Traverse Environmental

Water quality in the lower Taiari/Taieri River catchment

A summary of monitoring activities and findings

Prepared for: Upper Taieri Wai

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Water quality in the lower Taiari/Taieri River catchment: A summary of monitoring activities and findings

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Executive summary

The Taiari/Taieri (Taieri) River is the fourth longest river in New Zealand and has significant natural, ecological, recreational and cultural values. The Upper Taieri Wai, a community-led catchment group dedicated to resource management issues in the upper Taieri catchment, is both overseeing and supporting activities to understand and enhance water quality throughout the entire Taieri catchment, including through the Healthy Taieri Integrated Farm Planning (IFP) project. Although the IFP project operates catchment-wide, separate reports have been prepared for communities in each of the upper, mid and lower Taieri catchments to provide a focus on water quality at a more localised scale. This report addresses the lower Taieri catchment, covering the area downstream of Outram Glen and the catchments of Lakes Mahinerangi, Waipori and Waihola.

This report:

- outlines details of current and historical water quality monitoring carried out by the Otago Regional Council (ORC) and other organisations to date,
- summarises what is known about water quality state and trends from monitoring and investigations, and
- identifies water quality issues and associated information gaps and monitoring priorities.

A detailed summary of each of these topics is included within the body of the report.

Monitoring activities and information

A considerable amount of information exists on water quality in the lower Taieri River catchment. The ORC's state of the environment (SOE) monitoring programmes currently include physical, chemical and microbiological water quality monitoring at seven river sites, three lake sites and four groundwater sites. Ecological monitoring is more limited, although macroinvertebrates are monitored at some river sites and aquatic vegetation has been surveyed in Lake Waihola. The Taieri River at Outram and Lake Waihola are also monitored weekly over summer as part of the ORC's recreational water quality monitoring programme.

Other organisations collecting significant amounts of water quality information on an ongoing basis include:

- the Dunedin City Council (DCC) in relation to raw water sourced for drinking water supplies, and
- the Clutha District Council in relation to the discharge of treated wastewater from Waihola township into an outlet channel of Lake Waihola.

The University of Otago has also carried out extensive research in the Lower Taieri involving the collection of water quality, ecological and other data, particularly in and around Lake Mahinerangi and the Lakes Waipori-Waihola Wetland Complex. More recently, the Department of Conservation has completed ecological surveys of various stream sites in the lower Taieri catchment as part of its Te Mana o Taiari project. Several schools have also carried out monitoring in the Ōwhiro Stream catchment.

Current state and trends in water quality

Recent ORC assessments (mostly spanning 2017–2022) indicate that water quality in the Taieri River is 'good' when compared with other lowland rivers in New Zealand. However, water quality in the river deteriorates across the intensively farmed lower Taieri Plain due to multiple inputs of agricultural drainage water and nitrate-enriched groundwater. Other streams on the lower Taieri Plain are similarly impacted, in particular the lower reaches of the Silver Stream and Ōwhiro Stream which are classified and maintained as scheduled drains under the ORC's flood protection management bylaw. The Silver Stream at Riccarton Road West has reduced baseflows in summer which, in combination with nitrate-enriched groundwater inflow, stimulates nuisance algal growth. Macroinvertebrate health is also degraded at this site, falling into Band D – below the minimum acceptable state – under the National Policy Statement for Freshwater Management (NPS-FM 2020). Most monitored river and stream sites have poor stream habitat for macroinvertebrates – streambed siltation, a lack of riparian shade and low diversity in flow types are widespread issues.

Weekly monitoring of *E. coli* concentrations in the Taieri River at Outram Glen over summer indicates that this site is suitable for swimming except during or following significant rainfall in the upstream catchment. In contrast, faecal contamination is frequent and significant at monitored sites in the middle and lower Taieri Plain (the Silver Stream at Taieri Depot, Meggat Burn at Henley-Berwick Road and Taieri River at Allanton).

The ORC's most recent water quality trend assessments indicate plant-available and total phosphorus concentrations decreased (i.e., an improvement) at both sites on the mainstem of the lower Taieri River and the lower Silver Stream over the 10-year period ending June 2022, while nitrate nitrogen concentrations increased at a rate of over 9% per year in one groundwater well north of Mosgiel. The reasons for the observed trends are unclear. Little information is available on trends in ecological health owing to limited data.

Water quality in Lake Waihola is poor and fails to meet minimum acceptable standards for several attributes under the NPS-FM. The lake is nutrient- and algae-enriched (eutrophic), and cyanobacteria blooms pose a risk to contact recreation in most summers. No clear improving trends have been reported in lake water quality although a recent vegetation survey by NIWA found the lake has retained good native plant values. Lake Waipori is also eutrophic and although no recent trend information exists, its condition is unlikely to have changed significantly since it was last assessed in 2017.

Information gaps and monitoring considerations

Visual water clarity (the suspended fine sediment attribute in the NPS-FM) is currently estimated by the ORC from turbidity measurements using a national equation that was not intended to apply to tannin-stained waters such as the Taieri River, Waipori River and Meggat Burn. This contributes to monitoring sites on these rivers being classified in more degraded states of Band C or D under the NPS-FM. Visual clarity measurements are needed for a more meaningful assessment of the suspended fine sediment attribute.

The Ōwhiro Stream has not been monitored by the ORC since 2018 but is likely still in a very degraded state. Consistently elevated concentrations of ammoniacal nitrogen at Riverside Road suggest the stream may be impacted by wastewater. This warrants investigation through faecal source tracking.

Long-term ecological and physical stream habitat data are lacking for rivers and streams in the lower Taieri catchment. Monitoring of periphyton biomass and streambed sediment cover is currently limited to the lower Silver Stream. Overall, regardless of what monitoring is carried out, most natural streams on the lower Taieri Plain are managed as scheduled drains and will likely remain in poor ecological condition from activities associated with maintaining them as such (e.g., removal of substrate and spraying of stream banks). Therefore, a greater priority than monitoring is to explore with the ORC's flood protection staff what can be achieved in the way of habitat enhancement to support the native fish values that currently still exist, without unduly compromising flood capacity.

Most of the farming in the vicinity of Lake Waipori on the lower Taieri Plain takes place on poorly drained soils and would not be possible without the construction of extensive artificial drainage to lower the underlying groundwater table. Although the ORC has ceased monitoring both the Main Drain and Contour Channel, these drainage systems still receive significant concentrations of sediment, nutrients and other contaminants. Both effectively represent point-source discharges to the Lakes Waipori-Waihola Wetland Complex and, similar to treated wastewater discharges from the Dunedin Airport and Waihola township, should be monitored under a consenting framework. Sites on these waterways could equally be monitored as part of a programme to assess the effectiveness of policies for managing contaminants from agricultural land use and septic tanks in the pending new Land and Water Plan. In any case, an up-to-date assessment of nutrient loads entering the Lakes Waipori-Waihola Wetland Complex from all sources would help inform strategies to improve water quality in both lakes.

No recent monitoring data exists for the Taieri River Estuary. Although a baseline assessment in 2007 reported the estuary to be in good health, more recent catchment and estuary modelling suggests that this may not be the case. Similarly, Lake Mahinerangi is not monitored by the ORC and its current condition is unknown.

Lastly, with residential development in Mosgiel and surrounding areas such as the East Taieri rapidly expanding, the impact of urban stormwater on water quality in the lower Taieri appears to be an information gap. Wet weather water quality monitoring in the Silver Stream by the DCC in 2022 found elevated concentrations of copper and zinc at Riccarton Road West compared with upstream of Mosgiel. Metal concentrations are likely higher at other locations, including within more highly trafficked and industrial areas.

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1 Introduction

The Taieri/Taiari[1] River is the fourth-longest river in New Zealand and has significant natural, ecological, recreational and cultural values. The river's headwaters originate in the Lammermoor and Lammerlaw Ranges in Central Otago. The river flows through three plains – the Upper Taieri, Strath Taieri and Lower Taieri – enroute to the sea, 30 km south of Dunedin. The Otago Regional Council (ORC) carries out water quality monitoring within each of the plains as part of its statutory role in managing river health. In recent years, consistent with a nationwide trend, landowners and catchment-based groups have also carried out monitoring, helping to fill important gaps in understanding of river health.

This report was prepared for the Upper Taieri Wai to support the activities of the Healthy Taieri Integrated Farm Planning (IFP) project. Water quality is one of three major focal points for the project. Although the IFP project operates catchment-wide, separate reports have been prepared for communities in each of the upper, mid and lower Taieri catchment areas to provide a focus on water quality at a more localised scale. This report is focused on the lower Taieri catchment and covers the area between Outram Glen and Taieri mouth, including Lakes Mahinerangi, Waipori and Waihola.

1.1 Report purpose and scope

The primary aim of this report is to collate what is known about water quality in the lower Taieri catchment to inform freshwater farm plan development associated with the Taieri IFP project and other activities, such as community-based monitoring and restoration. Specifically, the report:

- outlines details of current and historical water quality monitoring carried out by different organisations,
- summarises what we know about water quality state and trends, based on existing readily available reports and data, and
- identifies water quality issues and associated information gaps and monitoring priorities.

A series of ArcGIS layers has been provided with the report containing the key details of surface water quality monitoring and investigation sites, as well as groundwater quality, river level/flow and rainfall monitoring sites. These layers also include monitoring sites across the upper and mid Taieri; separate reports, similar in format to this one, have been prepared for those areas (see Milne & Rados 2024, Milne 2024).

1.2 Limitations

This report has relied heavily on existing reports and collated or summarised data from third parties. Incomplete details, conflicting information and errors were followed up where possible, but it was beyond the scope of this project to re-examine data sets. Additional analyses of already reported data were also out of scope but some further analysis was done to help illustrate or understand particular issues.

Although water quality information associated with university research projects and resource consents is summarised, the search was not exhaustive and it is likely that additional information exists to that captured here.

[1] The Taiari River, Waipōuri River and Lake Waihora are the correct Māori names for the Taieri River, Waipori River and Lake Waihola, respectively. These names are yet to be formally adopted within the catchment. To avoid potential confusion with the names of long-established monitoring sites and, the more widely known spellings of Taieri, Waipori and Waihola are used in this report except where the correct spellings form part of an established identity or project name.

2 Lower Taieri catchment

The lower Taieri catchment is located west of Dunedin, within the jurisdictions of Dunedin City in the north and east, and within the Clutha District in the south and west. Mosgiel, on the eastern margins of the lower Taieri Plain, is the most densely populated township, with a population of 14,800 and growing[2]. The 180 km^2 plain is flanked by the Maungatua Range in the north (895 m) and a seaward range of which Saddle Hill (473 m) and Scrogg's Hill (355 m) are the highest points.

After entering the lower Taieri Plain at Outram, the Taieri River meanders south crossing the plain towards Allanton, creating two distinctly separate areas, locally referred to as 'East Taieri' and 'West Taieri'. The river then turns southwest at Allanton and exits the plain at Henley Ferry (Figure 2-1).

The two main tributaries of the lower Taieri River are the Silver Stream and Waipori River. The Silver Stream originates in the Silver Peaks Range in the northeast and joins the Taieri River north of Allanton. The Waipori River rises in the Lammerlaw Range and flows southeast. Dammed in its middle reaches for hydroelectric power generation in the early 1900s – creating Lake Mahinerangi in the process – the Waipori River joins the Taieri River downstream of SH 1 at Henley Ferry. At this point the Taieri River turns south-southeast, flowing through the Lower Taieri (Henley) Gorge before flowing into the Pacific Ocean at Taieri Mouth. Multiple streams and cut-off drainage channels are contained entirely within the lower Taieri River catchment. These include Mill Stream, Ōwhiro Stream, Lee Creek, Contour Channel, Main Drain and Meggat Burn (Figure 2-1).

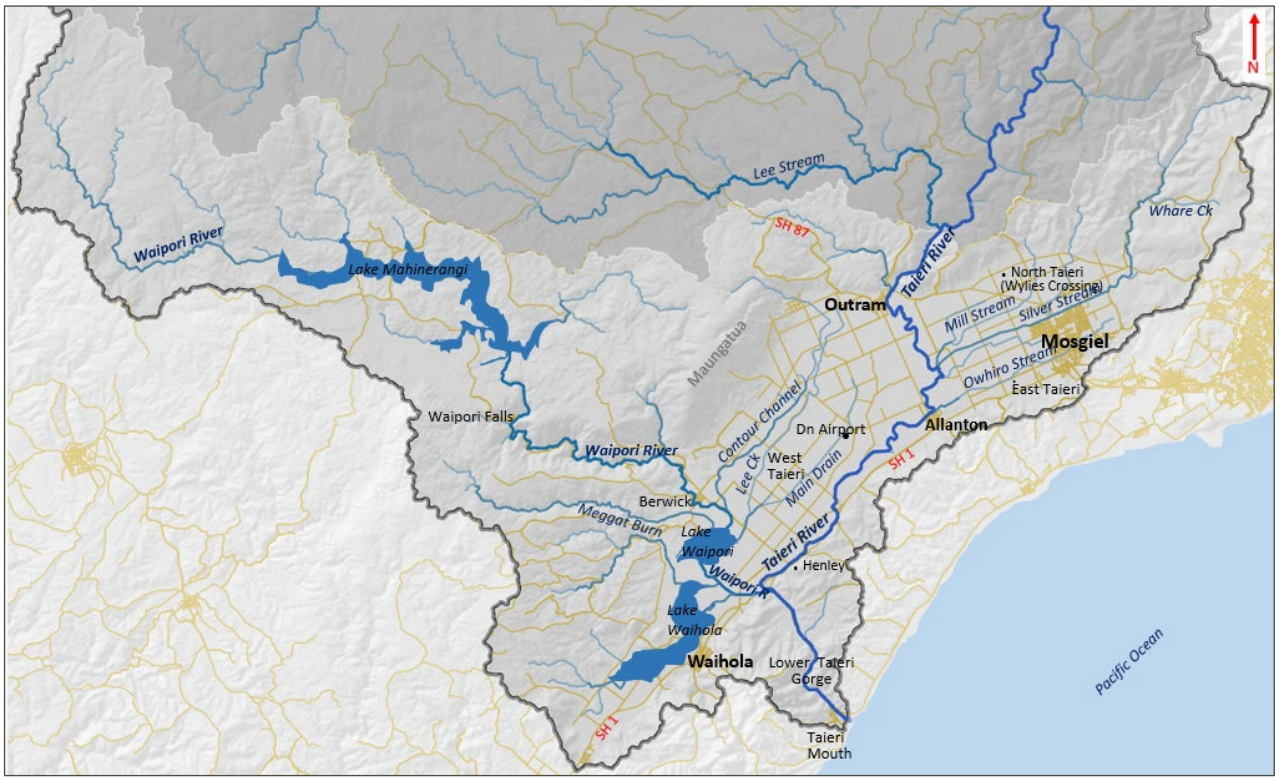

Figure 2-1: The lower Taieri catchment and key locations, roads and water bodies referred to in this report. Outram Glen marks the upstream boundary for the this part of the catchment.

The lower Taieri Plain is very low-lying and in its lower reaches the Taieri River is tidally influenced. The tidal influence varies with river flow but extends a considerable distance upstream, at least as far as Allanton (O'Sullivan et al. 2013). This results in a significant backflow of Taieri River water up the lower Waipori River, and into Lakes Waihola and Waipori and their associated wetlands. Groundwater levels are also tidally influenced and this affects water levels in several drains, including the lower reaches of the Main Drain (e.g., Schallenberg et al. 2003).

[2] Statistics NZ, based on Census 2018 data.

Multiple reports describe the topography, soils, vegetation, land use, climate, geology, hydrology and the natural, ecological, recreational and cultural values of the lower Taieri catchment (e.g., ORC 2021, Ryder & Tocher 2020, O'Sullivan et al. 2013, Rekker & Houlbrooke 2010). Selected key points drawn from these and other reports are summarised below to provide some context for understanding water quality in the lower Taieri catchment.

2.1 Climate

The lower Taieri Plain has a sub-humid cool-temperature climate, characterised by mild summers and cold winters. Average annual air temperatures fall in the range of 10-11ºC, with records for Dunedin Airport indicating that, on average, maximum temperatures exceed 25ºC on 20 days per year and minimum temperatures fall below 0ºC on 66 days per year. The hottest and coldest temperatures recorded at Dunedin Airport between 1981 and 2010 were 35.7ºC and -8.8ºC (Macara 2015).

Average annual rainfall is between 700 and 800 mm on the lower Taieri Plain. In contrast, annual average rainfall in the surrounding hills is much higher at around 1,200 mm. Rainfall is distributed relatively evenly over the seasons, although rainfall totals are lower in winter than summer. At Dunedin Airport between 1981 and 2010, 31% of the annual rainfall fell in summer (December to February). On average, there were 107 days a year when greater than 1 mm of rainfall was recorded, with late spring/early summer recording the greatest number of these 'wet' days (Macara 2015).

2.2 Hydrology

The hydrology of the lower Taieri Plain has been substantially altered from what it once was following large-scale clearance and drainage of predominantly marsh and wetland vegetation with the commencement of European settlement from the 1860s onwards. This includes channelisation of natural streams once they reach the Lower Plain and an extensive artificial drainage network (see section 2.2.1). An example is the Contour Channel, which was constructed to collect runoff from the streams that drain the Maungatua Range and divert it into Lake Waipori. Some streams are ephemeral (i.e., do not flow year-round).

Flows in the lower reaches of the Taieri River are generally lowest towards the end of summer and highest during spring. The ORC has set a minimum flow of 2.5 m^3/s at Outram, below which all consented water takes linked to this site must cease.

The Taieri River's primary tributary, the Waipori River (median flow 4.1 m^3/s at Berwick), is dammed in four locations, allowing the generation of hydro-electric power at Waipori Falls. This results in highly regulated flows in the middle reaches below Lake Mahinerangi, with seasonal hydro-electricity generation influencing the balance between freshwater and saline inputs – and therefore water quality – downstream in Lake Waipori.

In terms of groundwater on the lower Taieri Plain, according to Rekker and Houlbrooke (2010):

- The general direction of flow mirrors the land surface, flowing from northeast to southwest; from north of Mosgiel to low-lying areas such as the West Taieri Drainage Scheme and the Lakes Waipori–Waihola Wetlands complex (Figure 2-2). Groundwater abstraction, the West Taieri Drainage Scheme and the lakes contribute to variation in groundwater levels on a localised scale.
- Supplies are replenished by a combination of recharge from rainfall and river water infiltration (via riverbed seepage). For example, the Silver Stream loses in the order of 30 L/s of its flow in the ~2 km stretch between Puddle Alley and Wingatui Road in Mosgiel. Some inflow also takes place into the West Taieri Drainage Scheme because of upward groundwater seepage from the underlying aquifer.
- Groundwater in Mosgiel and North Taieri appears to lack confining sediment layers found further down the lower Taieri Plain, meaning that there is a stronger interaction with the overlying surface waters in this area of the Plain compared with the West Taieri. Moderate to high nitrate concentrations occur at depth in these areas, indicating soil drainage infiltrates the underlying groundwater. In contrast, nitrate concentrations are much lower in the west Taieri where a silt/sand confining layer prevents contaminated surface water from farming operations infiltrating the groundwater (Kensington et al. 2004).

- A few areas of artesian groundwater exist at Wylie's Crossing in the East Taieri and the lower West Taieri Drainage Scheme area.

