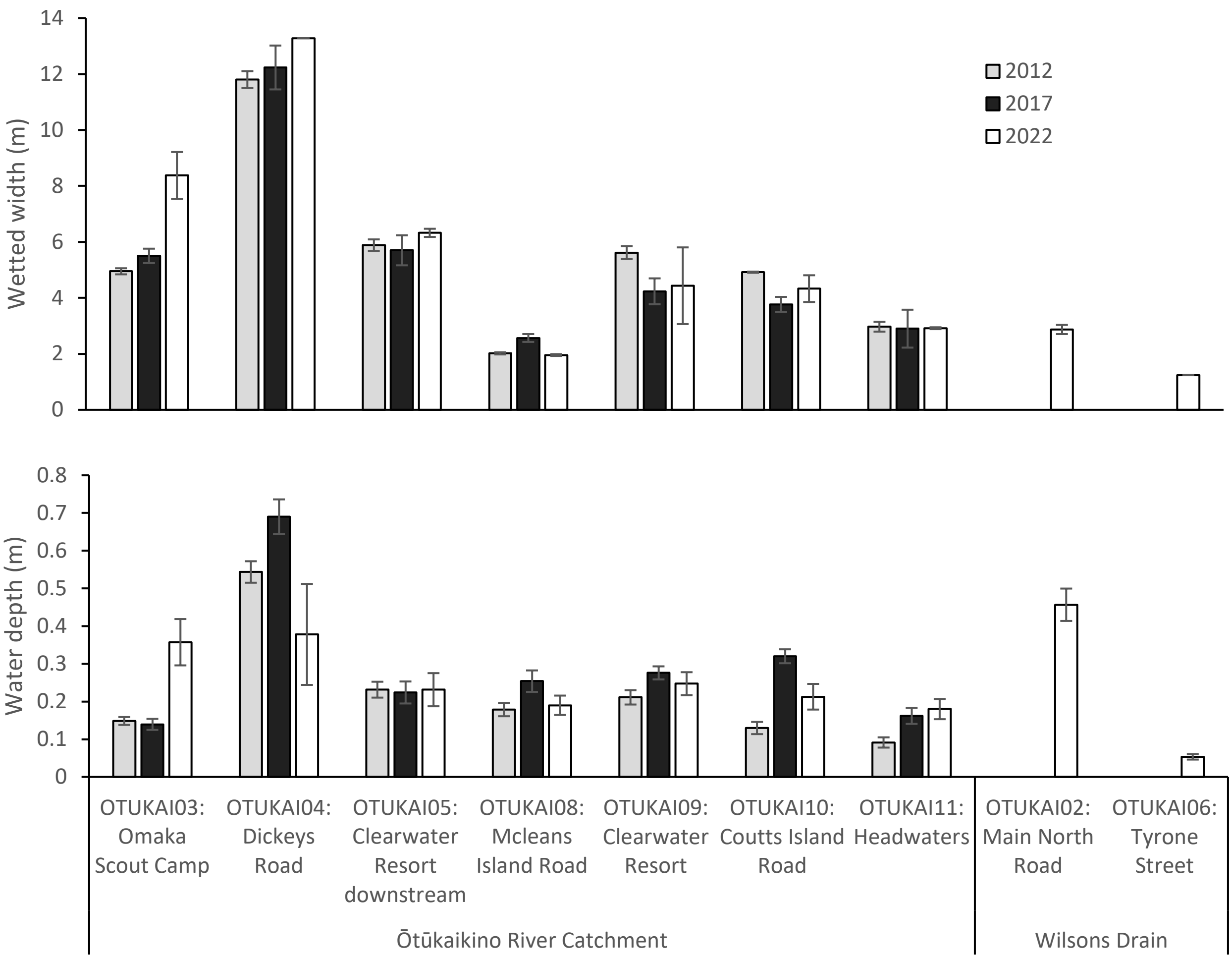

Figure 10: Mean (±1SE) wetted width (top) and water depth (m) (bottom) measured from three transects across the nine sites surveyed within the Ōtūkaikino River catchment and two sites within Wilsons Drain in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (dark grey bars, Boffa Miskell Ltd, 2017). *Only one transect was taken from OTUKAI04 in 2022. 2022 was the first five-yearly monitoring year at sites OTUKAI02 and OTUKAI06.*

Annual monitoring

Wetted width was similar at annual monitoring sites between years, except at HEATH27 where width had decreased from 2.9 m in 2021 to 2.1 m in 2022 (Figure 11). Trend analyses showed no significant increasing or decreasing trend (Mann-Kendall P>0.05) in stream width at HEATH28. There was insufficient data available for trend analysis at all other annual monitoring sites.

Water depth was similar between years at OTUKAI06 but was approx. 25 cm deeper at OTUKAI02 in 2022 compared to 2021 (Figure 11). Both sites in Cashmere Stream were shallower in 2022, compared to 2021. Trend analyses showed a slight, but significant, increasing trend (Mann-Kendall P=0.047) in water depth at HEATH28. There was insufficient data available for trend analysis at all other annual monitoring sites.

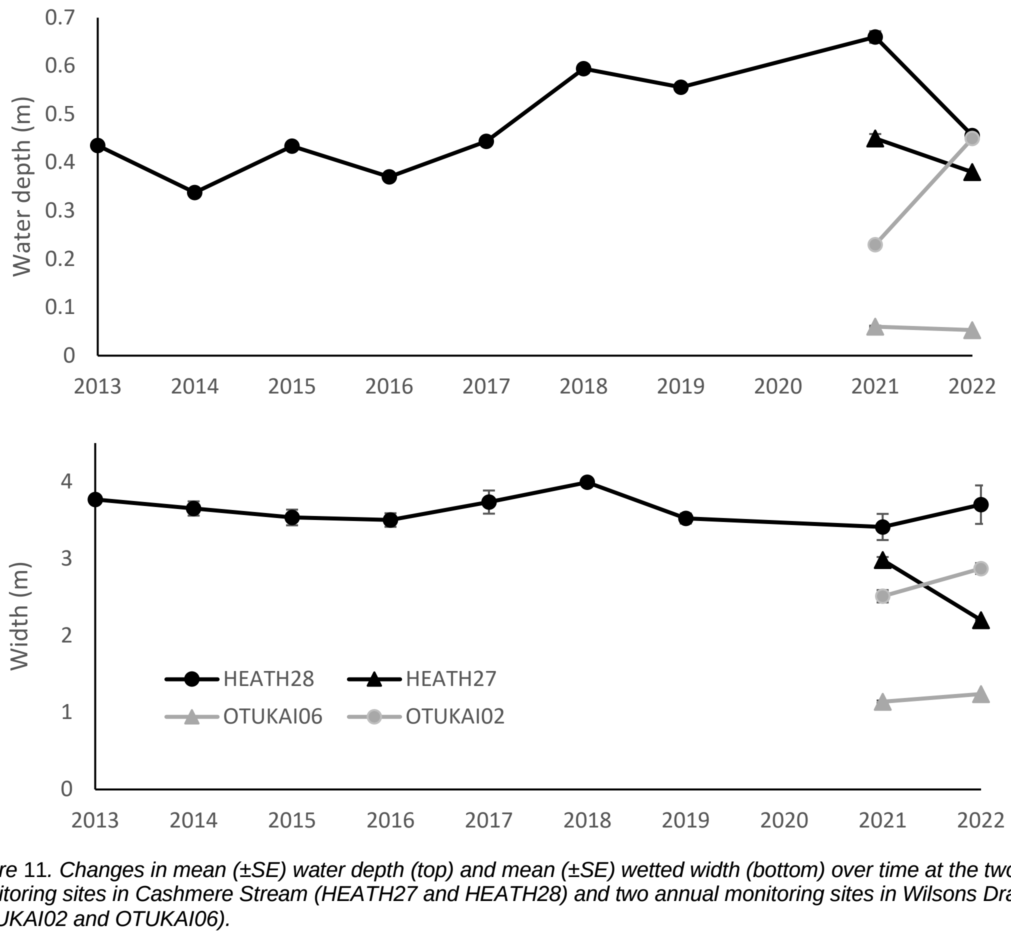

Figure 11. Changes in mean (±SE) water depth (top) and mean (±SE) wetted width (bottom) over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI02 and OTUKAI06).

3.4 Velocity

Five-yearly monitoring

Velocity in 2022 was highest in Ōtūkaikino Creek at OTUKA09, and slowest in Wilson Drain at OTUKAI06. At OTUKAI11 in the headwaters, velocity was immeasurable due to high emergent macrophyte cover and a high percentage of still and backwater created from encroaching grey willow.

Velocity was significantly different among sites (ANOVA: $F_{10,459} = 172.74$; $P < 0.001$), and significantly different between years (ANOVA: $F_{2,459} = 307.57$; $P < 0.001$) (Figure 12). Velocity was variable at sites in the Ōtūkaikino River catchment in 2022 compared to 2012 and 2017. OTUKAI03, OTUKAI04, and OTUKAI08 were notably slower in 2022 compared to 2017 (Figure 12). Velocity at OTUKAI11 was immeasurable in 2022 due to backwaters and willow jams.

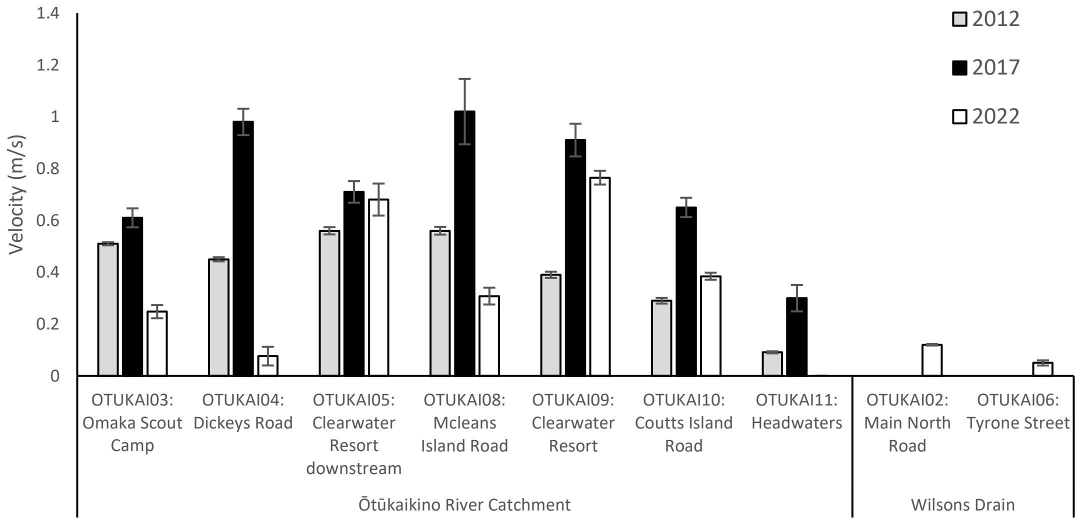

Figure 12: Mean (±1SE) velocity measured from three transects across the nine sites surveyed within the Ōtūkaikino River catchment and two sites within Wilsons Drain in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (dark grey bars, Boffa Miskell Ltd, 2017).. *Only one transect was taken from OTUKAI04 in 2022.*

Annual monitoring

Velocity was similar between years at OTUKAI06 but was slower at OTUKAI02 in 2022 compared to 2021. Both sites in Cashmere Stream had a higher velocity in 2022, compared to 2021 (Figure 13). Notably, velocity had increased from 0.1 m / s in 2021 to 0.4 m / s in 2022.

Trend analyses showed no significant increasing or decreasing trend (Mann-Kendall P>0.05) in velocity at HEATH28. There was insufficient data available for trend analysis at all other annual monitoring sites.

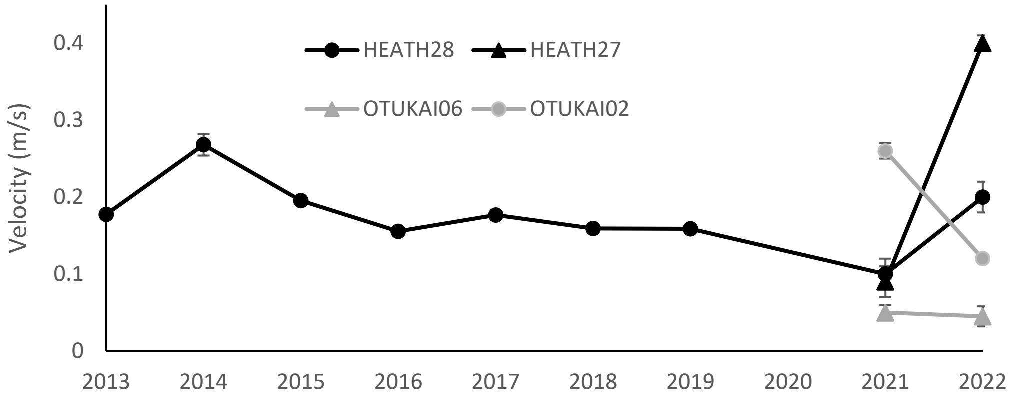

Figure 13. Changes in mean (±SE) velocity over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI02 and OTUKAI06).

3.5 Substrate index

Five-yearly monitoring

The substrate index (SI), calculated from five replicate measures of percent substrate composition taken along each of the three transects at each site, generally ranged between 3.02 and 5.5. OTUAKAI08, Ōtūkaikino Creek at Mcleans Island Road had the greatest SI of 5.5, indicating coarser substrates dominated by large cobbles, rather than smaller substrates (gravels, pebbles, and silt) that were found at the other sites. OTUKAI02 Ōtūkaikino Creek at Main North Road had the lowest SI of 3.02, indicating the substrate was dominated by silt and sand (Figure 14).

SIs were significantly different between years (ANOVA: $F_{10,459} = 60.38$; $P < 0.001$), and significantly different between sites (ANOVA: $F_{2,459} = 58.87$; $P < 0.001$). Substrate index was generally lower in 2022 compared to previous sampling years at OTUKAI03, OTUKAI04, OTUKAI05, and OTUKAI08 indicating an increased cover of finer substrates like sand and silt over time. At all other sites in the Ōtūkaikino River catchment, SI was generally similar compared to 2017 or higher compared to 2012, indicating a stable or decreasing cover of fine sediment over time.

