# Southland Science Report

## Southland Freshwater Quality
## Implications for rural communities

THRIVING SOUTHLAND

LANDPRO
Make the most of your land

**Prepared For**
Thriving Southland

**Prepared By**
Landpro Ltd
13 Pinot Noir Drive
PO Box 302
Cromwell
Tel +64 3 445 9905

**QUALITY INFORMATION**

| | |
|---|---|
| Reference: | Landpro (2020) Southland Freshwater Quality, Implications for rural communities. Prepared for Thriving Southland. |
| Date: | 12 November 2020 |
| Prepared by: | Mike Freeman, Nick Boyens, Brodie Costello, and Matilda Ballinger |
| Reviewed by: | Claire Perkins. |
| Client Review: | Miranda Hunter, Thriving Southland |
| Version: | Final |

# Executive Summary

Thriving Southland is a community-led group that is working with the community to drive positive change in the primary sector in Southland, by working with farmers and supporting catchment groups. Thriving Southland commissioned this report to provide an understanding of the background state of the environment relating to freshwater quality, risks and pressures that catchments in the region are facing, the implications for farmers, and gaps in information that need to be filled to assist farmers meet the future challenges.

Freshwater quality in Southland has been declining in developed parts of the region, and is under threat from various sources, both urban and rural. Southland's 23 catchment groups provide a local, community response to water quality issues specific to their area.

In response the declining freshwater quality nationally, central government has recently announced changes to the National Policy Statement for Freshwater Management (NPSFM), new National Environmental Standards for Freshwater (NES) and changes to the Resource Management Act.

Environment Southland, in partnership with Te Ao Marama Inc, is currently working on a Progressive Implementation Programme that will result in a new proposed change to the current proposed Southland Water and Land Plan that will establish freshwater objectives and set limits to implement the NPSFM by 31 December 2025.

These changes will result in additional controls in Southland that will be focussed on reducing the loss of contaminants (particularly nitrogen (N), phosphorus (P), microorganisms and sediment) from land to groundwater and surface water. This means that in most parts of Southland there will be new rules that directly or indirectly will set limits on the amounts of N and P that can be lost to water. There are also likely to be new rules aimed at reducing losses of sediment and microorganisms to water.

Catchment groups are in the ideal position to collectively work together on strategies that can be designed to address specific catchment challenges. While the focus of general strategies outlined in the report is on individual farms, catchment groups will be in the best position to tailor packages that enable adjoining landowners to work together.

Catchment groups need to be provided with tailored information and advice as soon as practicable to ensure that as many people in the catchment as possible understand the nature of our current water quality issues, the changes that are coming, the scale of the likely changes that will be needed, and the measures that can be taken individually and collectively to ensure that communities are moving towards the achievement of agreed objectives.

# Table of Contents


**1. BACKGROUND** ..... **1**

**2. INTRODUCTION** ..... **1**

**3. SOUTHLAND'S CATCHMENT GROUPS** ..... **2**

**4. WHAT INFLUENCES WATER QUALITY IN SOUTHLAND** ..... **5**

4.1 Climate ..... 5
*4.1.1 Climate change ..... 5*
4.2 Geology and soils ..... 7
4.3 Hydrology and hydrogeology ..... 7
*4.3.1 Streams and rivers ..... 7*
*4.3.2 Artificial drainage ..... 8*
*4.3.3 Groundwater ..... 8*
4.4 Land use ..... 10

**5. WATER QUALITY IN SOUTHLAND – WHAT'S HAPPENING** ..... **11**

5.1 Surface water quality ..... 11
5.2 Groundwater quality ..... 16
5.3 Wetlands ..... 19
5.4 Estuaries ..... 21
5.5 Water quality and biodiversity ..... 22

**6. MANAGING FRESHWATER QUALITY IN SOUTHLAND** ..... **23**

6.1 Freshwater management units (FMUs) ..... 23
**6.2 Surface water management units** ..... 23
6.3 Groundwater management zones (GMZs) ..... 23
6.4 Physiographic zones ..... 24

**7. POLICY AND PLAN DIRECTION** ..... **29**

7.1 National level ..... 29
*7.1.1 Legislative Tools ..... 29*
*7.1.2 National Policy Statement for Freshwater Management 2020 (NPSFM) ..... 30*
*7.1.3 National Environmental Standards for Freshwater 2020 ..... 32*
*7.1.4 Regulations ..... 32*
*7.1.5 Other relevant statutory requirements ..... 33*
7.2 Regional Level ..... 33
*7.2.2 Proposed Southland Water and Land Plan ..... 33*
*7.2.3 Regional Water Plan 2010 ..... 34*
*7.2.4 Southland Regional Policy Statement 2017 ..... 34*
*7.2.5 Regional Coastal Plan for Southland 2013 ..... 34*
*7.2.6 Regional Effluent Land Application Plan 1998 ..... 34*
*7.2.7 Te Tangi a Tauira – The Cry of the People, Ngāi Tahu ki Murihiku Natural Resource and Environmental Management Plan 2008 ..... 34*
7.3 Future Direction ..... 35
*7.3.1 Resource Management Act Changes ..... 35*
*7.3.2 Regional Plan Changes ..... 35*

