Waiau **catchment**

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Te Taiao Tonga

Waiau catchment

This document summarises scientific information, opportunities for action and the socioeconomic context for the Waiau catchment, which drains into Te Waewae Bay.

It is one of twelve catchment summaries prepared for the Murihiku Southland region.

The scientific data presented in this summary has been collated at the catchment scale to provide an understanding of freshwater quality and quantity challenges and their underlying factors. This summary provides an evaluation of the current state of freshwater within the catchment and highlights the magnitude of change necessary to meet freshwater aspirations.

The information in this document should be considered alongside other information sources, including mātauranga Māori.

Main features

Land area: 822,000ha

Major rivers and streams:
Waiau River, Eglinton, Mararoa, Upukerora, Whitestone, Monowai, Wairaki, Lill Burn, Orauea

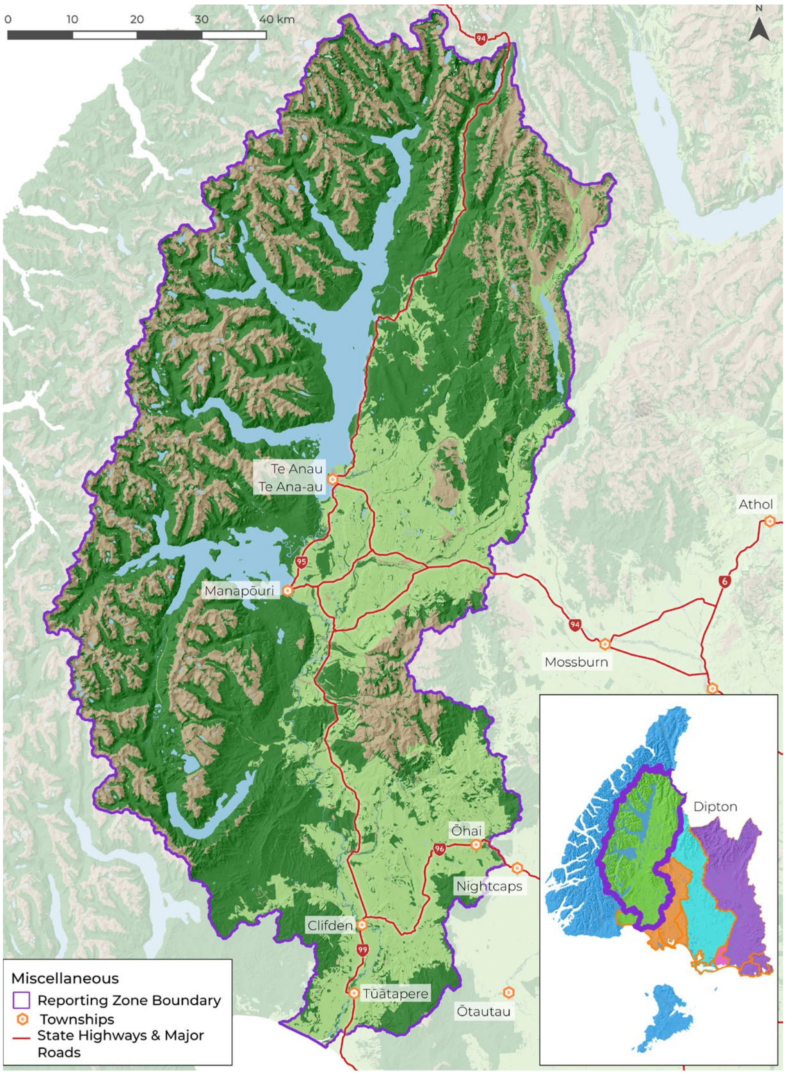
Aquifers:
Te Anau, Blackmount, Te Waewae

Lakes:
Te Waewae (Waiau) Lagoon, Te Ana-au, Manapōuri, Hauroko, Mavora Lakes, Lake Gunn, numerous in Fiordland National Park

Townships:
Te Anau, Manapōuri, Tūātapere

Population:
Approximately 6,000

Catchment outline



For most attributes, current state is assessed using data from the 2018 – 2022 period.

Key messages

Issues

- Monitoring indicates that freshwater ecosystem health in the Waiau catchment is generally in better condition than in other main Southland catchments. However, there are locations where freshwater health is poor for some key attributes, including periphyton.
- Te Waewae (Waiau) Lagoon is in a 'fair' state. Nutrients are the main ecosystem health issue, reflected in nutrient concentrations, increased macrophyte growth and higher phytoplankton.
- Where attributes do not meet hauora targets, outcomes are less likely to support healthy, resilient ecosystems and the economy that depends on these.
- Contaminant load reductions required to achieve hauora targets are large (best estimate: 73% for nitrogen). Scenario modelling indicates these reductions will not be achieved by improved management practices alone.
- Approximately 998 ha (10%) of wetlands have been lost since 1996 in the Waiau catchment.

Opportunities for action

- Implement property-scale mitigations and best possible management practices tailored to the agricultural system, physiographic setting and the sensitivities of the receiving environments.
- Consider opportunities to facilitate land use change that reduces environmental impact or encourages deintensification to occur over time. This may be through long-term catchment plans and projects, pilots and promotion of alternative land use options, or regulation.
- Apply catchment-scale mitigations, which could include restoration or creation of wetlands, riparian shading, stock exclusion and habitat retention at scale, large detention bunds and edge-of-field mitigations.
- Detect and remediate local point source contaminant discharges.

Possible active restoration techniques are only likely to improve the long term catchment and lagoon health if contaminant inputs are also reduced.

Socioeconomic context for action

Western Southland and the communities in and around the Waiau catchment have been shaped by historic socio-economic shifts in the latter part of the 20th century (McLachlan, 2021). The impacts of neoliberal deregulation from the 1980s removed agricultural subsidies and export assistance, creating a period of austerity for many farming communities. Other industry declines, such as coal extraction in the Ohai-Nightcaps area and the timber industry in the Tūātapere/ Longwood Forest area, led to a deterioration of socio-economic conditions for local dependent townships, driving population decline. The rise in dairy farming across the region in the 1990s began to reverse economic conditions for the more expansive zone, ushering in land use change and industry and demographic changes.

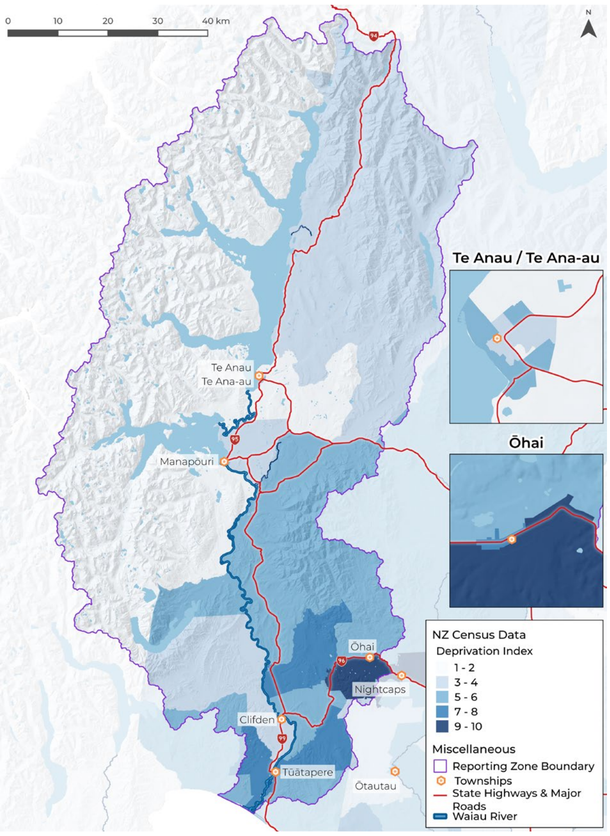
However, the populations in the Waiau catchment remain closely associated with the agriculture, forestry and fishing. In the 2018 Census, more than a third of the population of Longwood and Mararoa areas were directly involved in these industries (Stats NZ, 2018). Te Anau is predominantly involved in accommodation and food services, but also spread across multiple industries (Stats NZ, 2018). Likewise, Whitestone is similar to Te Anau but also more heavily involved in agriculture, forestry and fishing (Stats NZ 2018).

Following a general population decline from the 1990s to the mid-2000s, the Waiau catchment and Southland generally have shown steady increases in both population and ethnic diversity in the region (Stats NZ, 2018). Te Anau experienced a more substantial increase in population since 2013, predominantly people aged 30 years and over. Whitestone area also experienced a steadily increasing population over almost 3 decades (Stats NZ, 2018).

The age distribution in Waiau is reasonably consistent with the wider Southland district. The main demographic disparity in the zone shows fewer younger people (15-29) who often leave for tertiary education or employment opportunities elsewhere in Southland or outside of the Southland region. Although housing prices have increased regionally and nationally since 2020, Southland, mainly inland western Southland (except Te Anau), has remained some of the most affordable places to buy or rent in New Zealand.

Although Southland District is among the least socio-economically deprived areas in New Zealand, the Longwood area (7-9 on the index), contains some of the most deprived areas in Southland District. This is not the case for Mararoa, Whitestone or Te anau areas.

Social Deprivation Index

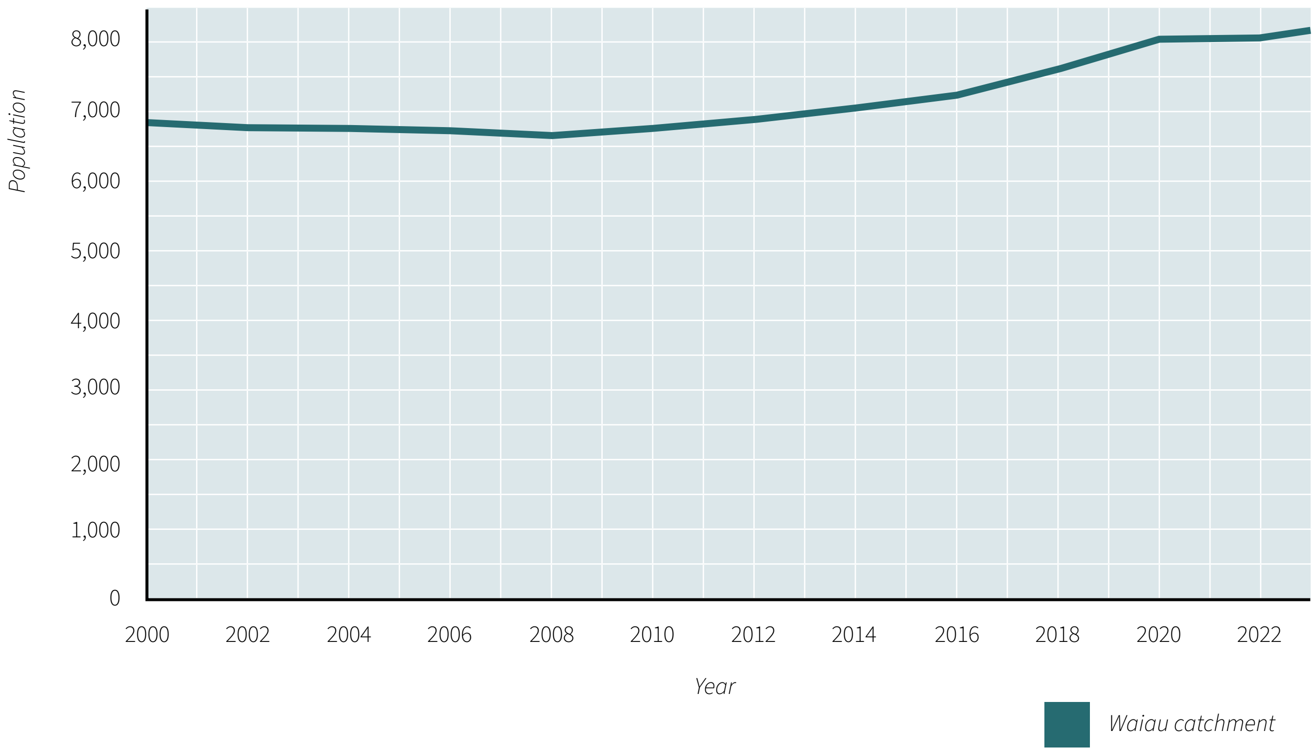


Social Deprivation Index

The Deprivation Index measures relative socioeconomic deprivation using census-based information. It incorporates indicators including income, crime rate, Jobseeker Support receipt, rental affordability, purchasing affordability, home ownership, new business registrations, gaming machine proceeds per capita, secondary school retention and educational attainment

The Waiau catchment comprises multiple statistical areas across two territorial authorities. Some parts of these statistical areas lie outside the catchment boundary. As a result, this graph shows general population trends across these areas rather than the catchment population itself.

Estimated population trends (Dot Loves Data, 2024)



Summary

- Much of the rural economy relies heavily on intensive lowland agriculture, which increases exposure to risks arising from industry change or regulatory reform.
- Higher levels of deprivation in southern settlements within the catchment may reduce community resilience and contribute to poorer wellbeing outcomes.
- Educational attainment varies across the catchment. Lower attainment in parts of the southern catchment may limit overall capacity to adapt to economic, technological and environmental change.
- Established catchment groups, including Te Anau Basin, Lower Waiau and Orauea River, provide support networks for members and may help communities adapt to external pressures and challenges.