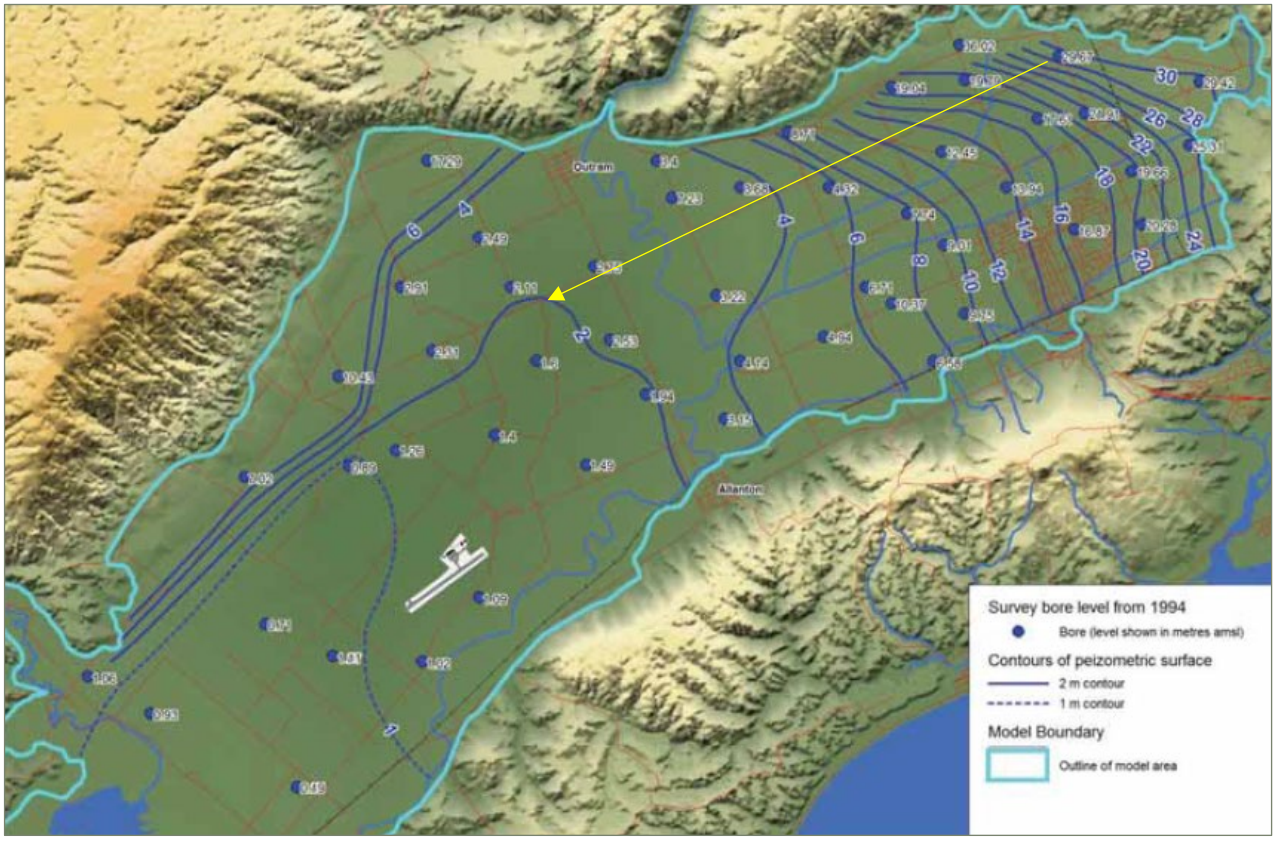

Figure 2-2: Contours of potentiometric surface from a 1994 survey of groundwater levels on the Lower Taieri Plain, with the approximate groundwater flow direction indicated in yellow. Modified from Rekker and Houlbrooke (2010).

2.2.1 Drainage and flood protection

The lower Taieri Plain has a long history of flooding, and development of drainage and flood protection works goes back to the early 1900s. The land is very low-lying, gently sloping from about 40 m above mean sea level at its northern end to within a couple of metres of sea level in the southwest (Rekker & Houlbrooke 2010). Some West Taieri farmland is slightly below mean sea level; the lowest parts of the plains, excluding drains and ditches, lie about 1.5 m below mean sea level.

The ORC's Lower Taieri Flood Protection Scheme comprises a series of flood banks, artificial drainage channels, detainment ponds, pump stations and spillways (Figure 2-3). These features connect with the Taieri River and the various streams that traverse the Plain.

There are separate drainage schemes for the East Taieri and West Taieri. The East Taieri Drainage Scheme is split into two areas by the Silver Stream; drains on the northern side of the stream generally flow toward the Upper Ponding area while drains on the southern side flow toward the Lower Ponding area (Figure 2-3). When the flow of the Taieri River is low, these drains flow out to the river by gravity. Pump stations are used when flows in the Taieri River are high (Figure 2-4, ORC website).

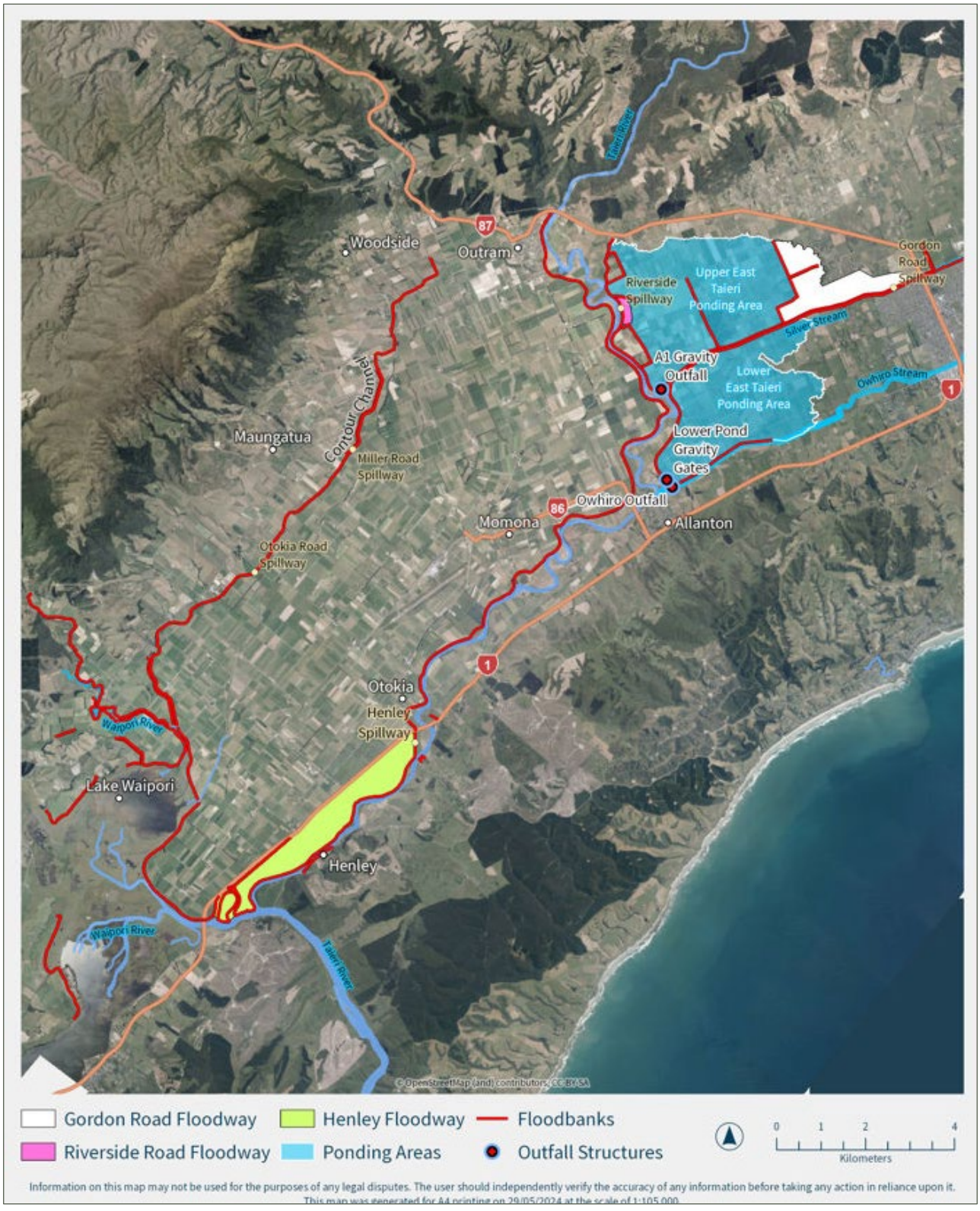

Figure 2-3: The Lower Taieri Flood Protection Scheme. Source: ORC website[3].

[3] https://www.orc.govt.nz/managing-natural-hazards/flood-defences/flood-drainage-and-river-management/lower-taieri-flood-protection-scheme/ (accessed July 2024).

Figure 2-4: The East (left) and West Taieri drainage schemes. Source: ORC website[4].

The West Taieri Drainage Scheme incorporates the Contour Channel, an artificial drain that intercepts streams from the Maungatua Range before they can enter the drainage scheme area. Water in the Contour Channel is conveyed south-westward where it flows into Lake Waipori, via the lower Waipori River (Figure 2-4). A series of other drains operate across the West Taieri, including the Taieri Main Drain along the central plain which collects flows from Kirk Drain and Lee Canal (Drain) before being pumped into Lake Waipori at the Waipori pump station on the eastern side of the lake.

As most of the West Taieri Plain lies at or below 1 m of sea level, the Waipori pumping station is relied upon even during normal low-flow conditions, to prevent the area from transforming back to its former swamp-like state (Ozanne et al. 2017). There are also pump stations at Lake Ascog and Henley (Figure 2-4).

2.3 Land cover, soils, land use and irrigation

The lower Taieri catchment comprises a mix of farmland and exotic forestry, interspersed with indigenous forest, tussock and urban areas. Drystock farming dominates in the Lake Mahinerangi subcatchment while dairying dominates on the lower Taieri Plain. Sheep, beef and deer are also grazed on the lower Taieri Plain, supported by forage cropping. Market gardening was once significant in the Outram and East Taieri areas but in recent decades has largely made way for rural residential lifestyle blocks. Mosgiel and East Taieri have also grown significantly and rapidly over the last 15-20 years (DCC 2024) and are likely some of the fastest growing areas of Dunedin City.

Landcare Research's online Soils Map Viewer indicates that brown soils dominate the higher elevation areas of the lower Taieri catchment while the lower Taieri Plain is dominated by waterlogged gley soils, a reflection of the very high groundwater table. Recent soils are found in the alluvial floodplains of the Taieri River and Silver Stream.

Mercury Energy's Mahinerangi Wind Farm is located to the north of the Lake Mahinerangi and has been operational since early 2011.

[4] https://www.orc.govt.nz/managing-natural-hazards/flood-defences/flood-drainage-and-river-management/lower-taieri-flood-protection-scheme/ (accessed July 2024).

The lower Taieri Plain is home to Dunedin International Airport and includes sections of two highways (SH 1 and SH 87). In addition to primary industry, the lower Taieri Plain includes secondary processing, manufacturing and service industry land uses.

The Lakes Waipori-Waihola Wetland Complex is located at the southwestern end of the plain and is a remnant of a much larger wetland that once covered much of the plain. It incorporates a mix of willows, flax and indigenous wetland species (raupo and mingimingi scrub).

Surface water in the lower Taieri River catchment is fully allocated, with irrigation and potable water supply the primary uses (although the Dunedin City Council's (DCC) potable supply is taken from groundwater, the water is considered a surface take because the wells are shallow and known to draw almost exclusively on Taieri River water entering via bank infiltration). In contrast, groundwater only supplies a small proportion of irrigation needs relative to surface water, and plenty of allocation remains (Rekker & Houlbrooke 2010). Up until December 2017, when the DCC switched Mosgiel's water supply from bore water to the Dunedin City water supply[5], the Mosgiel water supply represented the largest use on a volumetric basis of lower Taieri groundwater, followed by the extraction and re-injection of groundwater used in 'ground source' heat exchangers at Dunedin International Airport (Rekker & Houlbrooke 2010). Many rural residential private water supplies still rely on the underlying groundwater for domestic or stockwater supply. Most groundwater wells are at a depth of between 0 and 40 m.

Multiple dairyshed wastewater discharges and the Mosgiel Wastewater Treatment Plant once discharged to surface water in the lower Taieri catchment. Today, three consented discharges of treated wastewater to surface water remain:

- Dunedin International Airport and Momona Village (currently consented until October 2026 to discharge up to 154 m^3 per day of treated wastewater into the Main Drain),
- Waihola township (up to an average of 160 m^3 per day until May 2028), and
- Waipori Falls Village (up to an average of 15 m^3 per day until October 2029).

Septic tanks or other on-site wastewater systems are used in some parts of the lower Taieri catchment, including Outram, Berwick and Henley.

2.4 Aquatic ecological and recreational values

Some key values:

- The Lakes Waipori-Waihola Wetland Complex is a regionally significant wetland. Several other small regionally significant wetlands exist, including Otokia Swamp, Henley Swamp and Takitakitoa Swamp.
- Multiple native fish species are known to be found in the lower Taieri catchment, including kōaro and common bully in the Lammerlaw Stream. Two species, the Eldon's and Dusky galaxiids, are classified as nationally endangered. A further two galaxiid species, the Roundhead and Flathead galaxiids, are nationally vulnerable. Both the longfin eel and lamprey are classified as declining.
- The Taieri River supports a regionally significant trout fishery, with many tributaries (e.g., the Silver Stream) providing important habitat for trout spawning and juveniles. The Waipori River also provides habitat for trout.
- Lake Mahinerangi is stocked with brown trout and some perch, and popular for recreational fishing.
- Popular spots for swimming include the Taieri River at Outram Glen and Taieri Mouth. The Taieri River at Henley and Lake Waihola are popular for boating-based activities.

[5] The switch was made to minimise potential health risks associated with supplying untreated bore water and followed a review of risks following a public health outbreak in Havelock North (Otago Daily Times, 5 Dec 2017: https://www.odt.co.nz/news/dunedin/dcc/mosgiel-switch-city-water-supply).

3 Water quality monitoring – who has done and is doing what?

Routine water quality monitoring in the lower Taieri catchment dates back to the mid-1980s. While the ORC has carried out most of the monitoring to date, the University of Otago has carried out extensive monitoring as part of various research projects. Other organisations and groups have also collected data on a one-off, short-term or ongoing basis to meet resource consent requirements or support community interests and initiatives.

This section presents a summary of the readily available monitoring and investigation activities carried out to date, with a focus on what each organisation or entity has monitored, where and when. Collating a record of monitoring activities in the catchment provides an important first step in identifying gaps in understanding and priorities for future monitoring.

Water quality and ecosystem health

Water quality includes physical, chemical and biological characteristics. Water quality in rivers, streams and groundwater is usually described and assessed in terms of its suitability to support particular uses or values, such as recreation, ecosystem health, drinking and food gathering.

Good water quality is important for supporting healthy freshwater ecosystems but is only one of five components of river health defined under the National Policy Statement for Freshwater Management (NPS-FM) 2020. The other components are *aquatic life* (e.g., plants, macroinvertebrates, fish), *habitat* (e.g., the composition of the riverbed, shade), *ecosystem processes* (e.g., nutrient cycling) and *water quantity* (e.g., flows).

Although water quality is the focus of this report, current and historical monitoring activities are summarised across all five components of river health. Soil quality monitoring is also summarised because of the known linkages between soil health and water quality.

3.1 Otago Regional Council

The ORC carries out both routine State of the Environment (SOE) monitoring and recreational water quality monitoring in the lower Taieri. On occasion the ORC also carries out one-off or short-term investigations targeting specific water quality issues or information gaps.

3.1.1 State of the Environment monitoring

A primary goal of SOE water quality monitoring is to track changes in water quality over time. This requires consistency in monitoring site locations, indicators and methods. In reality, sites, indicators and methods do change, primarily as a result of reviewing the cost and value of the information gained from monitoring, the emergence of new national legislation (e.g., the NPS-FM 2020) or environmental pressures, and developments in monitoring practices (e.g., National Environmental Monitoring Standards) and technology.

River water quality and ecology

The ORC currently has seven SOE monitoring sites in the lower Taieri catchment (Figure 3-1): two each on the Taieri River (Outram and Allanton) and Silver Stream (Three Mile Hill Road and Taieri Depot), and one each on the Waipori River (Waipori Falls Reserve), Whare Creek (Whare Flat Road) and the Meggat Burn (Berwick Road). In the past, some other sites were also monitored, including the Ōwhiro Stream at Riverside Road, the Taieri River at Henley Ferry Bridge and two drains: the Contour Channel (No. 4 Bridge) and Taieri Main Drain at Waipori Pump Station.

Although monitoring at some sites dates back to the 1980s, the record has started and stopped over time. However, both Taieri River mainstem sites now have an unbroken monthly record of at least 10 years.

At each SOE site, water samples are collected monthly[6] and measured for water temperature, pH, turbidity and concentrations of dissolved oxygen (DO), conductivity, plant-available nutrients (ammoniacal nitrogen, nitrate-nitrite nitrogen and dissolved reactive phosphorus (DRP)), total nitrogen (TN), total phosphorus (TP) and *E. coli* indicator bacteria. This measurement suite is similar to that adopted by most regional councils, the main difference being that most councils also routinely measure visual water clarity (as discussed later in this report, the ORC estimates this from turbidity measurements).

Once a year during stable river flows in late summer/early autumn, the riverbed invertebrate community (e.g., insects, snails and worms) is sampled and rapid assessments made of physical habitat quality (e.g., bank stability, riparian vegetation, shade) at wadeable sites. In addition, periphyton biomass and deposited fine sediment cover are monitored monthly on the lower Silver Stream, while at Outram Glen:

- water temperature has been monitored at high frequency (every 5-15 minutes) since February 1999,
- DO has been monitored at high frequency since March 2023, and
- the amount of riverbed periphyton (algae) was assessed monthly – when river flows allowed – as chlorophyll *a* biomass (rock scrapings) between August 2019 and June 2022.

Both water temperature and DO vary across the day and seasonally, so high frequency monitoring is needed to capture the extreme lows and highs that can influence river and stream health. These measurements are also needed to calculate ecosystem metabolism, an indicator of energy producing and consuming processes in rivers and an attribute regional councils must monitor under the NPS-FM 2020.

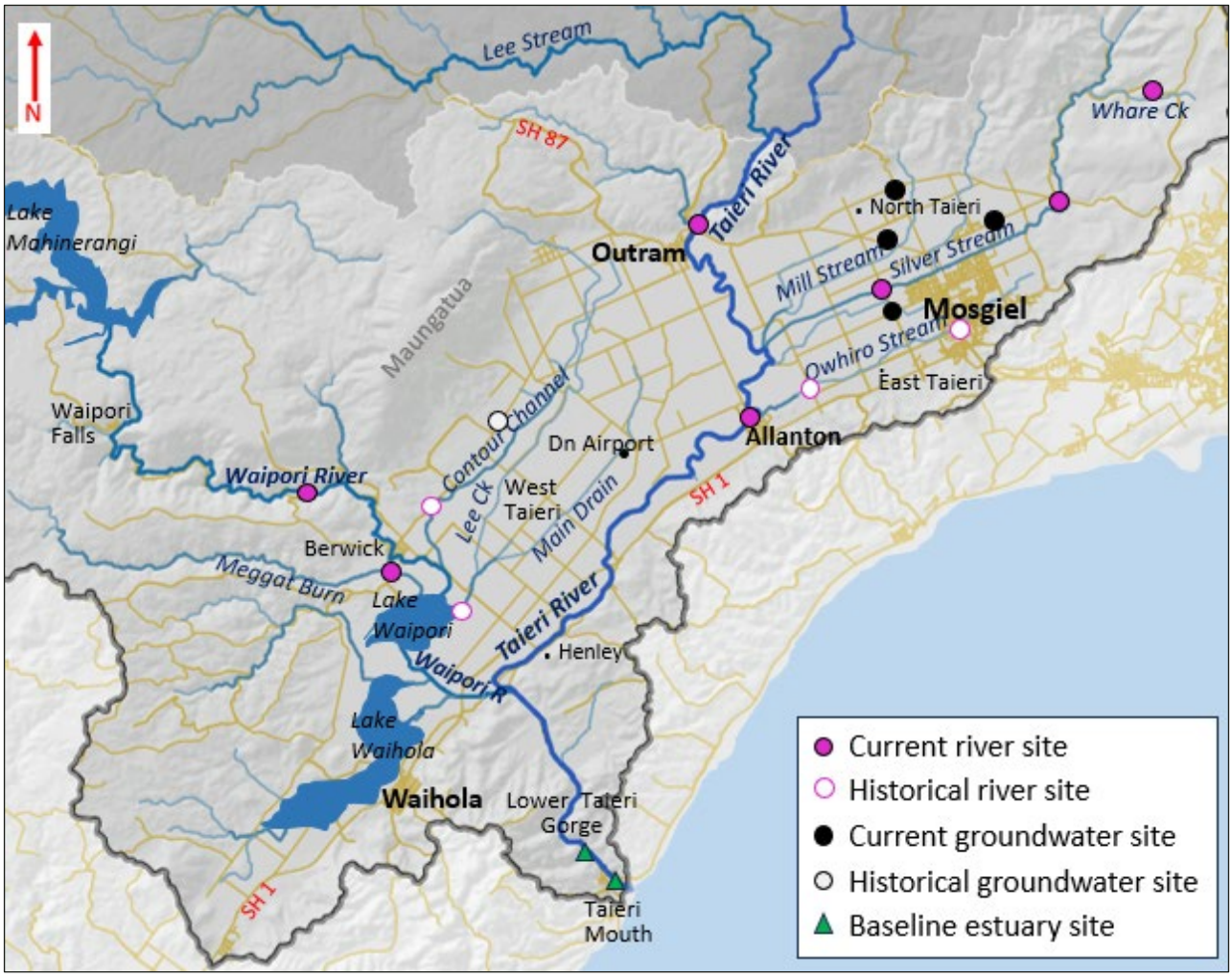

Figure 3-1: Current and historical ORC SOE river and groundwater quality monitoring sites in the lower Taieri catchment. Baseline estuary monitoring sites are also shown.