**8. AN OVERVIEW OF TANGATA WHENUA PERSPECTIVES** ..... **36**

**9. IMPLICATIONS FOR CATCHMENT GROUPS** ..... **38**

9.1 Land use and practices that result in the greatest loss of contaminants to water ..... 38

9.2 TRENDS IN LAND USE CHANGE OVER THE PAST 30 YEARS ..... 39
**10. WHAT DOES THIS MEAN FOR FARMERS? ..... 40**
10.1 HOW WILL LAND USE/SYSTEM CHANGES BE IMPLEMENTED AND WHAT DOES THIS MEAN FOR FARMERS? ..... 40
10.2 PLANNING PROCESS FOR NUTRIENT REDUCTION ..... 40
10.3 WHAT CAN YOU DO TO HELP IMPROVE WATER QUALITY? ..... 41
*10.3.1 Good Management Practices ..... 41*
10.4 IMPLICATIONS FOR LAND USE AND WATER QUALITY MANAGEMENT ..... 43
10.5 WILL GMP AND NEW REGULATIONS/NESFW BE ENOUGH? ..... 44
10.6 HOW ACCURATE ARE PREDICTIONS ABOUT THE EFFECTIVENESS OF CONTAMINANT REDUCTION STRATEGIES? ..... 45
**11. ACTION ON THE GROUND ..... 45**
11.1 SPECIFIC STRATEGIES FOR REDUCING NITROGEN LOSSES ..... 45
11.2 SPECIFIC STRATEGIES FOR REDUCING PHOSPHORUS, SEDIMENT, AND MICROORGANISM LOSSES TO WATER ..... 48
11.3 CATCHMENT GROUP OPPORTUNITIES ..... 52
11.4 TAKE ACTION NOW OR WAIT? ..... 52
11.5 WHAT SHOULD YOU DO NOW TO BE READY FOR FUTURE NEW REGIONAL RULES? ..... 53
11.6 DEVELOP A MITIGATION TOOLBOX FOR YOUR FARM ..... 54
11.7 GROUNDWATER SPECIFIC ISSUES ..... 55
**12. RECOMMENDATIONS FOR FURTHER WORK ..... 55**
12.1 METHODS TO ASSESS THE EFFECTIVENESS OF SPECIFIC MITIGATION MEASURES ..... 55
12.2 CATCHMENT SPECIFIC CONTAMINANT REDUCTION TARGETS AND PACKAGES ..... 55
12.3 ESTABLISHMENT OF IMPROVED WATER QUALITY MONITORING PROGRAMMES - LOCAL AND REGIONAL ..... 56
12.4 IMPROVED INFORMATION ON THE CAUSES OF AREAS OF HIGH NITRATE NITROGEN IN GROUNDWATER ..... 56
12.5 INFORMATION AND PREPARATION FOR THE FUTURE CHANGES ..... 57
**13. REFERENCES ..... 58**
**14. BIBLIOGRAPHY ..... 60**
**APPENDIX A: INDIVIDUAL CATCHMENT GROUP AREA STATE AND TREND INFORMATION ..... 126**
BALFOUR WAIMEA UPPER MATAURA CATCHMENT GROUP ..... 127
*Surface Water Quality State and Trends ..... 128*
*Groundwater Quality State and Trends ..... 128*
BETWEEN THE DOMES CATCHMENT GROUP ..... 129
*Surface Water Quality State and Trends ..... 130*
*Groundwater Quality State and Trends ..... 130*
GORE WAIMUMU CATCHMENT GROUP ..... 131
*Surface Water Quality State and Trends ..... 132*
*Groundwater Quality State and Trends ..... 132*
HEDGEHOPE MAKAREWA CATCHMENT GROUP ..... 133
*Surface Water Quality State and Trends ..... 134*
*Groundwater Quality State and Trends ..... 134*
LOWER APARIMA CATCHMENT GROUP ..... 135
*Surface Water Quality State and Trends ..... 136*
*Groundwater Quality State and Trends ..... 136*
LOWER MATAURA CATCHMENT GROUP ..... 137
*Surface Water Quality State and Trends ..... 138*
*Groundwater Quality State and Trends ..... 138*
MAKAREWA HEADWATERS CATCHMENT GROUP ..... 139
*Surface Water Quality State and Trends ..... 140*
*Groundwater Quality State and Trends ..... 140*

MID-APARIMA CATCHMENT GROUP ........ 141
*Surface Water Quality State and Trends* ........ *142*
*Groundwater Quality State and Trends* ........ *142*
MID-ORETI CATCHMENT GROUP ........ 143
*Surface Water Quality State and Trends* ........ *144*
*Groundwater Quality State and Trends* ........ *144*
NEW RIVER ESTUARY FORUM ........ 145
*Surface Water Quality State and Trends* ........ *146*
*Groundwater Quality State and Trends* ........ *146*
OREPUKI CATCHMENT GROUP ........ 147
*Surface Water Quality State and Trends* ........ *147*
*Groundwater Quality State and Trends* ........ *147*
OTAMITA CATCHMENT GROUP ........ 148
*Surface Water Quality State and Trends* ........ *149*
*Groundwater Quality State and Trends* ........ *149*
POURAKINO CATCHMENT GROUP ........ 150
*Surface Water Quality State and Trends* ........ *151*
*Groundwater Quality State and Trends* ........ *151*
+THREE RIVERS CATCHMENT GROUP ........ 152
*Surface Water Quality State and Trends* ........ *153*
*Groundwater Quality State and Trends* ........ *153*
UPPER APARIMA CATCHMENT GROUP ........ 154
*Surface Water Quality State and Trends* ........ *155*
*Groundwater Quality State and Trends* ........ *155*
UPPER WAIAU – TE ANAU CATCHMENT GROUP ........ 156
*Surface Water Quality State and Trends* ........ *157*
*Groundwater Quality State and Trends* ........ *157*
WAIAU RIVER CARE GROUP ........ 158
*Surface Water Quality State and Trends* ........ *159*
*Groundwater Quality State and Trends* ........ *159*
WAIHOPAI CATCHMENT GROUP ........ 160
*Surface Water Quality State and Trends.* ........ *161*
*Groundwater Quality State and Trends* ........ *161*
WAIKAKA STREAM CATCHMENT GROUP ........ 162
*Surface Water Quality State and Trends* ........ *162*
*Groundwater Quality State and Trends* ........ *162*
WAIKAWA CATCHMENT GROUP ........ 163
*Surface Water Quality State and Trends* ........ *164*
*14.20.2 Groundwater Quality State and Trends* ........ *164*
WAIMATUKU CATCHMENT GROUP ........ 165
*Surface Water Quality State and Trends* ........ *166*
*Groundwater Quality State and Trends* ........ *166*

**APPENDIX B: SURFACE WATER MONITORING SITES ........ 167**

**APPENDIX C: ILLUSTRATION OF A SECURELY PROTECTED WELL HEAD (COURTESY HAWKES BAY REGIONAL COUNCIL) ........ 170**

## List of Figures


Figure 1: Location of Southland's catchment groups ..... 4
Figure 2: Three main aquifer types in Southland: unconfined, semi-confined and confined. Source: Environment Southland ..... 8
Figure 3: Riparian aquifer showing connectivity to land (via deep drainage) and surface water. Source: Environment Southland ..... 9
Figure 4: Terrace aquifer showing relationship with riparian aquifer, connectivity to land (via deep drainage), and surface water via springs. Source: Environment Southland ..... 9
Figure 5: Lowland aquifer showing relationship with riparian aquifer, connectivity to land (via deep drainage), and surface water via small streams. Source: Environment Southland ..... 10
Figure 6: Southland water quality monitoring sites graded according to the NPS-FM 2020 National Objectives Framework category: *E. coli* for Human Contact (Appendix 2A, Table 9). Data from LAWA 2018 state data set (LAWA, 2020) ..... 14
Figure 7: Southland water quality monitoring sites graded according to the NPS-FM 2020 National Objectives Framework category: Nitrate (Toxicity), River ecosystem health (Appendix 2A, Table 6). Data from LAWA 2018 state data set (LAWA, 2020) ..... 15
Figure 8: State of *E. coli* in groundwater in Southland. (Sites where *E. coli* has been detected are not suitable as a source of untreated drinking water.) ..... 17
Figure 9: State of Nitrate-Nitrogen in groundwater in Southland showing median concentrations relative to the DWSNZ maximum acceptable value of 11.3 mg/L ..... 18
Figure 10: Change in mapped wetland areas between 2007 and 2014/2015 (from Dare & Ewans, 2018) ..... 20
Figure 11: Southland's monitored estuaries (from ES, 2020) ..... 21
Figure 12: Example of contaminant pathways and attenuation for the Peat Physiographic Zone. Source: Environment Southland ..... 24
Figure 13: The five freshwater management units (FMUs) in Southland as at November 2020 ..... 25
Figure 14: Environment Southland Groundwater Management Zones from the proposed Southland Water and Land Plan ..... 26
Figure 15: Environment Southland's physiographic zones from Hughes *et al.* 2016 ..... 27
Figure 16 Surface water management units specified in the pSWLP ..... 28
Figure 17: The number of milking cows in Southland 1990 - 2019 ..... 39
Figure 18: Diagrammatic representation of a simplistic change in catchment N loads and water quality ..... 41
Figure 19: The relative cost and effectiveness of farm strategies to mitigate N losses to water. Cost is shown as the cost per kg of N mitigated relative to the most expensive strategy. The centre of the squares represents the mid-point in the range for each strategy, while the size represents the relative variability of each strategy (Diagram reproduced with permission of AgResearch) ..... 47
Figure 20: The relative cost and effectiveness of farm strategies to mitigate P losses to water. Cost is shown as the cost per kg of P mitigated relative to the most expensive strategy. The centre of the squares represents the mid-point in the range for each strategy, while the size represents the relative variability of each strategy (Diagram reproduced with permission of AgResearch) ..... 50
Figure 21: The relative cost and effectiveness of farm strategies to mitigate sediment losses to water. Cost is shown as the cost per kg of sediment mitigated relative to the most expensive strategy. The centre of the squares represents the mid-point in the range for each strategy, while the size represents the relative variability of each strategy (Diagram reproduced with permission of AgResearch) ..... 51