Catchment overview

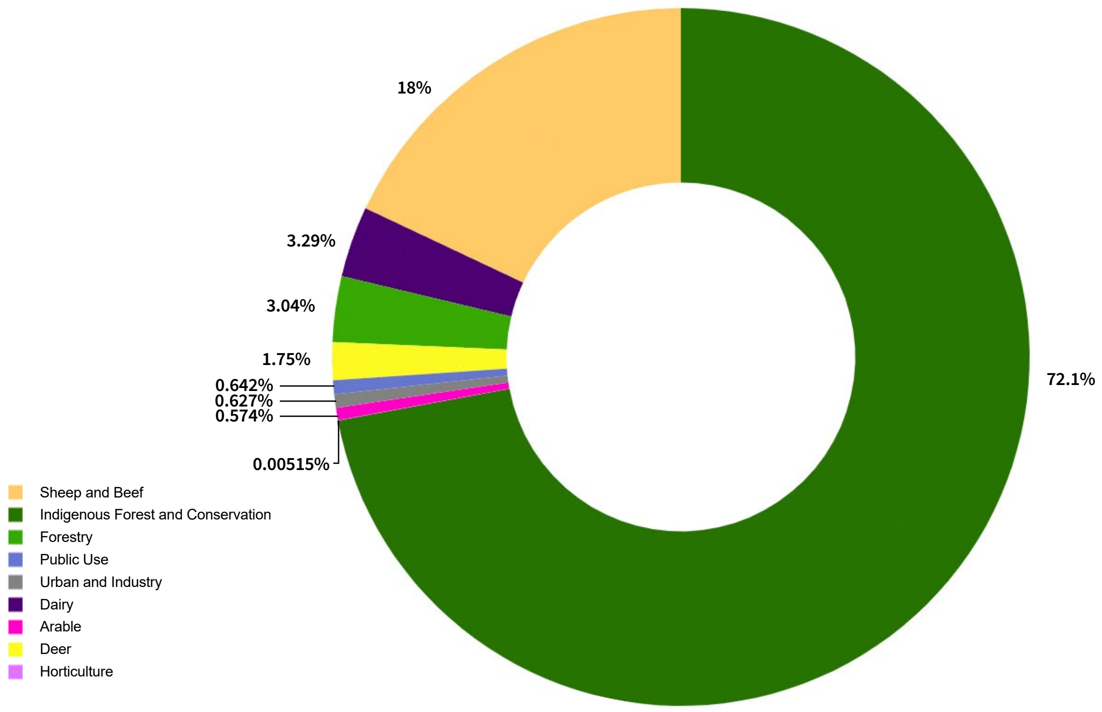
The Waiau River catchment originates in Fiordland National Park, incorporating Lakes Te Anau and Manapōuri, many tributaries join the Waiau River before it outflows into Te Waewae Bay. Its headwaters drain alpine, tussock and forested land, while the middle and lower reaches drain predominantly pastoral land.

The catchment's hydrology is distinctive within Southland because of extensive hydroelectric development. The Manapōuri and Monowai power schemes regulate lake levels, river flows and flow pathways, with water from Lake Manapōuri conveyed through a power station approximately 200 metres below lake level and discharged to Deep Cove/Patea. The Manapōuri scheme began operating in 1969 and became fully operational in 1972; a second tailrace completed in 2002 increased its maximum continuous generation capacity to 850 MW, although generation is limited to 800 MW by resource consent conditions.

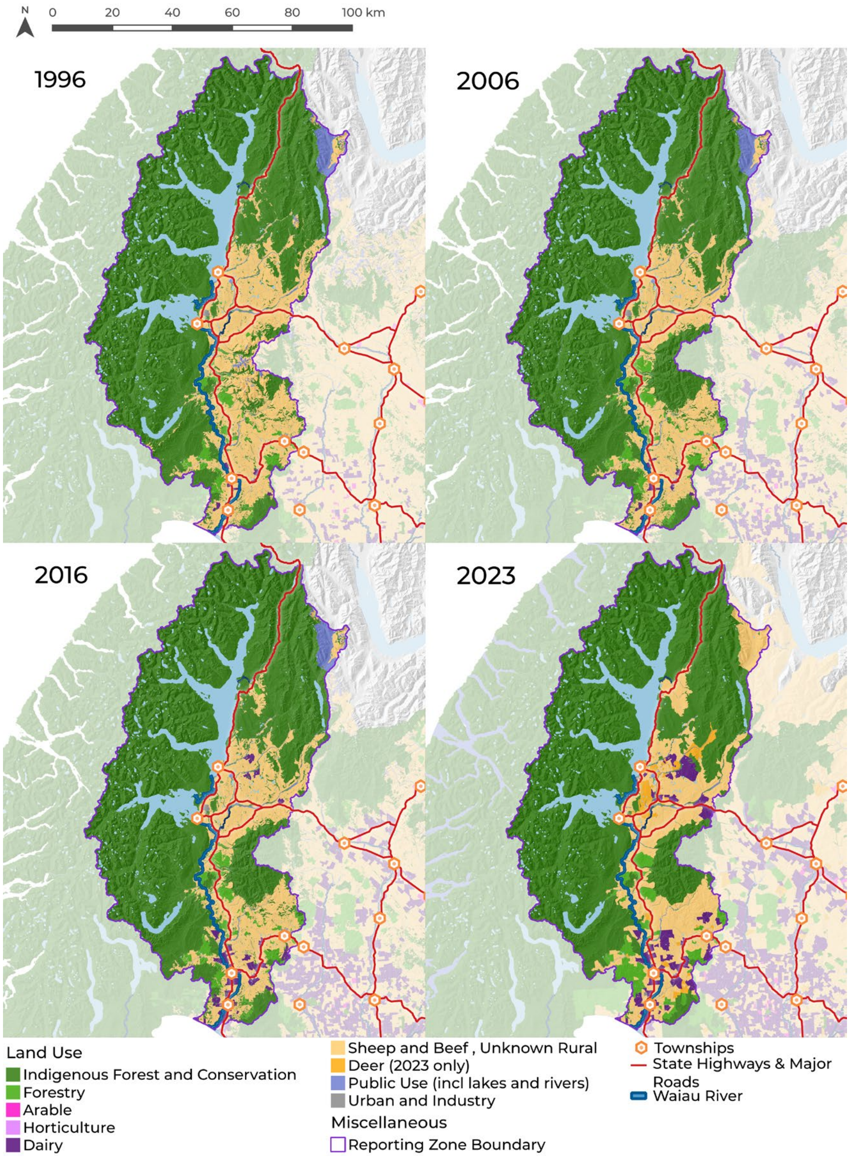
After several decades of operation, this consented regime has become integral to the Waiau River's current hydrological and ecological character, making the existing flow regime an important reference point for assessing the benefits and limitations of future management.

Land use

The Waiau catchment covers approximately 822,000 hectares of land. Of this area, around 72% is indigenous forest, 23% is farmed and 3% is in forestry.



Historic land use



There have been changes in land use in the last 25 years. In particular, the sequence of maps shows the growth of dairy farming in the catchment, although not to the same extent as in other Southland catchments. This change represents an increase in agricultural land use intensity over time, placing increased pressure on natural resources.

Please note that these maps and figures are indicative only due to land use class aggregation and differences in mapping methods.

Climate

Understanding climate at a catchment scale helps to explain spatial and temporal variation in water quality and quantity.

Current climate

The Waiau catchment is typically considered to have a cool-wet climate. Mean annual temperatures generally range from below 0°C and 15°C. Average summer temperatures are typically between 12°C and 15°C, while winter temperatures are mostly between 3°C and 6°C.

Rainfall across the Waiau catchment is variable. The western areas and headwaters receive higher average annual rainfall, up to 5,000-6,000 mm per year. This pattern reflects the orographic rainfall in the west and an associated rain shadow effect to the east.

The average number of wet days per year (greater than 1mm of rainfall) ranges from around 100 days in eastern parts of the mid-catchment to up to 250 days per year in wetter areas. The heaviest rainfall events are typically experienced in the western parts of Fiordland.

Future climate

Climate projections for Te Anau and Tūātapere illustrate how conditions may change in different parts of the Waiau catchment. The projections show changes relative to 1995–2014 for the middle and end of the century under SSP2-4.5 and SSP3-7.0.

Te Anau

At Te Anau, mean temperatures are projected to increase by approximately 1.0–1.2°C by 2050 and 1.8–2.8°C by 2090. Annual rainfall is projected to increase by 6.5–8.8% by 2050 and approximately 12% by 2090. Maximum annual one-day rainfall totals are also expected to increase, indicating heavier extreme rainfall events.

Warmer conditions are projected to result in more hot and heatwave days and substantially fewer cold nights. By 2090, Te Anau may experience approximately 11–27 additional hot days and 35–44 fewer cold nights each year. Dry days are projected to increase slightly, particularly under SSP3-7.0 later in the century.

Tūātapere

At Tūātapere, mean temperatures are projected to increase by approximately 0.9–1.2°C by 2050 and 1.7–2.7°C by 2090. Annual rainfall is projected to increase by approximately 6% by 2050 and 10–11% by 2090, accompanied by increases in maximum annual one-day rainfall totals.

Tūātapere is also projected to experience more hot and heatwave days and fewer cold nights. By 2090, there may be approximately 14–30 additional hot days and 22–28 fewer cold nights each year. The annual number of dry days is projected to remain relatively stable or decrease slightly under most scenarios, although a small increase is projected under SSP3-7.0 by 2090

Future climate predictions

Te Anau

	SSP2-4.5		SSP3-7.0	
	2050	2090	2050	2090
Projected mean temperature changes (°C).	1.0	1.8	1.2	2.8
Projected total annual rainfall changes (%).	6.5	12.2	8.8	12.2
Projected changes in maximum annual 1-day rainfall total (mm/day).	8.5	17.6	7.4	12.2
Projected changes to annual number of hot days (>25°C)(days).	5.7	10.8	8.3	26.5
Projected changes in number of annual cold nights (<0°C)(days).	-21.8	-34.7	-25.0	-44.3
Projected changes to annual time spent in heatwave (days).	6.0	12.3	8.4	30.5
Projected potential evapotranspiration deficit accumulation changes (mm).	-2.0	0.7	3.0	11.9
Projected changes in number growing degree day (base 10°C) (days).	196.7	358.6	249.6	608.8
Projected annual dry day changes (days).	1.7	1.2	0.6	3.6
Projected windy days (wind speed >10m/s) changes (days)	4.3	6.0	3.4	6.2

Tūātapere

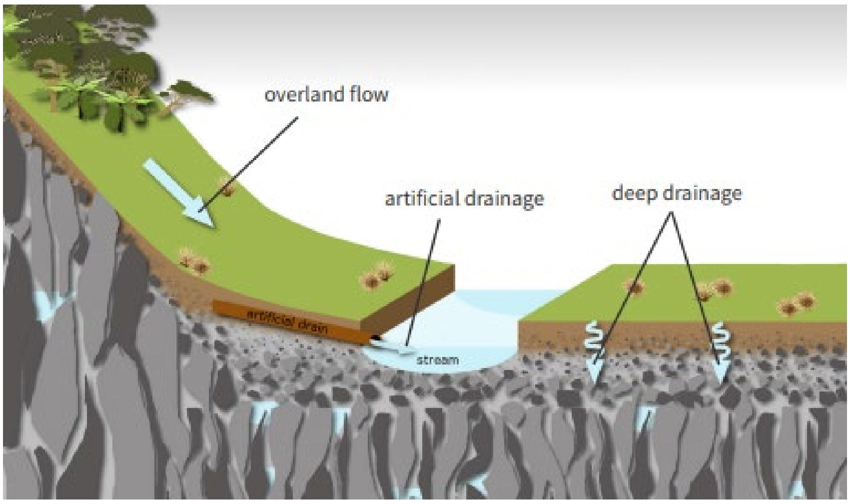
	SSP2-4.5		SSP3-7.0	
	2050	2090	2050	2090
Projected mean temperature changes (°C).	0.9	1.7	1.2	2.7
Projected total annual rainfall changes (%).	5.5	10.6	6.6	10.2
Projected changes in maximum annual 1-day rainfall total (mm/day).	5.0	9.0	7.8	10.4
Projected changes to annual number of hot days (>25°C)(days).	8.0	13.9	11.2	29.8
Projected changes in number of annual cold nights (<0°C)(days).	-13.3	-21.7	-16.4	-28.4
Projected changes to annual time spent in heatwave (days).	6.3	10.7	8.6	24.0
Projected potential evapotranspiration deficit accumulation changes (mm).	-0.3	2.8	7.2	11.1
Projected changes in number growing degree day (base 10°C) (days).	207.9	380.4	264.3	647.5
Projected annual dry day changes (days).	-1.6	-1.1	-1.7	2.0
Projected windy days (wind speed >10m/s) changes (days)	5.1	4.9	4.3	6.5

Catchment landscapes and hydrology

The biogeochemical and physical processes occurring within a catchment influence water quality. Understanding hydrology, geology and soil types helps to explain variation in water chemistry and water quality outcomes that is independent of land use.