Annual monitoring

SI was similar between years at OTUKAI02 and HEATH28 (Figure 14). At OTUKAI06 and HEATH27, SI was higher in 2022 compared to 2021, indicating a fine sediment cover had decreased over time. There was insufficient data to perform a time trend analysis, as no substrate index data prior to 2021.

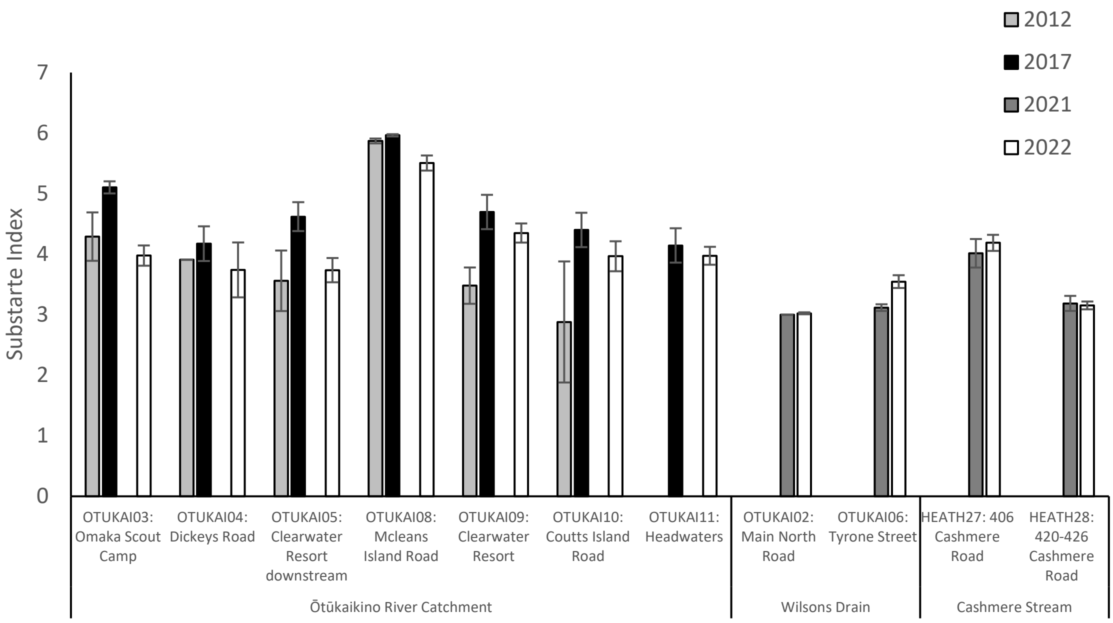

Figure 14: Mean (±1SE) Substrate Index measured at three transects across the seven sites surveyed within the Ōtūkaikino River catchment, two sites in Wilsons Drain, and two sites within the Cashmere Stream catchment in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012),March 2017 (black bars, Boffa Miskell Ltd, 2017) and March 2021 (dark grey bars, InStream Consulting Ltd, 2021). *Only one transect was taken from OTUKAI04 in 2022.*

3.6 Embeddedness

Five-yearly monitoring

Embeddedness in the Ōtūkaikino River catchment ranged between 12% at OTUKAI08 to 100% at OTUKAI02 (Figure 15). The sites with the lowest embeddedness estimates also had the highest SI scores, which is unsurprising given that a low SI indicates bed substrates dominated by fine particles, and these particles are what embed (surround) coarser substrates.

Embeddedness was generally higher in 2022 compared to 2012 and 2017, indicating an increased cover of fine substrates like sand and silt over time. Embeddedness was measured once per site in 2012, thus due to a lack of replication, no statistical analysis were performed on embeddedness data.

Annual monitoring

Embeddedness was similar between years at OTUKAI06 and HEATH28. At OTUKAI02, embeddedness had increased to 100% in 2022, compared to approx. 40% in 2021. At HEATH27, embeddedness was lower in 2022 compared to 2021, indicating a decreased cover of fine substrates like sand and silt at this site. There was insufficient data to perform a time trend analysis, as no embeddedness data was available prior to 2021.

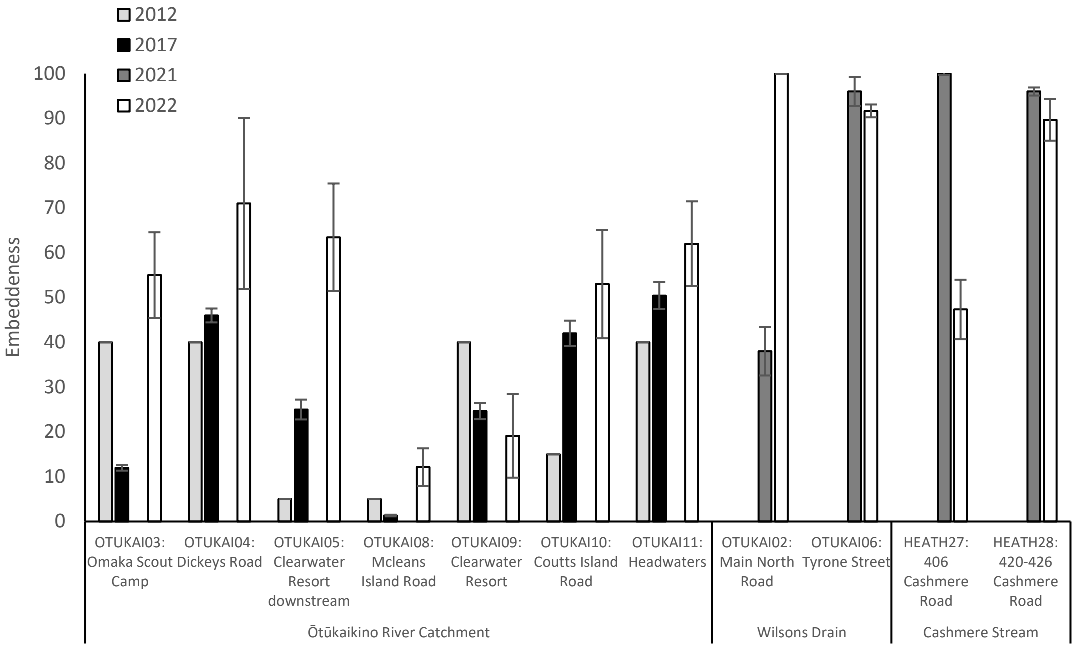

Figure 15: Mean (±1SE) embeddedness measured at three transects across the seven sites surveyed within the Ōtūkaikino River catchment , two sites in Wilsons Drain, and two sites within the Cashmere Stream catchment in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012),March 2017 (black bars, Boffa Miskell Ltd, 2017) and March 2021 (dark grey- bars, InStream Consulting Ltd, 2021). Embeddedness was recorded once per site in 2017.*

3.7 Sediment depth and cover

Five-yearly monitoring

Soft sediment depth across all sites was varied. The site with the greatest soft sediment depth was OTUKAI02, which had an average of 51.3 cm. The majority of the sample sites had between 5 and 10 cm of soft sediment depth (Figure 16). With the exception of OTUKAI06, the soft sediment measures were comparative to the embeddedness estimates at each of the sites; OTUKAI02 had the highest embeddedness estimate and also the deepest sediment depth, whereas OTUKAI08 had the lowest embeddedness estimate, and little fine sediment found at the site.

Soft sediment depth was significantly different between sites (ANOVA: $F_{10,459} = 52.24$; $P < 0.001$), and different between years (ANOVA: $F_{2, 459} = 20.81$; $P < 0.001$). Overall, sediment depth was greater at all sites in 2022, than in 2017 or 2021 (Figure 16).

Fine sediment cover in 2022 was variable across sites, ranging from 100% cover at OTUAKI02 to 16% at OTUKAI08. Fine sediment cover was greater at all sites in 2022 compared to 2012 or 2017. All sites, except OTUKAI08, exceeded the CSNDC attribute target level of <20% for total fine sediment cover in 2022. Whereas only two sites, OTUKAI04 and OTUKAI11, exceeded the 20% target level in previous years. Sediment cover was measured once per site in 2012, thus due to a lack of replication, no statistical analysis were performed.

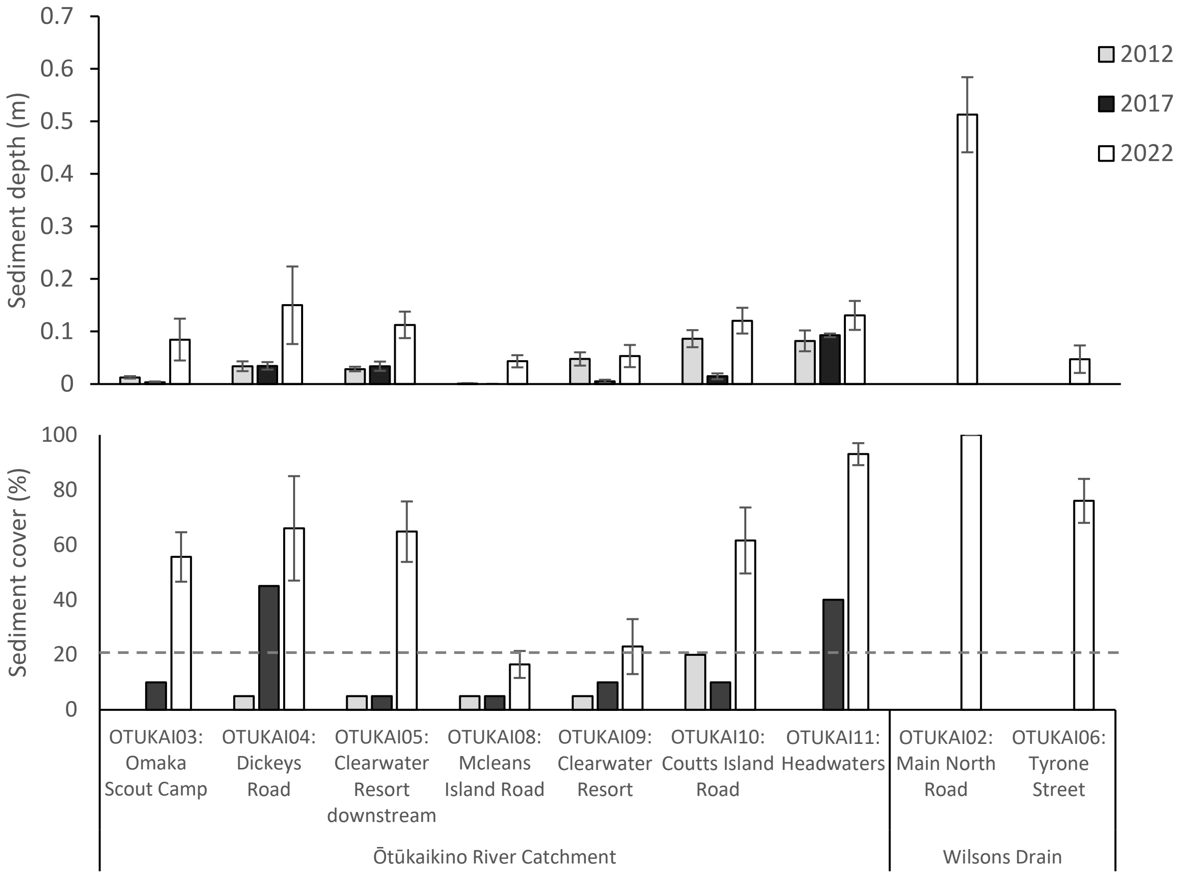

Figure 16: Mean (±1SE) depth (top) and % cover (bottom) of soft sediment covering the stream bed recorded at five locations along each of three transects at the nine sites surveyed within the Ōtūkaikino River catchment and two sites within Wilsons Drain in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012),March 2017 (black bars, Boffa Miskell Ltd, 2017); the dashed grey line represents the LWRP guideline for total fine sediment cover (20 %). *Only one transect was taken from OTUKAI04 in 2022. Note sediment cover was recorded once per site in 2012 and 2017.*

Annual monitoring

Sediment depth was greater at all annual monitoring sites in 2022 compared to 2021, except for HEATH27 where depths were similar across both sampling years (Figure 17). A deeper layer of sediment on the stream bed indicates an increased presence of fine substrates over time.

Trend analyses showed no significant increasing or decreasing trend (Mann-Kendall P>0.05) in sediment depth at HEATH28. There was insufficient data available for trend analysis at all other annual monitoring sites.

Sediment cover was high at all annual monitoring sites in 2022, ranging from 70% at HEATH27 to 100% at OTUKAI02. Cover at OTUKAI02 and HEATH27 was similar in 2022 compared to 2021 but had decreased by approx. 15% at OTUKAI06 and approx. 5% at HEATH28. All annual monitoring sites exceeded the CSNDC attribute target level of 20% (maximum) for sediment cover.

Trend analyses showed a significant decreasing trend (Mann-Kendall P= 0.03) in fine sediment cover at HEATH28. This decrease in sediment cover is unlikely to be biologically meaningful, as cover well exceeded the attribute target level for total fine sediment cover in all years. There was insufficient data available for trend analysis at all other annual monitoring sites.