# List of Tables

Table 1: Southland Region landcover class change between 1996 and 2012 (LAWA, 2020) .............................. 11
Table 2: Estuary health monitoring results as at 2018 (from ES (2019)) ............................................................ 22
Table 3: A summary of general farm practices, mitigation measures and the contaminants targeted ............... 43
Table 4: Implications of new RMA provisions for contaminant loss management ............................................. 43
Table 5: Summary of nitrogen loss reduction strategies ...................................................................................... 48
Table 6: Summary of phosphorus, sediment and faecal bacteria loss reduction strategies ............................... 52

# 1. Background

Thriving Southland is a community-led group with a vision to create a prosperous Southland, healthy people, and a healthy environment from the mountains to the sea. Established in 2019, Thriving Southland is working with the community to drive positive change in the primary sector in Southland, by working with farmers and supporting catchment groups.

The purpose of this report is to provide an understanding of the background state of the environment relating to freshwater quality, risks and pressures that catchments in the region are facing, the implications for farmers, and gaps in information that need to be filled to assist farmers meet the future challenges.

This report includes a review of the available literature and reports relevant to water quality in the Southland region.

- A state of the environment summary covering; climate; geology and soils; hydrology and hydrogeology; land use; and a summary of water quality issues in Southland.
- High level policy and plan direction, including an overview of Tangata Whenua perspectives and values.
- Key catchment water quality issues and what farmers can do to both help improve water quality now and be prepared for future rules to improve water quality.

One key driver for this work is the recent and pending regulatory changes initiated by central and regional government to improve water quality. Other important water related issues such as water flows, fish passage, and broader ecosystem health are beyond the scope of this report. Another key driver is the desire of communities to maintain existing high quality water quality and to improve degraded water quality.

A wide range of literature was found during the search process. Key publications are referred to directly in the text and other publications are summarised in the Bibliography.

The published work undertaken by individuals and organisations, particularly Environment Southland and Crown Research Institutes has provided key information and insights that has enabled us to summarise it in a form that should assist Southland farmers to meet the current and future land use and water quality challenges.

# 2. Introduction

Freshwater is essential to New Zealanders in several ways, for example:

- Water is a taonga for Māori – playing a unique role in the traditional economy and culture of Tangata Whenua.
- Health and domestic use – Everyone needs clean water to drink, as well as to clean themselves, do washing and cooking, and to clean their homes.
- Economic – Water is used across a variety of industries, such as manufacturing, industry, and farming. For example, between 2017 and 2018, 58% of consented freshwater abstractions were for irrigation.
- Food – Many people gather food from New Zealand's waters, such as salmon, trout, eels, and whitebait.
- Energy – Over half of New Zealand's energy is generated from hydroelectricity. This helps avoid a reliance on electricity generated by gas and coal, which in turn limits our greenhouse gas emissions.
- Biodiversity – Many of New Zealand's unique ecosystems rely on water. Healthy freshwater environments allow our unique plants and animals to thrive.
- Recreation – Many people use water for swimming, boating, fishing, and other recreational activities.

The decline in freshwater quality across developed parts of New Zealand's landscape has received much attention in recent times. The health of our rivers, lakes, streams and aquifers is influenced by natural factors, such as climate, soil and rock type. However, water quality is also affected by the collective actions of people, via both direct discharges and runoff from the land.

In Southland there are three main contaminants that affect water quality:

1. **Sediment**, which accumulates on the bottom of our rivers, lakes and estuaries; and is suspended in the water column. This has an adverse effect on aquatic life.
2. **Nutrients, primarily Nitrogen (N) and Phosphorus (P),** which become a problem when too much enters waterways, resulting in excess algae and aquatic plant growth.
3. **Microorganisms** which potentially cause disease in both people and animals[1].

There are other contaminants that are discharged to water in Southland such as heavy metals, petroleum compounds, and other contaminants in stormwater from urban areas, pesticide residues, organic contaminants with a high biological oxygen demand, etc. However, the evidence strongly indicates that the most pressing water quality issues in Southland are related to one or more of the three contaminants listed above.

Water in Southland is under pressure from multiple sources and the whole Southland community needs to be able to respond and adapt to continue to be prosperous and maintain and improve freshwater quality. There are key pressures and environmental settings that need to be understood to be prepared for change and adaptation in the way the Southland population, including farmers, operate in the future. Catchment groups play a vital role in locally relevant freshwater management in Southland.

## 3. Southland's Catchment Groups

Southland's catchment groups provide a local, community response to water quality issues in their area. They typically have a strong farmer membership, and are supported by businesses, rural professionals, farm sector support groups, councils, and national and regional organisations.

Southland has 23 Catchment Groups forming a network covering 80% of the Southland region (excluding national parks), and this network is expanding rapidly (Figure 1). Each group is set up to improve water quality in an area that is special to them. The group chooses their boundary, identifies their issues, and develops solutions. Southland's catchment groups were initially supported by the sector groups, then due to a community / cross sector focus were transitioned to being supported by Landcare Trust (as part of the Sustainable Farming Fund). With funding now provided by the Ministry of Primary Industries (MPI) Sustainable Land Use fund, these groups are being support by Thriving Southland, along with other partners and stakeholders (such as Sector groups and Environment Southland).

Each group is unique but they all work to:

- Improve water quality
- Identify local issues and solutions
- Raise awareness and education
- Provide a community voice and contact point
- Help people get ready for changes in policy and regulations

[1] *Escherichia coli* (*E. coli*) is used as a microbiological indicator for fresh water to indicate the presence of pathogens (disease-causing organisms) from animal or human faeces.

The focus of the catchment groups and this report is on the catchment of rivers and streams. It is recognised that some catchment groups will have land that borders a lake, an estuary or lagoon. However, the background and implications will apply across all catchments.

In addition to the 23 Catchment Groups there are currently a range of partners and stakeholders involved with the Waituna catchment through Whakamana te Waituna[2]. Thriving Southland is currently communicating with the community to gauge their needs and the scope for working together.