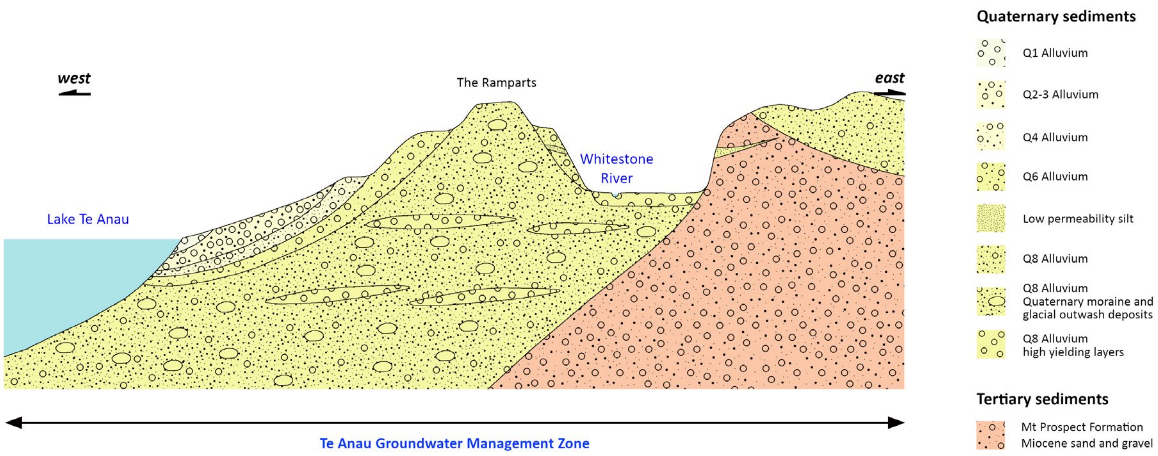
Headwaters

Rain falling in the headwaters of the Waiau catchment flows downslope through the largely naturally vegetated areas of Fiordland National Park and the headwaters of the Mararoa and its tributaries. These headwater hills are characterised by thin organic forest or scrub soils underlain by a wide variety of bedrock lithologies.



▲ *Conceptual depiction of typical hydrological and landscape settings in the upper catchment hill country.*

As this relatively pristine water reaches the bottom of the headwater valleys, it begins to infiltrate and flow through recent alluvial gravel deposits. Here it mixes with localised recharge from surrounding land. Through interactions with soils and low-intensity agriculture in the hill country areas outside of the national park and forested areas, water quality shows modest increases in nutrients, sediment and *E. coli*.



Mid catchment

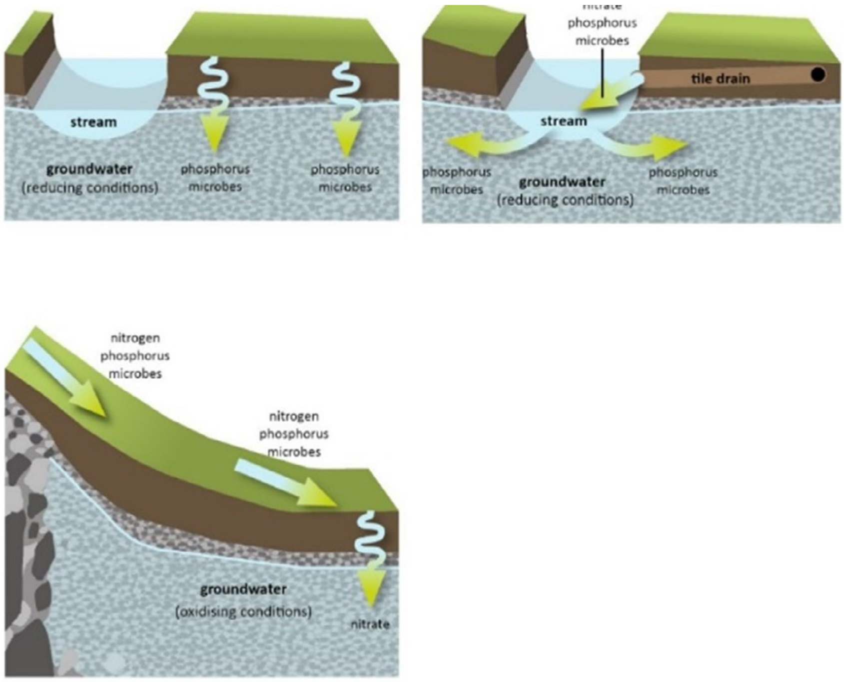
Further downslope, the majority of soil types are alluvial, shallow and well drained. Water is therefore able to readily infiltrate from the land surface into underlying sediments.

Glacial moraine and alluvial outwash materials form a thick stratified unconfined aquifer system. Gravel materials comprising large moraine terraces are generally low to very low yielding, although isolated layers of higher-permeability gravel and sand may occur where glacial materials have been reworked by rivers and streams. These deeper water-bearing layers are typically semi-confined. Localised areas of perched groundwater, where water tables sit on low-permeability silt layers (often comprising buried loess), occur beneath higher moraine terraces. Where these features intersect the land surface, they form springs and seeps on terrace risers.

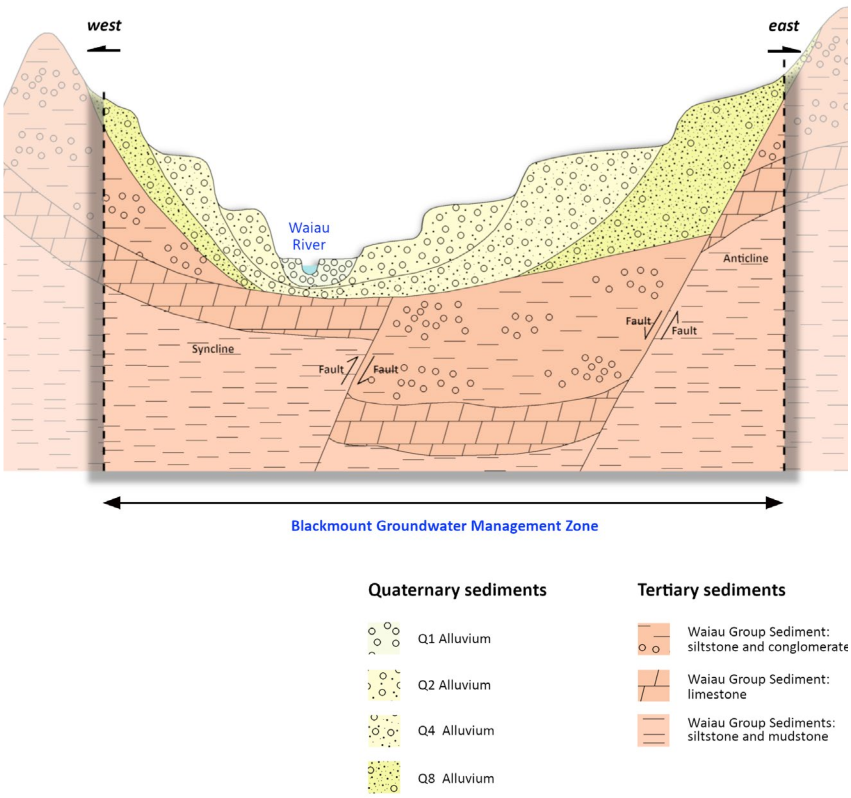
Well drained soils limit the potential for attenuation of nutrient concentrations through denitrification. However, loess deposits and lower-permeability layers within moraine deposits increase the potential for lateral flow through the soil zone.

Shallow groundwater is typically oxidising, with conditions potentially becoming more reduced at depth. This limits the potential for denitrification in groundwater once water has infiltrated beyond the soil zone. The potential for elevated nitrate concentrations is generally offset by the high volume of land surface recharge, relative to other areas of Southland, and the relatively low-intensity land use. Phosphorus is typically strongly bound to soils. Microbial contamination of groundwater is typically limited by natural attenuation within the soil zone and underlying aquifers.

Where drainage and stream modification have occurred on agricultural land, water moves more rapidly through the landscape. On the flatter alluvial plains, water interacts with soils under more intensive agricultural use and can carry nutrients, sediment, *E. coli* and other contaminants. Adjacent to the main rivers, soils comprise recent fluvial deposits that are shallow, stony and well drained. Further from the rivers, older and more poorly drained pallic soils occur, formed from windblown sediments and interspersed with waterlogged gley soils in parts of the mid catchment. The distribution of these soil types influences flow pathways and the transport of contaminants though the landscape.



Conceptual depiction of typical hydrological and landscape settings in the mid catchment.

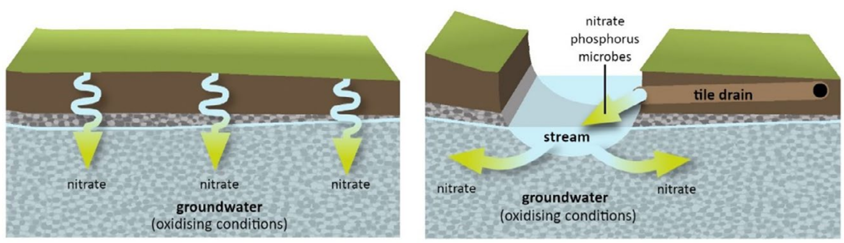


Lower catchment

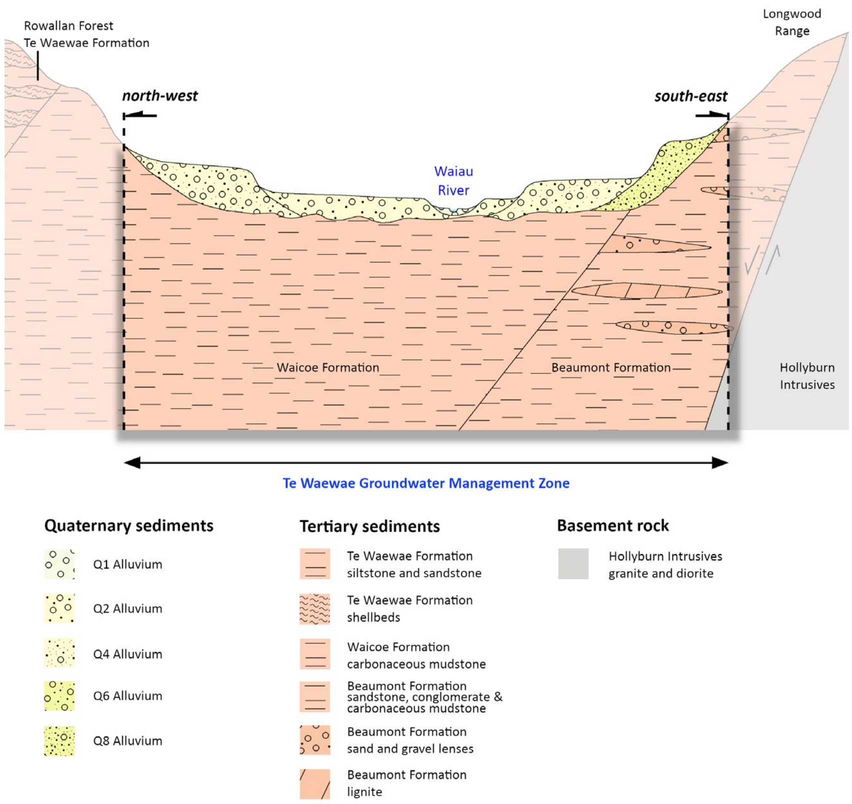
The lower catchment is characterised by a series of broad, flat-lying alluvial terraces that flank the lower reaches of the Waiau River. These alluvial deposits are underlain by Tertiary sediments of the Waiau Group, comprising mudstone, siltstone and conglomerate, with limestone present in places. Near the Longwood Range, the Quaternary alluvium is underlain by sandstone, conglomerate and carbonaceous mudstone of the Beaumont Formation. To the west, low hills are formed by siltstone, sandstone and shellbeds of the Te Waewae Formation.

Soil types range from shallow, stony, well drained soils along the margins of the Waiau River to moderately well drained or imperfectly drained soils on higher terraces along the valley margins. Groundwater and surface water resources are closely linked. Groundwater beneath higher terraces feeds spring-fed streams that originate along the base of terrace risers. These streams in turn lose flow, recharging underlying aquifers across intermediate terrace surfaces, before ultimately discharging into springs and wetland areas adjacent to the river.

Soils in the lower catchment are imperfectly to well drained, limiting the potential for attenuation of nutrient concentrations through denitrification. Nitrate concentrations are generally elevated on terraces away from the Waiau River, particularly where groundwater conditions are oxidising and land use intensity is high. This also increases the potential for localised microbial contamination.



Conceptual depiction of the hydrogeological setting in the lower Waiau catchment.