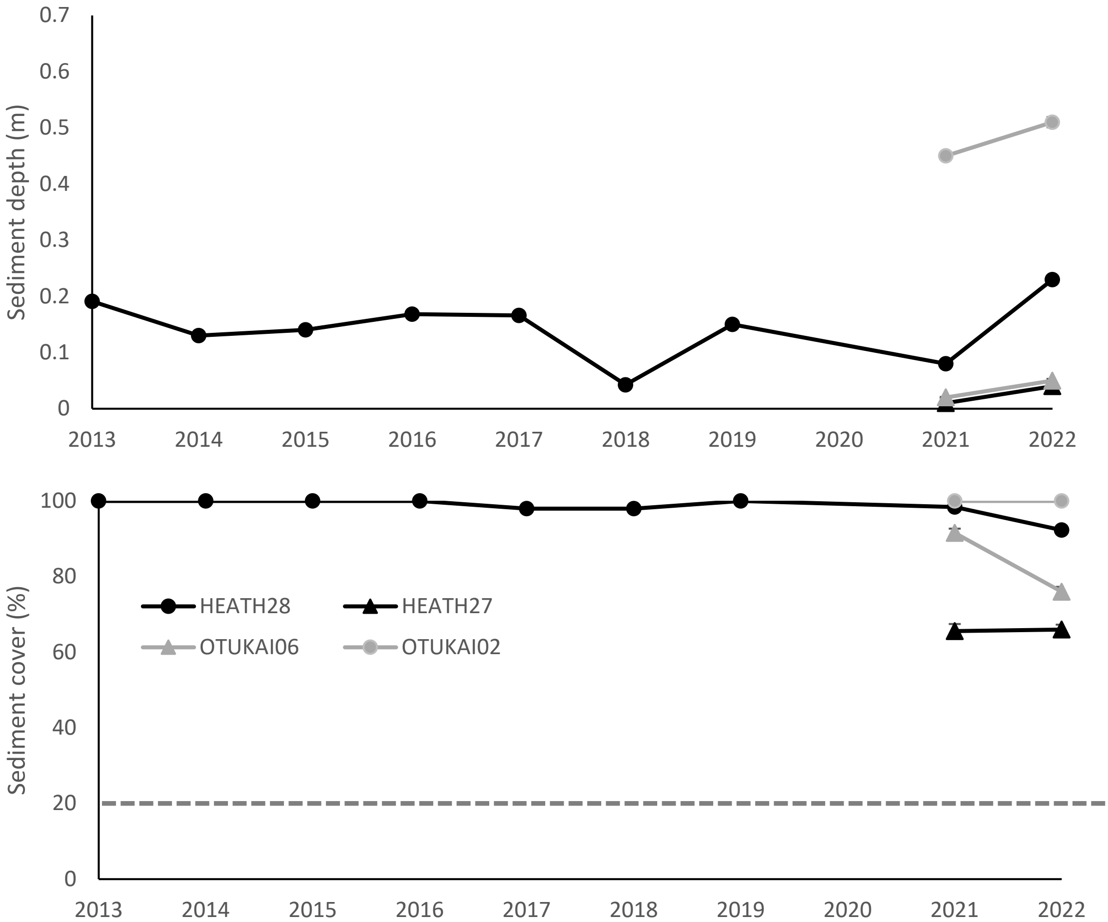

Figure 17. Changes in mean (±SE) sediment depth (top) and mean (±SE) sediment cover (bottom) over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI01 and OTUKAI06), noting sediment cover was measured once per site at HEATH28 from 2013-2019. The dashed grey line indicates the consent value for total fine sediment cover (20 %).

3.8 Macrophytes

Five-yearly monitoring

Total macrophyte cover was variable across all sites in 2022, with the highest cover (80%) at OTUKAI08 and the lowest cover (1.6%) at OTUKAI06 (Figure 18). Low cover at OTUKAI06 was presumably due to relatively high canopy cover and shading of the stream at this site.

Four of the sites (OTUKAI04, OTUKAI08, OTUKAI10, and OTUKAI11) exceeded the total macrophyte cover guidelines of the LWRP for spring-fed plains waterways (maximum cover of 50%) in 2022. Previously, only one site (OTUKAI08) had exceeded this guideline (in 2017).

The sites that exceeded the threshold for macrophyte cover had little, or no canopy cover and the margins were often thick with monkey musk (*Mimulus guttatus*) with scattered duckweed (*Lemna minor*), or watercress (*Nasturtium officinale*). This highlights the importance of riparian vegetation, and especially tall trees, to provide shading and decrease macrophyte and algae growth.

Total macrophyte cover was greater at all sites in 2022, than in 2017 or 2012 (Figure 18). Macrophyte cover was measured once per site in 2012, thus due to a lack of replication, no statistical analysis were performed on macrophyte cover data.

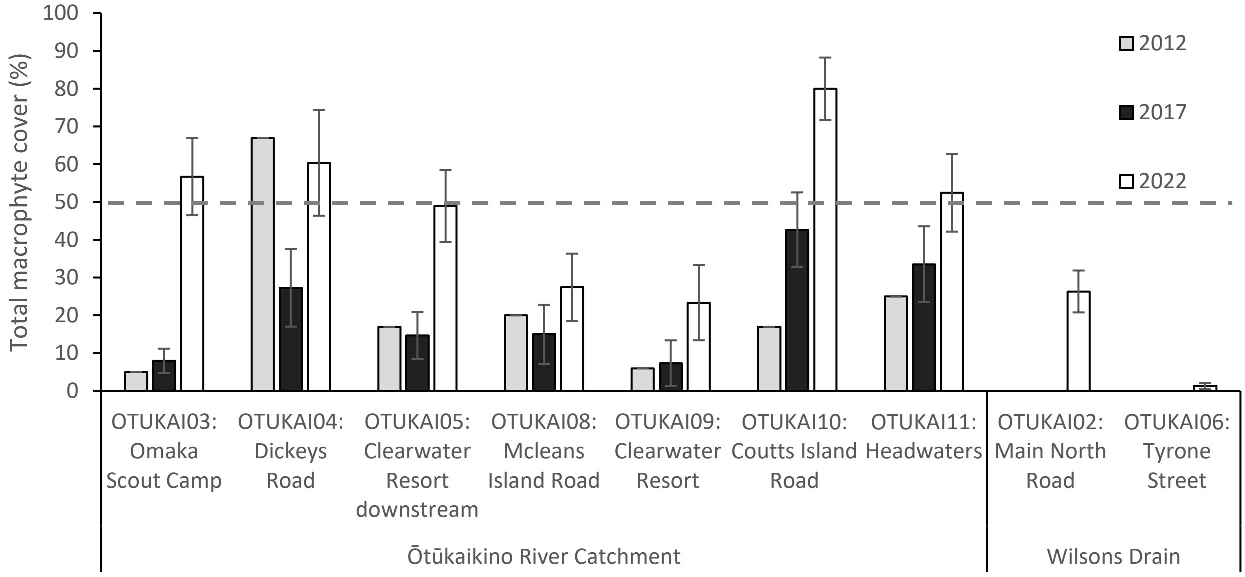

Figure 18: Mean (±1SE) total macrophyte cover recorded at five locations along each of three transects at the nine sites surveyed within the Ōtūkaikino River catchment and Wilsons Drain in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (black bars, Boffa Miskell Ltd, 2017). The dashed grey line indicates the LWRP guideline for 'spring-fed – plains waterways' of 50% maximum total cover of macrophytes. *Only one transect was taken from OTUKAI04 in 2022.*

<u>Annual monitoring</u>

Total macrophyte cover was variable across annual monitoring sites in 2022. All sites, except OTUKAI02, had a lower macrophyte cover in 2022 compared to 2021. Cover only exceeded the LWRP guideline at one site, HEATH27 in 2022 (Figure 19).

Trend analyses showed no significant increasing or decreasing trend (Mann-Kendall P = 1) in macrophyte cover at HEATH28 over time. There was insufficient macrophyte cover data available for trend analysis at all other annual monitoring sites.

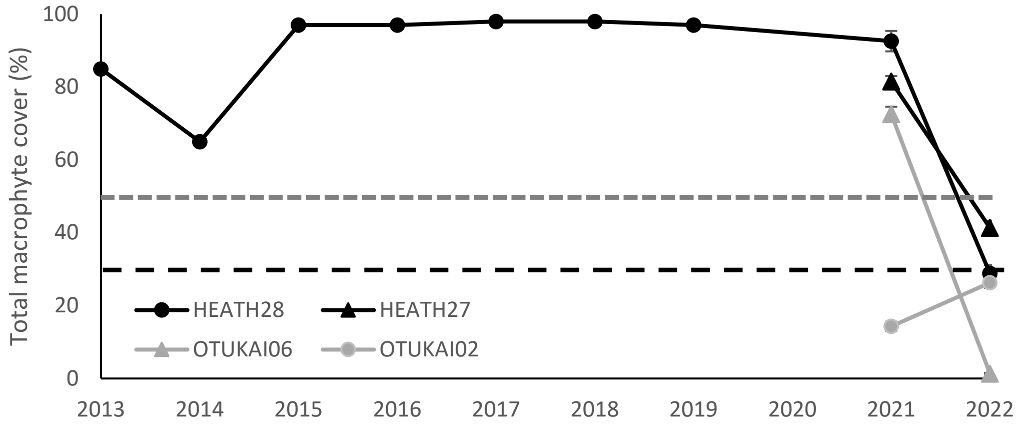

Figure 19. Changes in mean (±SE) macrophyte cover over time at the two annual monitoring sites in Cashmere Stream (HEATH27 and HEATH28) and two annual monitoring sites in Wilsons Drain (OTUKAI02 and OTUKAI06), noting macrophyte cover was measured once per site at HEATH28 from 2013-2019. The dashed grey line indicates the LWRP guideline for 'spring-fed – plains' of 50% maximum total cover of macrophytes, the dashed black line indicates the LWRP guideline for 'banks peninsula' of 30% maximum total cover of macrophytes.

3.9 Filamentous and mat algae

Five-yearly monitoring

Long (>20 mm) filamentous algae were rare in, or absent from, most sites surveyed in 2022, with the greatest total cover of 0.7% estimated in OTUKAI09 at Clearwater Resort (Figure 20).

Filamentous algae was similarly absent in 2012, but cover was variable at sites in 2017 (Figure 20). The fluctuating abundance of filamentous algae between years indicates no clear temporal trend. All sites were below the LWRP water quality standards which set a maximum value of 40% filamentous growth.

In this survey (2022) at sites OTUKAI05, OTUKAI08, OTUKAI09, and OTUKAI10 there were mats of the toxic cyanobacteria *Phormidium* (see photo in Appendix 1), ranging from approx. 1% - approx. 18% cover. Toxic cyanobacteria was not noted in either the 2012, 2017 or 2021 surveys. The presence of toxic algae raises concerns for human health, particularly at the Omaka Scout Camp (OTUKAI03), and the dog park downstream.

Annual monitoring

Filamentous algae was absent at annual monitoring sites, except at OTUKAI02 in 2021 where cover was 0.06%. There was insufficient data to perform a time trend analysis, as no filamentous algae data was available prior to 2021.

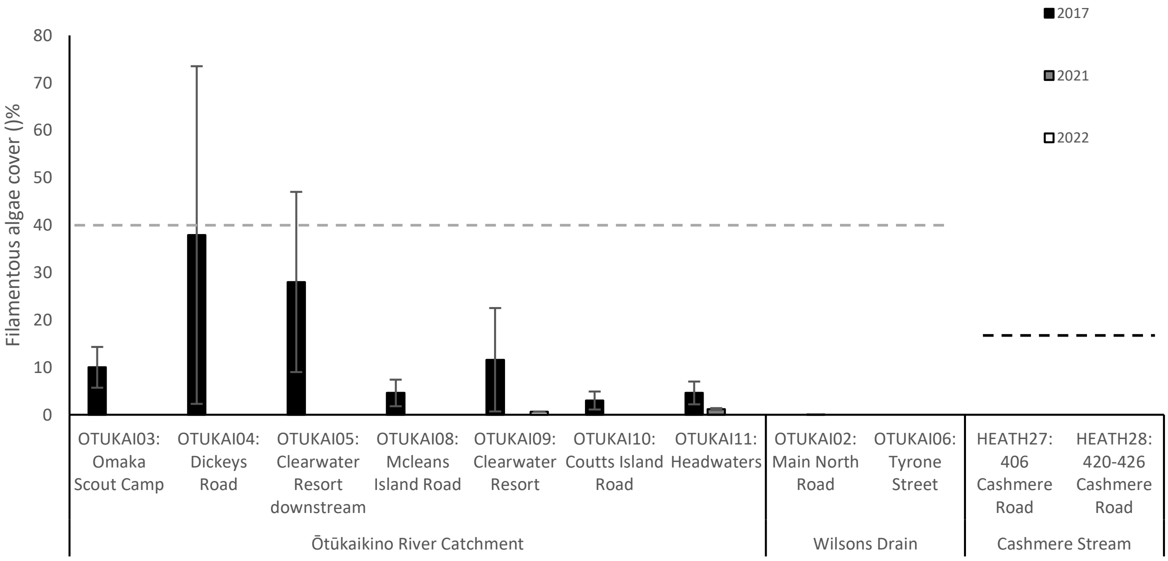

Figure 20: Mean (±SE) filamentous algal cover recorded at five locations along each of three transects at the seven sites surveyed within the Ōtūkaikino River catchment, two sites in Wilsons Drain, and Cashmere Stream catchment in March 2022 (white bars), March 2017 (light grey bars, Boffa Miskell Ltd, 2017) and March 2021 (dark grey bars, InStream Consulting Ltd, 2021. The grey dashed line is the maximum total cover (40%) of long filamentous algae cover recommended in the LWRP 'spring-fed – plains' guidelines, and the black dashed line is the maximum total cover (20%) of long filamentous algae cover recommended in the LWRP 'banks peninsula" guidelines. *Only one transect was taken from OTUKAI04 in 2022.*

3.10 Sediment quality

Table 8 provides a summary of the grain size (%) composition found in the sediment sample collected from each site. Full sediment analysis results are provided in Appendix 2.

OTUKAI02 had the highest proportion (68.9%) of silt/clay (<0.063mm) substrata, out of all three sediment monitoring sites. OTUKAI01 also had a relatively high proportion (44.7%) of silt/clay substrata.

Metal contaminants are usually found in higher concentrations in sediment samples with the higher silt and clay contents (i.e., substrata <0.063 mm in size), as the greater surface area of smaller particles increases the absorption. This is particularly relevant as higher metal concentrations at a site may primarily be driven by a higher proportion of small particles (i.e., better attachment of the metals).

With the exception of OTUKAI03, total recoverable copper, lead, and zinc for all sites were below the LWRP guidelines and the ISQG-high and ISQG-low of the ANZECC (2000) sediment quality guidelines (Table 8). The concentration of zinc in the stream bed material at OTUKAI03 was above the LWRP guideline, but below ISQG-low ANZECC (2000) sediment quality guideline. Where the sediment concentration is below the ISQG-low, it is considered that there is low risk of adverse effects to aquatic life. The concentrations of zinc at OTUKAI03 was markedly greater (approx. at least 9 times greater) than that recorded in 2019. OTUKAI03 was downstream of farmland and is used recreationally for swimming by scout groups.

There are no listed ANZECC (2000) guidelines for total phosphorus (TP) or total organic carbon (TOC). However, the levels measured in the three sites surveyed were similar to levels detected in other catchments within the Christchurch City limits (e.g., InStream Consulting Ltd, 2019, 2020).