[2] https://www.waituna.org.nz/

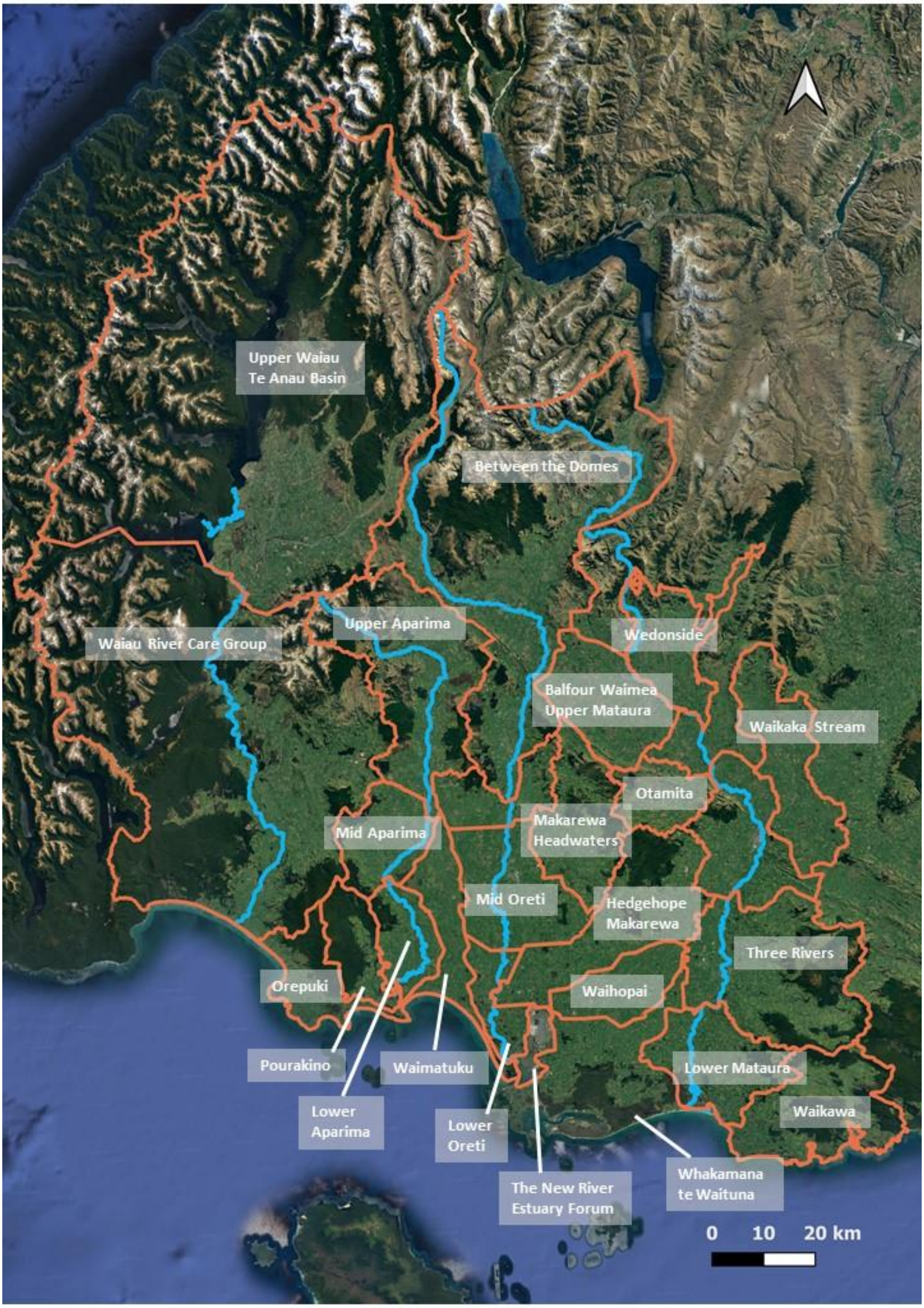



**Figure 1: Location of Southland's catchment groups**

# 4. What influences water quality in Southland

This section describes the main influences of water quality across Southland, and is focused on a high-level region-wide viewpoint. For a brief summary of monitoring results at a catchment group scale please refer to Appendix A. (The data in Appendix A is limited to the data available on the LAWA[3] website with state and trend information. Additional information may be held by ES.) Fiordland catchments that drain to the west are not considered in this work.

## 4.1 Climate

The climate of Southland is strongly influenced by the topography, especially the Fiordland Mountains, and by the strong westerly flow of maritime weather that it receives directly from the Southern Ocean. Overall, the region is relatively wet with between 800-1200mm of annual rainfall across the plains and extreme rainfall of up to 8000mm a year in Fiordland. It is important to appreciate that climate varies in parts of Southland. For example, relatively high rainfall close to Fiordland with significantly less average annual rainfall to the east. Summer droughts do occur, for example during 2012/13; and in some years there were significant reductions in annual average rainfall, for example in 2017[4]. Southland receives less sunshine than the rest of New Zealand and temperatures are generally lower with frequent frosts and snowfalls (Macara, 2013).

### 4.1.1 Climate change

Climate change is expected to bring many challenges and the need for adaption across many parts of society. NIWA (Zammit et al., 2018) has undertaken climate change modelling for each region in New Zealand, including Southland. Findings indicate that changing temperatures and rainfall patterns are likely to have significant impacts on farming productivity in Southland. An increase in drought conditions is likely in the central-northern parts of the region. Increases in dry days are projected for much of the Waiau catchment and large increases in Potential Evapotranspiration Deficit (PED) are expected in the northern Mataura catchment.

Areas that currently rely on irrigation during dry months may find that there's not enough water to go around. Recharge patterns for aquifers will likely change with changing patterns in rainfall. Further, coastal aquifers may be at risk of saltwater intrusion as sea levels rise, rendering them unsuitable for abstraction.

Increased rainfall is likely for much of the region during winter months. This will have implications for managing nutrients and waste, particularly on dairy farms. Increased rainfall events will also affect surface flooding, which could affect production on vulnerable land.

Another key element to climate change is the global movement of plant and animal pests. Warmer temperatures and fewer frosts in Southland could result in increased numbers and fertility of invasive weeds. Farmers in Southland may have to change to growing plant species more commonly grown further north at present.

Rising temperatures and drier summers also put forested areas at risk of wildfires. As well as the affecting corporate growers, the increased risk of wildfires may affect farmers with planted blocks who rely on the sale of timber to supplement their income.

Further details regarding the modelled future climate of the Southland region are outlined below.

**Temperature changes**

Temperatures will likely increase within a range of 0.5-1°C by 2040 and by 0.7-3°C by 2090. This is a broad range

[3] LAWA = Land Air Water Aotearoa, www.lawa.org.nz Regional councils cooperate by uploading surface water and groundwater quality data onto this website. Common sampling, reporting and data analysis methods are used.

[4] NIWA Annual Climate Summary 2017

and reflects the range of uncertainty in the modelling. It is expected that Autumn will be the season that sees the most change.

Extreme temperatures will also see change with the average number of hot days expected to increase with time (0-10 days by 2040 and 5-55 days by 2090). A heatwave is defined by NIWA as being a period of three or more consecutive days, whereby the maximum daily temperature is higher than 25°C. Southland has three main sites that currently experience the most heatwaves: Te Anau, Riversdale and Lumsden. Heatwaves in these areas are predicted to increase from the current three days per year to about 25 days per year by the end of the century. Therefore, the risk of drought is likely to increase in these areas as the century progresses.

The number of frost days is expected to decrease in the region by 0-5 days by 2040 and by 10-20 days by 2090.

**Rainfall patterns and drought**

Predicted changes in rainfall patterns are expected to show marked seasonality and variability across the region. Annual rainfall for the region as a whole is expected to increase slightly by 2040 at 0-5% while the longer-term outlook (2090) is for an increase of 5-20% with the largest increase in the northern part of the region. Despite the increase in annual rainfall the number of wet days is expected to decrease by up to 10 days across most of the region and by 10-20 days in the Waiau River catchment. It is important to appreciate that specific catchments are likely to have specific responses to climate change that may be different than the regional averages.