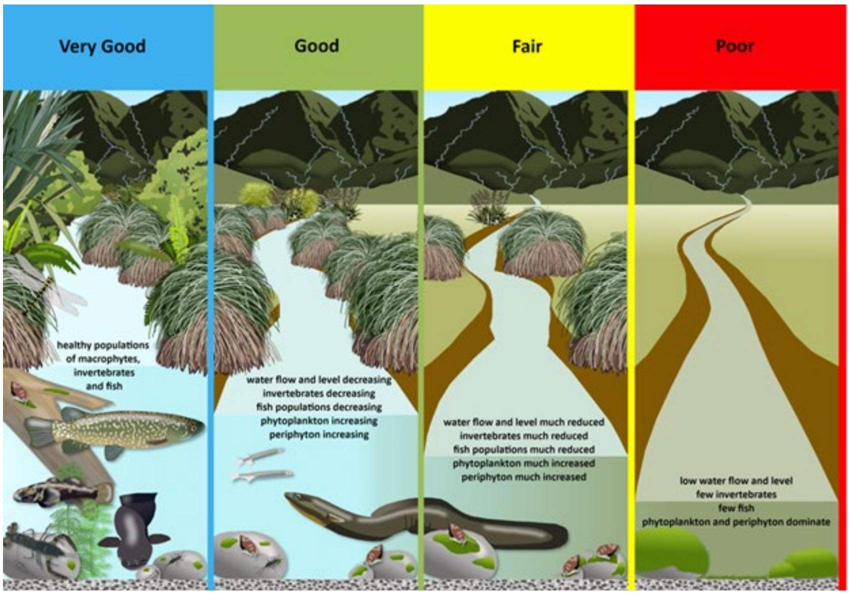


What are the water issues for this catchment?

Freshwater outcomes and how we measure them

Freshwater outcomes can be described along a spectrum from ‘very good’ to ‘poor’. Using this spectrum helps to describe the current state of the freshwater environment and to understand what outcomes may be sought in the future. This concept is illustrated for rivers and streams in the image below.

While many factors contribute to freshwater outcomes, only some can be directly measured. These measurements are used to provide an indication of ecosystem health. The aspects of the freshwater environment that are measured are known as ‘attributes’.



Attributes (the things we measure)

Attributes relate to the physical and chemical environment, or to biological components of the ecosystem such as periphyton, macroinvertebrates and fish. The measured state of an attribute provides information about a specific aspect of the freshwater environment. Together, attributes build a picture of overall ecosystem health. Monitoring a wide range of attributes provides a clearer understanding of freshwater outcomes.

Attributes may relate to ecosystem health or to human health outcomes, such as E. coli or cyanobacteria concentrations. Some attributes are graded using ‘A-D’ categories: A (very good), B (good), C (fair) and D (poor). In some cases, *E. coli* also has an additional E (very poor) grade. Other attributes are assessed using simple ‘pass’ or ‘fail’ grades.

Overall ecosystem health improves as the number of attributes with higher grades increases. Conversely, where a higher number of attributes have poorer grades, overall ecosystem health is reduced.

Hauora target attribute states

In 2020, Environment Southland and Te Ao Mārama Inc (TAMI) approved in principle the use of hauora as a freshwater target to be achieved within a generation. These targets provided the basis for the Regional Forum recommendations on how freshwater aspirations may be achieved.

The concept of hauora encompasses far more than the numeric attributes and targets described here. For simplicity, a reduced number of attribute states are presented in this document as they relate to ecosystem and human health. Hauora is a state of healthy resilience and is generally associated with the A 'very good' and B 'good' attribute states. However, attribute states that support hauora can be anywhere on the scale from A 'very good' to C 'fair', depending on the natural characteristics of that freshwater environment. The natural characteristics have been differentiated through the use of classes. We use monitoring results to compare the current attribute state with the hauora target state for different classes in the Waiau Catchment.

Streams and rivers

River classes

'River classes' group rivers (or parts of rivers) with similar characteristics. Similarities can include natural characteristics of the rivers, such as climate, gradient and flow. The river classes used in Murlhiku Southland are: Mountain, Hill, Lowland, Spring-fed, Lake-fed and Natural State.

All six river classes are represented in the Waiau catchment. Almost two-thirds of rivers are classified as Natural State, while Hill and Lowland rivers together account for around 30% of total river length. Although the Lake-fed river class represents a small portion of the river network by length, it includes the mainstem of the Waiau River and is therefore strongly represented in the monitoring network for the Waiau catchment.

Target states can differ between attributes and between different river classes, which may have different target states for the same attribute.

Periphyton is an example of an attribute with different target states for different river classes.

This reflects differences in the natural characteristics of these river environments.

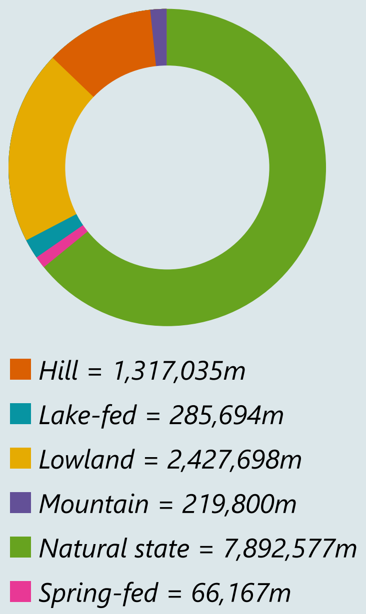
- C target state: Lowland class
- B target state: Hill class
- A target state: Mountain, Spring-fed and Lake-fed classes.

Natural State waterbodies can be identified for management purposes but are assigned attribute targets according to their underlying river classification (displayed here).

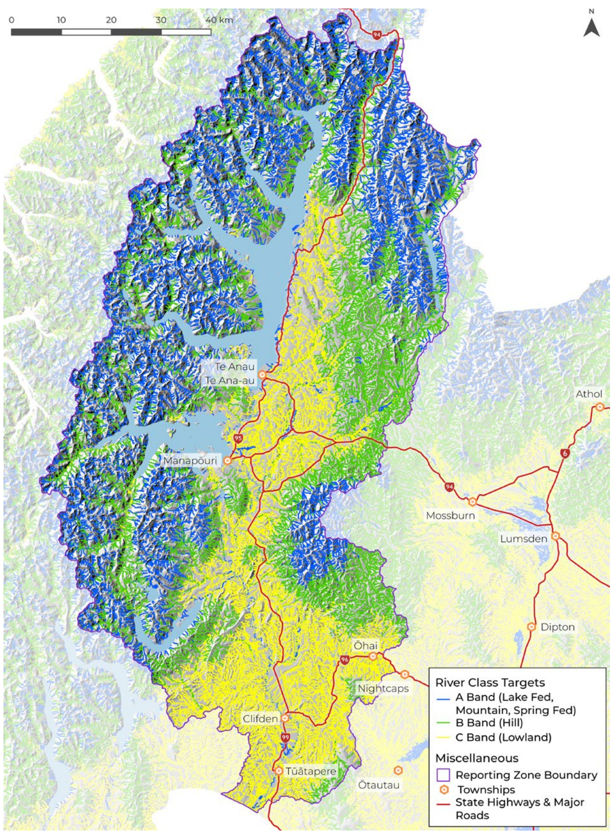
The map shows the distribution of periphyton target states in the Waiau catchment, based on the river classes present.

The map shows the distribution of periphyton target states in the Waiau catchment, based on the river classes present.

Length of river network in each class



River class hauora targets



Results for the river classes

Hauora targets and current states for ecosystem and human health attributes are summarised in the table below for the catchment's should be Lowland, Hill, Spring-fed, and Lake-fed river classes. Table colours correspond to the 'ABCDE' grading for attributes described previously. Results show that Lowland rivers in the catchment have the most water quality issues. Current state is assessed using data from the 2018-2022 period.

	Lowland		Hill		Mountain	
Ecosystem health attributes	Hauora target	Current state	Hauora target	Current state	Hauora target	Current state
Periphyton	C	C	B	B	A	-
Nitrate toxicity	A	B	A	A	A	-
Ammonia toxicity	A	A	A	A	A	-
Suspended fine sediment	C	B	C	A	A	-
Macroinvertebrates (MCI, QMCI)	C	D	B	D	B	-
Deposited fine sediment	A	A	A	A	A	-
Dissolved reactive phosphorus	B	B	B	A	A	-
Water temperature (summer)	C	-	C	-	-	-
Human contact attributes						
Benthic cyanobacteria	A	A	A	C	A	-
E. coli	A	E	A	D	A	-
Visual clarity	B	C	B	A	A	-

"-" no data available.

	Spring-fed		Lake-fed	
Ecosystem health attributes	Hauora target	Current state	Hauora target	Current state
Periphyton	A	-	A	D
Nitrate toxicity	A	A	A	A
Ammonia toxicity	A	A	A	A
Suspended fine sediment	B	D	B	B
Macroinvertebrates (MCI, QMCI)	B	C	C	D
Deposited fine sediment	A	-	A	C
Dissolved reactive phosphorus	B	B	A	A
Water temperature (summer)	B	-	B	A

Human contact attributes				
Benthic cyanobacteria	A	-	A	D
E. coli	A	A	A	D
Visual clarity	A	-	A	B

"-" no data available.

Case study : Ecological flow study – Lower Waiau River

Overview

A study assessing flow requirements for aquatic flora and fauna to help inform the development of ecological flow limits and actions to support improved ecological outcomes IN the lower Waiau River.

Why it matters

Flow levels and variability greatly affect river life, from the freshwater insects that trout feed on to native fish. This study uses bioenergetics and drift–flow modelling to assess the impacts of different flow levels on habitat-flow relationships, to inform ecological flow limits that balance water use and ecological health.

What was done

Researchers used advanced two-dimensional computer models to:

- predict how different flows affect optimal habitat availability for different species of freshwater fish, insects and algae
- understand how invertebrates (small aquatic animals) drift in the river, which is an important food source for drift feeding fish (e.g. trout)
- estimate The energetic benefit to trout from drift feeding under different flow regimes

Key findings

- Predicted habitat–flow relationships indicate the current flow regime supports a high proportion of good physical habitat for trout and their invertebrate food sources
- Adult trout require higher flows (from 38 to 80 m^3/s) for optimal habitat
- Native fish, such as torrentfish, benefit from lower flows than introduced sports fish like trout
- Algae types respond differently to flow: healthy types (such as native diatoms) prefer higher flows, while nuisance types are less affected by changes in flow
- The study area included both single and split river channels, with split channels being more sensitive to flow changes

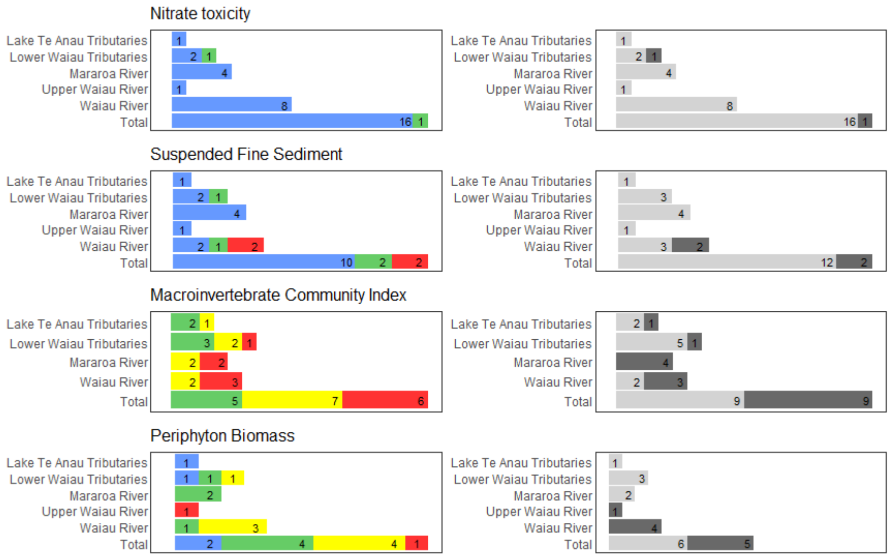
Conclusion

The study provides a comprehensive scientific basis for setting minimum flows and water allocation limits that protect the river's life supporting capacity while allowing for water use. It highlights the need to balance flow requirements of different fish species, including native fish and sport fish like trout, their invertebrate food resources, and periphyton over low- to mid-range flows, to support a thriving Waiau River ecosystem.

Results for the main streams and rivers

Ecosystem health

Results for monitoring sites in the Waiau catchment are summarised below for nitrate toxicity, suspended fine sediment, macroinvertebrate community index (MCI) and periphyton biomass. The number of sites that meet hauora target states is also shown (right-hand graphs). Nitrate toxicity is in 'very good' state at all monitored sites except one. Suspended fine sediment is in a 'very good' or 'good' state at all sites except two on the mainstem Waiau River, which do not achieve the hauora target. It is important to note that different sediment classes are used to account for the natural characteristics of different waterbodies. As a result, although these sites are graded as 'poor', they may have lower suspended sediment concentrations than sites graded in a higher state band within a different sediment class.