[6] Prior to July 2014, water sampling was two-monthly and, in some years, samples were only collected on five occasions.

Lake water quality and ecology

The ORC began routine monitoring of water quality in Lake Waihola in 1994. Initially monitoring was limited to the jetty on the southern side of the lake. A programme dedicated to understanding the nutrient status of both Lakes Waihola and Waipori was implemented at five sites from spring 2002 to spring 2004 (ORC 2005), and repeated from spring 2014 to spring 2016 (ORC 2017). SOE water quality monitoring continues to the present day at two sites in Lake Waihola and one site in the middle of Lake Waipori. Water level is measured at each site along with a suite of water quality tests, including nutrients, chlorophyll *a* and suspended sediment. The ORC also monitors water level in Lake Waipori at the Waipori Pump Station.

Lake trophic state monitoring

The trophic level index (TLI) is a common descriptor of lake water quality and health based on the amount of nutrients and phytoplankton (algae) in the lake. Lakes in pristine condition typically have very low nutrient and algal biomass levels. As lakes become more enriched due to changes in land-use and land management practices, lake nutrient levels and algal productivity increases, lakes become murky and their health is compromised.

The TLI is typically calculated from at least two years of monthly measurements of water column concentrations of total nitrogen, total phosphorus and chlorophyll *a*. Sometimes a fourth variable, visual water clarity, is also included (known as TLI-4).

The TLI ranges from 0 (ultra-microtrophic or practically pure water) to > 6 (hypertophic or extremely high nutrient enrichment), based on national lake monitoring guidance produced by Burns et al. (2000). It is a common indicator used in regional and national SOE reporting of lake health.

In 2023, the ORC engaged NIWA to complete a baseline survey of the structure and composition of aquatic vegetation present in Lake Waihola. This is the most comprehensive survey to date and is intended to be repeated at regular intervals (Hugo Borges, pers. comm. 2024). Five sites were assessed for both native and introduced aquatic plants using the Lake Submerged Plant Index (LakeSPI), a nationally recognised method for assessing the ecological condition of lakes. Key assumptions of the LakeSPI method are that native plant species and high plant diversity represent healthier lakes or better lake condition (Clayton & Edwards 2006, de Winton et al. 2012).

Lake Mahinerangi is not currently monitored by the ORC. Some historical water quality data exist (see section 3.4).

Coastal water quality and ecology

In 2007 the ORC commissioned Ryder Consulting to carry out a baseline survey of the Taieri River Estuary (Stewart 2008). This included mapping of the estuarine habitat and a detailed assessment at two sites (Figure 3-1) of sediment particle size and quality (organic matter, metals and nutrient content) as well as invertebrates and algal cover. This monitoring was intended to form part of a long-term estuary monitoring programme but no further monitoring has been carried out to date (Sam Thomas, ORC, pers. comm. 2024). However, nutrient loads entering the estuary and the estuary's eutrophication status have been recently modelled as part of a regional assessment of estuaries in Otago (Snelder 2021, Plew 2021).

River flow/level and rainfall

River flow monitoring is currently carried out at three sites: Taieri River at Outram (since April 1968), Silver Stream at Gordon Rd (July 1975) and Waipori River at Berwick (July 1988). Based on the ORC's Environmental Data Portal, a further eight sites are routinely monitored for water levels (river stage): Taieri River at Mill Creek Pump, Ōwhiro Stream Gated Outfall Structure, Otokia and Henley Pump, the Silver Stream at Silver Stream Pump, Silver Stream Pump at East Taieri Detention Pond, Henley Pump, and the Main Drain at Waipori Pump Station. Monitoring records for most of these sites date back to the early 1990s or 2000s.

The ORC monitors rainfall in the Silver Stream catchment at Swampy Spur and on the Taieri Plain at Taieri Depot. The Swampy Spur site, along with rainfall and flow sites within parts of the mid-Taieri catchment (see Milne 2024), are collectively used to warn of potential flood flows reaching the lower Taieri Plain.

Groundwater quality

The first comprehensive monitoring of groundwater quality in the lower Taieri catchment started in 1994 with a one-off ORC-sponsored survey of 100 groundwater wells tested for pH, conductivity and concentrations of iron and nitrate nitrogen (Rekker & Houlbrooke 2010). As at June 2024, the ORC monitors groundwater quality in four wells in the Lower Taieri aquifer (17.5 to 40.5 m deep) (Figure 3-1). Based on the ORC's Environmental Portal data, routine sampling in these wells began in November 2007. At that time, water samples were collected twice a year and tested for a typical SOE groundwater quality suite, including ammoniacal nitrogen, nitrate nitrogen, DRP, trace elements (e.g., calcium, magnesium) and *E. coli* bacteria. The frequency of water quality sampling increased to quarterly intervals from around mid-2011 in line with monitoring of other SOE groundwater wells across the Otago region. The static water level in the well is also measured quarterly (prior to water sample collection).

Other wells were likely monitored between the late 1990s and mid-2000s prior to the establishment of the current SOE monitoring wells. For example, well H44/0007 was monitored at least three times a year in most years between Oct 1998 to Sept 2022.

Soil quality

Soil quality is a relatively new (and still developing) addition to SOE monitoring in Otago and is based around a subset of sites on different land uses (e.g., drystock farming, dairying, cropping, forestry) that are monitored at different frequencies. Inappropriate land use practices, such as overstocking and over-cultivation, can result in a long-term reduction in soil quality. Poor soil quality can also produce lower agricultural yields, a less resilient soil and land ecosystem, and increase the risks of contamination of underlying groundwater and nearby surface water bodies.

To date, five monitoring sites in the lower Taieri catchment have been sampled, including three drystock farms on the East Taieri and a dairy farm on the central Taieri Plain (all in October 2022). A fifth site near Mahinerangi under forestry land use was also sampled in October 2023. Soil properties tested include soil acidity (pH), nutrient and organic carbon content, and two indicators of soil compaction (bulk density and macroporosity).

3.1.2 Recreational water quality monitoring

During December to February each year, the Taieri River at Outram Glen and Lake Waihola at Jetty are monitored at approximately weekly intervals for *E. coli* as part of the ORC's summer recreational water quality programme. This monitoring is additional to the SOE monitoring. All *E. coli* test results are reported on the Land Air Water Aotearoa (LAWA) website. Additional 'follow-up' testing is usually carried out when a routine sample result exceeds 260 *E. coli*/100mL, the amber/alert level of the MfE/MoH (2003) national microbiological water quality guidelines. At this level, there is an elevated (but still acceptable) level of risk of infection from contact recreation. Any result exceeding the red/action level of 540 *E. coli*/100 mL[7] is deemed to pose an unacceptable health risk.

Due to a history of blooms, the Lake Waihola site is also monitored for cyanobacteria over the summer months. This is a visual assessment; if there is any sign of a bloom, cyanobacteria cell count and biovolume are measured on a water sample and the results compared against the national guidelines (MfE/MoH (2009). Weekly sampling then continues until there are at least two consecutive results at the 'green/surveillance' level of the guidelines (H. Trotter, ORC, pers. comm 2024).

[7] The MfE/MoH (2003) guidelines specify a red/action level of 550 *E. coli*/100 mL but this became 540 when *E. coli* was included in the NPS-FM as a human health attribute for primary contact recreation.

3.1.3 Targeted investigations and monitoring

The ORC has not carried out any recent investigations of water quality in the lower Taieri catchment. A comprehensive assessment of the factors affecting water quality was carried out by Ryder (1995) and a 12-month assessment of surface water quality across 30 river, stream and drain sites followed in 2001/02 (ORC 2004). A groundwater allocation study was also carried out by Rekker and Houlbrooke (2010). The latter included a summary of existing groundwater quality data, flow gaugings along the Silver Stream to understand flow losses to, and flow gains from, the underlying groundwater, and development of a numerical model to determine potential groundwater allocation limits and restriction levels for the lower Taieri Plain.

In 2018, at the request of the ORC, existing SOE water quality monitoring data were used to assess the effects of the pumped discharge of agricultural drainage water in the Main Drain into Lake Waipori via the Waipori pump station. The assessment (Ludgate 2018) included water quality state and trends, and estimation of the annual loads of nutrients, sediment and *E. coli* discharged into the lake from each of the Main Drain, the Contour Channel and the Waipori River.

The ORC has also carried out assessments of natural hazards on the lower Taieri Plain, with a particular focus on flooding. The reports (e.g., Sullivan et al. 2013, Payan & Goldsmith 2014, Goldsmith et al. 2015) include information on the operation of the drainage network that are relevant for understanding the effects of drainage on water quality.

3.2 NIWA

The National Institute of Water and Atmospheric Research (NIWA) monitored river water quality monthly in the Taieri River at Outram between January 1989 and January 2016 as part of its National River Water Quality Monitoring Network. Water samples were tested for a similar range of tests to the ORC's SOE programme but, unlike the ORC (and most long-term council programmes), consistency in laboratory provider and test methods was able to be maintained for the majority of the 27-year monitoring record. The monitoring also included monthly assessments of riverbed periphyton cover and annual macroinvertebrate sample collection.

The ORC recommenced monitoring at Outram in early 2014 to provide a two-year overlap in monitoring with NIWA.

3.3 MetService

The MetService operates a weather station at Dunedin Airport. Rainfall records at this site date back to 31 October 1991.

3.4 University of Otago

The University of Otago has carried out extensive research in the lower Taieri involving the collection of water quality, ecological and other data. Relevant examples include:

- assessments of changes in the condition of Lake Mahinerangi and major tributaries between the 1960s and 1980s as agricultural development in the catchment increased (e.g., Malthus & Mitchell 1988),
- assessment of the geology and quality of groundwater on the Lower Taieri Plain (Litchfield et al. 2002),
- development of a water balance model for the Lakes Waipori-Waihola Wetland Complex and assessment of implications for ecological health (Schallenberg et al. 2003a and 2003b),
- Campylobacter contamination at ten sites in the lower Taieri River over different seasons (e.g., Eyles et al. 2003),
- assessment of the spatial distribution of different forms of nitrogen in groundwater across the lower Taieri Plain (Kensington et al. 2004),
- a grab-sample survey of vegetation in Lake Waihola in summer 2002/03 (Schallenberg & Waite 2004) and vegetation survey across three transects in 2005-08, and
- investigation into the effects of winter farm regimes on water quality in the lower Taieri Plain (Cullen 2007).

3.5 Dunedin City Council

The Dunedin City Council (DCC) has an extensive water quality monitoring programme in the Taieri catchment to meet statutory requirements for drinking water supplies established by Taumata Arowai (2022). As part of these requirements, the DCC monitors the quality of the raw water sourced for treatment and supply to West Taieri, Outram and Dunedin City. The following locations are monitored in the lower Taieri[8]:

- the headwaters of the Silver Stream and upper reaches of Whare Creek (~0.7 km downstream of the ORC's SOE site) and associated tributaries (e.g., McQuilkans Creek, Sligos Creek),
- the Waipori River upstream of Berwick (~2.7 km downstream of the ORC's SOE site), and
- shallow groundwater in four supply wells adjacent to the Taieri River at Outram.

The monitoring frequency and water quality variables tested often varies according to the (minimum) requirements for networked drinking water supplies set out by Taumata Arowai (2022). The DCC's current monitoring is based around:

- continuous monitoring of conductivity, pH and turbidity (i.e., using installed sensors),
- fortnightly monitoring of *E. coli* and nitrate-N,
- monthly monitoring of iron, manganese and colour, and
- six-monthly monitoring of total concentrations of heavy metals.

In addition to testing associated with source waters for drinking water supplies, during 2021 and 2022 the DCC collected water samples from three locations on the Silver Stream (Three Mile Hill Road, Puddle Alley and Riccarton Road West) in dry and wet weather to gain an understanding of the impacts of stormwater on the stream. This was carried out in support of a DCC strategic planning work programme (S. Campbell[9], DCC, pers. comm. 2024).

3.6 Clutha District Council

The Clutha District Council (CDC) carries out water quality monitoring in an outflow channel of Lake Waihola as part of resource consent requirements for the discharge from the Waihola Wastewater Treatment Plant (WWTP). Treated wastewater is discharged to the outflow channel on an outgoing tide.

Over time there have been changes in what is monitored and when, reflecting changes in WWTP operation and consent requirements. The current consent, granted in May 2022 for a term of six years, requires monthly testing of treated wastewater and the lake outflow channel 50 m upstream and 50 m downstream of the discharge point for 5-day biochemical oxygen demand (BOD_5)[10], total suspended solids (TSS), soluble and total nutrients, particulate organic matter and *E. coli* and faecal coliform indicator bacteria. The volume of the discharge is also monitored, and field measurements are taken of water temperature, DO, conductivity, pH and visual water clarity.

3.7 Waipori Falls Village

The Waipori Falls Body Corporate carries out water quality monitoring in the Waipori River once a year as a requirement of its resource consent to discharge up to 15 m^3/day of treated wastewater from Waipori Village to the river. There have been changes in what is monitored over time. Under the current consent, the discharge is monitored for BOD_5 and total suspended solids (TSS) four times a year, and the river is monitored 20 m upstream and 20 m downstream for *E. coli* once a year in January.

[8] Sites on Deep Stream and Deep Creek are also monitored in the mid Taieri catchment as raw source water supplies to Dunedin City – see Milne (2024) for details.

[9] Scott Campbell, Regulation and Policy Team Leader, Dunedin City Council.

[10] BOD_5 is a measure of the organic content of the discharge and is measured over 5 days. When BOD concentrations are high, stream bacteria and other micro-organisms require a lot of oxygen to break the organic matter down, reducing DO levels in the receiving waters.

3.8 Department of Conservation

The Department of Conservation (DOC) has carried our various fish surveys in the lower Taieri catchment as part of its freshwater conservation mandate. In the last few years, there has been more intensive ecological monitoring through Te Mana o Taiari, a project within Ngā Awa, a whole of catchment ('mountains to the sea') river restoration programme launched by DOC in 2019. This has included the use of eDNA testing to complement existing fish monitoring methods. Surveys in 2023/24 also incorporated assessments of water and sediment quality at the following sites in the lower Taieri:

- Silver Stream above Riccarton Road,
- Taieri River upstream of Silver Stream confluence,
- Waipori River downstream of Waipori Falls, and
- a tributary of Lake Waihola (southern end).

Kai Tahu is a partner in the catchment-wide project and has been involved in the monitoring, including completion of cultural health assessments.

As part of Te Mana o Taiari, DOC has also commissioned comprehensive assessments of the predicted impacts of climate change on aquatic and terrestrial ecosystems in the Taieri catchment. Predicted changes in rainfall and river flows have been assessed as part of this. These assessments are reported in Goldsmith (2023) and Closs et al. (2024).

3.9 Taieri College and East Taieri School

Over the past three years, the New Zealand Landcare Trust (NZLT) has supported school monitoring activities in the Ōwhiro Stream catchment in East Taieri. Students from Taieri College have monitored sites on Ōwhiro Stream at Ōwhiro Ave and Riverside Road at approximately quarterly intervals while East Taieri School students have monitored Quarry Creek. Monitoring is based around the NIWA Stream Health Monitoring and Assessment Kit (SHMAK) but has also included trapping for fish and water sample collection for eDNA testing. Some stormwater sampling has also been carried out (C. Simpson, Watershed Solutions, pers. comm. 2024).

3.10 Mercury/Trustpower

In support of its resource consent application to construct the Mahinerangi Wind Farm, Mercury Energy, formerly Trustpower, engaged Kingett Mitchell to carry out a baseline ecological assessment of multiple streams in the area. The assessment, carried out in the mid-2000s, included surveys of Lammerlaw Stream and North West Creek, tributaries of Lake Mahinerangi. Other sites were located on tributaries and the main stem of the Lee Stream (Lee Stream is included in the mid Taieri catchment report – see Milne 2024).

3.11 Wenita

Wenita Forests manages radiata pine forest in the lower Taieri catchment on land at Berwick, Maungatua and Mount Allan and has been carrying out stream monitoring as part of its operations since 2001 based around NIWA's SHMAK kit.[11] Wenita is looking to establish a formal monitoring programme to understand more about the impact and recovery cycles of rivers where intensive forestry operations are being carried out. This is likely to be focused on sediment and stream habitat indicators (Mac Molly, Wenita Forests, pers. comm. 2024).

3.12 Summary

- Routine ORC SOE surface water quality monitoring in the lower Taieri catchment commenced in the 1980s. Many changes in sites and tests have been made over time.

[11] https://www.wenita.co.nz/environment/

  - Current river monitoring sites are the Taieri River (at Outram and Allanton), Whare Creek, Silver Stream (two sites), Waipori River and the lower Meggat Burn. All seven sites have been sampled monthly since at least 2018; most sites have a longer data record but sampling was less frequent pre-2014 and there are periods when no monitoring was carried out. Surface water sample tests include nutrients, turbidity and *E. coli*. In addition, both water temperature and dissolved oxygen are measured at high frequency in the Taieri River at Outram and periphyton biomass and deposited fine sediment cover are monitored on the lower Silver Stream. Macroinvertebrate samples are also collected annually at wadeable sites.
  - Lake water quality monitoring currently occurs monthly at two sites on Lake Waihola and at one site on Lake Waipori. Water sample tests include chlorophyll *a*, suspended sediment, nutrients and *E. coli*. A baseline aquatic vegetation survey was completed in Lake Waihola in 2023 and surveys will be repeated periodically in the future.
- Additional (weekly) *E. coli* testing is carried out in the Taieri River at Outram Glen and Lake Waihola (at the jetty) over the summer months as part of the ORC's regional recreational water quality monitoring programme.
- No routine monitoring is carried out in the estuarine reach of the Taieri River. The ORC commissioned a baseline ecological survey of the estuary in 2007 and modelling of the estuary's trophic condition in 2021.
- Flow monitoring on the Taieri mainstem dates back to 1968 at Outram. The ORC also monitors flow in Silver Stream (since 1975) and Waipori River (since 1998) and water level at a further eight sites.
- Rainfall is monitored by the ORC at Swampy Spur and on the Taieri Plain at Taieri Depot, as well as by MetService at their weather station at Dunedin Airport.
- Routine groundwater quality monitoring started around late 2007. The ORC currently monitors water four wells on the lower Taieri Plain quarterly as part of its regional groundwater SOE monitoring programme. Water level and concentrations of nutrients, metals and *E. coli* are some of the variables monitored.
- ORC has recently established soil quality monitoring in the lower catchment. Three drystock and one dairy farmland and forestry sites have been sampled once to date for various properties, including pH, nutrient and organic carbon content, and indicators of soil compaction.
- No targeted water quality investigations have been carried out by the ORC in the lower Taieri since 2002. In 2018, existing monitoring data were used to estimate contaminant loads discharged into Lake Waipori from the Main Drain compared with the Contour Channel and Waipori River.
- The University of Otago has carried out extensive research in the Lower Taieri involving the collection of water quality, ecological and other data, particularly in and around Lake Mahinerangi and the Lakes Waipori-Waihola Wetland Complex.
- DCC regularly monitors the quality of raw water sourced for drinking water supplies from the Waipori River upstream of Berwick, the headwaters of the Silver Stream and Whare Creek, and shallow groundwater adjacent to the Taieri River at Outram.
- CDC monitors water quality monthly in an outflow channel of Lake Waihola in relation to the discharge of treated wastewater from Waihola township. Water quality tests are similar to those carried out in ORC's SOE monitoring and include nutrients and *E. coli*. The Waipori Falls Body Cooperate also carries out annual *E. coli* monitoring in the Waipori River upstream and downstream of the discharge of treated wastewater from the Waipori Falls village.
- DOC has completed ecological surveys at different stream sites in the lower Taieri catchment over the last few years as part of its Te Mana o Taiari project.
- Monitoring of stream health is carried out by schools in the Ōwhiro Stream catchment with the support of NZLT.
- NIWA has carried out water quality monitoring in the past and baseline ecological assessments of several streams were commissioned by Trustpower in the early 2000s to support the consenting of the Mahinerangi Wind Farm.

4 Current state – what we know

In this section we summarise what is known about current condition (state) of water quality in the lower Taieri catchment. We use recently reported information from ORC's routine surface water quality monitoring sites and high-frequency water temperature and dissolved oxygen monitoring results for the Taieri River at Outram Glen. Because of the interactions between surface and ground water, we also consider the ORC's most recent assessment of groundwater quality and the results of recent soil quality testing. We then look at the results of recent additional monitoring and investigations.