Across both the 2040 and 2090 predictions the number of heavy rain days (>50mm/day) are expected to increase throughout Southland, apart from a small part of the Eastern Waiau catchment.

'Dry days' are defined as days with less than 1mm rainfall. Currently the northern Mataura catchment has the highest number of dry days, with an annual average of 225-250 days. The central part of Southland has an annual average of 200-225 dry days per year, while the western Waiau catchment has an annual average of 175-200 dry days per year. Southern Fiordland has the fewest dry days with an annual average of 100-150 per year.

Predictions for the future are mixed. Some parts of Southland will likely experience more dry days, while others have fewer (i.e., are wetter). By 2040, up to 10 *fewer* dry days per year are expected for central parts of the region, as well as parts of northern and western Fiordland. Up to 10 *more* dry days per year are expected for much of the Fiordland and Waiau catchments, the southern Mataura and Oreti catchments, and Stewart Island.

By 2090 most of the region will experience a *decrease* in dry days, outside of the Waiau catchment, eastern Fiordland, and Stewart Island. The largest *increases* are projected for the eastern Waiau catchment, where 10-20 more dry days per year are expected.

Meteorological drought (assessed using Potential Evaporation Deficit) is expected to increase mostly in the central-northern part of the region across all time periods and scenarios. Potential Evaporation Deficit is expected to increase by 40-80mm per year for most of the region by 2040 and by up to 100mm by 2090 under the highest emissions scenario modelled.

**Hydrological regime**

The climate change scenarios were used to model potential effects on the hydrological regime in the region. Overall spring flows are expected to be slightly higher, summer flows are expected to slightly decrease, while autumn and winter flows are expected to increase.

Impact on low flows are expected to be variable across the region with flows in Fiordland and the Waiau River catchment expected to increase and for the rest of the region expected to decrease, apart from coastal areas of the Ōreti and Matāura catchments.

Floods, as characterised by the Mean Annual Flood, are expected to increase in size across the whole region.

## 4.2 Geology and soils

Southland has a varied and complex geology and topography. The Fiordland mountains dominate the western third of the region and are comprised of hard bedrock that has been severely glaciated and formed into very steep terrain. This area is largely in conservation land and covered with forest or alpine vegetation. Another geological feature of significance is the Southland Syncline that runs from the Takitimu Mountains across Southland to the coast at the Catlins. This forms the Hokonui Hills that separate the two areas of plains present in Southland. The Southland Plains extend from the Waiau River in the west across to the border with Otago region to the east of Gore. North of the Hokonui Hills are the Waimea Plains that flank the mid-reaches of the Ōreti and Matāura Rivers (Grant, 2020).

Southland's complex geology is reflected in its soils. Environment Southland recognises about 170 different soil types in Southland that have different physical, chemical and biological components. Soil structure is integral to its functioning, affecting water movement and storage, plant rooting depth and the availability of water and nutrients, as well as the ability of soil to resist erosion. Soils also differ in how they take up, store and transport the building blocks of life, including carbon, nitrogen and phosphorus. For more information on Southland soils and how they function, see Environment Southland's physiographics reports.

## 4.3 Hydrology and hydrogeology

Other than the catchments that drain to the west in Fiordland (these are not considered in this study), the Southland Region is drained by four major rivers: the Waiau River, the Ōreti River, the Matāura River, and the Aparima River. The first three have their headwaters in the high mountainous areas (Fiordland, Thomson Mountains and Eyre Mountains) in the northwest of the region; and the Aparima begins in the Takitimu Mountains. Higher in the catchments where there is plentiful sediment supply the rivers form a braided morphology, but this quickly changes to a wide meandering morphology as they flow across the gently sloping plains towards the south coast (Mager & Horton, 2018). Along with these main rivers there are many thousands of kilometres of natural streams and artificial drains that originate in the mountains or on the plains and feed into the main rivers.

### 4.3.1 Streams and rivers

The morphology of streams and rivers has been changed dramatically in parts of lowland Southland. In order to hasten water flow from the land to the coast, and bring more land into primary production, many streams and rivers have undergone substantial channelisation and straightening works. For example, much of the lower Waihopai River has been straightened and flood banks built along its margins. Streams draining into the lower Aparima River have also undergone straightening in order to manage flooding in the lower catchment.

Southland's largest river-straightening project was the Makarewa Scheme. To protect flood-prone land, the river was straightened to hasten drainage. This was done by short-cutting its multitude of meanders across very flat land. A hundred miles of river was channelled using dragline excavators between 1965 and 1968. The river was shortened by about 80.5 kilometres[5].

The Waiau River has also undergone a significant change in terms of flow. The Waiau River used to be the largest river in the region, and second largest in the New Zealand, with a mean flow of 550m$^3$/s (Mager & Horton, 2018) but since the commissioning of the Manapouri Power Scheme in the 1970's most of its flow is diverted through

---

5
https://www.lawa.org.nz/explore-data/southland-region/river-quality/waihopai-stream/
http://www.stuff.co.nz/southland-times/culture/in-the south/10622762/Crewman-takes-a-punt

the power station to Doubtful Sound. Now the mean flow is lower at 167 $m^3/s$ and consequently the downstream river morphology has changed (Mager & Horton, 2018).

### 4.3.2 Artificial drainage

Before development for agriculture, much of lowland Southland was covered in wetlands. There are about 18,240$km^2$ of agricultural land in Southland, of which about 13,870 $km^2$ (about 76%) are located in areas that were historically wetlands and now have some form of artificial drainage. Artificial drainage is essential to lowering the water table, making areas of former wetland suitable for agriculture (Pearson, 2015).

Pearson (2015) looked at the extent of artificial subsurface drainage in Southland. She concluded that artificial subsurface drainage systems cover about three quarters of agricultural land in Southland. In Southland, an average of approximately 120 metres of tiles per hectare are required in mole-tile systems to achieve adequate drainage.

Areas of high to very high density drainage systems are found mostly in the Central Southland Plains areas and around the Waituna wetland. Artificial drainage networks are most active during wetter months when they transport large volumes of soil water to nearby areas of surface water, such as ditches or streams.

### 4.3.3 Groundwater

Groundwater is sub-surface water that sits in saturated soils and geological materials located below the water table. Aquifers are areas of where groundwater exists in sufficient and accessible quantities to be abstracted for human use. We have three main types of aquifer in Southland: unconfined, semi-confined and confined aquifers Figure 2).