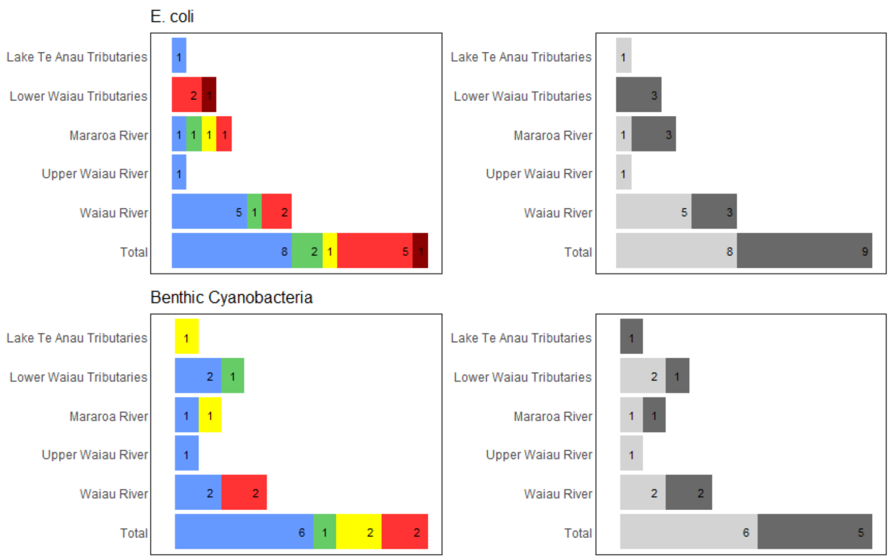


MCI scores range from 'good' to 'poor', with all sites in the Mararoa River and mainstem Waiau River graded as 'fair' or 'poor'. Most sites that do not achieve the hauora target are located in these areas. One site in the Lake Te Anau tributaries (Upukerora River) and one site in the lower Waiau tributaries (Lill Burn) also do not achieve the relevant hauora target.

Periphyton biomass ranges from 'good' to 'poor' across the monitored sites. All monitored sites in the upper Waiau River and mainstem Waiau River do not achieve the hauora target. These sites are all classified as 'Lake-fed' and therefore have a more stringent hauora target of 'very good'.

Human health/contact

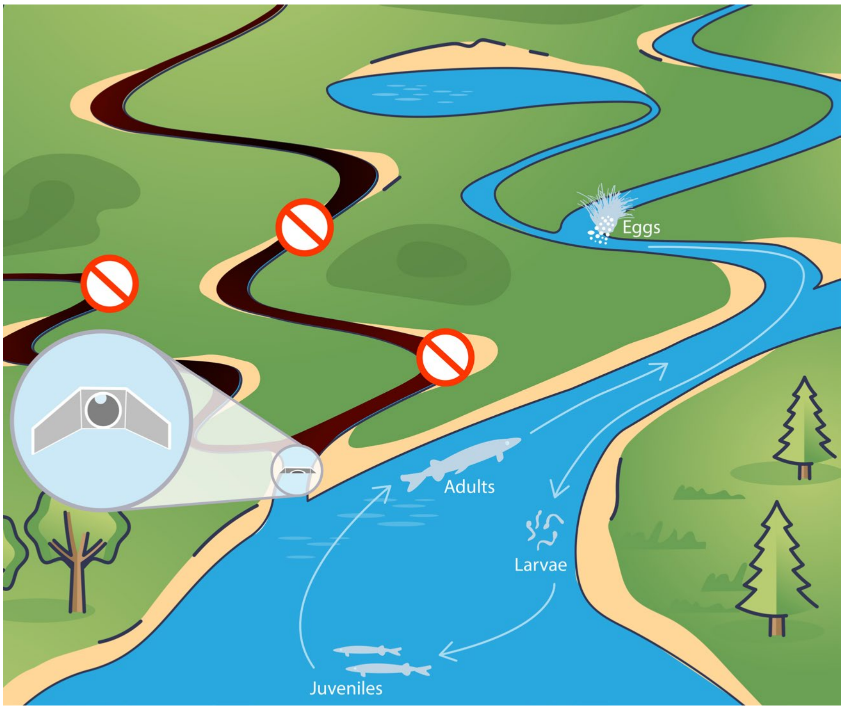
Approximately half of monitored sites in the Waiau catchment have a 'very good' state and achieve the hauora target. Sites in the Mararoa River and mainstem Waiau River range from 'very good' to 'poor', while sites in the lower Waiau tributaries are in a 'poor' or 'very poor' state.



For benthic cyanobacteria, approximately half of monitored sites achieve the hauora target of 'very good'. Sites in the mainstem Waiau River are either in a 'very good' or 'poor' state. Sites in the lower Waiau tributaries are in 'very good' or 'good' state, while the monitored site in the Lake Te Anau tributaries (Upukerora River) is in 'fair state.

Fish passage

Whitebait lifecycle



Fish passage barriers obstruct the passage of fish species. This particularly affects migratory species that complete their lifecycles in both freshwater and the ocean, such as tuna (eels), kanakana (pouched lamprey) and migratory galaxiids (whitebait). In general, the closer a barrier is to the coast, the greater the extent of upstream habitat that becomes inaccessible to migratory fish, making these barriers a higher priority for restoring passage.

Common examples of fish passage barriers include culverts, weirs and dams, although natural features such as waterfalls can also act as barriers. Different fish species, and different life stages within a species, have varying swimming and climbing abilities. As a result, a structure that is a barrier for one species or life stage may not be a barrier for another.

The Waiau catchment contains several large-scale fish passage barriers associated with hydroelectric power schemes. Some of these structures include mechanisms designed to support fish migration. In some cases, fish passage devices with suitable gradients are installed to allow upstream movement. Migration can also be achieved through ‘trap and transfer’ systems, where fish congregate in a trap and are then transferred around the barrier and released in a suitable location.

Meridian Energy and NIWA are undertaking research on tuna using trap and transfer systems in the Waiau catchment. Elvers (juvenile eels) are tagged prior to release, allowing their movement within the catchment to be tracked. This research may help inform future release locations and fish passage management.

In addition to large structures, there are numerous smaller structures throughout the catchment that can act as fish passage barriers. Culverts are the most common type. Considering fish passage during culvert design and installation, along with regular maintenance, can help improve fish passage outcomes.

Lakes

Lakes are grouped into classes based on natural characteristics, such as depth. These classes are used in a similar way to river classes, as described above. The Waiau catchment contains many lakes. The deep lakes Te Anau and Manapōuri, and the brackish Te Waewae (Waiau) Lagoon, are regularly monitored.

The two monitored deep lakes are in a 'very good' or 'excellent' state and achieve the hauora targets for all monitored ecosystem health attributes.

Te Waewae (Waiau) Lagoon is in 'fair' state for the majority of measured ecosystem health attributes. Of these, only total nitrogen achieves the hauora target. An exception is the toxicity attributes: the hauora target of 'very good' is achieved for nitrate toxicity, while the ammonia toxicity attribute is in a 'good' state, and does not meet the hauora target of 'very good'.

For human contact attributes, planktonic cyanobacteria achieve the hauora target of 'very good' in all monitored lakes in the Waiau catchment. *E. coli* is graded as 'good' in Te Waewae (Waiau) Lagoon, slightly below the hauora target of 'very good'. *E. coli* is not monitored in the deep lakes.

An invasive water flea (*Daphnia pulicaria*) has been detected in Lakes Te Anau and Manapōuri, as well as in other lakes in New Zealand. This species reproduces rapidly and can form dense populations through both active reproduction and the hatching of resting eggs (ephippia). It can also form temporary, highly concentrated swarms in response to environmental cues such as predation or food availability. These blooms, often observed as patches of white flecks in the water, may influence lake ecosystems by altering food web dynamics, particularly through grazing on phytoplankton, which can affect water clarity and nutrient cycling. To date, monitoring has not identified clear, sustained impacts on water quality, aside from localised and short-lived visibility effects.

Lakes Te Anau and Manapōuri also contain the diatom *Lindavia intermedia*, first confirmed in 2019. This species produces a mucilage, known as 'lake snow', which can clog water filters and foul fishing lines. Its presence is likely to have influenced food webs and ecological functioning within the lakes. The presence of *Lindavia intermedia* may have increased the availability of higher-quality food for zooplankton such as *Daphnia*. Experiments undertaken in Otago lakes by the University of Otago have shown that *D. pulicaria* readily feeds on *Lindavia*. While not yet confirmed for Lakes Te Anau and Manapōuri, it is possible that shifts in phytoplankton community composition from cyanobacterial dominance to diatom dominance may have occurred, similar to those observed in Otago lakes.

	Deep lakes			Brackish lakes and lagoons	
Ecosystem health attributes	Hauora target	Current state (Lake Te Anau)	Current state (Manapōuri)	Hauora target	Current state (Waiau Lagoon)
Ammonia toxicity (mg/L)	A	A	A	A	B
Nitrate toxicity	A	A	A	A	A
Total nitrogen	A	A	A	C	C
Total phosphorus	A	A	A	B	C
Trophic state (Trophic Level Index)	A+	A+	A+	B	C
Macrophytes	NA	-	-	B	C
Phytoplankton	A	A	A	B	C

	Deep lakes			Brackish lakes and lagoons	
Human contact attributes	Hauora target	Current state (Lake Te Anau)	Current state (Manapōuri)	Hauora target	Current state (Waiau Lagoon)
E. coli	A	-	-	A	B
Planktonic cyanobacteria	A	A	A	A	A

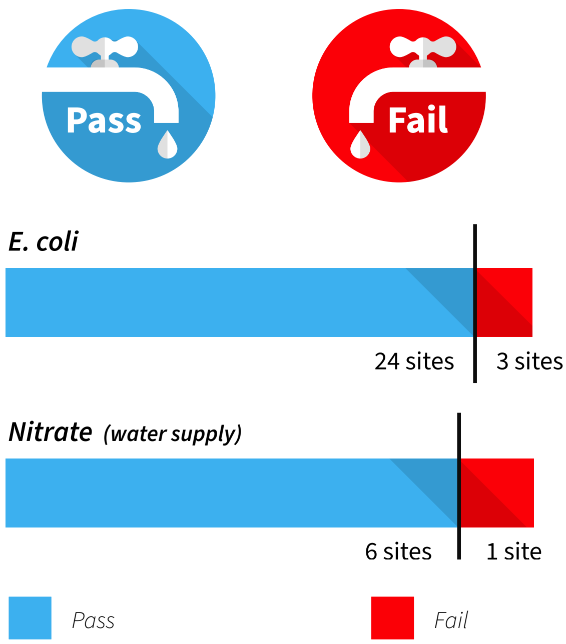
Groundwater

Human consumption – is it safe to drink?

The presence of pathogens (*E. coli*) and nitrate are the main factors affecting the suitability of groundwater for drinking. Target states for groundwater are based on the New Zealand drinking water standards and are assessed using a pass/fail system.

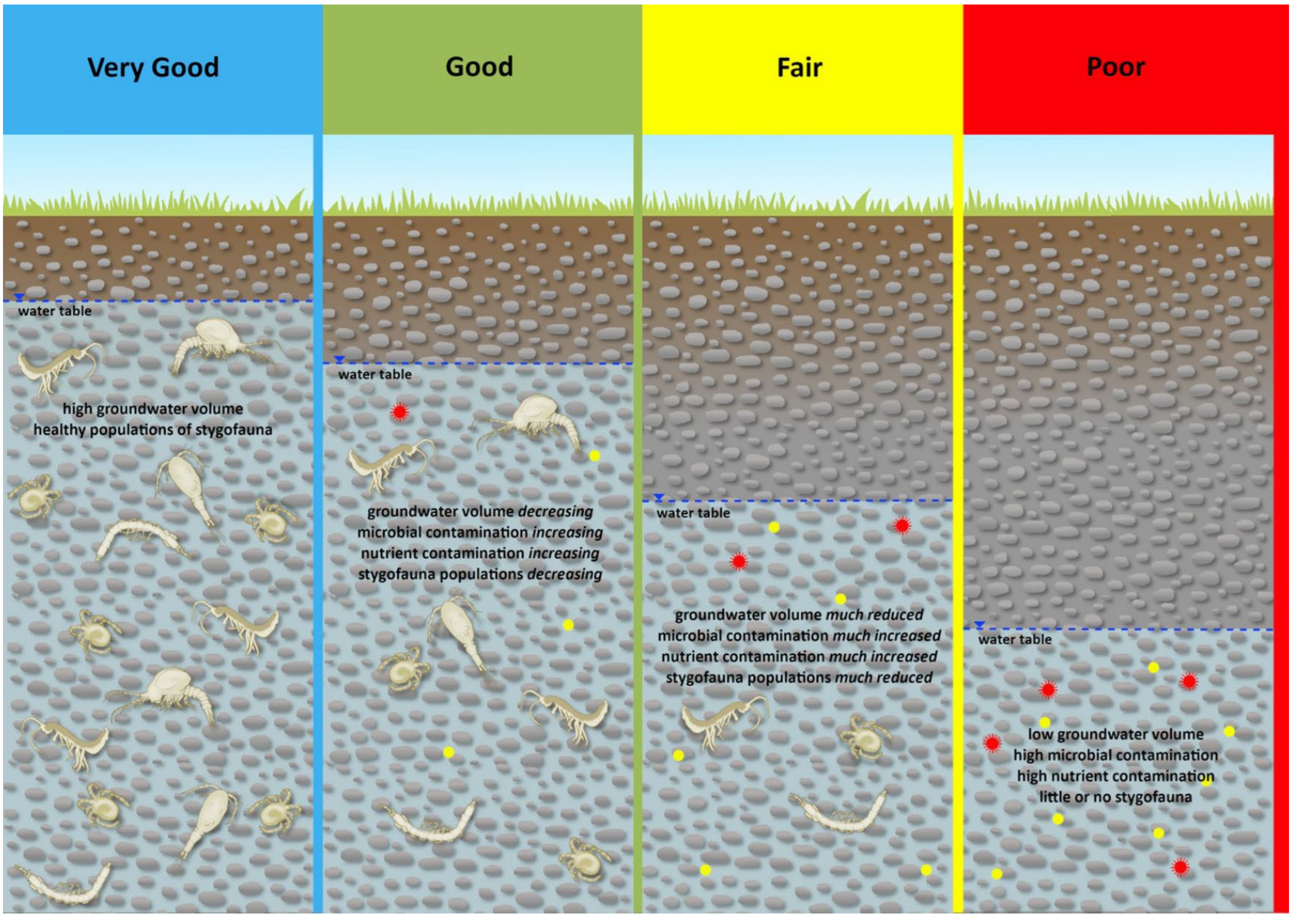
The results shown below indicate that all monitored sites in the Blackmount groundwater management zone (GMZ), and most monitored sites across the Waiau catchment, meet drinking water standards for *E. coli*. Only one monitored site, located within the Blackmount GMZ, does not meet the drinking water standard for nitrate.