Note: A mixture of nitrate nitrogen (nitrate-N) and nitrite-nitrate nitrogen (NNN) are used in this section, reflecting differences in what was forms of nitrogen were tested or reported across different time-periods. In essence these two forms of plant-available nitrogen are broadly equivalent because nitrite-N concentrations are typically very low in surface waters. Ammoniacal nitrogen (ammoniacal-N) is the other main form of plant-available nitrogen.

4.1 Recent ORC State of the Environment (SOE) reporting

The most recent assessment of water quality state in the lower Taieri catchment was carried out as part of an Otago-wide assessment of river, lake and ground water quality prepared by Ozanne et al. (2023), for the period July 2017 to June 2022. The primary focus of the river and lake components of the report was SOE variables that are mandatory ecosystem health attributes under the NPS-FM 2020. Consequently, not all of the available data were examined and the current state assessment only classified or graded each attribute into NPS-FM bands of A to D (or A to E in the case of *E. coli*). Where readily available, the results of other recent state assessments (e.g., ORC 2021, LAWA) are used to fill in some of these gaps.

What is an attribute and what do Bands A to E mean?

An attribute is a specific term used in the NPS-FM 2020. It refers to a measurable characteristic, such as the concentration of nitrate nitrogen, that is used to assess how well a certain freshwater value (e.g., ecosystem health, recreation) is provided for within a river or lake. Attribute state is generally:

- calculated from regular measurements over a fixed time period (e.g., as a median of monthly measurements over five years), and
- expressed as one of four or five numerically defined bands (A to D or A to E).

In many cases, the NPS-FM specifies a minimum acceptable state (or national bottom line) for an attribute. Councils must monitor and regularly assess current attribute states to track progress towards meeting the future target states established with community input. Target states must be set to maintain or improve river health from a baseline state that was established at a set time (typically 2017).

Attribute bands can be thought of as a bit like a report card where A is the highest and D/E the lowest. However, a lower grade for a particular attribute does not always mean a river is in poor health. A river's natural characteristics, such as the brown tannin staining of the Taieri River or local geology, mean Band A may be an unrealistic and unnecessary target, even in near pristine headwaters. In this section, attribute states of band C or lower are identified to flag potential issues that are then revisited in section 6.

Not all variables monitored in SOE programmes and investigations are NPS-FM attributes (e.g., water temperature, stream habitat). However, national guidelines can be used to assess these variables.

4.1.1 River and stream health

Eight lower Taieri sites are reported in Ozanne et al. (2023) one of which, the Contour Channel at No. 4 Bridge, is an artificial drain. Water quality at this site is summarised in Figure 4-1 for context only as the NPS-FM attribute bands do not apply to drains. Section 6 includes a discussion on drainage water quality in the lower Taieri catchment.

4.1.1.1 Water quality

The ORC's 2017–2022 river water quality state assessment (Table 4-1) found all seven river monitoring sites had low potential for ammoniacal or nitrate nitrogen toxicity (Band A) and DRP concentrations were in Band A or B. However:

- suspended fine sediment (measured as visual water clarity under the NPS-FM and estimated by the ORC using turbidity data) was graded C for the Taieri River at Outram and Band D (i.e., below the national bottom line) at three other sites, and
- *E. coli* was graded D at three sites.

The grading for suspended fine sediment was based on a conversion of turbidity measurements to visual clarity and comparison against NPS-FM attribute bands. However, this conversion is problematic for naturally tannin-stained waters such as the Taieri and Waipori rivers and the Meggat Burn. This is revisited in section 6.

Table 4-1: Summary of overall* NPS-FM 2020 attribute grades assigned to ORC SOE sites in the lower Taieri catchment. Letters in brackets are estimates based on fewer data points than required by the NPS-FM. Summarised from Ozanne et al. (2023). Suspended fine sediment is visual clarity, estimated from measurements of turbidity.

Site	Ammonia toxicity	Nitrate toxicity	DRP	Suspended fine sediment	*E. coli*
Taieri R at Outram	A	A	B	C	B
Whare Ck at Whare Flat Rd	A	A	A	(A)	(A)
Silver S at Three Mile Hill Rd	A	A	A	(A)	(B)
Silver S at Taieri Depot	A	A	B	A	D
Taieri R at Allanton Br	A	A	B	D	D
Waipori R at Waipori Falls Reserve	A	A	A	D	A
Meggat Burn at Berwick Rd	A	A	B	D	D

* For many NPS-FM attributes, more than one metric (e.g., median, 95th percentile) is graded but the metric with the lowest grade determines the overall grade.

Toxicity versus other effects

Bands A to D of the NPS-FM for ammoniacal nitrogen and nitrate nitrogen only relate to *toxic effects* on aquatic life. As such, the bands are set at very high concentrations relative to the median concentrations reported for the majority of rivers in New Zealand. However, adverse effects on river ecosystems can occur at much lower nitrogen concentrations through stimulating nuisance growth of periphyton (algae) and macrophytes (aquatic plants). Eutrophication can significantly affect stream life, including through depletion of water column oxygen levels when algae/plants die and break down.

The nutrient concentrations at which nuisance aquatic plant growth occurs are river-specific and are influenced by other factors such as water temperature, shading and the frequency of rivers flows of a sufficient magnitude to 'flush' the riverbed clean. Some guidance has been developed by MfE (2020, 2022) to provide a starting point for setting nutrient concentrations to manage periphyton biomass (as required by the NPS-FM). The 2020 guidance has been used by the ORC (e.g., ORC 2021) to estimate river trophic state in Otago in the absence of any significant periphyton biomass monitoring data.

The NPS-FM bands are coarse so looking at median turbidity and median concentrations of nutrients and *E. coli* over the five-year period ending June 2022 provides more insight into differences in water quality between sites (Figure 4-1). This comparison illustrates that water quality deteriorates once rivers and streams reach the lower Taieri Plain. This is most marked looking at the median nutrient and *E. coli* concentrations, which are much lower for the four sites located outside or on the edge of the plain (Taieri River at Outram, Waipori River at Falls Reserve, Whare Creek at Whare Flat Road, and Silver Stream at Three Mile Hill Road).

The lower Silver Stream (at Taieri Depot) recorded the highest median NNN concentration of any site, likely due to inflow of nitrate-enriched groundwater. Overall, with the exception of this site, plant-available forms of nitrogen (i.e., ammoniacal nitrogen and NNN) are present at low concentrations across most SOE monitoring sites in the lower Taieri. Based on LAWA data, both Taieri River sites rank in the best 25% of all river and stream sites monitored in lowland rural areas across New Zealand[12] (i.e., 75% of monitored sites have higher medians). The median DRP concentrations at these sites rank in the best 50% of monitored sites.

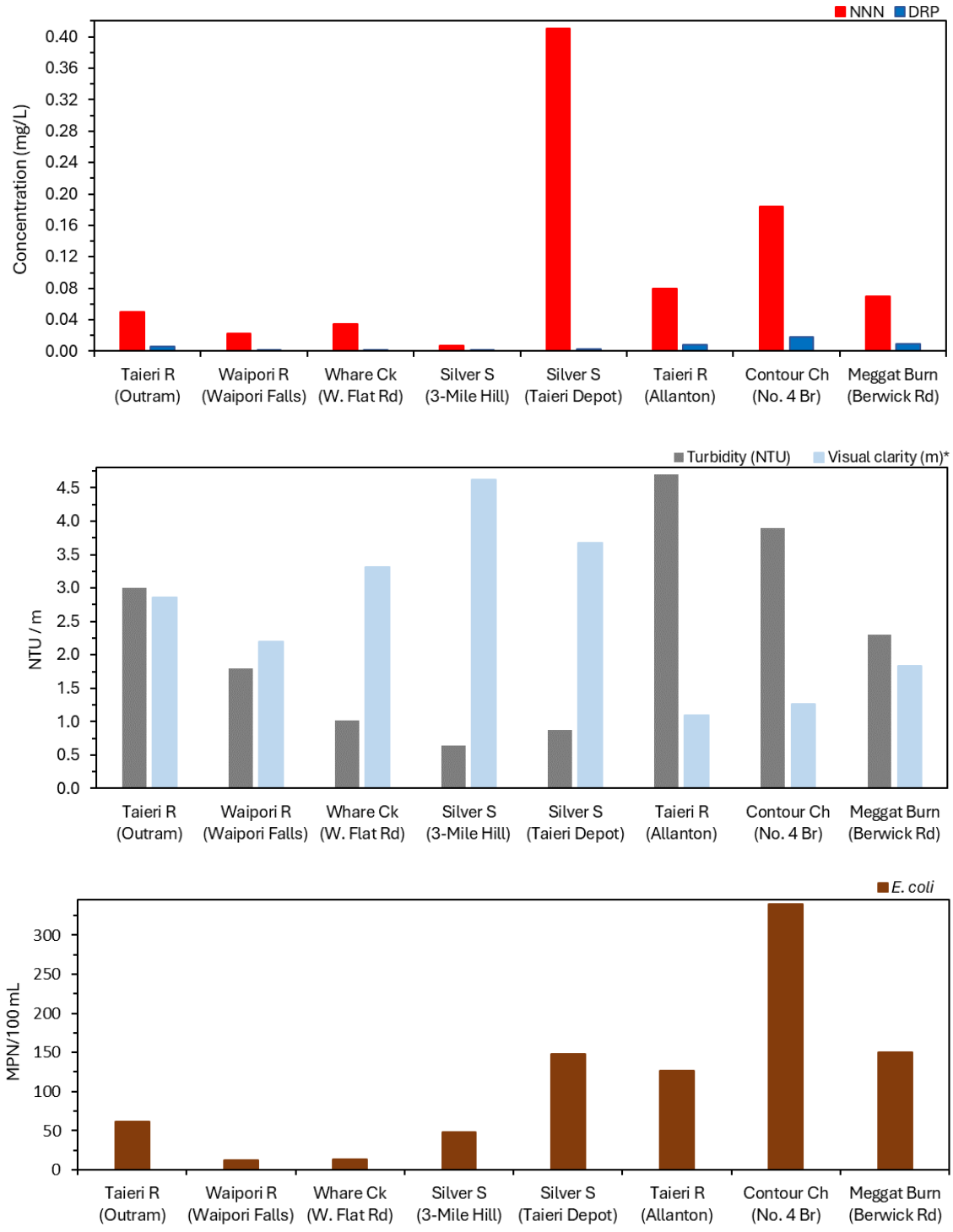

Figure 4-1: Median nutrient, turbidity, visual clarity* and *E. coli* values at ORC's SOE river water quality monitoring sites in the lower Taieri catchment. Based on the results of monthly sampling between July 2017 and June 2022, reported in Appendix 1 of Ozanne et al. (2023).
* Visual clarity was estimated from turbidity measurements using a national equation.

[12] Based on the median concentrations reported over the five-year period ending 30 June 2022, accessed from LAWA in July 2024.

The *E. coli* attribute grade in the NPS-FM is determined from four statistical metrics, not just the median. Because it represents the middle datapoint (50th percentile) in a dataset, the median concentration is useful for understanding risks to human health in dry weather. However, also of interest is how often a site exceeds the amber/alert and red/action guidelines of 260 and 540 *E. coli*/100mL, respectively. Figure 4-2 provides this information and shows that across 60 sampling occasions between July 2017 and June 2022, *E. coli* counts in the Waipori River at Waipori Falls Reserve and Whare Creek at Whare Flat Rd consistently fell within the green/surveillance guideline. In contrast, the other sites recorded elevated *E. coli* counts on multiple occasions, with the three sites on the lower Taieri Plain each exceeding the red/action guideline more than 10% of the time.

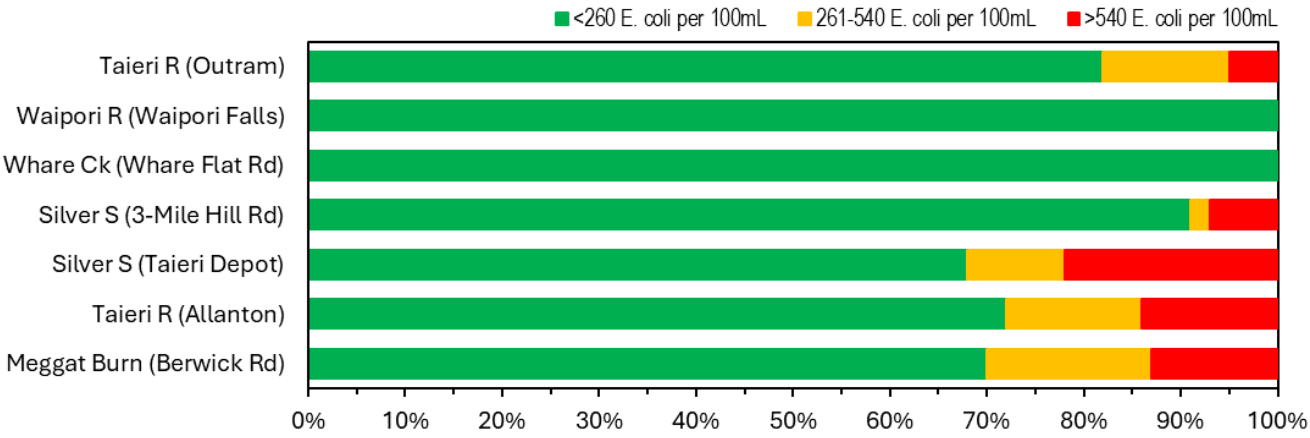

Figure 4-2: *E. coli* counts across all river SOE water quality monitoring sites in the lower Taieri catchment, summarised as the percentage of sample results falling into the green/surveillance, amber/alert and red/action levels of the national MfE/MoH (2003) contact recreation guidelines. Based on monthly sampling between July 2017 and June 2022, reported in Appendix 1 of Ozanne et al. (2023).

While monthly year-round *E. coli* data provide information on potential risks to human health across all monitored sites, not all sites are commonly used for primary contact recreational activities such as swimming. For primary recreation sites, the NPS-FM also requires weekly surveillance monitoring over summer to determine the current microbial health risk and warn the public during periods of elevated risk. The results of this monitoring are summarised in section 4.2.

Water temperature and dissolved oxygen

High frequency measurements made in the Taieri River at Outram Glen over the 25-year period ending 21 February 2024 indicate that water temperature at this location exceeded 20°C just over 3% of the time (Figure 4-3). The highest water temperature recorded to date is 25.5°C early on the evening of 30 January 2018, following an extended period (starting in early December 2017) of peak daily water temperatures above 22°C. Water temperatures above 22°C were also recorded at times in other summer periods, including in early February 2023.

In New Zealand, the Cox Rutherford Index (CRI) is commonly used to characterise summertime water temperatures and interpret the potential effects of water temperature on aquatic ecosystems. The CRI is the midpoint between the daily average and daily maximum temperatures and can be averaged over the five hottest days of a summer from a continuous water temperature record (Davies-Colley et al. 2013). Table 4-2 summarises the two component values of the CRI for the warmest summer (2017/18) and two additional summers, calculated from ORC's Outram Glen data. The values are graded in accordance with bands A to D developed by Davies-Colley et al. (2013).

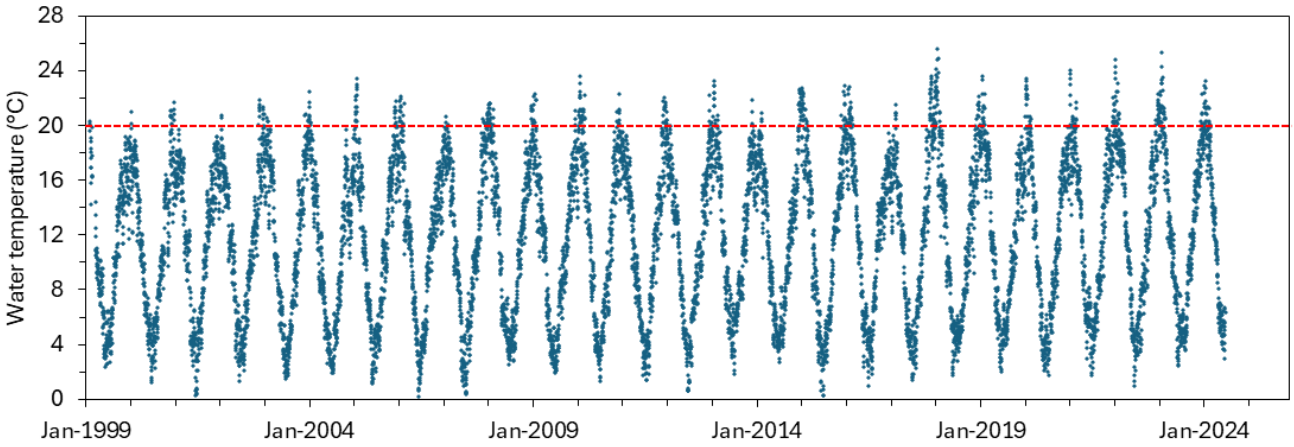

Figure 4-3: Daily maximum water temperatures recorded in the Taieri River at Outram. Summarised from 5-minute measurements downloaded from the ORC Environmental Data Portal. The red dashed line represents an indicative threshold above which some sensitive aquatic fish and macroinvertebrate species may start to experience stress.

Table 4-2: Cox Rutherford Index water temperature values for the Taieri River at Outram Glen for the warmest five days in recent summers. Calculated from ORC data collected at 5-minute intervals.

Summer	5-day period	Water temperature (°C)		Davies-Colley et al. (2013)*	
		Average daily	Average daily maximum	Band	Description
2017/18	28 Jan–01 Feb	23.2	24.5	C	Some thermal stress on occasion, with loss of certain sensitive insects and absence of certain sensitive fish
2018/19	29 Jan–02 Feb	20.9	22.1	C	
2021/22	15 Jan–19 Jan	22.0	23.7	C	
2022/23	01 Feb–05 Feb	22.6	23.9	C	

* Suggested bands only – water temperature is not an NPS-FM attribute.

One consequence of elevated summertime water temperatures is a reduction in dissolved oxygen (DO) levels (warm water holds less oxygen), which can further stress invertebrate and fish life. Continuous DO monitoring only dates from March 2023 at Outram Glen but DO levels over the 2023/24 summer never fell below 84% saturation or a concentration of 7.5 mg/L. This equates to a Band A classification under the NPS-FM and indicates that DO levels were unlikely to have stressed aquatic life.

Looking at the full available record to date, the Taieri River at Outram has a median DO close to 100% saturation. This is significantly higher than the median of 80% recorded at Waipiata in the upper catchment (Milne & Rados 2024).

4.1.1.2 Ecological health

Periphyton biomass – measured as chlorophyll *a* concentrations from rock scrapings – was the only ecological indicator included in the ORC's most recent state and trend report.[13] However, a separate ORC (2023) biomonitoring report card for the 2017–2022 period summarised additional ecological data for lower Taieri sites. Only one site, Silver Stream at Taieri Depot, was monitored for a wide range of ecological indicators.

The available summary information (Table 4-3) suggests ecological health is poor across most monitored river and stream sites. Most of the sites recorded five-year median macroinvertebrate community health scores in the C or D band of the NPS-FM. The Taieri River at Outram returned the highest scores despite having nuisance algal growth at times. Despite low streambed coverage of fine sediment – a known stressor on macroinvertebrates – the lower reaches of the Silver Stream were graded Band D (below the national

[13] Data were only collected at the two sites summarised in Table 4-3. In the ORC (2021) report, periphyton biomass was estimated for all SOE sites using water column nutrient concentrations provided in MfE (2020). This resulted in assignment of a Band C across most SOE sites, translating under the NPS-FM to "periodic short-duration" nuisance (algal) blooms.

bottom line) for macroinvertebrate health. This likely reflects excess nutrient enrichment and low flows that contribute to regular occurrence of nuisance amounts of algae at this site (Band D).

Although there were insufficient macroinvertebrate data to include Whare Creek in the 2023 biomonitoring report card, data provided by the ORC for 2022 and 2023 indicate the site at Whare Flat Road supports a healthy macroinvertebrate community (MCI scores equivalent to Band B under the NPS-FM).

Table 4-3: Summary of NPS-FM 2020 ecological attribute grades assigned to ORC SOE river sites in the lower Taieri catchment. Letters in brackets are estimates based on fewer data points than required by the NPS-FM. Summarised from Ozanne et al. (2023) and ORC (2023).