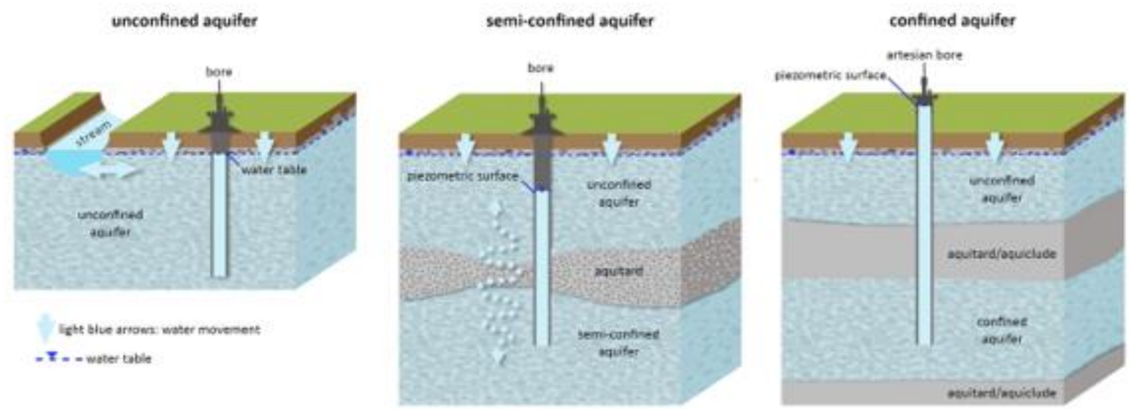



**Figure 2: Three main aquifer types in Southland: unconfined, semi-confined and confined. Source: Environment Southland**

Unconfined aquifers are directly connected to the land above. They tend to have a shallow water table and can be highly connected to streams and rivers. Unconfined aquifers can be divided into three main types:

1. **Riparian aquifers:** Located under the recent floodplains of major river systems. These aquifer systems exhibit a high degree of interaction with surface water (recharge and discharge), which can influence the quality and quantity of both ground- and surface water. Riparian aquifers can be found along the margins of all Southland's major rivers.

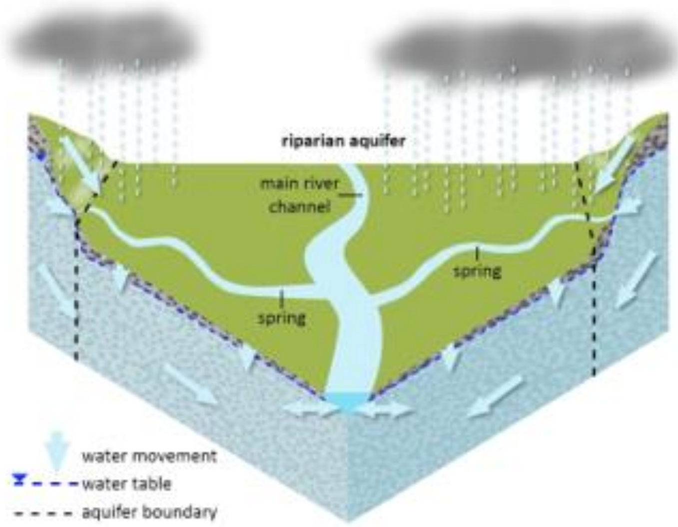



**Figure 3: Riparian aquifer showing connectivity to land (via deep drainage) and surface water. Source: Environment Southland**

2. **Terrace aquifers:** Located under elevated gravel terraces along the margins of river valleys. They usually have little interaction with surface water. However, some terraces have large springs where groundwater resurfaces at the terrace edge. Some of these springs are significant in size and during low flow periods can contribute a significant proportion of stream baseflow in some areas.

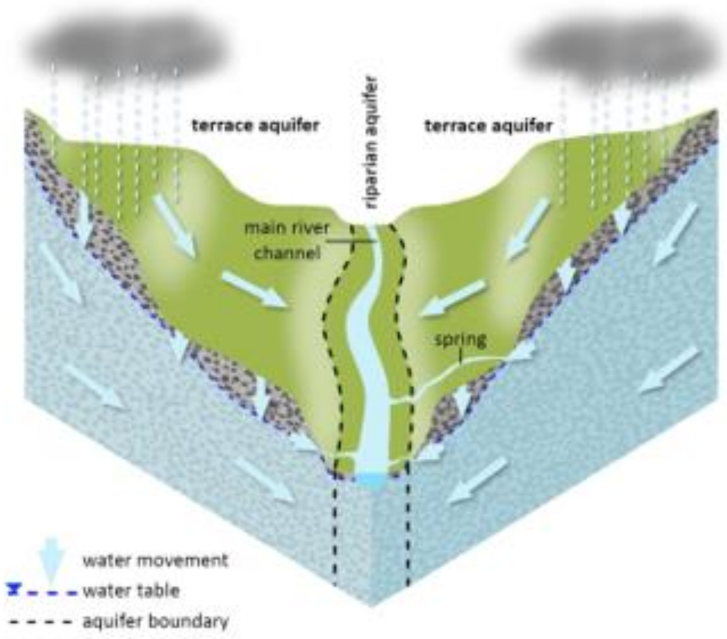



**Figure 4: Terrace aquifer showing relationship with riparian aquifer, connectivity to land (via deep drainage), and surface water via springs. Source: Environment Southland**

3. **Lowland aquifers:** Located in the remnants of older, highly weathered gravel beds. They are criss-crossed by numerous small streams.

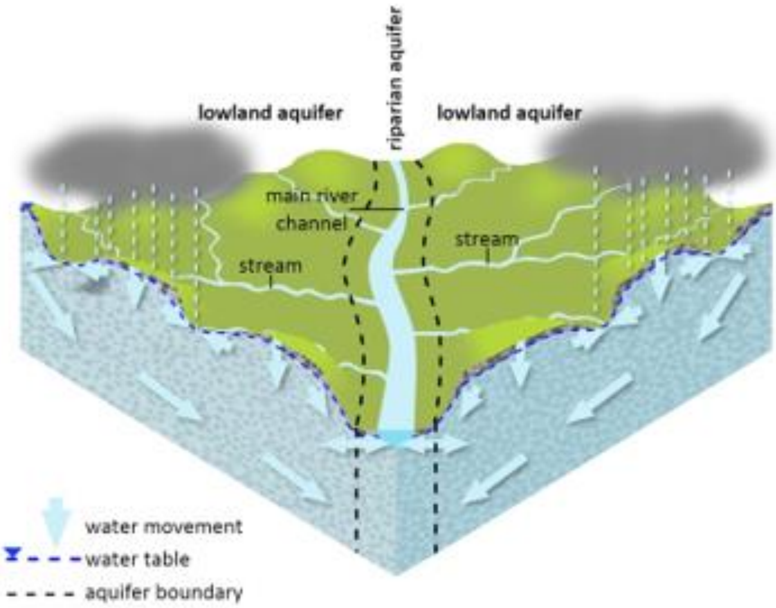



**Figure 5: Lowland aquifer showing relationship with riparian aquifer, connectivity to land (via deep drainage), and surface water via small streams. Source: Environment Southland**

Confined aquifers are located at depth, often sitting below shallow unconfined aquifers. They are bounded above and below by rock or other largely impermeable materials. Semi-confined aquifers differ from confined aquifers by having a top layer that is of low permeability. Water is able to flow very slowly between a semi-confined and an unconfined aquifer located above.

## 4.4 Land use

Southland's pre-human vegetation was comprised of forest, scrub, and wetland. The early Polynesian settlers cleared areas of forest by burning and were replaced by tussock. Early European settlers cleared much of the remaining forest from the plains and began to artificially drain wetter areas and plant exotic grasses (Newson, 2000; Grant, 2020).

The general land cover pattern for the region has been relatively stable for at least the last 25 years, with some notable exceptions (Table 1). For example, there has been a 32% increase in exotic forest and artificial bare surfaces increased 43%.The conservation area in the western third of the region has remained the same and the broad land use class of exotic grassland has dominated the area of the Southland Plains for the same period as illustrated in the table below (LAWA, 2020). Since 1985 agricultural expansion into new areas has largely ceased but change has still occurred with the significant shift from sheep and beef farming to dairy farming (Ledgard, 2013).