Waiau groundwater assessment

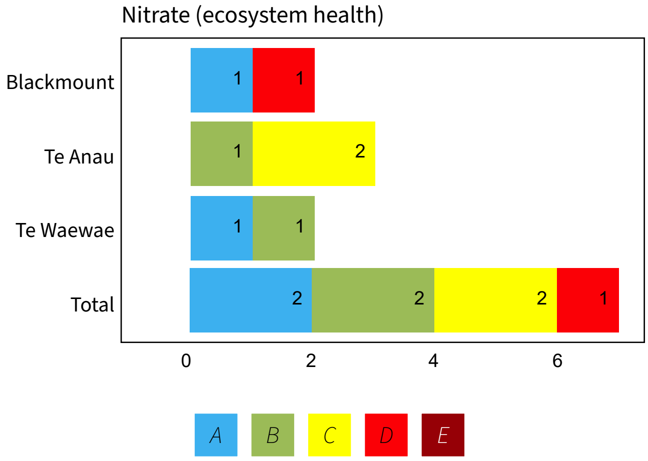


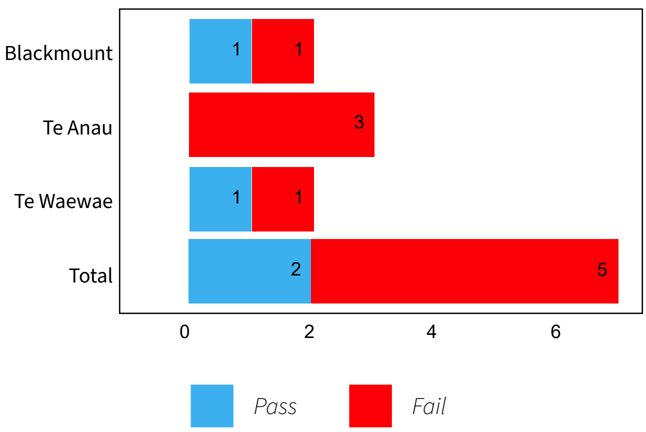
Ecosystem health

Nitrate concentrations are also used to assess ecosystem health for groundwater ecosystems and connected surface waterways. Groundwater ecosystem health outcomes are represented conceptually in the figure below. Nitrate concentration is one of several factors that contributes to overall ecosystem health. The nitrate thresholds used to assess groundwater and surface water ecosystem health outcomes differ from those applied to drinking water standards, as described above.



Results show that most monitored sites do not achieve the hauora target of 'very good', and that almost half of sites are graded as 'fair' or 'poor'.



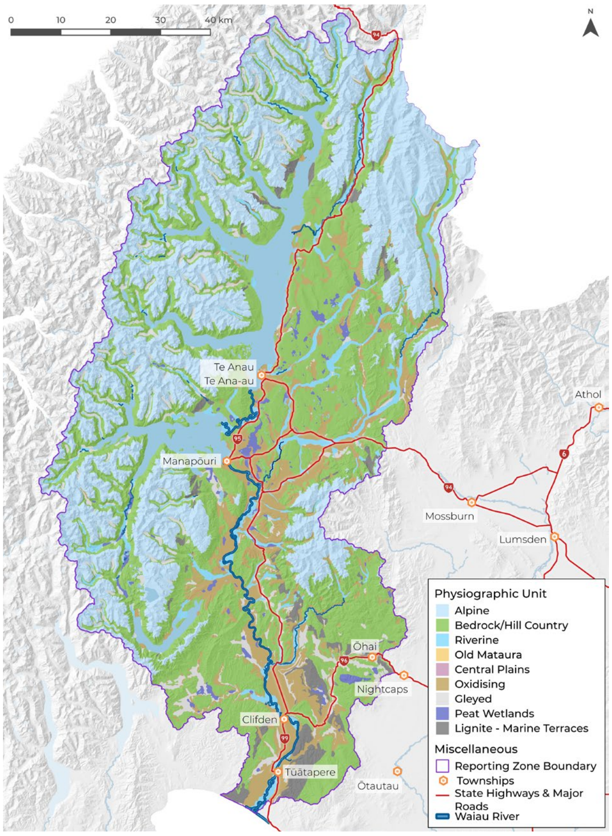


Groundwater contamination 'hotspots'

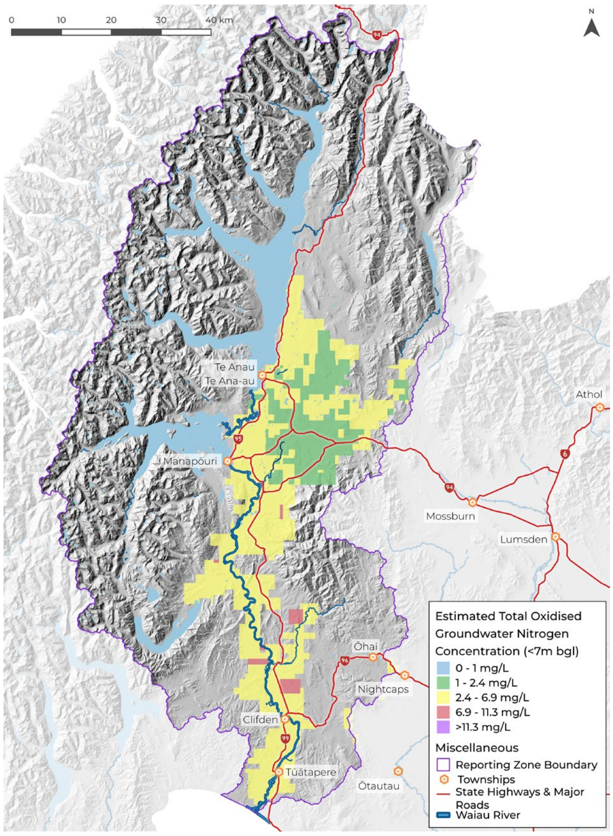
There are areas within the Waiau catchment where groundwater nitrogen concentrations are elevated. Where high concentrations are identified through sampling and modelling (shown in red on the map), these areas are referred to as 'hotspots'. Elevated nitrogen concentrations affect groundwater ecosystem health and can contribute to contamination and eutrophication in connected surface water environments. The physiographic map highlights areas that are more susceptible to groundwater contamination as a result of overlying land use and the natural characteristics of soils and geology.

These are identified by the Oxidising and Riverine physiographic zones.

Physiographic zones



Groundwater nitrogen concentrations



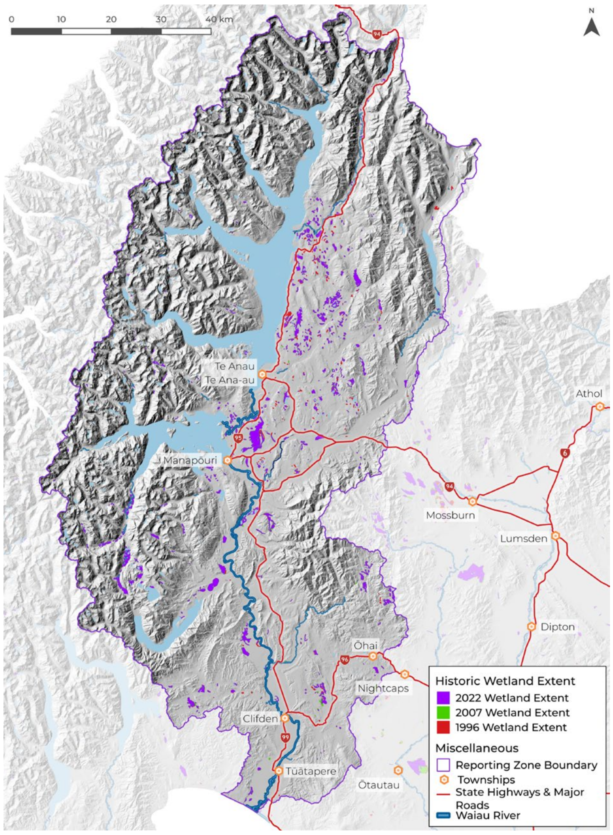
Wetlands – how many do we have left?

Wetlands and water quality

Wetlands are increasingly being recognised for their functional values within the landscape. For example, their ability to intercept and attenuate agricultural runoff is now recognised as an important contribution to farm nutrient management. Wetlands purify water through sediment capture and storing nutrients in their soils and vegetation. This is particularly important for the agricultural nutrients nitrogen and phosphorus, which contribute to the eutrophication of receiving environments such as rivers, lakes and estuaries. For the purposes of this document wetlands are generally defined as per the Southland Water and Land Plan definition. The following areas were not included as wetlands in this classification:

- Wet pasture or where water ponds after rain
- Pasture containing patches of rushes less than 50% total cover
- Ponds of any kind unless associated with 0.5 or more hectares of terrestrial wetland.
- Areas of forest unless previously identified as wetland.
- Areas associated with the main active flood channels of rivers.

Historic wetland extent



This map shows changes in wetland extent across three time periods, with wetland areas lost since 1996 shown in red and areas lost since 2007 shown in green.

Current state

There are currently 8,998 hectares of wetlands in the Waiau catchment.

	1996 to 2007	2007 to 2022	Overall 1996 to 2022
Change in wetland area	↓ 8% 844 ha	↓ 2% 154 ha	↓ 10% 998 ha

Remaining wetlands

The Waiau catchment is large, with 47 regionally significant wetlands identified. Of the remaining wetlands, there is a moderate risk of further wetland loss in the near future.

Water quantity – how much do we have, and how much are we using?

Surface water allocation

Surface water takes are managed through two types of allocation blocks. A primary allocation block restricts the amount of water that can be taken during low flows, with allocation limited to 30% of Q95. A supplementary allocation block applies when flows are above median or mean levels, depending on the time of year. This allows allocation of 10% of mean flow between December to March, and 10% of median flow between April and November.

Stream depletion occurs when groundwater is abstracted from areas that are hydraulically connected to nearby surface waterways, resulting in reduced stream flows. As a result, stream depletion must be accounted for in both surface water and groundwater allocation management.

Under the Southland Water and Land Plan, surface water allocation is managed at any point within a surface water network. Allocation totals therefore change along rivers to reflect the balance between the natural addition of water and the abstraction of water.

Surface water allocation for this FMU is currently divided into three units: the Waiau River catchment upstream of the Mararoa Weir, the Waiau River catchment downstream of the Mararoa Weir and the Mararoa River catchment. A table of allocation values is not provided for this FMU, as it is considered fully allocated as a result of the Manapōuri Power Scheme.

Water allocation in the Waiau FMU is dominated by abstraction for hydro-electric power generation, including the Manapōuri Hydroelectric Power Station and the Monowai Power Scheme. Smaller allocations are also present for tourism and recreation, irrigation and water supply schemes.

In general, surface water allocation from tributaries of the Waiau River is very low (less than 10% of the seven-day mean annual low flow; 7-day MALF) and is associated with a low risk of adverse environmental effects. However, cumulative allocation across the Waiau catchment is extremely high (574 m^3/s compared with a mean flow of 520 m^3/s), largely reflecting the scale of diversion to the Manapōuri Power Scheme.

Groundwater allocation

Most groundwater allocation thresholds are set as a proportion of annual rainfall recharge to aquifers, with the proportion varying depending on aquifer type.

There are three groundwater management zones associated with the Waiau catchment.

	Groundwater allocated (%) (22/23 season)
Blackmount	1.0
Te Anau	1.2
Te Waewae	3.4

The majority of allocated groundwater is consented for dairy farming (59%), followed by dewatering (19.1%) and irrigation (13.6%). Other uses, including municipal water supply (7.6%), account for a smaller proportion of groundwater allocation. However, allocation patterns vary between groundwater management zones, with the Te Anau zone dominated by irrigation.

	Groundwater use (%) (22/23 season)
Dairy farming	59.0
Dewatering	19.1
Irrigation	13.6
Municipal water supply	7.6
Mining	0.4
Stockwater	0.2
Industrial	0.1

How much do we need to reduce contaminants to achieve a state of hauora?