TP and TOC concentrations ranged from 290 to 1413 mg / kg TP, and 0.22 to 7.4 g / 100 g TOC. The highest concentration of both TP was recorded at OTUKAI03, indicating this site (and possibly others) may be impacted by fertilisers. TOC was highest at OTUKAI01, contaminants such as fertilisers, pesticides, and industrial chemicals can cause elevated TOC concentrations. Canopy cover and overhanging vegetation was also high at this site, which could have influenced the TOC concentration.

Total PAHs of all sites, normalised to 1% TOC (as recommended in ANZECC 2000), were also well below the ISQG-high and ISQG-low guidelines of the ANZECC (2000) sediment quality guidelines. The highest recorded PAH concentration was at OTUKAI02 (Table 8).

Only one site, OTUKAI03, was comparable between 2017 and 2022. Metal contamination was similar between years, with the exception of total phosphorus and zinc concentration, which were both lower in 2022 compared to 2017. No sediment quality data was collected in 2012.

Table 7: Particle size distribution (%), copper, lead, zinc, total organic carbon, total phosphorus, total polycyclic aromatic hydrocarbons (PAHs), and semi-volatile organic compounds (SVOCs) in the sediment samples, from three collected in March 2022 and one site from 2017 (Boffa Miskell Ltd, 2017). Total PAHs were normalised to 1% of TOC, as recommended by ANZECC (2000). Values in red exceed guideline values. LWRP = Land and Water Regional Plan; CSNDC = CCC's Comprehensive Stormwater Network Discharge Consent.

	OTUKAI01: Ōtūkaikino River Groynes inlet	OTUKAI02: Wilsons Drain at Main North Road	OTUKAI03: Ōtūkaikino Creek Omaka Scout Camp (2022)	OTUKAI03: Ōtūkaikino Creek Omaka Scout Camp (2017)	LWRP and CSNDC	ANZECC (2018) guideline GV-high
Grain size						
Silt / clay: <0.063 mm	44.7	68.9	7.8	2.2	-	-
Fine sand: 0.063 - 0.250 mm	41.3	19.1	56.1	21.6	-	-
Medium sand: 0.250 - 0.500 mm	8.3	3.9	31.2	14.5	-	-
Coarse sand: 0.500 - 2.00 mm	5.7	6.1	4.4	2.5	-	-
Gravel and cobbles: >2.00 mm	0	1.8	0.52	59.2	-	-
Copper (mg / kg)	10.1	26.6	3.5	6	65	270
Lead (mg / kg)	9.5	43.6	6.1	8	50	220
Zinc (mg / kg)	69.6	326.6	29.6	46	200	410
Total organic carbon (g / 100 g)	7.4	5.6	0.22	3	-	-
Total phosphorus (mg / kg)	920	1413	290	470	-	-
Total PAHs (mg / kg)	0.26	4.13	0.05	0.30	10	50

3.11 Macroinvertebrate community

<u>Five-yearly monitoring</u>

Taxonomic richness was variable across sites in 2022, ranging from 13 at OTUKAI11 to 28 OTUKAI08 (Figure 21). Taxonomic richness was generally lower in 2022 (this study) compared to previous years, except for OTUKAI08 and OTUKAI11 where richness had increased. The greatest change between years was at OTUKAI10, where 29 taxa were found in 2017, but only 15 were found in this survey.

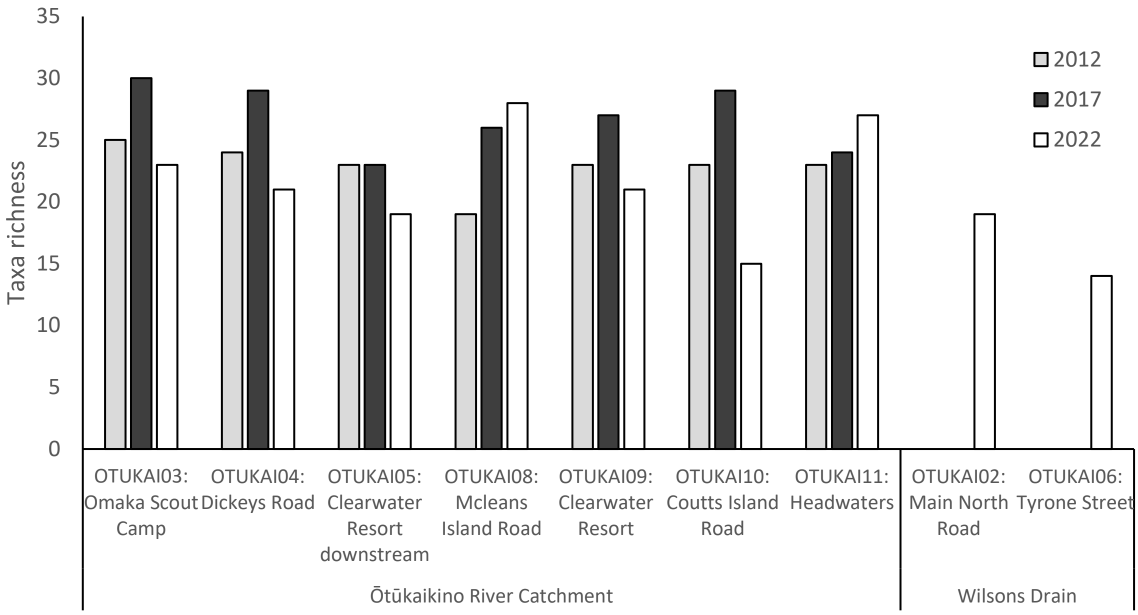

Figure 21. Number of macroinvertebrate taxa found at nine sites surveyed within the Ōtūkaikino River catchment and Wilsons Drain in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (black bars, Boffa Miskell Ltd, 2017).

Macroinvertebrate community composition in the Ōtūkaikino River catchment sites was similar in 2022 to previous years (Figure 22). The mud snail *Potamopyrgus antipodarum* and the stony-cased caddisflies *Pycnocentria evecta*, *Pycnocentrodes aureulus* dominated the macroinvertebrate community in all sampling years, accounting for approx. 50% of all individuals counted. Other abundant taxa include: the caddisflies *Aoteapsyche colonica, Hudsonema amabile* and *Oxyethira albiceps*, *Deleatidium* mayflies, orthoclad chironomid midge larvae, the freshwater snail *Physa,* and ostracod crustaceans. Seven of the ten most abundant taxa in 2022 had MCI scores of 5 or lower, which indicates they are very tolerant of poor water quality and habitat quality. The highest MCI score amongst the ten most abundant taxa was for *Deleatidium*, which has an MCI score of 8 (out of a maximum of 10).

Notably, the mayfly *Coloburiscus humeralis* (MCI =9), and the caddisflies *Olinga feredayi* (MCI =9) and *Helicopsyche albescens* (MCI =10) were present in 2022. *H. albescens* was present in similar abundances in 2022 compared to 2017, while *O. feredayi, and C. humeralis* were present at less sites and in lower abundances in 2022 compared to 2017 (Table 8). Moreover, the stonefly *Zelandobius*, was found in the catchment in 2012, but was not found in 2017, nor in 2022 (this study). This may be of concern (with the potential for rare taxa, such as *Zelandobius*, *O. feredayi*, and *C. humeralis* to be declining).

Table 8. Total number of notable macroinvertebrate species found at sites in the Ōtūkaikino River catchment in March 2022, and in 2017 (in brackets) (Boffa Miskell Ltd, 2017). Noting OTUKAI02 and OTUKAI06 were not sampled in 2017.

Site ID	Site name	*Coloburiscus humeralis*	*Olinga feredayi*	*Helicopsyche albescens*
OTUKAI02	Wilsons Drain at Main North Road	0	0	0
OTUKAI03	Ōtūkaikino Creek Omaka Scout Camp	0 (12)	1 (11)	0 (0)
OTUKAI04	Ōtūkaikino River upstream of Dickeys Road	0 (4)	1 (6)	0 (2)
OTUKAI05	Kaikanui Creek downstream of Clearwater Resort	0 (0)	7 (13)	0 (0)
OTUKAI06	Wilsons Drain at Tyrone Street	0	0	0
OTUKAI08	Ōtūkaikino Creek at Mcleans Island Road	1 (0)	1 (0)	0 (0)
OTUKAI09	Ōtūkaikino Creek at Clearwater Resort	0 (32)	11 (15)	26 (20)
OTUKAI10	Ōtūkaikino Creek off Coutts Island Road	0 (0)	0 (20)	1 (0)
OTUKAI11	Ōtūkaikino Creek Headwaters	0 (0)	0 (79)	0 (0)

The EPT insect orders (Ephemeroptera, mayflies; Plecoptera, stoneflies; and Trichoptera, caddisflies), which are generally sensitive to pollution and habitat degradation, are useful indicators of stream health. High EPT richness suggests high water and habitat quality, while low EPT richness suggests low water quality and degraded stream health.

EPT richness was variable across the nine sites in 2022, ranging from 11 EPT taxa (at OTUKAI04 and OTUKAI08) to 3 EPT taxa (at OTUKAI02, 06, and HEATH 27) (Figure 23). EPT taxa richness varied by only two or three taxa over time at most Ōtūkaikino River catchment sites sampled in 2012, 2017 and 2022.

The MCI scores across the nine sites surveyed were variable in 2022 (Figure 24). Site OTUKAI02, Wilsons Drain at Tyrone Street had the lowest MCI score of 60, while OTUKAI10, Ōtūkaikino Creek off Coutts Island Road had the highest MCI of 101.3. Note, the threshold for “good” stream health is an MCI of 100, which OTUAKI04, OTUKAI05, and OTUKAI09 almost met.

Five sites, OTUKAI03, OTUKAI08, OTUKAI11, OTUKAI02 and OTUKAI06 had low MCI scores and failed to meet the NPS-FM National Bottom Line value of MCI score of 90. In 2017, two sites, OTUKAI08, and OTUKAI11, also failed to meet the national bottom line, while all sites met the standard in 2012.

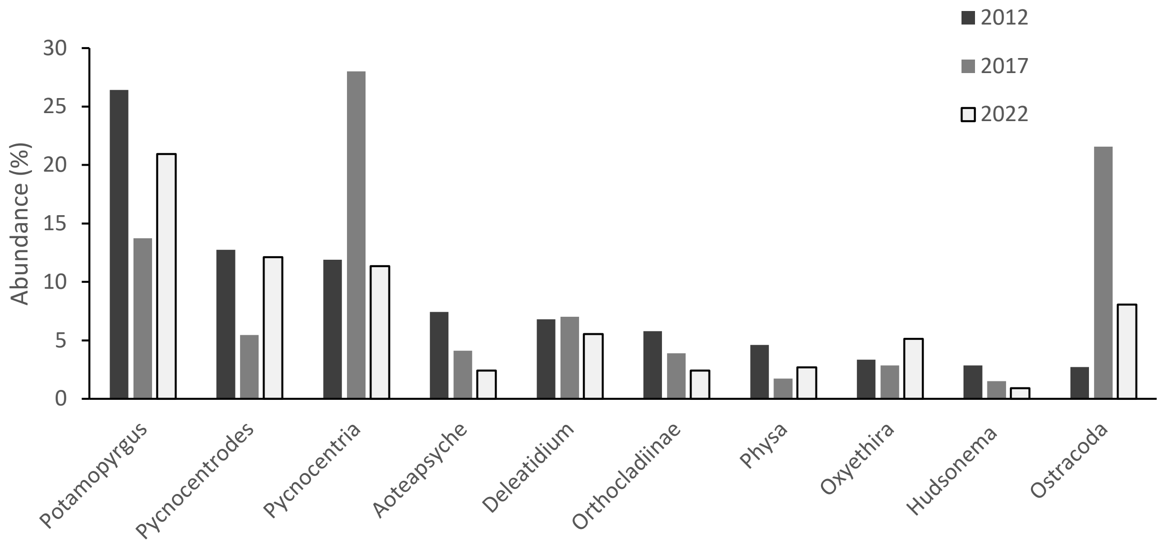

Figure 22. Abundance of the 10 most common taxa across all sampling sites within the Ōtūkaikino River catchment and Wilsons Drain sites in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (black bars, Boffa Miskell Ltd, 2017).

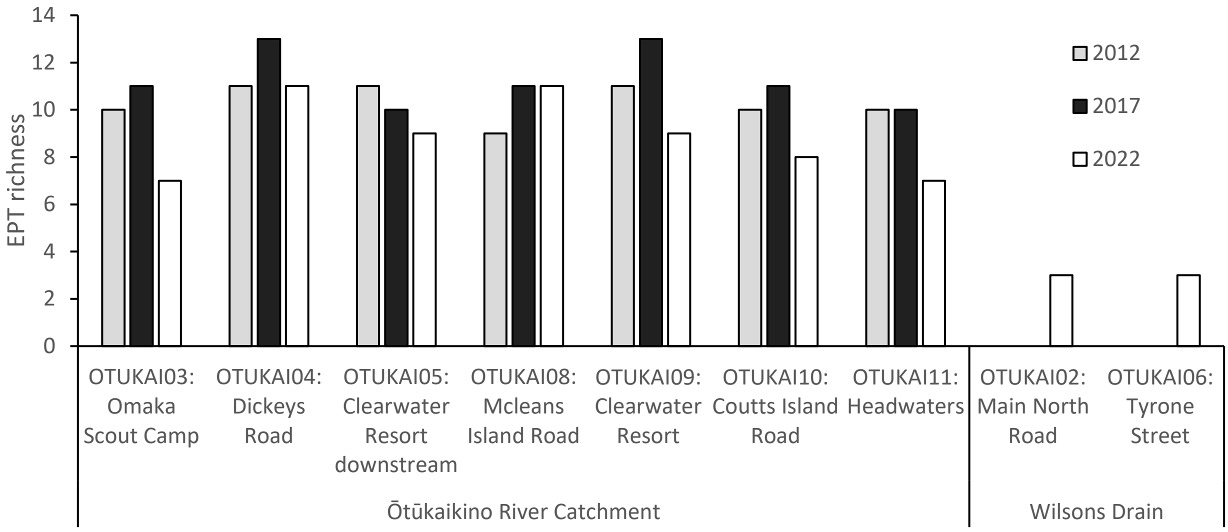

Figure 23. EPT richness at nine sites surveyed within the Ōtūkaikino River catchment and Wilsons Drain sites in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (black bars, Boffa Miskell Ltd, 2017).