**Table 1: Southland Region landcover class change between 1996 and 2012 (LAWA, 2020)**

| Land cover Class | Area Change | |
|---|---|---|
| | ha | % |
| Indigenous forest | -1,497 | <1% |
| Exotic forest | 24,003 | 32% |
| Indigenous scrub / shrubland | -7,114 | -4% |
| Exotic scrub / shrubland | -2,755 | -16% |
| Tussock grassland | -7,630 | -2% |
| Exotic grassland | -5,716 | -1% |
| Other herbaceous vegetation | -705 | -2% |
| Cropping/Horticulture | 345 | 5% |
| Natural Bare /Lightly-Vegetated Surfaces | 486 | <1% |
| Artificial bare surfaces | 217 | 43% |
| Urban area | 180 | 2% |
| Water bodies | 185 | <1% |

# 5. Water quality in Southland – what's happening

## 5.1 Surface water quality

Surface water quality across the Southland Region is variable and influenced by many factors. The quality of water in the headwaters of all the main catchments is highly likely to be very good due to the nature of the surrounding mountains or high-country landscape. As the rivers progress down across the plains and pick up more inputs from small streams, artificial drainage and groundwater recharge, there is strong potential for water quality to deteriorate.

The limited scope and scale of this report has meant that we have not analysed all the potentially relevant water quality variables. We selected microbiological (microorganism) and nitrogen contamination as two of the key variables that can define water quality. Information on nitrate-nitrogen and the microbiological status of water provides limited but important fundamental insights on the state of that water.

Contamination by microorganisms can make water unsafe for consumption and contact recreation. *Escherichia coli* (*E. coli)* are common bacteria found in the gut of warm-blooded animals including humans and are used as an indicator of faecal contamination of freshwater.

Nitrogen (N) exists in numerous forms in water and has multiple effects including encouraging plant/algae growth and as ammonia or nitrate, if present in sufficiently high concentrations, can be harmful for humans and aquatic species.

The pattern of changing water quality between mountains and sea can clearly be seen in Figure 6, which shows the *E. coli* grades under the NPSFM 2020 National Objectives Framework (NOF) "numeric attribute states"[6] for the monitored sites across Southland. Sources of this contamination are mainly associated with run-off from agricultural land and concentrations are usually higher following rainfall. Faecal source tracking by Moriarty *et al*. (2019a-d) across a wide range of sites found that the predominant source of faecal indicator bacteria was ruminant animals (sheep and cattle) and wildfowl, with occasional human sources. Often the proportion of ruminant pollution will increase following rainfall compared to under baseflow conditions that are dominated by wildfowl signatures (Moriarty *et al*., 2019a-d). It is also important to appreciate that the risk to human health may differ between different faecal sources.

It is important to appreciate that under the NPSFM, microbiological water quality for human contact is expressed as risk levels rather than as a simple "safe" or "not safe". However, the data represented in Figure 6 are generally interpreted as indicating that bands D and E indicate a significant infection risk.

Nitrate-nitrogen concentrations in surface waters are illustrated in Figure 7 with total oxidised nitrogen data ranked against the NPS-FM 2020 NOF numeric attribute states for nitrate-nitrogen. Total oxidised nitrogen (TON) has been used here as a proxy for nitrate-nitrogen as TON is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, so TON is taken to be approximately equivalent to nitrate-nitrogen concentrations.

The predominant reference point used for TON (nitrate-nitrogen) used in this report is the NPSFM 2020 water quality guideline (the NPSFM terminology is "numeric attribute state") for nitrate-nitrogen. This relates to nitrate toxicity rather than nitrogen as a nutrient source for plant (periphyton, macrophyte and phytoplankton) growth. Establishing nutrient concentrations targets for surface water will be an important part of catchment water quality management and we understand that Environment Southland is likely to propose such targets in the forthcoming Southland Water and Land Plan – proposed plan change (SWLPPC). However, currently there are no national or regionally specific nutrient concentration targets. The draft NPSFM included a dissolved inorganic nitrogen national bottom line of 1.0 mg/L for ecosystem health. This proposal was not included in the final NPSFM.

Therefore, this report uses the current NPSFM nitrate-nitrogen (toxicity) water quality numeric attribute state in the NPSFM 2020 and specifically the National Bottom Line (annual median 2.4 mg N/L and annual 95$^{th}$ percentile 3.5 mg N/L) as a primary nitrogen reference.

There is a risk that by using this reference point, concentrations in some catchments might indicate the absence of any nitrogen issues while in reality the concentrations may well be high enough to cause significant plant growth in the catchment. However, it is important to appreciate that even in catchments where nitrate-nitrogen concentrations do not breach the nitrate-nitrogen toxicity National Bottom Line, they are likely to still have significant nutrient related water quality issues such as periphyton extent and estuary eutrophication[7]. Conversely, if a catchment has nitrate-nitrogen concentrations that exceed the National Bottom Line, we consider that those catchments are likely to be identified as a priority for nitrogen loss reduction.

There are some catchment areas that are either not represented by existing monitoring or are under-

---

[6] NPSFM NOF = National Policy Statement National Objectives Framework. This provides for "numeric attribute states" (effectively national water quality standards) to be set via regional plans. The report uses the term "water quality standards to refer to both regional plan standards and NPSFM numeric attribute states.

[7] "*The trophic status of a lake or estuary refers to the primary productivity (amount of algae) produced in the water and the amount of nutrients (P and N) in the water. Oligotrophic waters usually have low primary productivity (high water quality and few algae) and are nutrient poor, while eutrophic waters have high primary productivity (low water quality and frequent algal blooms) due to excessive nutrients. Mesotrophic waters lie somewhere in between the two states. Eutrophication is an increase in the nutrients available in a waterbody which can subsequently increase primary productivity and degrade water quality, leading to a reduction in mahinga kai habitat and survival*." NIWA. https://niwa.co.nz/our-science/freshwater/tools/kaitiaki_tools/impacts/nutrients/eutrophication

represented in the current network. This has made it challenging to provide catchment group specific information and conclusions. It is important to have good data and to maintain a long-term monitoring programme to be able to both understand water quality issues and to track changes over time.