Site	Periphyton biomass (chl-a)	MCI	Average macroinvertebrate health score*	Deposited fine sediment
Taieri R at Outram	(C)	B	C	*Not monitored*
Whare Ck at Whare Flat Rd	*Not monitored*	*Insufficient data (see text)*		*Not monitored*
Silver S at Three Mile Hill Rd	*Not monitored*	D	C	*Not monitored*
Silver S at Taieri Depot	D	C	D	A
Taieri R at Allanton Br	*Not monitored*	D	D	*Not monitored*
Waipori R at Waipori Falls Reserve	*Not monitored*	C	C	*Not monitored*
Meggat Burn at Berwick Rd	*Not monitored*	D	D	*Not monitored*

* Determined from combining the MCI score with the scores of two indices of pollution-sensitive Ephemeroptera, Plecoptera and Trichoptera macroinvertebrate taxa. Referred to as the Average Score Per Metric (ASPM) in the NPS-FM.

4.1.2 Lake health

4.1.2.1 Water quality

The assessment of lake water quality in the ORC's most recent SOE report (Ozanne et al. 2023) was limited to two sites in Lake Waihola and a subset of mandatory attributes included the NPS-FM 2020. Consistent with earlier SOE reporting (e.g., ORC 2021, Uytendaal & Ozanne 2018), the health of the lake over the five-year period ending June 2022 is poor, reflected in high concentrations of nutrients and algae. The southern end of the lake was graded Band D (i.e., below the national bottom line) of the NPS-FM for total phosphorus, chlorophyll *a* and *E. coli* (Table 4-4) and was also characterised by higher median concentrations of all forms of nitrogen.

Table 4-4: Summary of overall* NPS-FM 2020 attribute grades assigned to ORC SOE lake sites in the lower Taieri catchment. Summarised from Ozanne et al. (2023) and are indicative grades only as they were determined using fewer data points than required by the NPS-FM.

Site	Ammonia toxicity	Total N	Total P	Chlorophyll *a*	*E. coli* (overall grade)
Lake Waihola – South	B	C	D	D	D
Lake Waihola – Mid	A	C	C	C	B

* For most attributes, more than one metric (e.g., median, 95th percentile) is graded but the metric with the lowest grade determines the overall grade.

The difference in *E. coli* gradings between the Waihola sites are driven solely by the southern site having a high 95th percentile *E. coli* value for the 5-year reporting period. This end of the lake is not well flushed and may be impacted more greatly by wind-induced suspension of bottom sediments and faecal inputs of waterfowl.

The total nitrogen, total phosphorus and chlorophyll *a* monitoring results can be combined and reported in terms of the trophic level index (TLI), a common descriptor of lake water quality. The most recent TLI score available for Lake Waihola is 4.9 (at the mid-lake site)[14], equating to eutrophic (poor) lake health. Of note is that the current median total phosphorus concentrations at both sites fall into the supertrophic (very poor) range (0.043–0.096 mg/L). In contrast, the median total nitrogen concentrations are more favourable, particularly when compared against the median concentrations recorded in other shallow, brackish lowland lakes monitored across New Zealand (e.g., Te Waihoro/Lake Ellesmere and Lake Waikare). However, nitrogen concentrations do not appear to be low enough to limit nuisance algal or plant growth.

Although the current state of water quality in Lake Waipori is not summarised in any recent reports (owing to insufficient data), based on earlier monitoring (Ozanne 2017, ORC 2005) and the Lake Waihola results, the lake is most likely still eutrophic (TLI of 4–5).

4.1.2.2 Ecological health

Plant life in lakes provides another useful indicator of lake condition, alongside the TLI. Results of a survey of submerged vegetation at five locations in Lake Waihola by NIWA in June 2023 (de Winton et al. 2023) ranked lake condition as "high" (Band B of the NPS-FM). This ranking is based on the commonly applied Lake Submerged Plant Index (LakeSPI) methodology, which combines separate indices of lakebed native and invasive plant cover. Both indices represent attributes in the NPS-FM and fell into Band B, equating *to "high ecological condition"* and *"invasive plants having only a minor impact"*, respectively.

The overall score of "high" reflects that native vegetation occupies most of the lakebed (64%). The most abundant native plants included blunt pondweed *(Potamogeton ochreatus)* and charophyte meadows (e.g., stonewort, *Chara australis*) (Figure 4-4). The only invasive plant present was Canadian pondweed (*Elodea canadensis*) (Figure 4-4). It was widespread but averaged <25% cover (de Winton et al. 2023), placing the lake in Band B (minor impact).

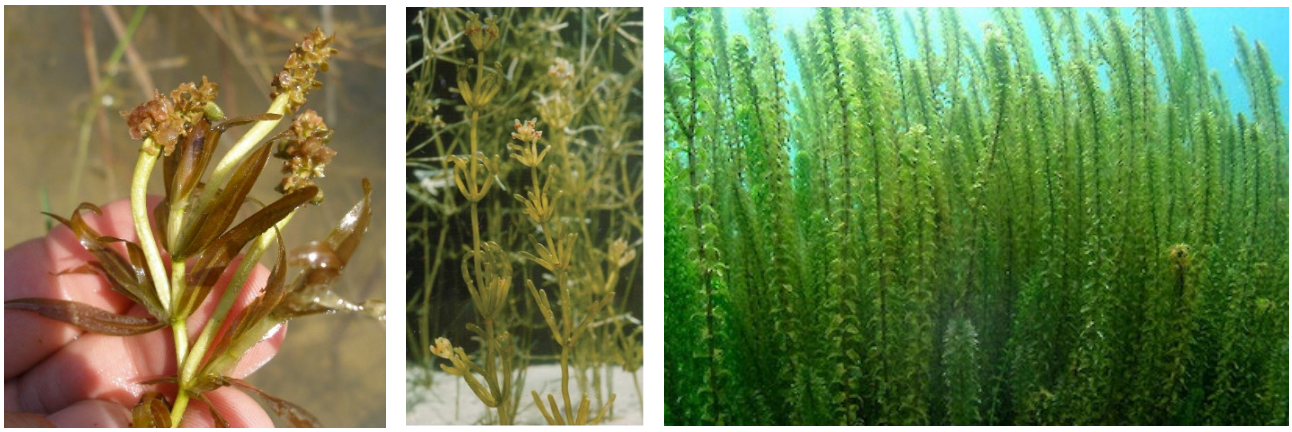

Figure 4-4: Blunt pondweed (left), stonewort and Canadian pondweed. All three plants were recorded in Lake Waihola in June 2023. Sources (left to right): Eyeweed (Flickr), J Beilby and Rohan Wells (NIWA).

4.1.3 Groundwater quality

The 2017–2022 groundwater quality state assessment reported in Ozanne et al. (2023) was limited to three variables: nitrate-N, *E. coli* and arsenic. Monitoring data were compared against the Maximum Acceptable Values (MAV) of the NZ Drinking Water Standards (NZDWS).

For the five SOE wells reported for the lower Taieri Plain:

- median nitrate-N concentrations ranged from 0.006 mg/L to 5.7 mg/L, well below the NZDWS MAV of 11.3 mg/L,
- *E. coli* was detected in three wells on two or more sampling occasions, breaching the NZDWS MAV of <1 *E. coli*/100mL, and

[14] Based on the LAWA website (accessed September 2024).

- arsenic concentrations were low and did not exceed the NZDWS MAV (0.01 mg/L) on any sampling occasion in any well.

The presence of *E. coli* does not necessarily indicate widespread aquifer contamination. All of the wells monitored by the ORC are privately owned and likely have poor well head/casing security (A. Levy, pers. comm. 2024).

Groundwater well I44/0821 (Dukes Rd North) recorded the highest nitrate-N concentrations, ranging between 5.1 and 6.9 mg/L. Although well below the NZDWS MAV, concentrations in this well are more than double the 2.5 mg/L threshold for groundwater impacted by low intensity land use (Morgenstern & Daughney 2012). Another well, I44/0519 (Gordon Rd North), also recorded a median concentration above this threshold (3.15 mg/L). The significance of this is that groundwater in the East Taieri, particularly shallow groundwater, interacts with the overlying surface water and can significantly increase concentrations in streams. Nitrate-enriched groundwater enters the lower Silver Stream and is likely contributing to the nuisance periphyton growth recorded at the Taieri Depot stream monitoring site.

An earlier groundwater quality report by Levy et al. (2021) identified elevated and fluctuating concentrations of DRP in several of the groundwater wells. Changes in land use and/or septic tank density and efficiency were raised as potential explanations for the fluctuations.

4.1.4 Soil quality

The test results for soil samples collected from drystock and dairy farms in 2022 and forestry land in 2023 have recently been reported as part of a regional soil quality 'report card' (Button 2024). The report card provides a summary by land use across Otago rather than by catchment, so for this report we compared the lower Taieri sample results against soil quality indicator targets developed for regional councils (McKay et al. 2013). This exercise showed that most indicators were within the target range applicable to the land use. The main exception was macroporosity, which was outside targets in soil samples collected from three of the five sites. Macroporosity is a measure of the proportion of large pores in the soil and provides information on soil aeration. In the case of the dairy farm sampled on the central area of the lower Taieri Plain, average macroporosity was very low, indicative of poor oxygen diffusion to plant roots and poor drainage. Average bulk density at this site was just inside the upper end of the target range, also suggesting the soils were likely compacted (e.g., by stock or machinery). Compacted soils do not allow water or air to penetrate, do not drain easily and restrict root growth, adversely affecting plant growth. There is also potential for increased run-off and nutrient loss to surface waters (Hill & Sparling 2009).

Of the three drystock farms in the east Taieri, average macroporosity was marginally below the target range at one site and at the low end of the target range at the other two sites. Similar to the dairying site, this may be indicative of poorly draining soils, which are common across parts of the lower Taieri Plain.

In contrast with the farmed soils, average macroporosity for the forestry site near Mahinerangi was slightly outside the upper target range. High macroporosity values are indicative of loose soil that may be subject to erosion from wind or running water (Manaaki Whenua Landcare Research 2024).

4.2 Recreational water quality

The Taieri River at Outram is the only river site in the lower Taieri catchment included in the ORC's summer recreational water quality monitoring programme. Based on the results from weekly *E. coli* monitoring over the last five summers this site has a current grade of "poor" for swimming. This grade is determined in accordance with national guidelines (MfE/MoH 2023) using the 95th percentile *E. coli* count (i.e., the near highest result over the monitoring period), making it a conservative grading. Data from the LAWA website, as well as the ORC's latest recreational water quality report card (ORC 2024) and the overall NPS-FM classification of Band B based on year-round monthly SOE monitoring (refer Table 4-1), indicate that the "poor" grade does not reflect the risk to human health from recreation in dry weather when swimming is most likely to occur. This is discussed further in section 6.

Lake Waihola at Jetty, the ORC's official contact recreation monitoring site in Lake Waihola, has a current grade of "good" for swimming, based on the results from monitoring of *E. coli* counts over the last five summers (ORC 2024). However, this site is prone to blooms of potentially toxic blue-green algae (cyanobacteria) in the summer months, which often make the lake unsuitable for swimming (Ozanne 2017).

4.3 Insights from other recent monitoring and investigations

4.3.1 Ōwhiro Stream community-based monitoring

Monitoring of Ōwhiro Stream and a tributary, Quarry Creek, by schools over the past three years has reinforced the results of earlier SOE monitoring of the stream by the ORC. The stream water at both Ōwhiro Avenue in Mosgiel and Riverside Road in the lower reaches is regularly turbid, with visual clarity measurements consistently below 1 m. Macroinvertebrate community health is also degraded, with pollution-tolerant snails and oligochaete worms dominating most samples. However, fish trapping and eDNA testing carried out with the support of NZLT and ORC's Ecofund has identified the stream still supports some good native fish values, including inanga, giant kōkopu, common bully and both shortfin and longfin eel (C. Simpson, pers. comm. 2024). Recent riparian planting has been carried out to enhance cover for fish but is not actively encouraged by the ORC as it reduces the stream's flow capacity in floods. This is revisited in section 6.

4.3.2 Resource consent monitoring

The only resource consent monitoring generating significant amounts of receiving water quality data is that associated with the Waihola WWTP. Following granting of a new resource consent in 2022, more than two years of monthly water quality data are now available for the Lake Waihola outflow channel upstream (west) and downstream (east) of the discharge outfall for treated wastewater from the Waihola WWTP. The results of this monitoring (Medel 2023, 2024) suggest the discharge is not having any noticeable effect on water quality; concentrations of soluble inorganic nutrients, suspended sediment and *E. coli* are similar upstream and downstream when wastewater is discharged. The potential impact of nutrients in the discharge is discussed further in section 6.2.

4.3.3 DCC monitoring and investigations

Monitoring carried out by the DCC in relation to water supply intakes confirms the headwaters of the Silver Stream and Whare Creek have very good water quality. Monitoring results for the Waipori River water intake site upstream of Berwick indicates that nutrient concentrations are lower (i.e., water quality is better) than at the ORC's site located almost 3 km further upstream, despite farming in the immediate vicinity. The higher water quality at this location likely reflects the influence of Mill Creek which enters the Waipori River a short distance upstream of the DCC's intake site. Much of the Mill Creek catchment is located within a DOC conservation area and dominated by native vegetation.

DCC investigations of water quality at three sites on the Silver Stream during rain events in January and July 2022 recorded dissolved and total forms of copper and zinc at the site downstream of Mosgiel only (Riccarton Road West, the same location as ORC's SOE monitoring site 'Taieri Depot'). The dissolved concentrations of both metals were above the ANZ Guidelines (2018) but measurements of other indicators that influence metal toxicity (water hardness, dissolved organic carbon and pH) and therefore needed to better understand the potential for adverse effects on aquatic life, were not collected.

Nitrate-N and DRP concentrations were also an order of magnitude (i.e., 10 times) higher in the Silver Stream at Riccarton Road West than the two upstream sites at Puddle Alley and Three Mile Hill Road. However, nitrate-N concentrations were higher at both base and wet weather stream flows, indicating that groundwater – rather than stormwater runoff – entering the stream in the vicinity of Riccarton Road West is the main source. Streambed sediment samples collected in March 2022 also showed phosphorus and zinc concentrations were much higher at Riccarton Road West than the other two sites, with zinc (290 mg/kg)

exceeding the default guideline value of 200 mg/kg in the ANZ Guidelines (2018).[15] Total petroleum hydrocarbons (a mixture of contaminants derived from crude oil) were not detected in stream water or sediment samples from any site.

4.4 Summary – key points

Based on recent ORC state assessments (2017–2022 and, in some cases 2016–2021) and the results of other monitoring and investigations carried out over the last few years:

- The lower Taieri River has higher median concentrations of plant-available nitrogen (ammoniacal-N and nitrate-N) than those reported for monitored sites on the upper and mid reaches. However, concentrations are lower than those found in 75% of lowland river sites monitored in New Zealand. Concentrations of plant-available phosphorus (DRP) at both Outram and Allanton fall into Band B of the NPS-FM, placing them in the best 50% of monitored lowland river sites.
- Nitrate-N concentrations in shallow groundwater in the east Taieri is elevated above the suggested threshold for groundwater in low-intensity land use areas, with a median of 5.7 mg/L recorded in a well adjacent to Dukes Road North. Inflow of nitrate-enriched shallow groundwater is influencing nitrate-N levels in the Silver Stream at (ORC) Taieri Depot monitoring site and, together with reduced stream flows in summer, is likely fuelling the significant algal growth recorded at this site.
- Visual clarity is rated 'poor' at monitoring sites on the Taieri River (Outram Glen and Allanton), Waipori River and Meggat Burn, based on a conversion of turbidity measurements and comparison against NPS-FM attribute bands. However, this assessment is problematic for tannin-stained waters (see section 6).
- There is significant faecal contamination in the lower Taieri catchment, particularly at sites located in the middle and lower Taieri Plain (the Silver Stream at Taieri Depot, Meggat Burn at Henley-Berwick Road and Taieri River at Allanton). Weekly monitoring at the Taieri River at Outram Glen and Lake Waihola at Jetty over summer indicates that both sites are unsuitable for swimming at times due to elevated concentrations of *E. coli* and cyanobacteria blooms, respectively.
- The continuous water temperature record for the Taieri River at Outram suggests some thermal stress for aquatic life on occasion in summer but, in contrast with upper and middle reaches of the river, water temperatures seldom exceed 25°C. Dissolved oxygen concentrations are also significantly higher than upstream, with a healthy median of 100% saturation.
- Macroinvertebrate health is degraded across most monitored river and stream sites, with median index scores falling into Band C or D of the NPS-FM. Poor stream habitat, including a lack of riparian cover and bank erosion are key contributing factors. The Taieri River at Outram returned the highest scores despite supporting nuisance algal growth at times. More recent monitoring data indicates that macroinvertebrate community health is much higher in Whare Creek (estimate of Band B at Whare Flat Road).
- Despite poor water clarity and significant channelisation and bank erosion in places, the Ōwhiro Stream supports multiple native fish species, including several threatened galaxiids.
- Lake Waihola is nutrient and algae-enriched (eutrophic) and this is likely also the case for Lake Waipori. However, a recent survey by NIWA indicates the lakebed has a high coverage of native aquatic plant communities. Treated wastewater from Waihola township does not appear to have a noticeable effect on water quality in the lake outflow channel into which it is discharged.
- Recent soil quality monitoring carried out at five lower Taieri catchment sites found most indicators were within the target range applicable to the land use. The main exception was macroporosity, which was outside targets in soil samples collected from three sites on the lower Taieri Plain, indicative of poor drainage.

[15] This guideline has been adapted from overseas guidance and broadly equates to a low level of risk of adverse effects.

5 Trends – is water quality getting better or worse?

The most recent assessment of trends in water quality over time in the lower Taieri catchment was carried out as part of a regionwide assessment of river, lake and ground water quality in Otago completed by LWP Ltd (Fraser et al. 2023a, 2023b) and reported in Ozanne et al. (2023). This section summarises the key findings of trends in water quality reported for:

- five SOE river sites over 10- and (where sufficient data existed) 20-year periods ending on 30 June 2022,
- two SOE lake sites over the 5-year period ending on 30 June 2022, and
- five SOE groundwater wells over 5- and (where sufficient data existed) 10-year periods ending on 30 June 2022.

The LAWA website also reports trends in river and lake health (for the last 5 and 10 years), with the assessments updated annually in September (for the most recent 5- and 10-year periods).

Understanding trend assessments

Assessment of trends over time complements information on current state by providing information on whether the state of water quality is getting *better or worse*. State and trend results therefore need to be considered together to understand river and lake health.

Trend assessment methods applied to water quality and ecological data in New Zealand are statistically based and have evolved over time, resulting in differences in interpretation and reporting. The current recommended approach (Snelder et al. 2021) has been used in national and most regional SOE reporting for at least five years. This approach is based on the view that a trend always exists, but often there is not enough precision in the dataset to confidently say if the trend is increasing or decreasing. Previously, trend results falling into this category were classified as "no trend" and where trends were detected, they were only reported if they had a very high of level of statistical significance.

Trend assessments are now reported based on bands of statistical confidence and associated descriptions, ranging from a low confidence of 33-66% ("as likely increasing as decreasing") to >99% confidence ("virtually certain"). The same bands and descriptions are not always universally applied.

Trend direction is sometimes reported on its own (e.g., LAWA, Ozanne et al. 2023) but this only provides a part of the picture. The trend *magnitude* or size is also important as this indicates the *rate of change* (increase or decrease) in water quality over the time period assessed. There may be a virtually certain increase in nitrate-N concentrations at a site over a 10-year period, indicating a deterioration in water quality, but the environmental significance of that increase depends on:

- what the current state of water quality is (e.g., is it above, below or approaching a critical guideline or standard?), and
- how quickly it is increasing (i.e., the rate of change).

Trend assessments also require the data analyst to make decisions about what data to include or exclude to ensure a robust assessment. Some of these 'data filtering' decisions are subjective, meaning two sets of assessments may not produce exactly the same results. This is often the case when multiple sites and long timeframes are being assessed (e.g., regional or national reporting) because of changes in the measurement frequency or methods that, if not accounted for, would prevent a robust comparison between sites. This applies to the ORC's SOE data and effectively means that sometimes not all of the data available for an individual site are used in regionwide trend assessments.

5.1 River and stream health

The 10- and 20-year periods show different trends in river and stream water quality. Two of the three sites with sufficient data for the 20-year assessment, the Silver Stream at Taieri Depot and the Taieri River at Allanton,

showed increasing trends in concentrations of *E. coli,* NNN and total nitrogen, indicating water quality deteriorated between July 2002 and June 2022. The Allanton site also recorded degrading trends in turbidity and concentrations of DRP.

Many more improving than degrading trends in water quality were observed for the more recent 10-year period ending 30 June 2022. Overall, the only trends (improving or deteriorating) classified as 'extremely likely' or 'virtually certain' and with a trend rate that could be quantified (Table 5-1) were:

- decreasing turbidity (i.e., improving visual clarity) in the Silver Stream at Taieri Depot,
- decreasing phosphorus concentrations in the Taieri River at Outram and Allanton, and in the Silver Stream at Taieri Depot (i.e., improving trends), and
- increasing total N concentrations in the Waipori River at Waipori Falls (i.e., a deteriorating trend).