Regional contaminant modelling

We have undertaken contaminant modelling to help us better understand water quality across Murihiku Southland. This modelling utilises monitoring data to estimate water quality in all waterbodies (excluding Fiordland and Islands). This expanded view of water quality allows us to estimate the reductions in contaminant load and concentrations required to achieve the identified target attribute states and to test the impact of different land use scenarios. For this work, we focus on four main contaminants of concern: nitrogen, phosphorus, sediment, and *E. coli*. Actions taken to reduce the impact of these contaminants on our freshwater systems will have benefits for ecological and human health outcomes.

How much do contaminant loads need to be reduced?

Load is a measure of the total mass of a contaminant (in kg or tonnes) coming from a given area past a given point over time. For example, the total amount of nitrogen delivered to the sea by a river in one year.

We use loads to quantify contaminants here because they describe the amount of contaminants lost over a whole catchment area. It is the land that consequently needs to be managed to reduce those loads. It is important to remember that concentrations (e.g., the mass of the contaminant per litre of water in the waterbody in kg/L) must also be considered. Concentrations in waterbodies are affected by the size of the contaminant load lost from land and the amount of water available to dilute that load. Hence, water takes and climate can affect concentrations too. Concentrations are the relative amount of contaminant present in a given volume of water at that time.

Concentrations are important because they have direct relevance to toxicity attributes as well as ecological processes. This modelling considers draft targets for the following attributes: Rivers Periphyton biomass, nitrate toxicity, dissolved reactive phosphorus, visual clarity, suspended sediment, *E. coli*. Lakes Total nitrogen, total phosphorus, phytoplankton. Estuaries Macroalgae. This modelling accounts for loads and concentrations required to achieve target states everywhere for all the above attributes.

Contaminant	Total load (best estimate*)	Percentage load reduction required to achieve hauora (best estimate*)
Total Nitrogen	2,827 Tonnes/Year	↓ 73% (53-88)
Total Phosphorus	185 Tonnes/Year	↓ 82% (68-92)
Sediment	457,000 Tonnes/Year	↓ 25%
E. coli	60 peta *E.coli*/Year	↓ 86% (64-96)

These values represent our best estimate. Levels of uncertainty are indicated by the 90% confidence interval shown in brackets where available. For estimates of uncertainty, see full reports.

What options do we have to reduce load?

We have modelled different scenarios to indicate how far each may go toward achieving the estimated load reductions required. We have also bundled multiple scenarios to test the effect of combining multiple strategies.

This work is not intended to assess individual properties or activities. Rather, it generalises land use so that we can make some broad catchment scale assessments of the impact of different actions. This can also help give information about the differences between possible allocation approaches. The results for each of the scenarios modelled are presented below. Explanations of each scenario can be found in our published reports. The coloured table cells indicate how far each scenario achieves the required load reductions. The results in the table below indicate that none of the individual mitigation scenarios we tested would fully achieve the reductions required to support a state of hauora. This is because the reductions are very large and will likely require more widespread changes to how land is used rather than maintaining the status quo and relying on implementing mitigations.

ID	Scenario	Reduction in nitrogen load (%)	Remaining deficit from target (%)
Individual methods			
1	100% adoption of established farm Good Management Practice (GMP) mitigations	3	70
2	Adoption of all established and developing farm mitigations	11	62
3	Wetlands returned to the same area as existed in 1996	2	71
4	Establishment of wetlands in a way that treats all surface runoff from agricultural land	30	43
5	Establishment of large community wetlands in inherently suitable areas	9	64
6	All wastewater point sources are discharged to land rather than directly to water	2	71
7	Reducing land use intensity on flood prone land	2	71
8	Reducing land use intensity on public land	3	70
9	Destocking (10% reduction drystock, 20% reduction dairy)	11	62
10	Riparian planting (full shading of streams <7m wide)	2 (indirect effect on periphyton)	71

Required reductions likely achieved *Within uncertainty range* *Deficit remaining*

ID	Scenario	Reduction in nitrogen load (%)	Remaining deficit from target (%)
Bundled methods			
11	1996 wetlands returned, wastewater discharged to land (3 + 6)	4	69
12	Established and developing farm mitigations, 1996 wetlands, wastewater to land (2 + 3 + 6)	15	58
13	Established and developing farm mitigations, 1996 wetlands, wastewater to land, repurposing public land (2 + 3 + 6 + 8)	18	55
14	Established and developing farm mitigations, 5% wetlands, wastewater to land, repurposing public land (2 + 4 + 6 + 8)	37	36
15	Established and developing farm mitigations, community wetlands, wastewater to land (2 + 5 + 6)	19	54
16	Established farm mitigations, wastewater to land, plantain on dairy farms, 1996 wetlands, repurposing of ES land, forestry expansion (1 + 6 + 3 + new individual methods)	9	64

Required reductions likely achieved *Within uncertainty range* *Deficit remaining*

Reducing load from pastoral land across the catchment

In addition to the scenarios outlined above, nitrogen load reduction scenarios were modelled for dairy and drystock farms.

The table below shows the total nitrogen load reduction achieved for different combinations of simulated reductions from dairy and drystock farming. Coloured cells indicate how far each combination contributes towards achieving the required load reductions. For example, a 40% reduction in nitrogen loss from dairy farms combined with a 40% reduction from drystock farms results in an approximate 25% reduction in total nitrogen load at the catchment scale.

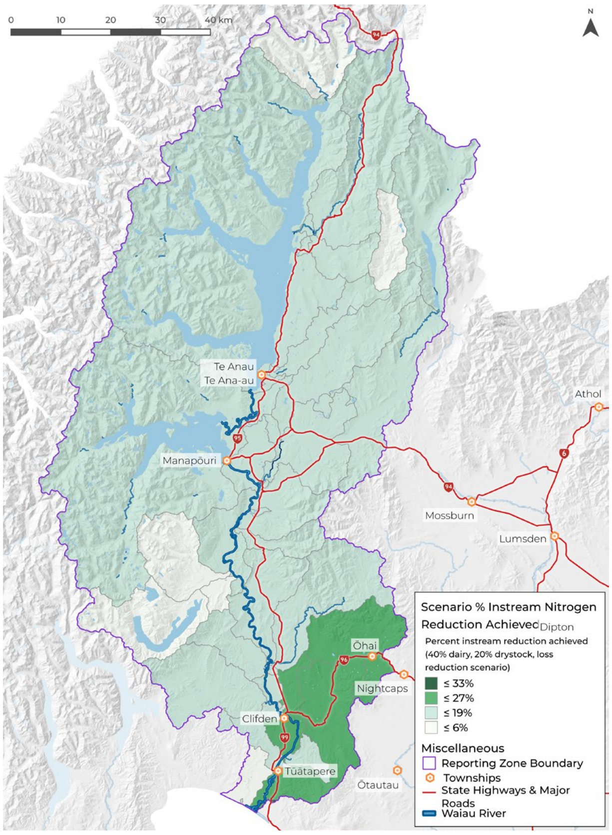
Basin-wide mean % TN reduction, relative to baseline

Drystock loss rate reduction (%) \ Dairy loss rate reduction (%)	0%	20%	40%	60%	80%
80%	38%	41%	44%	47%	50%
60%	29%	32%	35%	37%	40%
40%	19%	22%	25%	28%	31%
20%	10%	12%	15%	18%	21%
0%	0%	3%	6%	9%	12%

Dairy loss rate reduction (%)

Required reductions likely achieved *Within uncertainty range* *Deficit remaining*

Instream nitrogen reduction achieved (%)



The map shows how the modelled nitrogen reductions achieved are predicted to vary spatially across the sub-catchments under a 40% dairy and 20% drystock loss reduction scenario. It highlights that we might expect larger percentage reductions (up to 27%) achieved in some smaller sub-catchments, but the majority of the catchment area achieves a 19% or less reduction under that scenario.

Opportunities for action

We've put together opportunities for action for the Waiau catchment to reduce the load and impact of contaminants on freshwater.

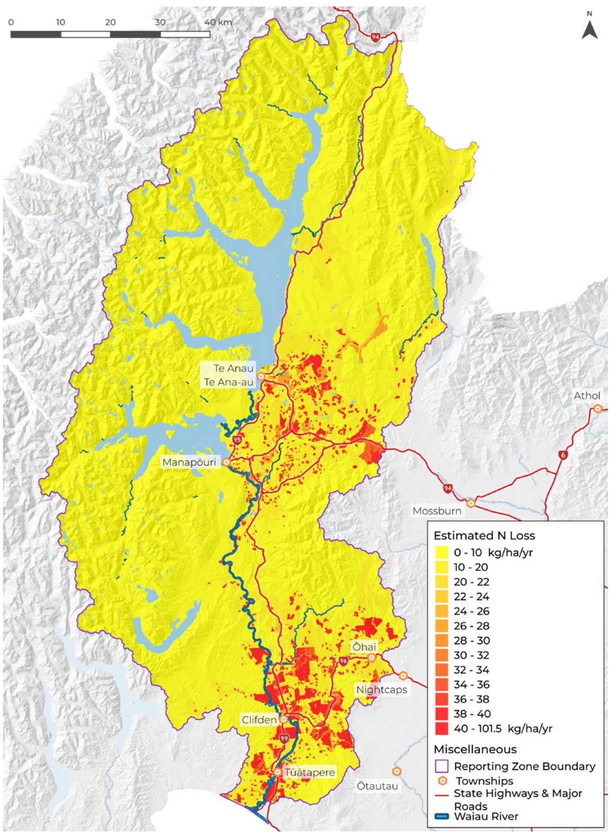
The catchment scale of the problem

The following map set shows the spatial distribution of intensive land use and the associated estimated nitrogen loss, the modelled in-stream nitrogen concentrations (using monitoring data) and the modelled excess nitrogen load patterns across the catchment. These maps help to demonstrate the spatial scale of the reductions required.

Excess loads depend on the modelled concentrations and all the defined targets, both local and downstream. This load excess map indicates the magnitude of nitrogen load reductions to achieve all river and estuary targets for the entire catchment area.

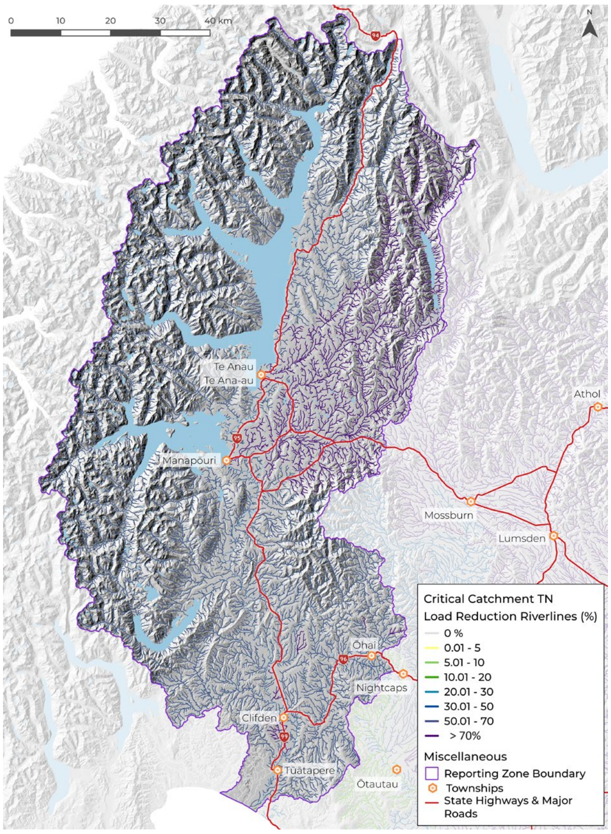
High nitrogen loads may be difficult to mitigate, and improved management practices alone are unlikely to achieve the desired outcomes for freshwater and the estuary/lagoon. Consideration should be given to the potential for large-scale catchment mitigations and changes to how land is used. Large nitrogen reductions over large spatial areas will likely require changes to land use over a long period. This might be through exploring and adopting different land uses or technological advances in farm systems and management. In addition, because the hydrology of the catchment has been extensively modified through stream channel straightening and artificial drainage, efforts to implement nature-based solutions and slow water flow are likely to have multiple benefits for water quality, biodiversity, flood mitigation and catchment resilience.