The QMCI is considered a better indicator of "health" than MCI, as it takes into account abundance and presence of macroinvertebrate taxa. The QMCI showed slightly different results to the MCI. In 2022 four sites, OTUKAI04, OTUKAI05, OTUKAI09 and OTUKAI10 complied with the consent target of a QMCI of 5 or greater (Figure 25). Sites OTUKAI03, OTUKAI08, OTUKAI11, OTUKAI02 and OTUKAI06 had a QMCI value lower than 5 and did not comply with the consent target in 2022. In previous survey years only one site, OTUKAI08 did not comply with the consent target. Notably, QMCI at OTUKAI03 declined from 5.5 in 2017 to 2.3 in 2022, and at OTUKAI11 it declined from 6 in 2017 to 3.2 in 2022.

Sediment depth, sediment cover and macrophyte cover had significantly increased at both OTUKAI08 and OTUKAI11 from 2017 to 2022. It is likely that the decline in QMCI was due to these changes in the physical habitat. This is also reflected in a change in macroinvertebrate community composition, where taxa who favor fine sediment substrates, such as oligochaete worms, were more abundant in 2022 than 2017.

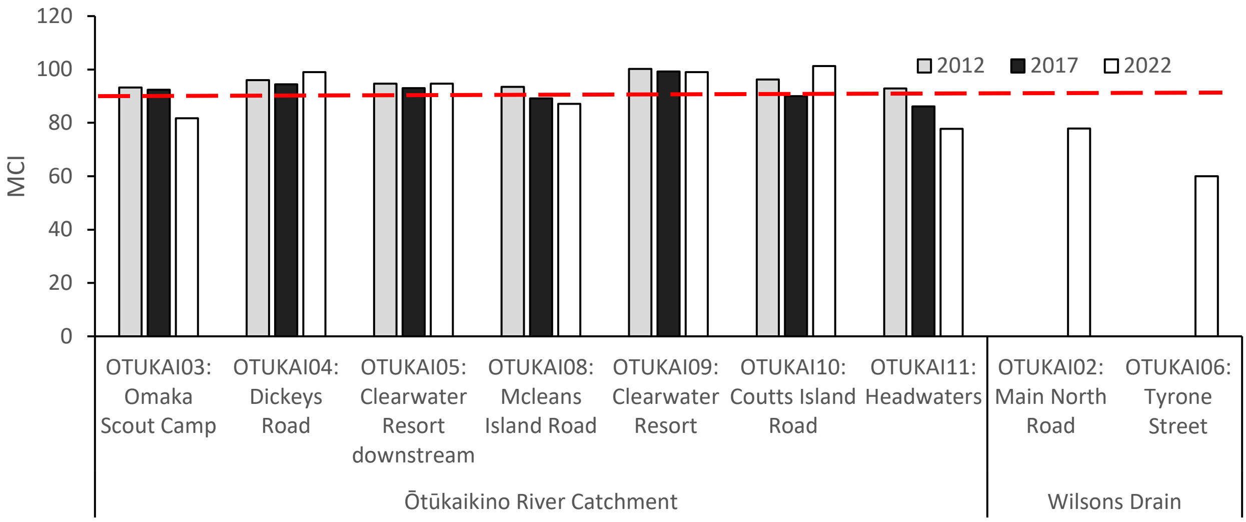

Figure 24. Macroinvertebrate Community Index (MCI) scores at nine sites surveyed within the Ōtūkaikino River catchment and the Cashmere Stream catchment in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (black bars, Boffa Miskell Ltd, 2017).The dashed red line indicates the NPSFM National Bottom Line value (90).

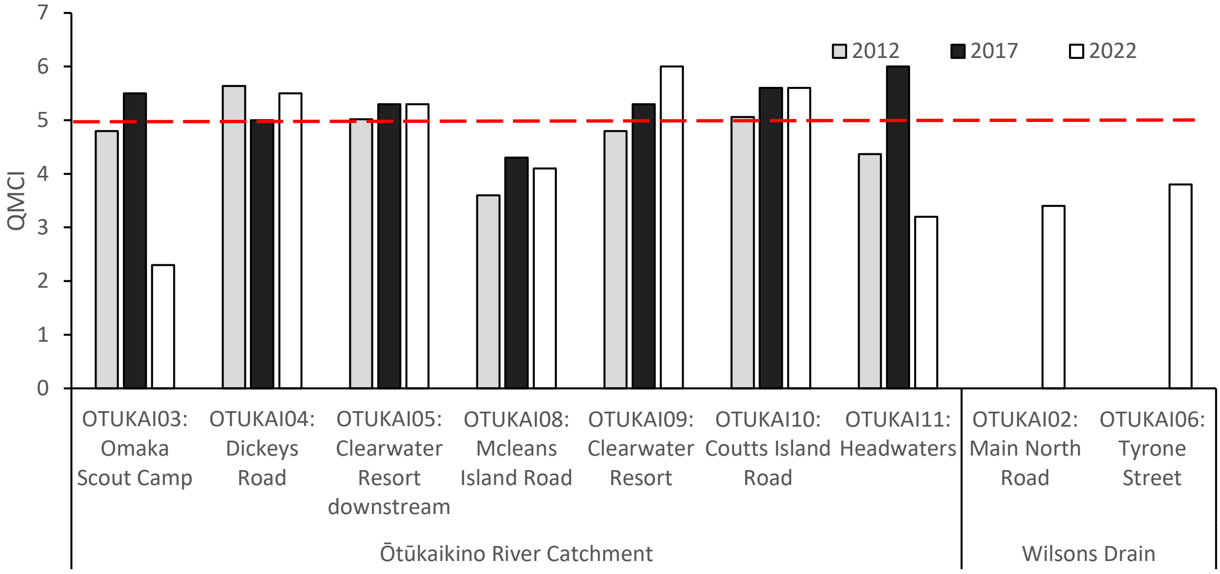

Figure 25. Quantitative Macroinvertebrate Community Index (QMCI) scores at nine sites surveyed within the Ōtūkaikino River catchment and Wilsons Drain in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (black bars, Boffa Miskell Ltd, 2017).The red dashed line indicates the consent target value (5).

Average Score Per Metric (ASPM) scores for all sites sampled in 2022 were variable (Figure 26). Six sites were above the NPS-FM National Bottom Line of 0.3, while OTUKAI11 was just below the bottom line, and OTUKAI02 and OTUKAI06 were well below (Figure 26).

All sites monitored in 2012 and 2017 met the National Bottom Line. The ASPM is a composite of %EPT, EPT taxa richness, and MCI scores, so a very low ASPM score is indicative of a lack of sensitive taxa and strong dominance of pollution-tolerant taxa. There was no overall increasing or decreasing trend evident in ASPM scores over time.

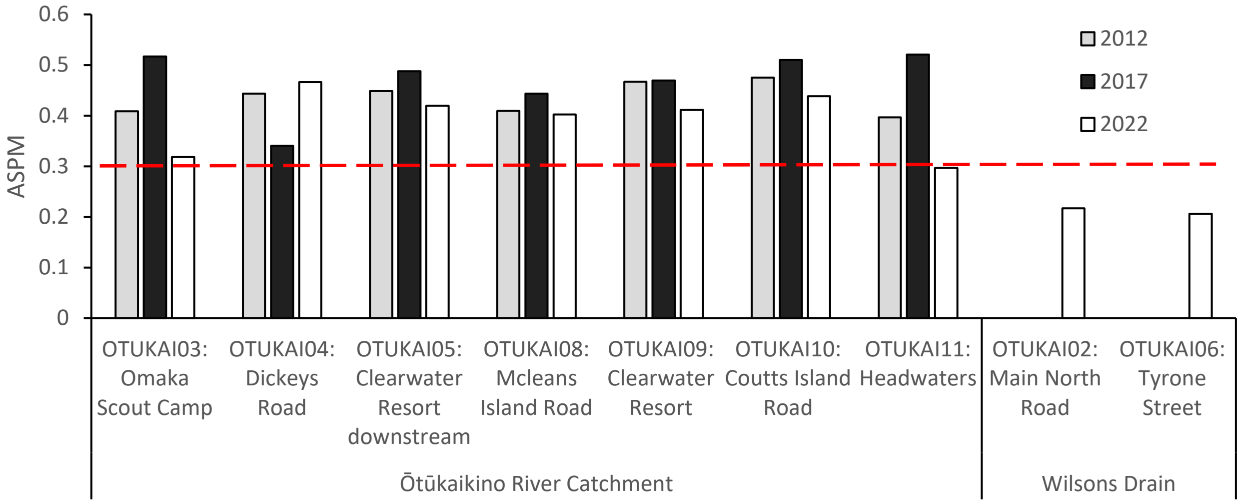

Figure 26: Macroinvertebrate Average Score Per Metric (ASPM) scores found at the sites surveyed within the Ōtūkaikino River catchment and Wilsons Drain in in March 2022 (white bars), 2012 (light grey bars, EOS Ecology, 2012), and March 2017 (black bars, Boffa Miskell Ltd, 2017). The red line indicates the NPS-FM 2020 National Bottom Line value (0.3).

The sediment index score was positively correlated with taxon richness, where sites with a greater SI had a greater diversity of macroinvertebrate taxa (P = 0.01), reflecting the ability of habitat heterogeneity to support a wider range of taxa. There were no other correlations between general habitat metrics (i.e., velocity, sediment depth, macrophyte cover, or water depth) and macroinvertebrate community indices (i.e., % EPT, EPT richness, MCI, QMCI, or ASPM).

There was insufficient data to perform a correlation analysis between sediment metals or PAHs and any macroinvertebrate community metrics at the two Ōtūkaikino River catchment sites sampled in 2022. Similarly, no correlations were attempted between data from CCC's monthly water quality monitoring sites and the ecology sites sampled in 2022, due to low sample size and weak statistical power. Visual comparison of macroinvertebrate indices with the monthly water quality results (Margetts and Marshall 2021) did not reveal any clear patterns.

<u>Annual monitoring</u>

The macroinvertebrate fauna at both <u>Wilsons Drain</u> sites was dominated by pollution-tolerant taxa, particularly *Potamopyrgus* snails and oligochaete worms, as well as amphipods. EPT taxa are represented only by caddisflies (Trichoptera), with no mayflies (Ephemeroptera) or stoneflies (Plecoptera) recorded, and EPT taxa richness is low overall. Only one pollution-sensitive taxon (with an MCI ≥7) has been recorded from these two monitoring sites over time. A single specimen of a free-living caddisflies *Polyplectropus* (MCI=8) was recorded OTUKAI02 in 2022.

The macroinvertebrate fauna at both Cashmere Stream sites is dominated by pollution-tolerant taxa, particularly *Potamopyrgus* snails, amphipods, and the freshwater clam (Sphaeriidae). EPT taxa are only represented by caddisflies (Trichoptera), with no mayflies (Ephemeroptera) or stoneflies (Plecoptera) recorded, and EPT taxa richness is low overall. Only three pollution-sensitive taxa (with an MCI ≥7) have been recorded from these two monitoring sites over time. The free-living caddisflies *Polyplectropus* and *Psilochorema* (both MCI=8) have been recorded at both monitoring sites over time.

The dominance of pollution-tolerant taxa results in low index scores for both Cashmere Stream and Wilsons Drain sites, with QMCI, MCI, and ASPM scores typically below guidelines (Figure 27).

Mann-Kendall trend analyses showed no significant increasing or decreasing trend in EPT richness (P = 0.25), MCI (P = 0.07), QMCI (P =0.25), or ASPM (P = 0.25) at HEATH28 over time. This means that there has been no change in the relative abundance of pollution-sensitive taxa over time, or in the total number of pollution-sensitive taxa at the site. There was insufficient macrophyte cover data available for trend analysis at all other annual monitoring sites.

A single kēkēwai (freshwater crayfish) was caught at HEATH27 via electric fishing methods. Kēkēwai is listed as listed as an At Risk - Declining species (Grainger et al., 2018) (see photo in Appendix 1).

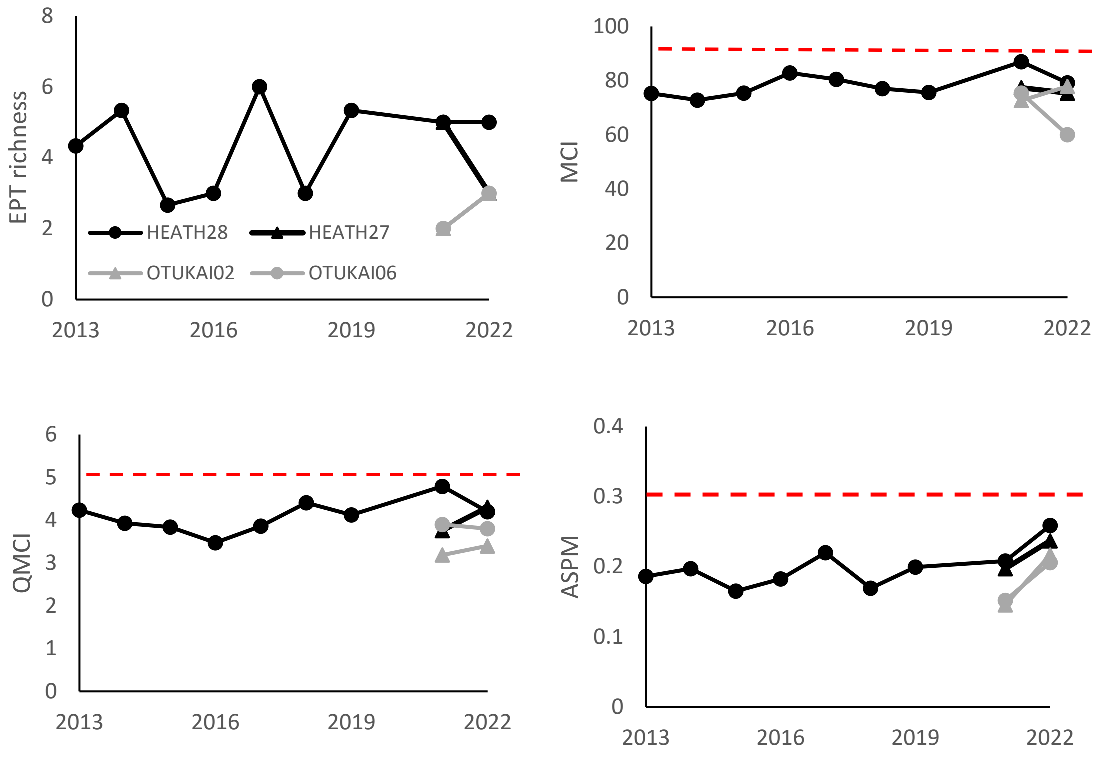

Figure 27. Changes in Macroinverbrate indices over time at the two annual monitoring sites in Cashmere Stream and two annual monitoring sites in Wilsons Drain. The lines indicate consent attribute target levels and NPSFM 2020 guidelines.