Table 5-1: Summary of key trends in water quality at river SOE monitoring sites within the lower Taieri catchment for the 10-year period ending 30 June 2022. Simplified from the results reported by Ozanne et al. (2023) – green and red cells indicate improving and deteriorating trends, respectively; yellow cells indicate the trend direction was unclear. Black arrows indicate both high confidence in the trend direction and a trend rate that was able to be quantified (presented as percentage change per year, extracted from LWP data files provided by the ORC). Amm. N is ammoniacal-N; NNN is nitrate-nitrite N.

Site	Amm. N	NNN	Total N	DRP	Total P	Turbidity	*E. coli*
Taieri R at Outram				↓ 6.1%	↓ 4.8%		
Whare Ck at Whare Flat Rd	*Not analysed / reported*						
Silver S at Three Mile Hill Rd	*Not analysed / reported*						
Silver S at Taieri Depot					↓ 4.5%	↓ 6.4%	
Taieri R at Allanton Br.				↓ 3.2%	↓ 2.4%		
Waipori R at Waipori Falls Res.			↑ 3.6%				
Meggat Burn at Berwick Rd	*Not analysed / reported*						

There is limited information available on macroinvertebrate trends over time. The only recently documented information is for the Silver Stream at Taieri Depot which was reported with an "unlikely" improving trend in MCI scores over the 10-year period ending 31 August 2020 (ORC 2021). The more recent assessment for this site available on LAWA (for the 10-year period ending in June 2023) is a "likely degrading" trend. Neither "unlikely" nor "likely" trends are associated with high statistical confidence.

5.2 Lake water quality

Trends in water quality were assessed at two sites in Lake Waihola over July 2017 to June 2022. The only directions of trend (i.e., improving or degrading) classified as 'extremely likely' or 'virtually certain' and with a trend rate that could be quantified were decreasing concentrations (i.e., improving trends) of ammoniacal nitrogen and NNN at the southern site in Lake Waihola. The trend assessment output files provided by the ORC indicate that the rates of decrease were extremely high (47% and 887%, respectively) but the assessment was limited to quarterly data (to enable comparison with other lakes monitored at this frequency) and only made use of 14 data points. Repeating the trend assessment using all available data could be useful.

A more informative picture of trends in the condition of Lake Waihola are provided in the annual TLI scores reported on LAWA (Figure 5-1). These scores show that apart from 2020, the lake has largely remained within the upper end of eutrophic range (i.e., poor) over the last 10 years.

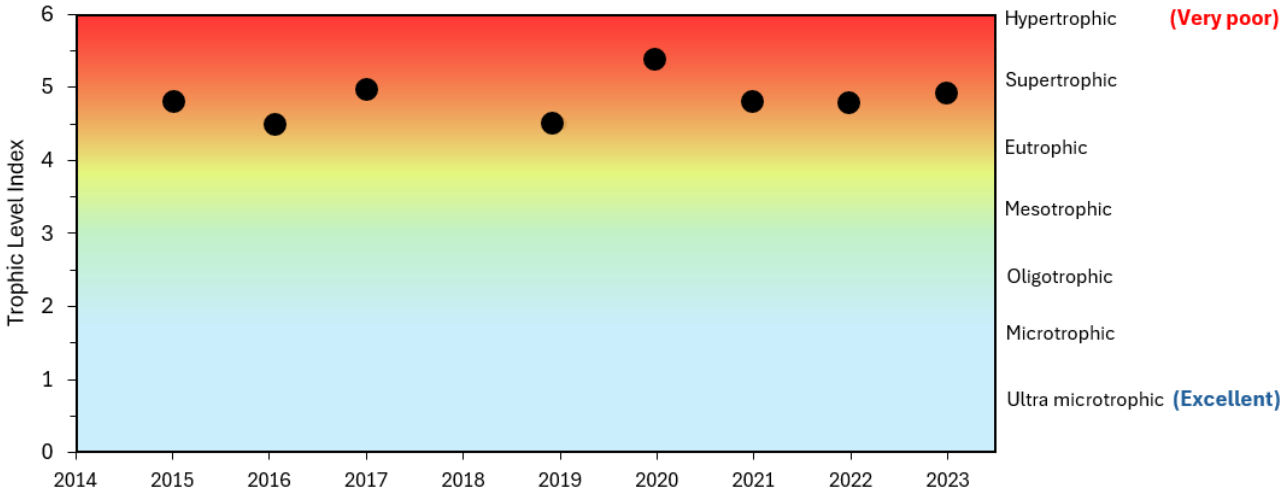

Figure 5-1: Annual TLI scores for Lake Waihola between 2014 and 2023. Based on the LAWA website (September 2024).

Although the ORC has monitored water quality in Lake Waipori on an ongoing basis since August 2018, no information was found on recent trends. A report (ORC 2005) on the results of the first monitoring of the trophic status based on monthly monitoring at two sites over 2002-04 arrived at a TLI of 4.6 (eutrophic). A second report (Ozanne 2017) for a repeated monthly monitoring of these sites between spring 2014 and spring 2016 also classified the lake as eutrophic (TLI of 4.2). It is unlikely that water quality has changed significantly in the lake since 2016, particularly since water quality in Lake Waihola has remained consistently poor over this period.

5.3 Groundwater quality

The groundwater quality trend assessment results reported by Ozanne et al. (2023) were limited to nitrate-N and arsenic but additional variables and information on rates of change were included in the trend assessment output files provided by the ORC. For the ten-year period ending 30 June 2022, a 'virtually certain' increase (9.1% per year) was reported for nitrate-N (and total N) concentrations in well I44/0519 on Gordon Road North (Figure 5-2). An 'extremely likely' increase of 2% per year was also reported in well I44/0964 (immediately downgradient of Mosgiel) over July 2017 to June 2022. In contrast, well I44/0821 near the Taieri Aerodrome recorded an 'extremely likely' decreasing (improving) trend of 1.8% per year over the same five-year period (Figure 5-2).

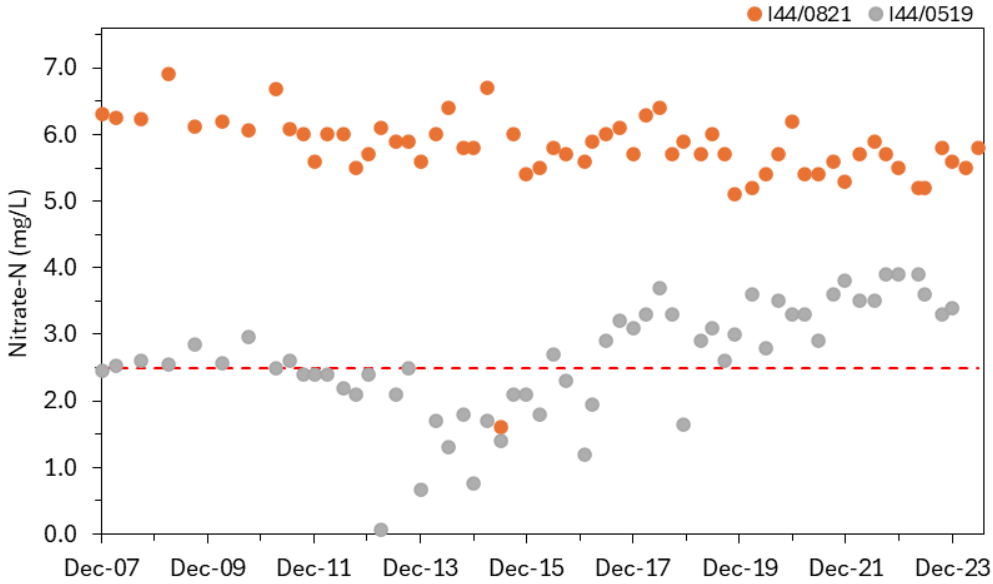

Figure 5-2: Nitrate-N concentrations in two groundwater wells over the full available monitoring record. The red dashed line indicates the threshold for low intensity land use (Morgenstern & Daughney 2012). Based on data downloaded from the ORC's Environmental Data Portal.

5.4 What might be behind the trends?

Ozanne et al. (2023) and earlier regionwide SOE state and trend reports (e.g., Uytendaal & Ozanne 2018), point to a lack of information on catchment- and local-scale land use and land management practices to provide evidence of drivers and direction of water quality trends. This makes it is difficult to state with confidence the reasons behind the trends summarised in this section. The improving trends in phosphorus concentrations in the Taieri River at Outram and Allanton are consistent with improving trends reported for the mainstem river in the upper and mid catchment (Milne & Rados 2024, Milne 2024).

5.5 Summary

- The ORC's most recent water quality trend assessments indicate plant-available and total phosphorus concentrations decreased (i.e., an improvement) at both sites on the mainstem of the lower Taieri River and the lower Silver Stream over the 10-year period ending June 2022. Turbidity also decreased in the lower Silver Stream over this period, while total nitrogen concentrations increased in the Waipori River. The reasons for the observed trends are unclear.
- Limited information is available on trends in ecological variables such as macroinvertebrates as until recently, few river and stream sites were regularly monitored for these variables.
- No strong trends are evident in the quality of Lake Waihola. Trophic level index scores have remained relatively consistent within the eutrophic band (4–5, 'poor').
- A 'virtually certain' increase in nitrate nitrogen concentrations (9.1% per year) was reported for one of the four SOE shallow groundwater monitoring wells on the lower Taieri Plain over the 10-year period to June 2022. Over the shorter five-year assessment, 'extremely likely' increases and decreases in nitrate nitrogen concentrations were observed in two and one groundwater well, respectively.

6 Issues, gaps and priorities

The monitoring and investigation results summarised in sections 4 and 5 indicate that water quality in the lower Taieri catchment is good at the catchment margins but degrades once rivers and streams begin to flow across the lower Taieri Plain. Water quality of the Taieri River at Outram is 'good' relative to other river sites draining rural lowland areas in New Zealand, with median concentrations of *E. coli* and plant-available nutrients ranked within the best 50% (i.e., lowest) of monitored lowland sites. While the Allanton site also falls into the best 50% of sites, water quality has deteriorated by this point (refer Figure 4-1), with noticeably higher median turbidity and concentrations of nutrients and *E. coli* compared with Outram. In terms median values for the monitored tributaries, the lower Silver Stream ranks favourably for visual clarity and plant-available phosphorus but is amongst the poorest (i.e. highest) 25% of monitored lowland sites for plant-available nitrogen concentration.

This section looks further at specific aspects of river and stream health, focusing on monitored sites on the lower Taieri Plain. It also addresses the health of Lakes Waipori and Waihola, and the Taieri River Estuary, which represent the ultimate receiving environments for significant inputs of agricultural drainage water from across the lower Taieri Plain. Water quality information for drain sites once monitored by the ORC is summarised along with the last assessment the ORC made of their former SOE monitoring site on the Ōwhiro Stream in East Taieri. Water quality knowledge gaps and priorities are also outlined.

6.1 Rivers and streams of the lower Taieri catchment

6.1.1 Sediment

Fine sediment (<2 mm in diameter) is a known 'master' stressor on river and stream health. In naturally cobble and gravel bedded rivers and streams like the Taieri River and its tributaries, fine sediment:

- reduces water clarity when suspended in the water column, reducing aesthetic values, light penetration for plant growth and the ability of fish to see their prey,
- can smother the bed, reducing the diversity and quality of the cobble substrate habitat for aquatic life with flow-on impacts (e.g., reduced diversity of aquatic life, loss of trout spawning habitat), and
- carries contaminants that readily attach to it, most commonly phosphorus, pathogens and metals, with flow-on effects for ecosystem health and reduced water quality for recreational and other uses.

The NPS-FM includes two sediment attributes, one for the water column (suspended fine sediment) and one for the riverbed (deposited fine sediment). There is more than one method to measure suspended and deposited fine sediment but the NPS-FM defines:

- suspended fine sediment as visual clarity, not the closely related measures of turbidity or concentration of suspended sediment, and
- deposited fine sediment as the percentage bed cover of fine sediment, determined as an average of visual estimates of cover made at 20 locations across the river.

In terms of suspended fine sediment, the ORC currently only routinely measures turbidity at SOE sites and uses a national equation established by Franklin et al. (2020) to convert turbidity measurements to an estimate of visual clarity so that an NPS-FM band can be determined. Although the NPS-FM allows for this, neither the national equation nor the NPS-FM attribute thresholds are applicable to naturally highly coloured brown-water streams (Franklin et al. 2019). This is because, while turbidity and visual clarity are usually closely correlated, visual clarity measurements (unlike turbidity) reflect both the concentration of suspended fine sediments and water colour (e.g., because of tannin staining). The current assignment of a D band (i.e., below the national bottom line or minimum acceptable state) for the Taieri River at Allanton, Waipori River[16] at Waipori Falls Reserve and Meggat Burn at Henley-Berwick Road will at least partially be due to the natural

[16] Waipori, when correctly spelt as Waipōuri, means 'dark water' in Māori.

tannin-staining in these waterways which contributes to poorer visual clarity. It is also worth noting that a river that is affected by natural processes such as tannin-staining is exempt from meeting the national bottom line for visual clarity.

Irrespective of the NPS-FM grading, there is a noticeable increase in turbidity in the main stem of the Taieri between Outram and Allanton (refer Figure 4-1). At least six tributary streams and drains enter the river between these sites and are regularly seen to carry high concentrations of suspended sediment arising from a combination of surface runoff conveyed via smaller on-farm drains, stormwater discharges in Mosgiel and other built up areas, and stream and drain bank erosion (Figure 6-1).

Figure 6-1: Examples of sediment sources to the lower Taieri River from tributary streams and drains. Clockwise from top left: Undercut bank on the Silver Stream at Riccarton Road West, one of numerous of smaller drains (with signs of a sprayed bank), bank erosion in a drain that discharges directly to the Taieri River downstream of Riverside Road, fine sediment on the bed of the Contour Channel at Huntly Road, turbid water and nuisance plant growth in Lee Creek (Canal) at Otokia Road West Road, turbid water and sediment build up on the bed of the Ōwhiro Stream at Riverside Road, and a partially exposed and undercut bank of the Ōwhiro Stream at Burns Street, Mosgiel.

The ORC's only routine monitoring of deposited fine sediment cover in the lower Taieri catchment occurs in the Silver Stream at the ORC's Taieri Depot (Riccarton Road). This site, like much of the Silver Stream, is characterised by clean fine gravels (top left of Figure 6-1), making it a favoured trout spawning site. However, as illustrated in Figure 6-1, deposited fine sediment is widespread on the beds of most streams on the lower Taieri Plain. This contributes to the degraded macroinvertebrate health observed across monitored sites on the plain.

The degraded state of Ōwhiro Stream

The Ōwhiro Stream is not currently monitored by the ORC but a site in the lower reaches at Riverside Road was included in the council's SOE river monitoring programme between mid-2012 and mid-2018. A site at Burns Street was also monitored between 2001 and 2012. The results for both sites showed water quality was severely degraded.

In an assessment of water quality state between mid-2012 to mid-2017, Uytendaal and Ozanne (2018) described the Ōwhiro Stream at Riverside Road as the having *"the worst level of compliance against Water Plan limits of any site across the Taieri River reporting region and in fact, the wider Otago region."* (ranked 57th out of 57 sites). An example of this is seen in ammoniacal nitrogen concentrations, which are frequently around or below laboratory detection level in most streams in New Zealand. Figure 6-2 illustrates this is the case for most sites in the Taieri catchment, with the Ōwhiro Stream at Riverside Road site being the primary and most significant exception. This site was also reported as having a significant increasing (i.e., deteriorating) trend in ammoniacal nitrogen concentrations between 2006 and 2017.

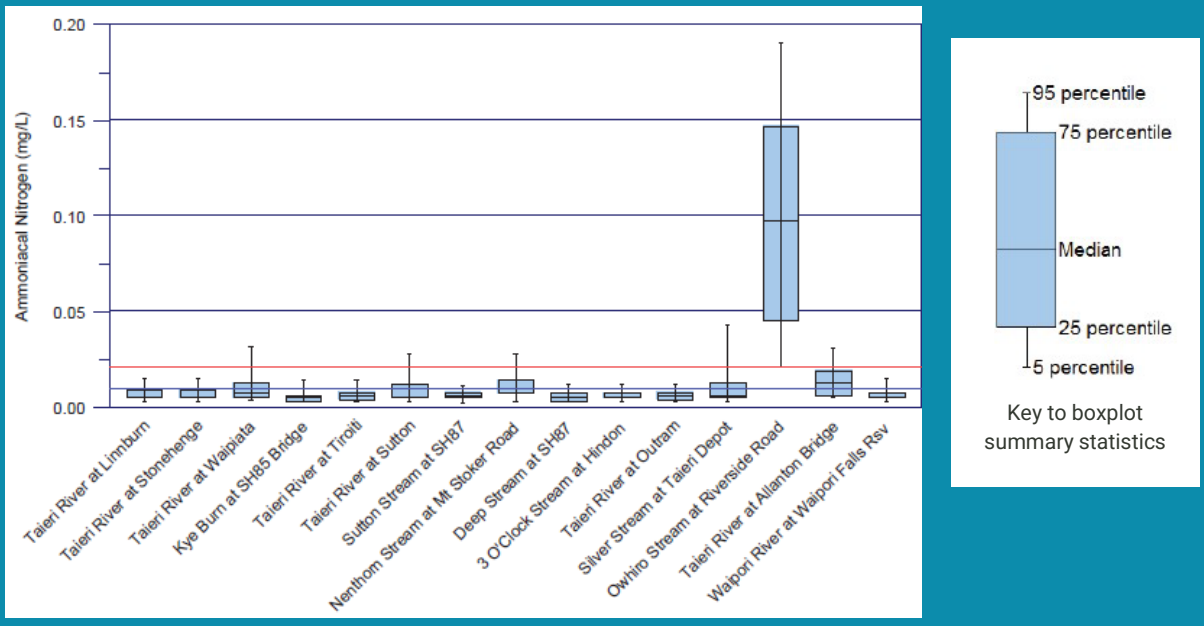

Figure 6-2: Box-plots summarising ammoniacal nitrogen concentrations recorded in SOE sites in the Taieri catchment between July 2012 and June 2017. The red line corresponds to the ANZECC (2000) guideline for lowland rivers (0.021 mg/L) commonly once used as a benchmark for triggering a closer investigation of water quality (when the median value in a dataset exceeded this). Reproduced from Uytendaal and Ozanne (2018).

The Ōwhiro Stream at Riverside Road also had significantly higher median concentrations of other forms of nitrogen as well as plant-available and total phosphorus relative to other streams in the Taieri and Otago, and very high turbidity and faecal contamination (*E. coli* was graded Band E under the NPS-FM, below the national bottom line) (Figure 6-3). Deteriorating trends over time were reported for both turbidity and *E. coli* (Uytendaal & Ozanne 2018).

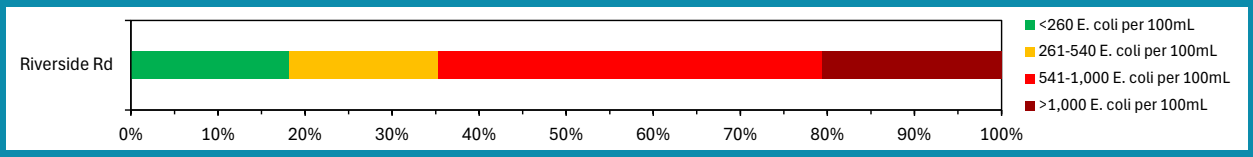

Figure 6-3: *E. coli* concentrations at Riverside Road summarised as the percentage of sample results falling into the green/surveillance, amber/alert, red/action levels of the national MfE/MoH (2003) contact recreation guidelines and a once commonly used stock drinking water guideline. Based on monthly sampling between 2012 and 2018. Data from ORC.

It is unclear if any investigations have been carried out in the Ōwhiro Stream catchment, but sewage contamination has been reported in the past (e.g., ORC 2004) and the consistently elevated concentrations of ammoniacal nitrogen and *E. coli* suggest sewage or animal waste was impacting water quality during the period the stream was monitored. Other than visual clarity, which is periodically measured by schools, the current state of water quality is unknown. It is likely still very poor.

6.1.2 Nutrients

6.1.2.1 Nitrogen

The forms of nitrogen most readily taken up by periphyton and aquatic plants (macrophytes) are the dissolved inorganic forms (ammoniacal-N, nitrite-N and nitrate-N), which are present at low concentrations in the lower reaches of the Taieri River, especially when compared with other lowland rivers monitored in rural areas of Otago and New Zealand[17]. Similar to all other monitored Taieri River sites, total N concentrations are much higher (Figure 6-4), indicating that most nitrogen is present in organic forms (e.g., amino acids, plant tissue and decayed leaf matter). Nutrient forms are not fixed; under the right conditions, one form can convert to another and become available, 'locked up' or lost from the system (e.g., by denitrification, a process that naturally occurs in wetland systems).