Estimated nitrogen loss

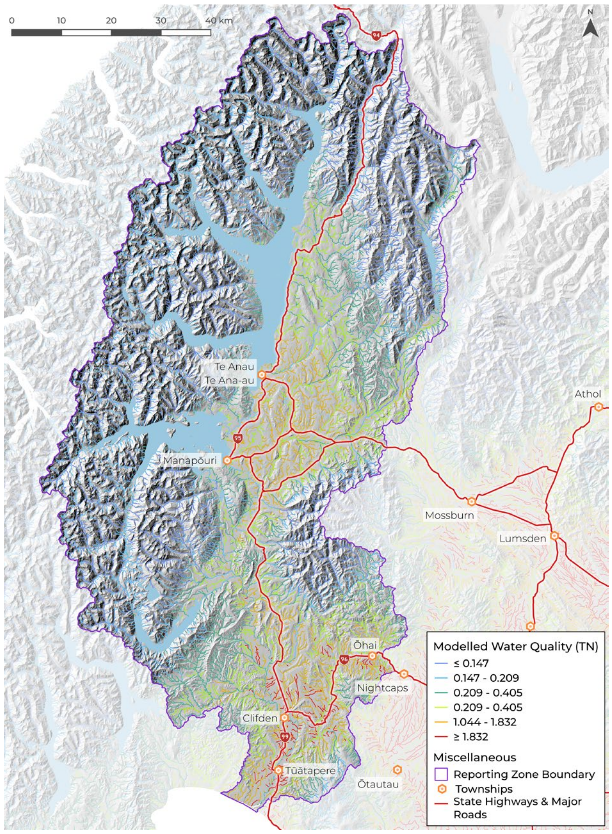


Nitrogen loss in this graphic is an approximation and is only differentiated by land use, soil drainage, rainfall/irrigation, and slope.

Critical catchment TN load reduction (%)



Modelled water quality (total nitrogen)



▲ *The coloured riverlines show the % of nitrogen excess at that location (large % excess in headwaters can be a result of downstream receiving environments and/or spatially variable target states).*

Farm scale opportunities for action

Farm-scale actions should be tailored to physiographic setting, as well as to catchment priorities and the broader context. In the Waiau catchment, load reductions are required for all major contaminants, including nitrogen, phosphorus, sediment and *E. coli*. Farm-scale observations, physiographic information and an understanding of water quality can be used together to help identify the most relevant actions for a given location or landscape.

Physiographic zones help explain how contaminants move through the landscape. Each zone has common attributes that influence water quality, including climate, topography, geology and soil type. Zones differ in how contaminants accumulate and are transported through soils, groundwater and into rivers and streams.

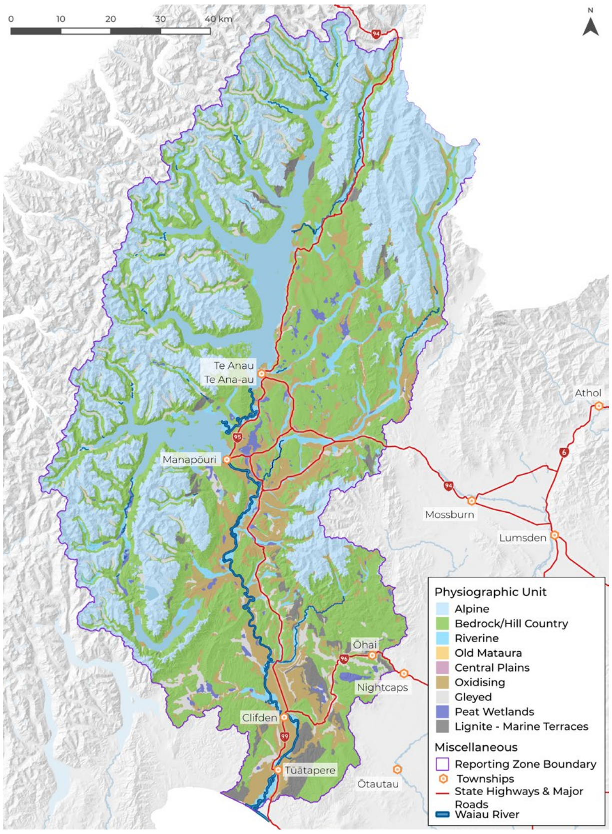
Contaminants can move from land to waterways through several key pathways, including:

- overland flow (or surface runoff)
- artificial drainage - e.g. tile drains and mole pipe drainage
- deep drainage (or leaching) - of either nitrogen or phosphorus to groundwater
- lateral drainage (or horizontal movement through the soil) - of phosphorus and microbes

These transport pathways vary between physiographic zones. Understanding these differences supports the development of targeted land use and management strategies to reduce impacts on water quality. Widespread implementation of property-scale actions to improve water quality can also deliver co-benefits for catchment hydrology, including reduced flood risk and increased resilience to our changing climate as well as improved biodiversity outcomes.

Some locations may have farm-scale or higher resolution physiographic information. We promote using the best available information to identify farm-specific risks and solutions.

Physiographic zones



The following maps help to identify the most important actions to focus on in different parts of the catchment.

Nitrogen

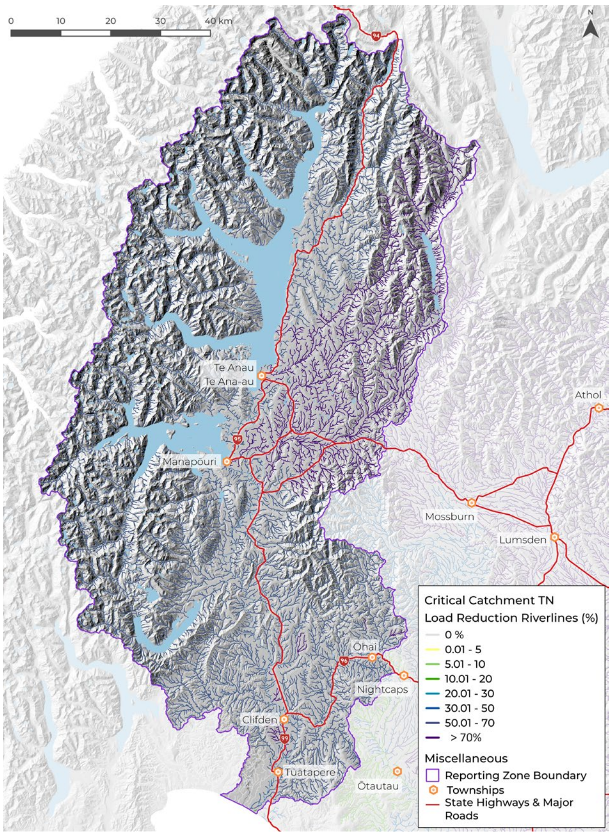
Over time, nitrogen load reductions are required across the entire catchment to achieve hauora targets in all receiving environments, including rivers and the lagoon.

Reducing nitrogen loss should be a priority in all farm-scale mitigation planning.

Physiographic zones can help identify what contaminant loss pathways likely need attention in different locations. As shown above, the excess load map shows parts of the catchment where nitrogen loss mitigation should be a particular focus in farm planning to reduce excess nitrogen loads.

This map indicates the magnitude of nitrogen load reductions needed to achieve all river and estuary targets for the entire catchment area.

Critical catchment TN load reduction (%)



Phosphorus

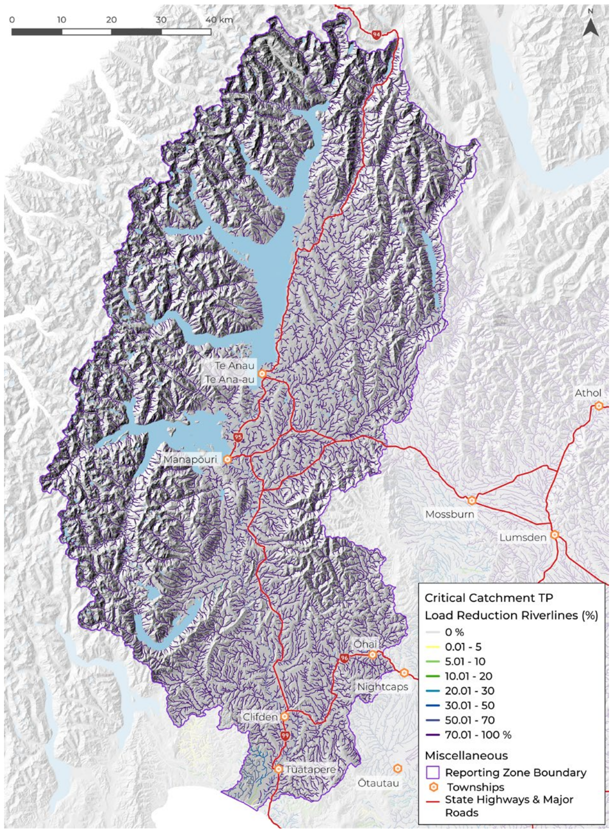
Over time, widespread load reductions will be required to achieve hauora targets.

Reducing phosphorus loss should be a priority in all farm-scale mitigation planning.

Determination of which mitigations to use will depend on each farm and its circumstances. Physiographic information can help inform what contaminant loss pathways most likely need attention in different locations. The excess load map shown here indicates where phosphorus loss mitigation should be a particular focus in farm planning.

This map indicates the magnitude of phosphorus load reductions needed to achieve all river and estuary targets for the entire catchment area.

Critical catchment TP load reduction (%)



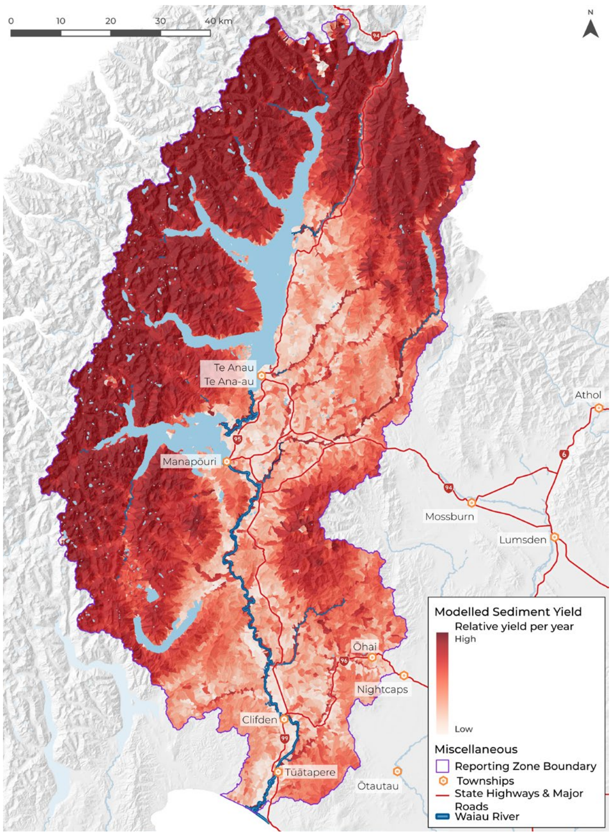
Sediment

The map (right) shows how sediment loss is expected to vary across the catchment. Some areas of higher sediment loss occur in the upper catchment and are associated with natural erosion processes.

While opportunities to reduce sediment loss in these areas are limited, there are parts of the agricultural landscape where sediment loss is higher and more amenable to management. These areas are typically associated with steeper land, erosion-prone soils and locations where stream bank erosion is likely to occur.

Sediment from agricultural land generally poses a greater risk to rivers and the bottom-of-catchment Waiau lagoon, as it is often finer and can carry higher concentrations of nutrients. Properties located in areas shaded darker red on the map should prioritise opportunities to reduce sediment loss through targeted mitigation actions.

Modelled Sediment Yield



E. coli

The risk of *E. coli* loss to water depends on landscape type, slope, stock and vegetation cover. Property scale assessments should be used to identify and prioritise mitigation of the highest-risk loss pathways on individual farms.

Te Waewae (Waiau) Lagoon – opportunities for action

Overall, Te Waewae (Waiau) Lagoon is in a fair condition with respect to water quality, phytoplankton and macrophytes (aquatic plants). Sediment is also likely to be influencing the lagoon condition, both currently and into the future.

Reducing sediment and nutrient inputs to the lagoon would therefore be expected to result in improved ecological condition.

Active restoration may include:

- removal of nuisance macrophytes from the lagoon
- targeted restoration of marginal lagoon vegetation and riparian margins along inlet streams.

However, active restoration techniques, such as macrophyte removal, are likely to result in long-term improvements in lagoon condition only if contaminant inputs to the lagoon are significantly reduced.

Groundwater contamination – opportunities for action

Nitrogen hotspots

Areas of highly contaminated groundwater will likely require targeted nitrogen action via management and changes in farm systems. Areas within the Oxidising and Riverine physiographic zones that are also shaded yellow and red in the physiographic map shown previously are likely high-risk areas. In these locations, landowners should implement management plans focusing on key pathways and the stockpile of property scale actions that target nitrogen loss via deep drainage.

E. coli in groundwater

E. coli contamination of groundwater, including groundwater used for drinking water supplies, is an issue across the Waiau catchment and more broadly across Southland.

Actions to reduce *E.coli* contamination of groundwater include:

- Ensuring effective wellhead protection is in place for all bores, particularly those used for drinking water
- Carefully considering the proximity of potential contamination point sources to bores, such as septic tanks, stock sheds and effluent storage areas
- Carefully managing effluent application on freely draining soils, or soils with a high likelihood of bypass flow, where conduits may allow effluent to move directly to groundwater.

Other priority catchment actions

- Removal or improvement of wastewater and stormwater discharges from the Tūātapere and Manapōuri townships
- Ensuring wastewater and stormwater systems are not cross-connected in municipal networks
- Targeted upgrades to on-site wastewater disposal systems to reduce the risk of human faecal contamination of freshwater
- Incorporation of best-practice stormwater management methods in urban development
- Stock exclusion of waterways and drains to reduce faecal contamination of surface waters.

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