The macroinvertebrate fauna of Balguerie Stream was dominated by EPT taxa, including mayflies, caddisflies, and low numbers of stoneflies. EPT richness varied over years but ranged from 7 EPT taxa found in 2007 to 18 in 2012. MCI values consistently complied with the NPS-FM National Bottom-Line values (of 90).

QMCI values consistently complied with the NPS-FM National Bottom-Line value of >4.5. QMCI generally complied with the CSNDC attribute target level of >5, except in 2007 and 2010 where QMCI was 4.9. The National Bottom Line ASPM value of 0.3 was complied with across all years (Figure 28).

Mann-Kendall time trend analysis revealed a significant increase in EPT taxa richness (P =0.006) over time. There was no significant increasing or decreasing trend in MCI (P =0.13), QMCI (P =0.08), or ASPM (P =0.09) at Balguerie Stream monitoring site. There was insufficient macrophyte cover data available for trend analysis at all other annual monitoring sites.

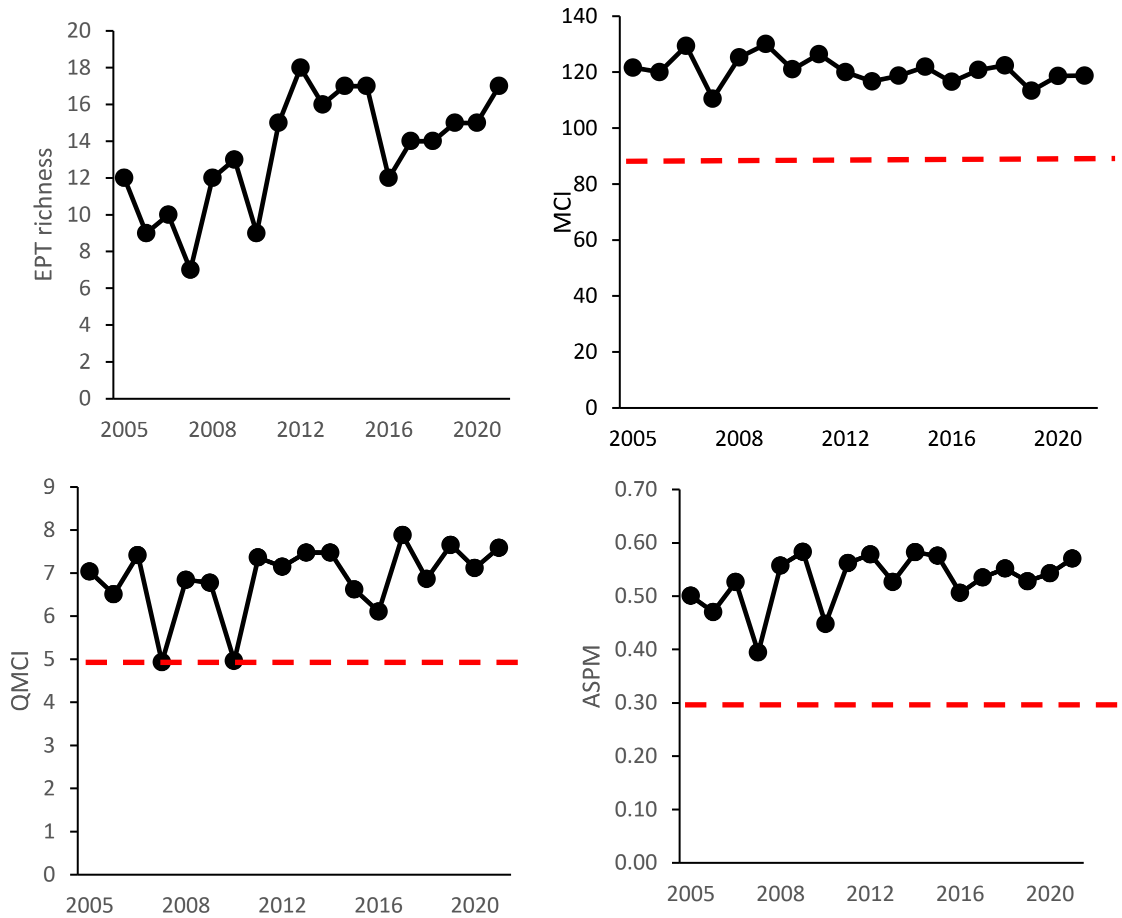

Figure 28. Changes in EPT richness, MCI, QMCI, and ASPM over time at an ECan monitoring site, BP03, on Balguerie Stream. The red dashed lines indicate consent attribute target levels and NPSFM 2020 guidelines.

3.12 Fish community

A total of 329 fish, belonging to 6 species, were captured in the eleven sites surveyed within the Ōtūkaikino River catchment and Cashmere Stream catchment in March 2022. The species captured were, in descending order of total abundance (i.e., across all sites): upland bully (*Gobiomorphus breviceps*), shortfin eel (*Anguilla australis*), longfin eel (*A. dieffenbachii*), common bully (*G. cotidianus*), brown trout (*Salmo trutta*), and inanga (*Galaxias maculatus*).

Longfin eel and inanga have a conservation status of "At Risk, Declining", upland bully, common bully, and shortfin eel are currently listed as "Not Threatened", and brown trout is an Introduced and Naturalised species (Dunn et al., 2018).

3.12.1 Species richness

The fish communities were depauperate, with species richness generally around two to five fish species present at a site. HEATH28 had the most diverse freshwater fish community with five species found, whereas HEATH27, OTUKAI02, OTUKAI04, OTUKAI06, OTUKAI08, and OTUKAI11 had the fewest species, with only two species being found at these sites.

Upland bullies were the most commonly encountered species, and were found at all sites, except for OTUKAI02, OTUKAI04, and OTUKAI06. Longfin eels were found at all sites except for HEATH27, OTUKAI03, OTUKAI06, OTUKAI08, and OTUKAI10, while shortfin eels were not found at OTUKAI02, OTUKAI04, and OTUKAI11. A single inanga was found only at HEATH28 (Table 9). The fish community at OTUKAI02, OTUKAI04, and OTUKAI11 was surveyed using traps and nets, rather than electric fishing.

3.12.2 Size distribution of fish

Table 9 summarises the size and species richness information of fish captured (or seen but not captured) at the eleven sites surveyed in March 2022. The largest fish captured at any site was a 1,500 mm longfin eel at HEATH28.

Longfin eels have previously been reported as less frequently found in the Ōtūkaikino catchment (Aquatic Ecology Ltd, 2013); this species was found at 54% (6 of 11) of sites across both catchments, and in lower numbers than shortfin eels. Elvers (juvenile eels, <100 mm) were found in varying densities at nine sites, a single elver was found at OTUKAI06 and OTUKAI10, while 25 were found at HEATH27.

Upland bullies were the dominant fish species caught at five sites, and ranged in size from 20 mm to 114 mm, a high proportion of which were below 50 mm indicating a high juvenile population. The larger bullies (between 90 mm and 120 mm) were relatively uncommon, in comparison, with only 2 common bullies and 1 upland bully in this size range found. It is important to note that the presence / abundance of inanga and larger brown trout are underestimated by electric fishing techniques, so these species may have been more abundant across the catchment than shown in Table 9.

*Table 9: Total number of fish caught (or seen) at each of the nine sites surveyed in March 2022. Size (mm) ranges are shown in parentheses. Where the minimum and maximum size were the same, only one value is shown. *Indicates fish were not all caught, and size was unable to be measured or estimated. Different fishing methods were used at sites. EFM = electric fishing; Traps = fyke nets and Gee minnow traps.*

Site ID	Site name	Fishing method	Common bully	Upland bully[5]	Bully species	Inanga[6]	Longfin eel	Shortfin eel	Eel species	Elver	Brown trout
OTUKAI02	Wilsons Drain at Main North Road	Traps	0	0	2 (36-38)	0	4 (450-700)	0	0	0	0
OTUKAI03	Ōtūkaikino Creek Omaka Scout Camp	EFM	0	25 (20-60)	16 (20-30)	0	0	7 (150-350)	0	5 (100-120)	1 (80)
OTUKAI04	Ōtūkaikino River upstream of Dickeys Road	Traps	4 (53-100)	0	2 (34)	0	4 (560-1010)	0	0	0	0
OTUKAI05	Kaikanui Creek downstream of Clearwater Resort	EFM	0	1 (56)	0	0	4 (300-1020)	11 (170-360)	5* (80-500)	7 (65-120)	0
OTUKAI06	Wilsons Drain at Tyrone Street	EFM	0	0	9* (28-30)	0	0	7 (150-800)	1*	1 (40)	0
OTUKAI08	Ōtūkaikino Creek at Mcleans Island Road	EFM	0	1 (68)		0	0	28 (155-1000)	9*	11 (110-150)	0

[5] Non-migratory bullies, such as upland bullies, can be underestimated by trapping (Joy et al. 2013).

[6] Inanga can be underestimated by electric fishing (Joy et al. 2013).

Site ID	Site name	Fishing method	Common bully	Upland bully5	Bully species	Inanga6	Longfin eel	Shortfin eel	Eel species	Elver	Brown trout
OTUKAI09	Ōtūkaikino Creek at Clearwater Resort	EFM	4 (30-40)	11 (30-50)	1 (20)	0	6 (150-600)	6 (150-250)	0	2 (100-120)	0
OTUKAI10	Ōtūkaikino Creek off Coutts Island Road	EFM	0	19 (40-64)	3 (30)	0	0	3 (200-320)	1 (600)	1 (110)	2 (100-150)
OTUKAI11	Ōtūkaikino Creek Headwaters	Traps	0	7 (64-114)	0	0	1 (1015)	0	0	0	0
HEATH27	Cashmere Stream behind 406 Cashmere Road (downstream of stormwater discharge)	EFM	0	25 (20-60)	0	0	0	10 (140-300)	0	25 (75-120)	0
HEATH28	Cashmere Stream behind 420-426 Cashmere Road (upstream of stormwater discharge)	EFM	1 (120)	1 (50)	0	1 (70)	3 (800-1500)	13 (200-1000)	0	15 (70-120)	0

3.12.3 Community composition

Upland bullies and shortfin eels were the most commonly encountered fish (Figure 29). Elvers dominated the community at HEATH28, while shortfin eels made up most of the fish community at OTUKAI05 and OTUKAI08. At sites that were trapped rather than electric-fished (OTUKAI02, OTUKAI04, and OTUKAI11) longfin eels were the only eel taxa captured. Upland bullies made up most of the fish community sites HEATH27, OTUKAI03, OTUKAI09, OTUKAI10, and OTUKAI11.

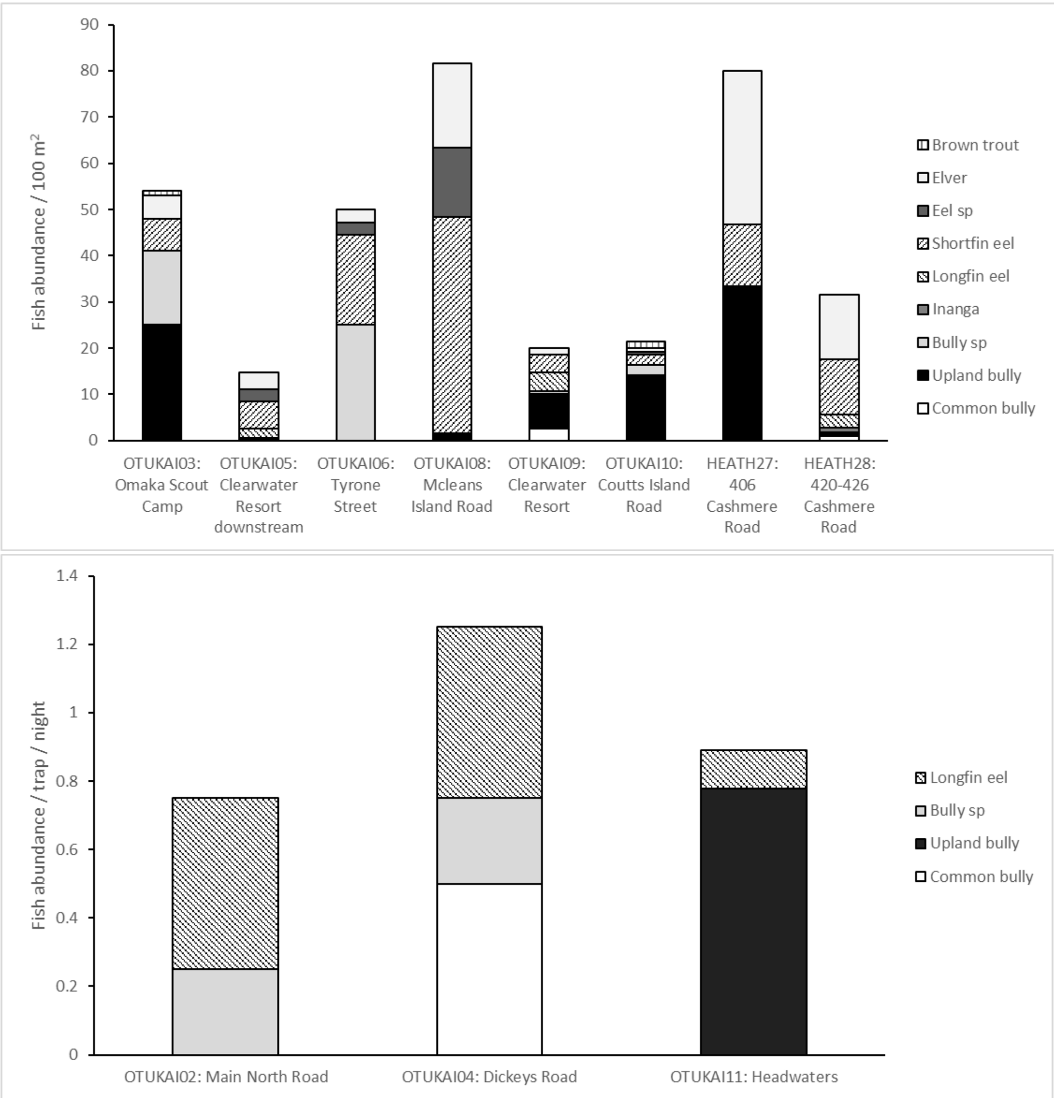

Figure 29: Total abundance of fish, separated by species, captured at each of the nine sites surveyed in March 2022. Numbers are show as catch per unit effort (CPUE): per 100 m2 of waterway surveyed using electric fishing (top); or per net / night where traps and nets were set overnight (bottom).