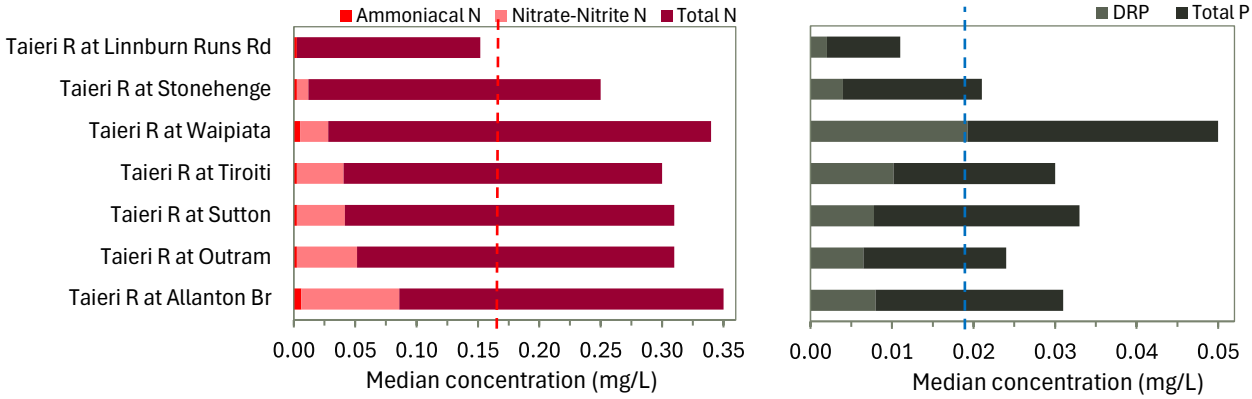

Figure 6-4: Median concentrations of different forms of nitrogen (left) and phosphorus (right) recorded by the ORC in mainstem Taieri River sites. Summary values from LAWA (accessed August 2024) for the period January 2018 to December 2022. The full length of each bar represents the total N or P concentration, with the lighter coloured portions representing the plant-available fractions. The vertical red dashed line represents the once commonly applied ANZECC (2000) NNN 'benchmark' for upland rivers (presented for context only, to illustrate that NNN concentrations are low even at the two sites on the lower Taieri Plain). The vertical blue dashed line represents the boundary of Bands C/D for DRP under the NPS-FM 2020 (note there is no national bottom line for DRP).

Concentrations of plant-available nitrogen are much higher in some tributaries, in particular the Silver Stream and Ōwhiro Stream (Figure 6-5). Water quality is no longer routinely monitored by the ORC in any drains but extensive historical data exist for the Contour Channel and Main Drain, which collect and convey significant portions of agricultural drainage on the West Taieri into Lake Waipori. The data indicate these drains carry very high concentrations of plant-available nitrogen compared with the Taieri main stem and most tributaries (Figure 6-5). The Main Drain, which runs down the centre of the plain, is fed by several other drains, including Lee Canal (Creek) and Kirks Drain and currently still receives treated wastewater from Dunedin International Airport. The wastewater discharge represents a significant point source of nutrients to the drain, historically contributing very high concentrations of ammoniacal nitrogen (Lindgren 2006). Several WWTP upgrades have improved the quality of the discharge but recent reports (Knipe 2023, 2024) indicate there have been difficulties meeting the current discharge quality limit for ammoniacal nitrogen since 2016.

Nitrate-N concentrations are much higher in winter than summer (Figure 6-6), as is typical in most surface waters (Whitehead et al. 2019). This typically reflects a 'flush' from soils in the catchment and less plant growth in winter, although the pattern is less marked in the lower Silver Stream, which is groundwater fed.

Shallow groundwater at the northeastern end of the lower Taieri Plain has the highest nitrate-N concentrations. In two of four monitoring wells, median concentrations are sufficiently elevated that they can be described as impacted by intensive land use (Morgenstern & Daughney 2012). Directions of trend are unclear; there are signs of increasing concentrations of nitrate-N in two wells but a decreasing trend in another. While the integrity of the wells is questioned by ORC, suggesting that the monitoring results may not

[17] Based on a comparison of median concentrations reported on LAWA (August 2024).

be truly representative of the underlying groundwater, poor well integrity is more likely to affect *E. coli* rather than nitrate monitoring results.

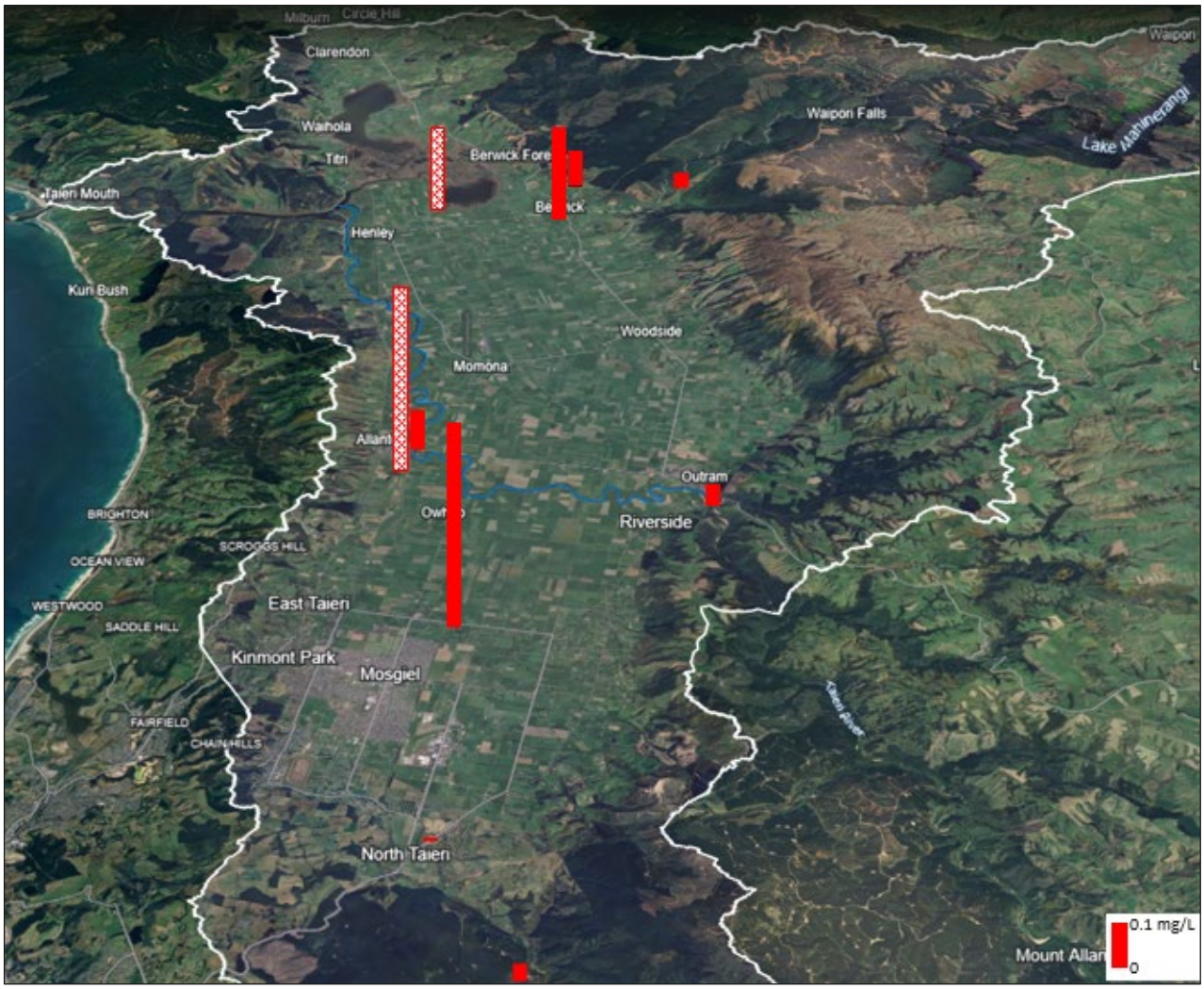

Figure 6-5: Concentrations of nitrate-N at different river, stream and drain sites on the lower Taieri Plain. The height of each bar is proportional to median concentrations for the 5-year period ending June 2022 (Ozanne et al. 2023). Hashed bars are historical medians (2014–18) for former ORC monitoring of the Ōwhiro Stream at Riverside Road and Main Drain at Waipori Pump Station. Base map: Google Earth.

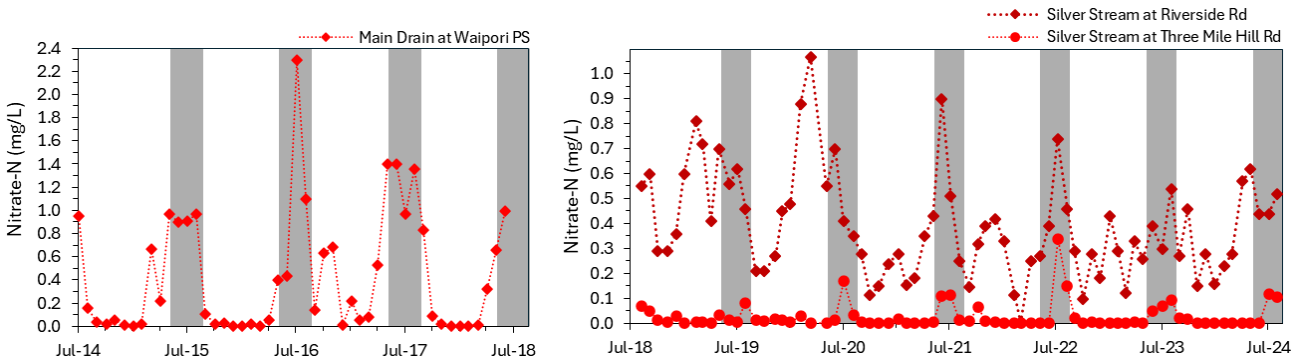

Figure 6-6: Nitrate-N concentrations in the Main Drain (left) and Silver Stream (right). The grey shading indicates samples collected during winter (June to August). Data from ORC.

While none of the monitored wells have nitrate-N concentrations above the NZ Drinking Water Standard, some nitrate-enriched groundwater enters surface water, such as the lower reaches of the Silver Stream where adverse effects in the form of nuisance algal or plant growth occur at significantly lower concentrations. Information on periphyton growth is limited to the Taieri River at Outram and Silver Stream at Taieri Depot but

ORC monitoring at both sites indicates that periphyton reaches nuisance levels, particularly at the Silver Stream site. Significant aquatic plant and weed growth is also present in many of the drains (refer Figure 6-1).

The Taieri River appears to be nitrogen-limited (McDowell and Kitto 2013, Kitto 2012, Ozanne 2012), at least in its upper and mid-reaches. This means that an increase in nitrogen would likely stimulate nuisance algal (or plant) growth more than additional phosphorus would.

6.1.2.2 Phosphorus

Similar to nitrogen, the majority of the phosphorus in the Taieri River main stem is present in organic form. Median plant-available DRP concentrations at Outram are significantly less than those further up the catchment between Waipiata and Sutton (Figure 6-7). This is likely due to a combination of lower nutrient inputs from tributaries downstream of Sutton and natural processing (attenuation) within the river. It is difficult to quantify the former because nutrient concentrations in Lee Stream have not been routinely monitored for more than 10 years (Milne 2024). However, another significant tributary, Deep Stream, is monitored and has very low DRP concentrations.

Overall, summary statistics on LAWA indicate that current five-year median DRP concentrations in the lower Taieri River and its monitored tributaries sit within the best 50% and 25% of monitored river and stream sites in rural areas of New Zealand, respectively. However, historical ORC monitoring data indicates median DRP concentrations in the Ōwhiro Stream at Riverside Road, Main Drain and Contour Channel are more than ten times higher than the Taieri main stem and would fall into Band D of the NPS-FM (Figure 6-7).

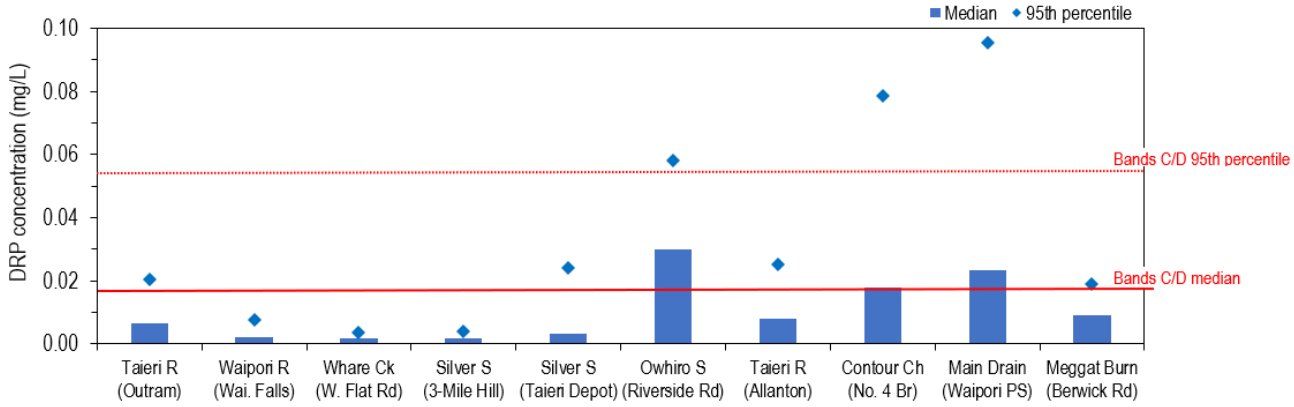

Figure 6-7: Median and 95th percentile (i.e., near maximum) DRP concentrations recorded from ORC SOE monitoring across different sites in the lower Taieri catchment. Based on 2017-2022 data from Ozanne et al. (2023) and estimates from historical data for the Main Drain and Ōwhiro Stream. The red lines represent the boundary of the poorest NPS-FM 2020 bands.

6.1.3 E. coli

Faecal contamination of waterbodies is widespread on the lower Taieri Plain. The ORC has graded *E. coli* at all three monitored sites on the central Plain area, the Silver Stream at Taieri Depot, Meggat Burn at Henley-Berwick Road and Taieri River at Allanton, in Band D of the NPS-FM 2020 based on year-round monitoring results over the five-year period ending June 2022. However, the Allanton site only falls into this band based on its 95th percentile and would otherwise be assigned Band C based on the other three *E. coli* metrics that determine the band classification. A 95th percentile is nearly always influenced by the effects of rainfall and elevated river flows when contact recreation is less likely to be occurring.

Faecal contamination is greater in some other waterways on the lower Taieri Plain. For example, the Contour Channel at No. 4 Bridge was graded Band E for the same five-year period and a 'virtually certain' increase in *E. coli* concentrations (i.e., a deteriorating trend) of 21% per year was reported for the 10-year period ending in June 2022 (Ozanne et al. 2023)[18]. Historical data suggest that the Ōwhiro Stream at Riverside Road also sits in

[18] Although it is an artificial watercourse, the Contour Channel receives water from many natural streams flowing off the Maungatua Range and was monitored monthly as part of the ORC's SOE programme between July 2014 and November 2023. The ORC included the results for this site in its most recent state and trend assessment (Ozanne et al. 2023).

Band E. Like the Contour Channel, the Ōwhiro Stream site recorded a very high median (50th percentile) *E. coli* count (Figure 6-8), indicating that contact with the water poses an unacceptable risk to human health most of the time. In contrast, the Taieri River at Allanton has a much lower median; as noted above, this site falls into the D band only due to a high 95th percentile *E. coli* value that is associated with rainfall.

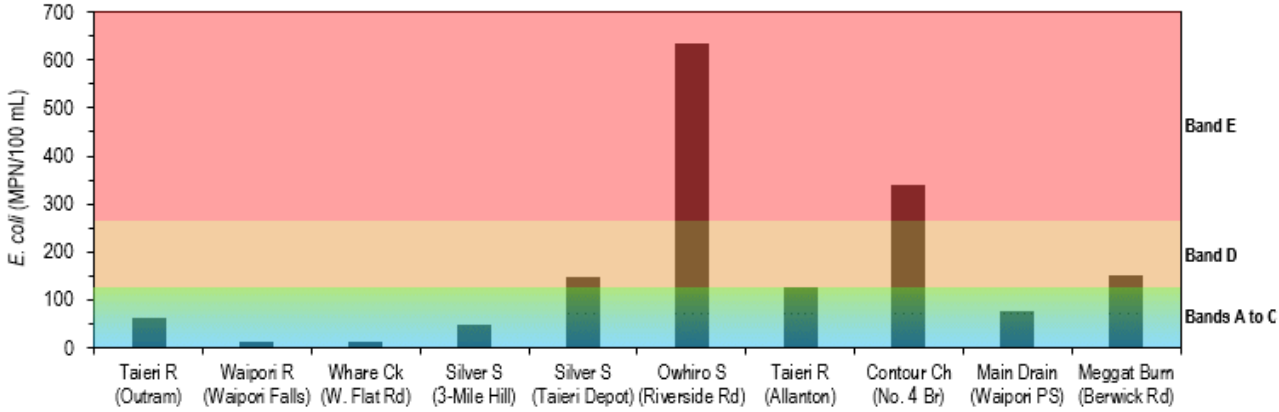

Figure 6-8: Median *E. coli* counts recorded from ORC SOE monitoring across different sites in the lower Taieri catchment. Based on 2017-2022 data from Ozanne et al. (2023) and historical data for the Main Drain and Ōwhiro Stream. The bands relate to medians from the NPS-FM 2020; they represent only one of four summary statistics used to grade *E. coli* but, as they correspond to the middle point (50th percentile) in a dataset, they provide a good indication of the 'average' risk contact with the water poses to human health in dry weather.

While the Ōwhiro Stream has recorded the highest *E. coli* concentrations, the Contour Channel has a much higher flow and so it discharges a greater faecal mass (load) to downstream receiving waters. *E. coli* counts in the Main Drain are not as high, with the 2014–2018 median less than the current median from some of the natural streams on the Plain (Figure 6-8). This may reflect *E. coli* die-off linked with an increased residence time (the drain is not continuously pumped) or, as suggested by Schallenberg and Armstrong (2004), the influence of antibiotics present in drainage water (e.g., arising from use on stock).

Overland runoff, drainage and stormwater are almost certainly the dominant sources of faecal contamination on the lower Taieri Plain. Direct stock access and waterfowl are likely additional sources in some areas, as may be contamination arising from cross connections or leaking wastewater pipes and poorly performing septic tanks. Some faecal source tracking would be useful, particularly in the Ōwhiro Stream catchment where the consistently elevated *E. coli* and nutrient concentrations point to likely wastewater inputs.

Are all faecal sources equal? Limitations with the current *E. coli* guidelines

E. coli is a long-established and accepted, but imperfect, indicator of the risk to human health from pathogens that are much more expensive to test for.

One limitation with the MfE/MoH (2003) guidelines on which the NPS-FM *E. coli* attributes bands are based is that they do not account for different levels of pathogenicity that may be associated with different sources of faecal matter. For example, in combining the results of faecal source tracking with a quantitative microbial risk assessment (QMRA)* in a rural catchment in Texas, Gitter et al. (2020) found that the highest health risk was associated with Norovirus, the pathogen representing human waste. This was despite faecal indicator bacteria from non-human sources being the most frequently present in repeated water testing. After humans, dairy cow faecal matter presented the next greatest risk, ahead of the wildlife sources (including birds). This suggests that the proportion of a single source contributing to the overall *E. coli* count does not indicate the overall human health risk.

The risks of gastrointestinal illness from exposure to recreational waters were also found to vary by source in the US; the risk differed little between waters impacted by human sources and fresh cattle faeces, but the impacts of gull, chicken and pig faeces appeared to be much lower (Soller et al. 2011).

* A QMRA is currently the most robust method available to assess the risks to human health from exposure to faecally contaminated water. It is regularly carried out in New Zealand when assessing the effects of wastewater treatment plant discharges to rivers, lakes or coastal waters.

6.1.3.1 Outram Glen – will we get sick if we swim?

The national water quality guidelines for primary recreation are set conservatively to protect human health. In the case of fresh waters, they have an added layer of protection built in because they are based on the risk of *infection* (from campylobacter, a common pathogen in New Zealand fresh waters), not the risk of *illness*. Not all people who are infected by a pathogen will become ill as a result.