3.12.4 Changes in fish community over time

Of the sites that were able to be compared (see page 14), there were slight differences in both species richness, community composition and abundance in 2017 (Boffa Miskell Ltd, 2017), 2021 (InStream Consulting Ltd, 2021) and 2022 (this study) (Table 10). Generally, the number of species found was the same in 2022 than in previous years, but abundances were variable.

Species richness found in 2017 and 2021 was between 2 and 5, and similarly between 2 and 4 in 2022. A species found in 2017 but not in 2022 was giant bully (*Gobiomorphus gobioides*) at OTUKAI04. All species found in 2022 were also found in 2017 or 2021 and these included longfin eel, shortfin eel, common bully, upland bully and brown trout.

Species abundance in 2017 and 2021 was between 2.4 and 78.1 fish CPUE, and the richness of the 2022 sample sites was similarly between 0.75 and 82. Abundance at OTUKAI03 had the biggest drop of 24 fish per 100m^2 between 2017 and 2022, while OTUKAI08 had an increase of 42 fish per 100m^2 between 2017 and 2022.

Upland bully was the species with the highest catch numbers in 2017 and 2022 sampling periods with 96 and 90 being caught in 2017 and 2022, respectively. Shortfin eels were found in greater numbers this year than in the previous surveys, increasing from 42 (2017 and 2021) to 85 in 2022. Longfin eels were detected in greater numbers in 2017 and 2021 combined, than in 2022. More brown trout were found in 2017 than in 2022 (this study).

Table 10: Fish species, including dominant species (based on abundance data), richness, and abundance found at eight sites surveyed in this study and previous work commissioned by the Christchurch City Council (Boffa Miskell Ltd, 2017; InStream Consulting Ltd, 2021).

Site number	Site name	Species found in 2022 (This study)	Species found in 2021 (InStream Consulting Ltd, 2021)	Species found in 2017 (Boffa Miskell Ltd, 2017)
OTUKAI02	Wilsons Drain at Main North Road	Dominant species: longfin eel Bully sp, longfin eel Richness = 2 Total abundance per trap=0.75	Dominant species: longfin eel Upland bully, common bully, longfin eel Richness = 3 Total abundance per trap= 2.4	
OTUKAI03	Ōtūkaikino Creek Omaka Scout Camp	Dominant species: upland bully Upland bully, bully sp, shortfin eel, eel sp, brown trout Richness = 3 Total abundance per 100 m2= 54		Dominant species: upland bully Upland bully, longfin eel, brown trout Richness = 3 Total abundance per 100 m2= 78.1

Site number	Site name	Species found in 2022 (This study)	Species found in 2021 (InStream Consulting Ltd, 2021)	Species found in 2017 (Boffa Miskell Ltd, 2017)
OTUKAI04	Ōtūkaikino River upstream of Dickeys Road	Dominant species: common bully and longfin eel Common bully, bully sp, longfin eel Richness = 2 Total abundance per trap= 1.25		Dominant species: longfin eel Common bully, giant bully, longfin eel, elver Richness = 3 Total abundance per trap= 7.4
OTUKAI05	Kaikanui Creek downstream of Clearwater Resort	Dominant species: shortfin eel Upland bully, longfin eel, shortfin eel, eel sp, elver Richness = 3 Total abundance per 100 m2= 14.8		Dominant species: shortfin eel Common bully, upland bully, inanga, shortfin eel, longfin eel, eel sp, elver Richness = 4 Total abundance per 100 m2= 25.6
OTUKAI06	Wilsons Drain at Tyrone Street	Dominant species: bully sp Bully sp, shortfin eel. Eel sp, elver Richness = 2 Total abundance per 100 m2= 50	Dominant species: Shortfin eel Inanga, shortfin eel, elver Richness = 2 Total abundance per 100 m2= 66.2	
OTUKAI08	Ōtūkaikino Creek at Mcleans Island Road	Dominant species: shortfin eel Upland bully, shortfin eel, eel sp, elver Richness = 2 Total abundance per 100 m2= 81.6		Dominant species: shortfin eel Upland bully, shortfin eel, longfin eel, eel sp, brown trout Richness = 4 Total abundance per 100 m2= 40

Site number	Site name	Species found in 2022 (This study)	Species found in 2021 (InStream Consulting Ltd, 2021)	Species found in 2017 (Boffa Miskell Ltd, 2017)
OTUKAI09	Ōtūkaikino Creek at Clearwater Resort	Dominant species: upland bully Upland bully, common bully, bully sp, longfin eel, shortfin eel, elver Richness = 4 Total abundance per 100 m2= 20		Dominant species: upland bully Upland bully, common bully, longfin eel, shortfin eel Richness = 4 Total abundance per 100 m2= 19.1
OTUKAI10	Ōtūkaikino Creek off Coutts Island Road	Dominant species: upland bully Upland bully, bully sp, shortfin eel, eel sp, elver, brown trout Richness = 3 Total abundance per 100 m2= 21.5		Dominant species: brown trout Upland bully, longfin eel, shortfin eel, brown trout Richness = 4 Total abundance per 100 m2= 18.3

4.0 Discussion

4.1 Current state and trends in aquatic ecology

Monitoring data from nine sites in the Ōtūkaikino River Catchment and two sites in the Cashmere Stream catchment showed that riparian habitat conditions were similar to previous years at most sites. OTUKAI04 and OTUKAI10 have improved riparian margins, where riparian planting of indigenous vegetation has taken place. The greatest regression in riparian conditions was observed at OTUKAI09 and OTUKAI11 where margins had become dominated by sprayed grass and grey willow, respectively. All other sites were typically buffered by mown or pasture grasses.

In-stream habitat conditions at all sites had generally worsened compared to previous years. Sites were typically wider, deeper, and slower than previous years, with a significantly higher cover of fine sediments. Changes to substrate index score, embeddedness, sediment depth, and sediment cover from previous years to this survey (2022) all indicate an increased presence of finer substrates, like sand and silt. Site OTUKAI08 was the exception, where the stream bed remained dominated by cobble and gravel substrates. Only one site, OTUKAI08, met the CSNDC attribute target level for maximum fine sediment cover. Moreover, macrophyte cover has increased at most sites, where five sites exceeded the CSNDC attribute target level for maximum macrophyte cover. Nuisance macrophyte growth can reduce velocity, catch suspended sediments, and reduce availability of coarser substates. The increased presence of fine sediment and macrophyte cover in the catchments means coarser substrates, like cobbles, are less available to aquatic biota (for grazing, egg laying, using as refugia).

Mats of the toxic cyanobacteria, *Phormidium*, were found at sites OTUKAI05, OTUKAI08, OTUKAI09, and OTUKAI10 ranging from 1% to 18% cover. Toxic cyanobacteria was not noted in either the 2012, 2017 or 2021 surveys. The presence of toxic algae is of concern to the recreational value of the stream as it can pose a risk to human and animal health. Blooms can been associated with higher water temperatures and elevated nutrient levels.

The basic water quality parameters of conductivity, pH, and water temperature were within ranges expected in spring-fed urban environments during base-flow conditions; measures were similar to previous years, and met the LWRP guideline value. Dissolved oxygen levels were variable among sites but were generally low; eight sites did not meet LWRP guideline value of 70% or greater saturation. DO can vary diurnally and seasonally, and macrophyte and algal abundances at a site can greatly influence DO concentrations, thus the increased cover of macrophytes at sites could explain some the lower saturation. The presence of taxa sensitive to oxygen levels, such as kēkēwai and trout may indicate that dissolved oxygen saturation in the catchments fluctuates higher than was recorded in our sampling. Two sites (OTUKAI06 and HEATH28) that did not meet 70% LWRP guideline value in 2022 (this study), failed to meet the guideline in the 2021 sampling round (InStream Consulting Ltd, 2021).

Sediment concentrations of copper, lead, and total PAHs were low in 2022 and complied with CSNDC target levels. Zinc levels exceeded CSNDC target levels at OTUKAI03; this may be associated with greater fine sediment content in 2022 samples. The CSNDC target levels for all contaminants were met in the previous sampling survey. Overall, sediment concentrations of metals and total PAHs were similar those recorded from the Avon and Heathcote River catchments (e.g., InStream Consulting Ltd, 2019, 2020).

Macroinvertebrates are an important and commonly used measure of stream, or ecosystem, health. Invertebrate community composition in 2022 was similar to previous years at the Ōtūkaikino River and Cashmere Stream catchment monitoring sites, being dominated by pollution-tolerant snails and the stony-cased caddisflies *Pycnocentria evecta*, *Pycnocentrodes aureulus.*

All five-yearly monitoring sites, except OTUKAI04, OTUKAI05, OTUKAI09, and OTUKAI10 were below the LWRP guideline of a minimum MCI of 5, or minimum QMCI of 90. The ASPM guideline values were exceeded at most five-yearly monitoring sites, except OTUKAI11, OTUKAI02, and OTUKAI06. Similarly, none of the annual monitoring sites met the MCI or QMCI guideline values, while the ASPM guideline was exceeded at all sites. The Balguerie Stream site exceeded MCI, QMCI, and ASPM guideline values on all occasions over the last 18 years, expect for two occasions; QMCI scores were below 5. MCI, QMCI, and ASPM varied between years at all sites, there was no overall increasing or decreasing trend evident over time.

Indigenous fish species were present at all eleven sites within the Ōtūkaikino River and Cashmere Stream catchments. Most importantly, six sites, supported longfin eels, an “At Risk, Declining” species. The presence of elvers (either longfin or shortfin) at most sites is encouraging and can be a good sign for population recruitment and persistence. Inanga, another “At Risk, Declining” species was also found in the Cashmere Stream catchment (HEATH28). Inanga may have been present at other sites; however, inanga can be underestimated using electric fishing techniques (Joy et al. 2013). Of the sites that were comparable between years, there was no overall trend in community composition over time.

4.2 Comparison to consent attribute target levels

The CCC's CSNDC has attribute target levels for sediment concentrations of copper, lead, zinc, and total PAHs, fine sediment cover, total macrophyte cover, long filamentous algae cover, and QMCI scores. Consent targets for sediment copper, lead, zinc, and total PAHs have been mostly compliant from in the 2017 and 2022 monitoring years with only zinc exceeding the consent target at one site (OTUKAI03) in 2022.

Fine sediment cover was within the guidelines at most sites in 2017, however in 2022 all but one site (OTUKAI08) exceeded the consent target of a maximum of 20% fine sediment cover. Consent targets for long filamentous algae cover have been met at all sites sampled over the last ten years (Table 11). Compliance with QMCI scores has decreased over time, with 88.8% of sites complying with the QMCI target of 5 or greater in 2017, and only 36% of sites complied in 2022 (Table 11). A summary of sites and the relevant guideline exceedance are provided in Table 12.

Table 11. Percent of sites in the Ōtūkaikino River and Cashmere Stream catchments that comply with the consent attribute target levels over time. No sediment quality data was gathered in 2012.

Parameter	Consent target level	2012 (9 sites)	2017 (9 sites)	2022 (11 sites)
Copper	65 (mg/kg)	-	100%	100%
Lead	50 (mg/kg)	-	100%	100%
Zinc	200 (mg/kg)	-	100%	90.9%
Total PAHs	10 (mg/kg)	-	100%	100%
Fine sediment cover	20 %	-	77%	9.1%
Maximum total macrophyte cover	SP: 50 % BP: 30 %	89%	100%	54.5%
Maximum total filamentous algae cover	SP: 30 % BP: 20 %	100%	100%	100%
QMCI	5	69%	88.8%	36%

Table 12. Summary of in-stream sediment quality, and aquatic ecology from 11 sites and relevant guideline exceedance.

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
OTUKAI01	Ōtūkaikino River	Ōtūkaikino River Groynes Inlet	• No guidelines exceeded	-	-
OTUKAI02	Ōtūkaikino River	Wilsons Drain at Main North Road	• No guidelines exceeded	• Moderate shading, low algae and macrophyte cover, dominated by fine sediment • Exceeded in fine sediment cover • Did not meet QMCI guideline • Unidentified bully species, and 'At Risk - Declining' longfin eel present	• Moderate shading, low algae and macrophyte cover, dominated by fine sediment • Exceeded in fine sediment cover • Did not meet QMCI guideline • Unidentified bully species, and 'At Risk - Declining' longfin eel present
OTUKAI03	Ōtūkaikino River	Ōtūkaikino Creek Omaka Scout Camp	• Exceeded lead guideline	• Moderate shading, high algae and macrophyte cover, moderate-high cover of fine sediment • Exceeded fine sediment cover, total macrophyte cover • Did not meet QMCI guideline • Unidentified bully species, upland bully, elver and shortfin eel present	-
OTUKAI04	Ōtūkaikino River	Ōtūkaikino River upstream of Dickeys Road	-	• Low-moderate shading, high algae and macrophyte cover, moderate-high cover of fine sediment	-

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
				• Exceeded fine sediment cover and total macrophyte cover • Unidentified bully species, common bully, and 'At Risk - Declining' longfin eel present	
OTUKAI05	Ōtūkaikino River	Kaikanui Creek downstream of Clearwater Resort	-	• Low shading, moderate algae and macrophyte cover, moderate-high sediment cover. • Exceeded fine sediment cover guideline • Upland bully, unidentified eel species, elver, shortfin eel and 'At Risk - Declining' longfin eel present	-
OTUKAI06	Ōtūkaikino River	Wilsons Drain at Tyrone Street	-	• High shading, low macrophyte cover no algae, dominated by fine sediment • Exceeded fine sediment cover, total macrophyte cover • Did not meet QMCI guideline • Unidentified bully species, unidentified eel species, elver and shortfin eel present	• High shading, low macrophyte cover no algae, dominated by fine sediment • Exceeded fine sediment cover, total macrophyte cover • Did not meet QMCI guideline • Unidentified bully species, unidentified eel species, elver and shortfin eel present
OTUKAI08	Ōtūkaikino River	Ōtūkaikino Creek at Mcleans Island Road	-	• Low shading, low algae and macrophyte	-

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
				cover, low sediment cover • Did not meet QMCI guideline • Upland bully, unidentified eel, elver, and shortfin eel present	
OTUKAI09	Ōtūkaikino River	Ōtūkaikino Creek at Clearwater Resort	-	• Moderate-high shading, low macrophyte cover, moderate-low cover of fine sediment • Exceeded fine sediment cover guideline • Unidentified bully species, common bully, upland bully, elver, shortfin eel and 'At Risk - Declining' longfin eel present	-
OTUKAI10	Ōtūkaikino River	Ōtūkaikino Creek off Coutts Island Road	-	• Low shading, high macrophyte cover, low algae cover, moderate cover of fine sediment • Exceeded in fine sediment cover and total macrophyte cover • Unidentified bully species, upland bully, elver, shortfin eel and 'At Risk - Declining' longfin eel present	-
OTUKAI11	Ōtūkaikino River	Ōtūkaikino Creek Headwaters	-	• High shading, high macrophyte	-

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
				growth, dominated by fine sediment • Exceeded in fine sediment cover and total macrophyte cover • Did not meet QMCI guideline • Upland bully and 'At Risk - Declining' longfin eel present	
HEATH27	Cashmere Stream	Cashmere Stream behind 406 Cashmere Road (downstream of stormwater discharge)	-	-	• Low shading, no algae and moderate-low macrophyte cover, moderate-high fine sediment • Exceeded in fine sediment cover and total macrophyte cover • Did not meet QMCI guidelines • Kekewai, upland bully, elver, and shortfin eel present
HEATH28	Cashmere Stream	Cashmere Stream behind 420-426 Cashmere Road (upstream of stormwater discharge)	-	-	• Moderate shading, no algae and moderate-low macrophyte cover. Dominated by fine sediment • Exceeded in fine sediment cover • Did not meet QMCI guidelines • Common bully, upland bully, Inanga, elver,

Site ID	Catchment	Site name	Five-yearly sediment monitoring	Five-yearly ecology monitoring	Annual ecology monitoring
					longfin eel and shortfin eel present
BP03	Balguerie Stream	Downstream of Settlers Hill (road)	-	-	• No guidelines exceeded

4.3 Recommendations

- Best practice stormwater management techniques should be considered, especially when urban development in the area is increasing. Untreated, or poorly treated, stormwater can bring fine sediments and contaminants into waterways, which smother the stream bed and can be directly consumed by freshwater fauna. Reducing inputs of fine sediments is essential when enhancing and protecting habitat for aquatic species such as pollution-sensitive macroinvertebrate taxa, and many freshwater fishes. This is especially important for the Ōtūkaikino River catchment where EPT taxa, including mayflies (and possibly stoneflies) still occur.

- Enhancement of the riparian margins, particularly at sites where minimal riparian buffer is observed, may assist in maintaining and improving ecological health of the Ōtūkaikino River and Cashmere Stream catchments. Only three sites, out of the eleven sampled, (OTUKAI02, OTUKAI04, and OTUKAI10) had riparian zones with indigenous species. The riparian zones at the rest of the sites largely consisted of mown or pasture grasses. Planting of riparian margins with indigenous and ecologically sensitive species provide canopy cover without concentrated leaf fall periods in the autumn, which aids in reducing macrophyte and algae growth, provides a buffer for overland flow run-off, and provides a consistent and appropriate supply of leaf litter resources (food) for the macroinvertebrate community.
    - Planting margins with taller shrubs and trees can provide greater shading for the stream and decrease water temperatures. Cooler water temperatures could discourage growth of toxic algae.

- For parts of the Ōtūkaikino River catchment that are highly channelised (such as at OTUKAI02), the addition of meandering sections may assist in increasing ecosystem health. Meandering sections will increase the diversity of flow regimes and provide a more diverse range of habitats for macroinvertebrate and fish species.

- Increases to in-stream habitat heterogeneity, especially where there is limited habitat, would assist in enhancing ecological health of the Ōtūkaikino River and Cashmere Stream catchments. The addition of habitats such as maintaining some macrophyte beds, woody debris and logs, leaf packs, and undercut banks, all support a diverse range of macroinvertebrate and fish communities and are essential for maintaining and improving stream health. Emergent and submerged boulders may also be lacking at many sites, and the addition of these would provide habitat essential for egg-laying substrates for both aquatic insects and fishes.

- Minimising intensive land-use change (e.g., urbanisation, intensive farming) in the catchment may assist in maintaining aquatic ecological health.

5.0 References

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Appendix 1: Site photographs from 2022

Upstream looking downstream at OTUKAI01

Downstream looking upstream at OTUKAI01

Upstream looking downstream at OTUKAI02

Downstream looking upstream at OTUKAI02

Upstream looking downstream at OTUKAI03

Downstream looking upstream at OTUKAI03

Upstream looking downstream at OTUKAI04

Downstream looking upstream at OTUKAI04

Upstream looking downstream at OTUKAI05

Downstream looking upstream at OTUKAI05

Upstream looking downstream at OTUKAI06

Upstream looking downstream at OTUKAI08

Downstream looking upstream at OTUKAI08

Upstream looking downstream at OTUKAI09

Downstream looking upstream at OTUKAI09

Upstream looking downstream at OTUKAI10

Downstream looking upstream at OTUKAI10

Upstream looking downstream at OTUKAI11

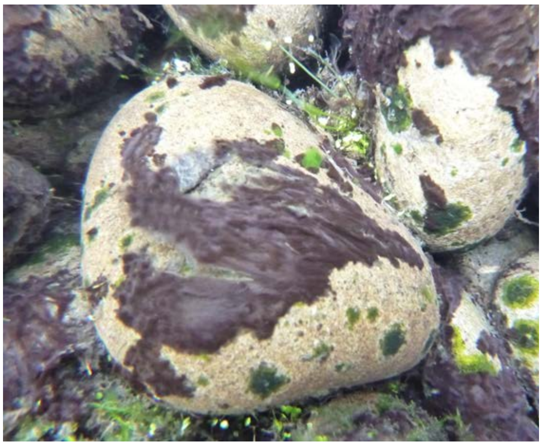
Downstream looking upstream at OTUKAI11

Upstream looking downstream at HEATH27

Upstream looking downstream at HEATH28

Downstream looking upstream at HEATH28

Concrete block TRB at OTUKAI03



Phormidium at OTUKAI08

Inanga caught at HEATH28

Kēkēwai caught at HEATH27

Appendix 2: Sediment quality laboratory results

Hill Laboratories
TRIED, TESTED AND TRUSTED

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Certificate of Analysis

Client:	Boffa Miskell Limited	**Lab No:**	2924838 SPv2
Contact:	Tanya Blakely C/- Boffa Miskell Limited PO Box 110 Christchurch 8140	**Date Received:**	21-Mar-2022
		Date Reported:	20-Apr-2022
		Quote No:	115912
		Order No:	
		Client Reference:	
		Submitted By:	Tanya Blakely

Sample Type: Sediment

Sample Name:		Otukai 01a 21-Mar-2022 11:20 am	Otukai 01b 21-Mar-2022 11:20 am	Otukai 01c 21-Mar-2022 11:20 am	Otukai 02a 21-Mar-2022 12:00 pm	Otukai 02b 21-Mar-2022 12:00 pm
Lab Number:		2924838.1	2924838.2	2924838.3	2924838.4	2924838.5
Individual Tests						
Dry Matter	g/100g as rcvd	19.9	15.4	17.0	33	32
Particle size analysis*‡		See attached report	See attached report	See attached report	See attached report	See attached report
Total Recoverable Copper	mg/kg dry wt	9.3	10.3	10.8	24	29
Total Recoverable Lead	mg/kg dry wt	9.4	9.7	9.4	41	47
Total Recoverable Phosphorus	mg/kg dry wt	730	1,020	1,010	1,350	1,470
Total Recoverable Zinc	mg/kg dry wt	69	69	71	290	340
Total Organic Carbon*	g/100g dry wt	6.2	8.6	7.4	5.6	5.2
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	< 0.18	< 0.3	< 0.3	5.2	3.5
1-Methylnaphthalene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.036	0.016
2-Methylnaphthalene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.026	0.016
Acenaphthene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.029	0.013
Acenaphthylene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.049	0.035
Anthracene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.128	0.069
Benzo[a]anthracene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.35	0.23
Benzo[a]pyrene (BAP)	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.39	0.28
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.008	< 0.010	< 0.009	0.41	0.31
Benzo[e]pyrene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.21	0.166
Benzo[g,h,i]perylene	mg/kg dry wt	0.009	< 0.010	0.011	0.27	0.20
Benzo[k]fluoranthene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.167	0.123
Chrysene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.39	0.28
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.054	0.039
Fluoranthene	mg/kg dry wt	0.010	< 0.010	< 0.009	0.76	0.53
Fluorene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.095	0.036
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.23	0.173
Naphthalene	mg/kg dry wt	< 0.04	< 0.05	< 0.05	0.03	0.03
Perylene	mg/kg dry wt	< 0.008	< 0.010	< 0.009	0.126	0.106
Phenanthrene	mg/kg dry wt	0.007	< 0.010	< 0.009	0.62	0.32
Pyrene	mg/kg dry wt	0.009	< 0.010	0.010	0.79	0.55
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	< 0.018	< 0.03	< 0.03	0.57	0.41
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	< 0.018	< 0.03	< 0.03	0.56	0.41

Sample Type: Sediment						
Sample Name:		Otukai 02c 21-Mar-2022 12:00 pm	Otukai 08a 21-Mar-2022 2:55 pm	Otukai 08b 21-Mar-2022 2:55 pm	Otukai 08c 21-Mar-2022 2:55 pm	
Lab Number:		2924838.6	2924838.7	2924838.8	2924838.9	
Individual Tests						
Dry Matter	g/100g as rcvd	30	73	78	76	-
Particle size analysis*‡		See attached report	See attached report	See attached report	See attached report	-
Total Recoverable Copper	mg/kg dry wt	27	3.6	3.6	3.4	-
Total Recoverable Lead	mg/kg dry wt	43	6.1	6.2	6.0	-
Total Recoverable Phosphorus	mg/kg dry wt	1,420	290	290	290	-
Total Recoverable Zinc	mg/kg dry wt	350	30	30	29	-
Total Organic Carbon*	g/100g dry wt	6.1	0.25	0.23	0.20	-
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	3.7	< 0.05	< 0.05	< 0.05	-
1-Methylnaphthalene	mg/kg dry wt	0.016	< 0.002	< 0.002	< 0.002	-
2-Methylnaphthalene	mg/kg dry wt	0.012	< 0.002	< 0.002	< 0.002	-
Acenaphthene	mg/kg dry wt	0.019	< 0.002	< 0.002	< 0.002	-
Acenaphthylene	mg/kg dry wt	0.035	< 0.002	< 0.002	< 0.002	-
Anthracene	mg/kg dry wt	0.106	< 0.002	< 0.002	< 0.002	-
Benzo[a]anthracene	mg/kg dry wt	0.24	< 0.002	< 0.002	< 0.002	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.30	< 0.002	< 0.002	< 0.002	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.31	< 0.002	< 0.002	< 0.002	-
Benzo[e]pyrene	mg/kg dry wt	0.160	< 0.002	< 0.002	< 0.002	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.181	< 0.002	< 0.002	< 0.002	-
Benzo[k]fluoranthene	mg/kg dry wt	0.129	< 0.002	< 0.002	< 0.002	-
Chrysene	mg/kg dry wt	0.25	< 0.002	< 0.002	< 0.002	-
Dibenzo[a,h]anthracene	mg/kg dry wt	0.039	< 0.002	< 0.002	< 0.002	-
Fluoranthene	mg/kg dry wt	0.59	< 0.002	< 0.002	< 0.002	-
Fluorene	mg/kg dry wt	0.051	< 0.002	< 0.002	< 0.002	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.168	< 0.002	< 0.002	< 0.002	-
Naphthalene	mg/kg dry wt	< 0.03	< 0.010	< 0.010	< 0.010	-
Perylene	mg/kg dry wt	0.091	< 0.002	< 0.002	< 0.002	-
Phenanthrene	mg/kg dry wt	0.43	< 0.002	< 0.002	< 0.002	-
Pyrene	mg/kg dry wt	0.54	< 0.002	< 0.002	< 0.002	-
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.43	< 0.005	< 0.005	< 0.005	-
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.43	< 0.005	< 0.005	< 0.005	-

Analyst's Comments

‡ Analysis subcontracted to an external provider. Refer to the Summary of Methods section for more details.

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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 Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-9
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%.	-	1-9
Polycyclic Aromatic Hydrocarbons Trace in Soil*	Sonication extraction, GC-MS analysis. Tested on as received sample. In-house based on US EPA 8270.	0.002 - 0.03 mg/kg dry wt	1-9

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. (Free water removed before analysis, non-soil objects such as sticks, leaves, grass and stones also removed). US EPA 3550.	0.10 g/100g as rcvd	1-9
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-9
Particle size analysis*	Malvern Laser Sizer particle size analysis from 0.05 microns to 3.4 mm. Samples are measured in volume %. Subcontracted to Earth Sciences Department, Waikato University, Hamilton.	-	1-9
Total Recoverable Copper	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.2 mg/kg dry wt	1-9
Total Recoverable Lead	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.08 mg/kg dry wt	1-9
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	1-9
Total Recoverable Zinc	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.8 mg/kg dry wt	1-9
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-9

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

Testing was completed between 23-Mar-2022 and 20-Apr-2022. 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.

Kim Harrison MSc
Client Services Manager - Environmental

About Boffa Miskell

Boffa Miskell is a leading New Zealand professional services consultancy with offices in Whangarei, Auckland, Hamilton, Tauranga, Wellington, Christchurch, Dunedin, and Queenstown. We work with a wide range of local and international private and public sector clients in the areas of planning, urban design, landscape architecture, landscape planning, ecology, biosecurity, cultural heritage, graphics and mapping. Over the past four decades we have built a reputation for professionalism, innovation and excellence. During this time we have been associated with a significant number of projects that have shaped New Zealand's environment.

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