For the Taieri River at Outram Glen, based on definitions in the NPS-FM 2020, the assignment of:

- a Band B (Table 9 of the NPS-FM, based on year-round monitoring) translates to, for at least half the time, an estimated risk of <1 in 1,000 (0.1% risk) and a predicted average infection risk of 2%, and
- a summertime "poor" grade (Table 22 of the NPS-FM) translates to an estimated risk of *Campylobacter* infection over 5% at least 5% of the time.

The summertime "poor" grade is based on the 95th percentile value from weekly water quality sampling over five summers. It therefore represents the near-maximum *E. coli* count from fairly extensive monitoring. The grade is useful in providing a guide to the overall health risk in the absence of further information on what specific conditions reduce the suitability of a site for swimming (i.e., if the 95th percentile value is low, then this indicates the site is likely suitable for swimming virtually all of the time). However, the long-term grade is less helpful for the vast majority of river sites, including the Taieri River at Outram, that do experience occasions when the water has elevated *E. coli* counts. This most commonly occurs during rainfall, which results in overland runoff and re-suspension of *E. coli* entrained in riverbed sediments (e.g., Muirhead et al. 2004). However, at some river sites across New Zealand, faecal contamination also occurs in dry weather arising from stock access, waterfowl and wastewater inputs.

ORC monitoring data indicates that over the past ten summers, *E. coli* counts at the Outram site exceeded the action level of the guidelines (540 *E. coli*/100mL) on 20 (9.5%) sampling occasions. A comparison of each of these occasions against river flows on the day of sampling and rainfall in the upstream catchment prior to sampling (Figure 6-9) indicates that:

- on half of the occasions, more than 10 mm of rain fell in the 72 hours prior to sampling, and
- on 85% of occasions, river flow was above the summertime median of 7.3 m^3/s, (and on the remaining occasions it was raining or had rained but flows had yet to rise significantly).

These findings strongly indicate that Outram is suitable for swimming most of the time in dry weather; the greatest risk to human health will be when hot, dry weather on the lower Taieri Plain, enticing for swimming, coincides with the tail end of 'dirty' high flows following rainfall further up the catchment. This risk can be managed if people are advised to limit swimming to dry weather and river flows below median (flow information is available on the ORC's website).

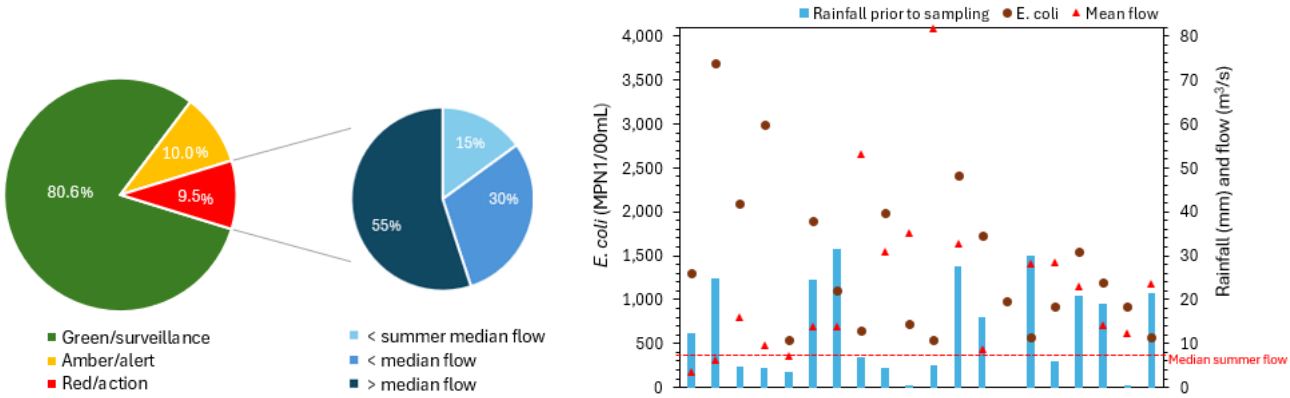

Figure 6-9: Left: Weekly *E. coli* counts at Outram Glen over the last ten summers, summarised as the percentage of sample results falling into the green/surveillance, amber/alert and red/action levels of the national MfE/MoH (2003) microbiological water quality guidelines (left) and river flow for each action level result. Right: Each *E. coli* count above the red/action level compared with rainfall and river flow. Rainfall recorded at Lambhill for the 72 hours prior to the day of sampling, and average flow on the day recorded at Outram, extracted from the ORC's Environmental Data Portal.

The ORC has carried out some faecal source tracking at Outram Glen when action level results have been recorded. Results of testing made on a water sample collected following wet weather in January 2023 attributed the high *E. coli* count to cows[19]. This is consistent with faecal source tracking carried out across rural river catchments in Southland in 2015 and 2016, which showed that ruminant animals typically dominated the faecal input in samples collected following rainfall (Moriarty et al. 2019a-d).

The other potential health risk to recreation at Outram Glen is *Microcoleus* cyanobacteria (previously known as *Phormidium*) which can form thick brown or black mats on the riverbed. Although *Microcoleus* mats have been recorded at the site (Helen Trotter, ORC, pers. comm. 2024), the ORC website indicates that they are more commonly an issue in the nearby Silver Stream.

6.1.4 Ecological health

Except for the lower Silver Stream, there is a lack of long-term ecological data for rivers and streams on the lower Taieri. Like water quality, macroinvertebrate health is degraded across most river and stream sites currently – or previously (e.g., Ōwhiro Stream) – monitored on the lower Taieri Plain. Sites upstream or on the edges of the Plain are in better condition, including Whare Creek at Whare Flat Road and the Taieri River at Outram.

Despite poor water clarity and significant channelisation and bank erosion in places, recent eDNA testing by DOC and NZLT found many streams on the lower Taieri Plain still support multiple native fish species, including threatened galaxiids. Several planting efforts have been made along reaches of the Ōwhiro Stream to improve cover for fish and overall habitat quality (Figure 6-10). However, as the stream, along with virtually all waterways on the lower Taieri, forms part of the Lower Taieri Flood Protection Scheme, this deems large extents of most natural waterways a 'scheduled drain' under the ORC's Flood Protection Management Bylaw 2022 and therefore limits planting and other stream habitat enhancement. For example, approval is required for planting any tree, shrub or hedge within 7 m of the water's edge (ORC 2022).

Figure 6-10: Riparian margins of Ōwhiro Stream in August 2024. Left: Recently planted tussock and sedges at Ōwhiro Avenue in Mosgiel. Middle: A grass-only reach at Burns Street. Right: Vegetation planted downstream of Riverside Road by the Taieri Trust over 20 years ago (under a more permissive version of the ORC's Flood Protection Management Bylaw).

6.2 The lakes and Taieri River Estuary

The Lake Waipori-Lake Waihola Wetland Complex and the Taieri River Estuary are the ultimate receiving environments for contaminants sourced from land use on the lower Taieri Plain and further up the catchment.

Available data indicate that both Lakes Waipori and Waihola are eutrophic (poor); water column nutrient and algae concentrations significantly exceed what are 'healthy'. The southern end of Lake Waihola is graded Band D (i.e., below the national bottom line of the NPS-FM) for total phosphorus, chlorophyll *a* and *E. coli* (refer Table 4-4) and so requires an improvement in water quality under the NPS-FM.

[19] Otago Daily Times, 14 January 2023: https://www.odt.co.nz/news/dunedin/bacteria-test-finds-river-unswimmable

No information is available on the current state of the Taieri River Estuary. The ORC's 2001-02 water quality investigation found enterococci bacteria counts within green/surveillance mode of the MfE/MoH (2023) recreational water quality guideline on all 12 sampling occasions (ORC 2004). Baseline mapping of the estuary's benthic (bottom) habitat by Ryder Consulting in late 2007 identified soft mud/sand lining the water channels and firm sand dominating the estuary mouth. Macroalgal beds incorporating patches of *Gracilaria chilensis* were reported on sand and mud flats along both banks of the lower estuary and within the confines of the gorge (Stewart 2008), but coverage was not at a nuisance level. The baseline survey also incorporated more detailed assessments of sediment quality, and the plants and animals at two locations on tidal sand flats. These assessments found low levels of heavy metals and nitrogen in the surface sediments, but elevated concentrations of total phosphorus (450 mg/kg). Mud crabs, mud snails, polychaete worms and amphipods dominated the fauna present, consistent with other estuaries in the Otago region. Despite patches of unhealthy anoxic sediment at the upper site, the estuary was considered only "moderately enriched" and, overall, in "good health" (Stewart 2008).

6.2.1 Key contaminant inputs

While concentrations of contaminants are of primary interest in rivers and streams, it is the contaminant load (i.e., the concentration multiplied by river flow) that has most relevance to receiving environments, partcularly when they have limited or partial flushing. In the case of both lakes and the estuary, the primary nutrient of concern is nitrogen; phosphorus is already in abundant supply and it is changes in plant-available nitrogen that are more likely to drive algal bloom dynamics in both environments.

Both the Lakes Waipori-Waihola Wetland Complex and the Taieri River Estuary are intricately linked via the backflow of Taieri River water into the wetland complex during flood tides. This, and the complex network of drains (many of which intercept tidally-influenced groundwater and are only intermittently pumped), makes it very difficult to accurately quantify the contributions of nitrogen and other contaminants from different sources. An initial attempt was made by Ryder (1995) based on a mass balance approach. This was then refined over 1 September 1997 to 10 September 1998 by Schallenberg et al. (2003) using additional measured data. This later work identified:

- The inflows of major importance in the lake-wetland complex are the Waipori River, tidal inflows (from the lower Taieri and Waipori rivers) and, possibly groundwater inflows.[20]
- Water in Lake Waipori has a very short residence time (1.9 days as an annual average), particularly during periods of peak hydro-electricity generation. In summer, reduced inflows from the Waipori River, facilitate tidal backflow into the lake and result in changes in the freshwater zooplankton community.
- The Main Drain contributes nutrient-rich water to Lake Waipori but, similar to direct rainfall and runoff from adjacent catchments, the contribution is minor relative to inputs from the Waipori and Taieri rivers.
- Water in Lake Waihola has an average residence time of 153 days and is higher in winter (201 days) than summer (121 days). Seasonal evaporation is a key driver of residence time and, although it only comprises 27% of the mid-tidal lake volume, the tidal compartment has a large influence on the lake relative to other, non-tidal, surface water inflows.

Two more recent assessments built on this initial mass balance work. The first of these was an assessment of the relative contributions of the Contour Channel (a tributary of the Waipori River) and the Main Drain to Lake Waipori (Ludgate 2018). This assessment found that, despite only contributing 1% of the average inflow to Lake Waipori over a flood tide, the annual contaminant contribution from the Main Drain to Lake Waipori is around 30% for NNN and over 60% for ammoniacal nitrogen (Table 6-1). The Contour Channel also contributes significantly, including almost 25% of the plant-available phosphorus load. While the Waipori River contributes the greatest contaminant loads on an annual basis, reflecting its much higher average flow input (38%), Ludgate (2018) demonstrated that during and after large flood events, the daily contaminant loads from the Main Drain could be higher than from the Waipori River.

[20] Subsequent groundwater modelling by the ORC suggested that groundwater inflows were not significant, although the inflows were not able to be quantified (Rekker & Houlbrooke 2010).

Although not considered by Ludgate (2018), the Dunedin Airport's WWTP discharge contributes a significant load of ammoniacal nitrogen to the Main Drain. Based on the average discharge volume and median concentration from the last two annual monitoring reports (Knipe 2023 and 2024), the ammoniacal nitrogen load is around 93 kg/day. If coarsely extrapolated in the same fashion as Ludgate (2018), this amounts to 34 tonnes/year. This is much higher than the Main Drain's contribution to Lake Waipori and suggests that there is likely some processing (attenuation) within the drain and dilution by surface and groundwater drainage inputs entering the drain with distance down the plain.

Table 6-1: Annual contribution of contaminants (tonnes/year, unless indicated otherwise) and percentage contribution into Lake Waipori from the Main Drain, the Waipori River and the Contour Channel. Reproduced from Ludgate (2018). Note these loads represent a coarse assessment as they were calculated from average annual flows and median contaminant concentrations.

Contaminant	Main Drain		Waipori River		Contour Channel		Total load
	Load	%	Load	%	Load	%	
Ammoniacal-N	6.9	63.9	2.7	25.0	1.2	11.1	10.8
NNN	7.5	30.4	12.3	49.8	4.9	19.8	24.7
Total N	26.7	24.1	70.9	64.0	13.1	11.8	110.7
Dissolved reactive P	0.3	17.6	1.0	58.8	0.4	23.5	1.7
Total P	1.7	20.5	5.1	61.4	1.5	18.1	8.3
E. coli (cfu/year)	1.8×10^{13}	28.1	4.6×10^{13}	71.9	1.3×10^{7}	0.0	6.4×10^{13}
Suspended solids	85.3	7.3	907	77.7	175	15.0	1,167

The second assessment estimated the relative contribution of nutrients from the Waihola WWTP to the lakes wetland complex, through discharge on an outgoing tide to the outlet channel of Lake Waihola (Ryder Environmental 2019). This assessment collated information from Ryder (1995), Scallenberg et al. (2003) and Ludgate (2018) and information on the Waihola WWTP reported by Aldon and Stewart (2018). The key findings were:

- based on the average volume of wastewater discharged in 2017 (102 m^3/day), the WWTP was likely contributing 0.61 tonnes/year of total N and 0.22 tonnes/year of total P, equating to 0.3% and 1.3%, respectively, of the contribution from all point and non-point sources, and
- contributions increased to 2.3% and 8.7% for total N and total P, respectively, at the maximum consented discharge volume (680 m^3/day).

In 2021 dye testing was carried out to look at options to minimise backflow of the Waihola WWTP discharge into Lake Waihola. The results (Medel 2021) confirmed that treated wastewater does flow back towards the lake through the northern and southern channel with the incoming tide. Further, while limiting discharge to an outgoing tide will see it shift 'downstream' towards the Taieri River, the current regime did not allow sufficient time for it to be flushed out through the estuary before the tide turns. While it was expected that a pump upgrade could enable a higher rate of discharge over the first half of the tide only (Medel 2021), no modelling was provided to confirm if this would be sufficient to prevent backflow.

One of the missing links from modelling to date appears to be an estimate of the total contribution of nutrients that enter the lake wetland complex via tidal backflow from the Taieri River. This is difficult to estimate given the complexity of tides and unknown contributions from groundwater. We do know that nutrient concentrations – and therefore nutrient loads – increase in the ~14 km reach between Outram and Allanton. Using the same approach as Ludgate (2018) in Table 6-1, the following coarse annual nutrient loads are estimated for the Taieri River at Allanton[21]:

[21] Based on 5-year median nutrient concentrations from LAWA and measured and estimated mean flows for the Taieri River at Outram (26.7 m^3/s) and at Allanton (28.4 m^3/s) by ORC consultant hydrologist, Dave Stewart (pers. comm 2024).

- Ammoniacal-N: 5.4 tonnes per year (2.5-fold higher than at Outram)
- NNN: 71.6 tonnes per year (1.7-fold higher)
- Total N: 313 tonnes per year (1.2-fold higher)
- Dissolved reactive P: 7.2 tonnes per year (1.3-fold higher)
- Total P: 27.8 tonnes per year (1.1-fold higher).

Additional nutrients enter the tidal teaches of the lower Taieri River downstream of Allanton from adjacent agricultural and flood drainage, including from the Otokia and Henley areas, but no recent data are available for these areas (the main stem at Henley Ferry was monitored was monitored by the ORC up until the mid-2000s). The most recent estimate of total N and total P loads entering the Taieri River Estuary are 1,410 and 139 tonnes per year, respectively, from modelling carried out by Snelder (2021). These loads equate to more than four times the estimated loads at Allanton but were calculated using daily flows so will better account for the much higher nutrient inputs that occur in wet weather flows. Using these estimated loads in a further modelling exercise, Plew (2021) determined that the Taieri Estuary is likely highly eutrophic which, for a shallow, short residence time tidal river estuary like the Taieri, would most likely be seen in the form of nuisance macroalgal growth. However, with the intertidal area limited to 10% (Plew 2021), suitable habitat for macroalgae to bloom appears to be limited. Actual on-the-ground measurements of macroalgal cover, sediment nitrogen concentrations and oxygenation by Stewart (2008) also did not suggest the estuary was highly eutrophic, although these measurements were made more than 15 years ago.

6.3 Gaps and priorities

Similar to in the upper and mid-Taieri, long-term ecological and physical stream habitat data are lacking for rivers and streams in the lower Taieri catchment. Monitoring of periphyton biomass and streambed sediment cover is limited to the lower Silver Stream. The ORC has increased the number of sites monitored for macroinvertebrates in the last few years which will, in time, provide a long-term data set. Overall, regardless of what monitoring is carried out, the ecological condition of streams on the lower Taieri Plain will remain poor owing to the classification of most natural streams as scheduled drains and the activities associated with maintaining them as such (e.g., removal of bottom sediment and spraying of stream banks). Therefore, a greater priority than monitoring is to explore with the ORC's flood protection staff what can be achieved in the way of habitat enhancement to support the native fish values that currently still exist, without unduly compromising flood capacity. A lack of riparian vegetation and excessive streambed sediment appear to be widespread issues.

Although the Ōwhiro Stream hasn't been monitored by the ORC since mid-2018, it is likely still in a very degraded state. Ammoniacal nitrogen concentrations were consistently elevated at Riverside Road right up until monitoring ceased and indicate that the stream may be impacted by wastewater. This warrants further investigation, such as through faecal source tracking. Schools have been involved with monitoring this stream in recent years and there may be merit in the ORC supporting an extension of this monitoring.

The Main Drain and Contour Channel are very significant contributors of nutrients and other contaminants to Lake Waipori, although the proposed re-direction of wastewater from Dunedin International Airport and Momona Village to the Dunedin City Council sewerage system from around 2026 (DIAL 2022) will reduce nutrient loads entering the Main Drain. While both the Main Drain and the Contour Channel are artificial and so were removed from the ORC's river SOE monitoring programme, they effectively act as point source discharges into the Lakes Waipori-Waihola Wetland Complex and should be monitored under a consenting framework given the eutrophic status of the lakes[22]. Sites on these waterways could equally be monitored as part of a programme to assess the effectiveness of policies for managing contaminants from agricultural land use and septic tanks in the pending new Land and Water Plan. Regardless of how they are monitored, an up-

[22] The ORC's discharge from the Main Drain into Lake Waipori was consented up until March 2018, after which it was deemed to be a permitted activity under Rule 12.C.1.1 of the Regional Plan: Water for Otago (Sophie Butt, ORC. pers. comm. 2024). However, from April 2026, permitted activity discharge thresholds in Schedule 16A apply under Rule 12.C.1.1A; based on the data presented in this report, the discharge from the Main Drain would be unlikely to meet the threshold for ammoniacal-N.

to-date assessment of nutrient loads entering the Lakes Waipori-Waihola Wetland Complex from all sources would help inform the work needed to improve water quality in both lakes.

No recent monitoring data exists for the Taieri River Estuary. Although a baseline assessment in 2007 reported the estuary to be in good health, more recent catchment and estuary modelling suggests that this may not be the case. The ORC has indicated that it may re-commence some monitoring of the estuary in the near future (S. Thomas, pers. comm. 2024).

Lake Mahinerangi is not monitored by the ORC and its current condition is unknown. The lake was the subject of several studies between the 1960s and 1980s (e.g., Mitchell 1971, Malthus & Mitchell 1988) which tracked changes in lake condition with increasing agricultural development in the catchment. This work included assessments of lake water quality and baseflow nutrient loads from the lakes' seven major tributaries (many of which drain the mid-Taieri catchment). In the approximately 18-year period between the first and last assessments, 35% of the catchment had been developed agriculturally and some changes in lake condition were identified (Malthus and Mitchell 1988). Since then, there has been further changes in land use activities, including forestry, that may have altered lake condition.

With residential development in Mosgiel and the East Taieri rapidly expanding, the impact of urban stormwater on water quality in the lower Taieri appears to be an information gap. Wet weather water quality monitoring in the Silver Stream carried out by the DCC in 2022 found elevated concentrations of copper and zinc at Riccarton Road West compared with upstream of Mosgiel. Metal concentrations are likely higher at other locations, including within more highly trafficked and industrial areas.

Lastly, with both the Taieri River and several tributaries characterised by natural tannin-staining, a site-specific relationship between turbidity and visual clarity is needed for monitoring sites on these systems to allow a more meaningful assessment of the suspended fine sediment attribute under the NPS-FM. This will require a period of paired turbidity and visual clarity measurements. A particular challenge will be to differentiate the influence of natural tanning staining on visual clarity from that of actual suspended sediment arising from overland flow, discharges and bank erosion.

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