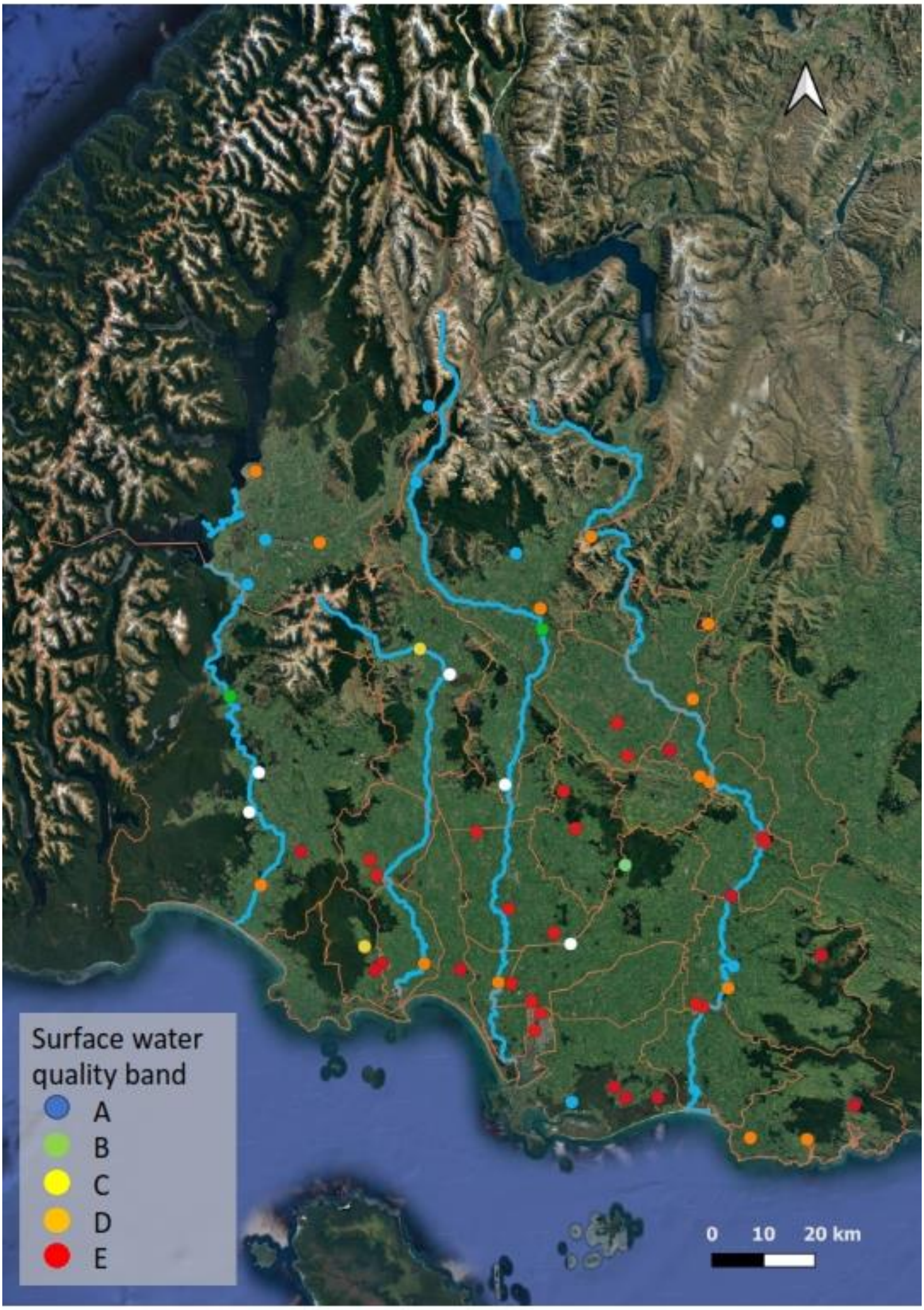



**Figure 6: Southland water quality monitoring sites graded according to the NPS-FM 2020 National Objectives Framework category: *E. coli* for Human Contact (Appendix 2A, Table 9). Data from LAWA 2018 state data set (LAWA, 2020)**

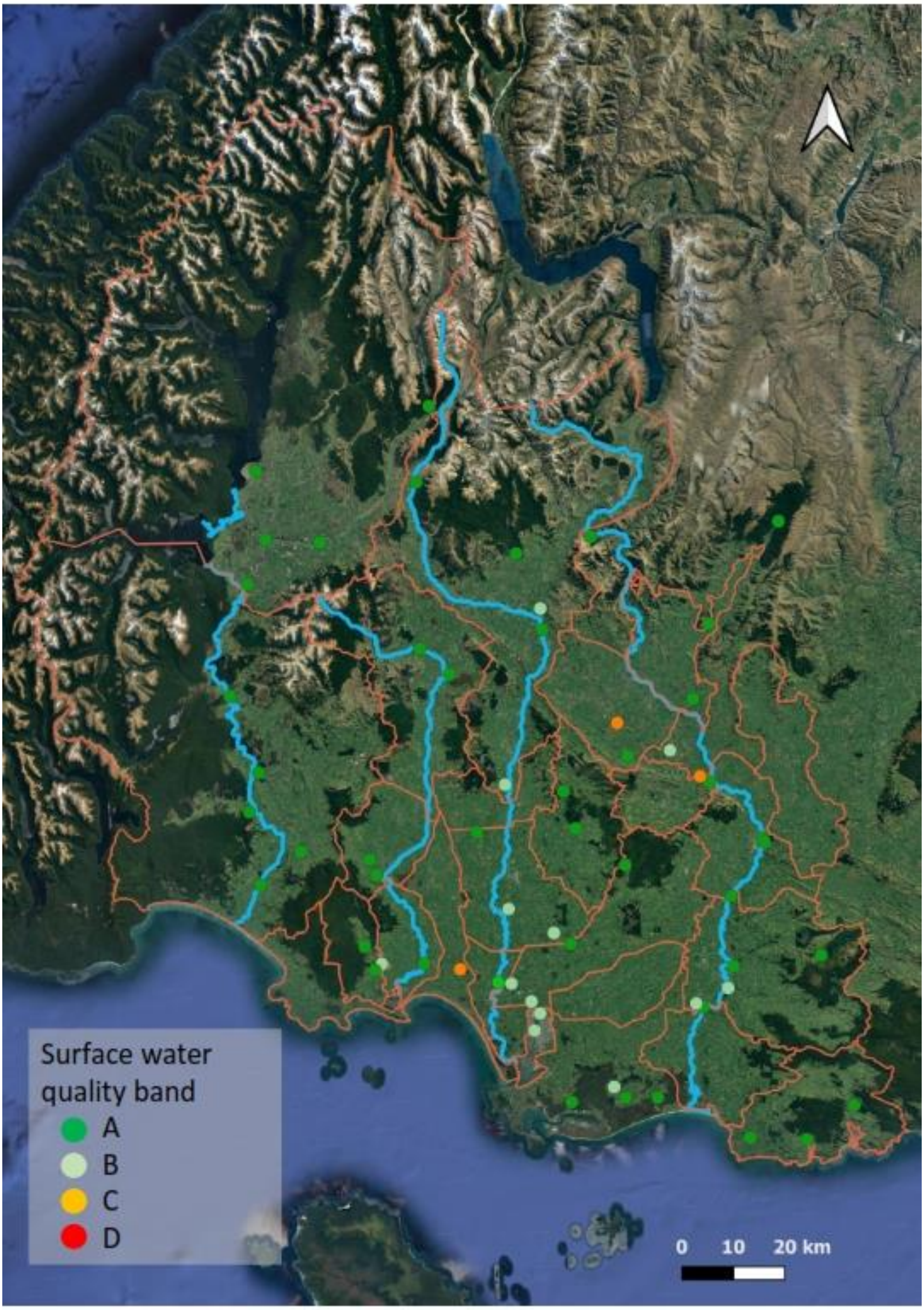



**Figure 7: Southland water quality monitoring sites graded according to the NPS-FM 2020 National Objectives Framework category: Nitrate (Toxicity), River ecosystem health (Appendix 2A, Table 6). Data from LAWA 2018 state data set (LAWA, 2020)**

## 5.2 Groundwater quality

Groundwater quality varies significantly across the region and is affected by many variables. Many of the unconfined aquifers are relatively shallow and have high water tables (i.e. groundwater can lie close to the surface, particularly during wet periods). The unconfined nature means they are often recharged directly by rainfall that filters through the overlying materials. This process can provide a conduit for contaminants to move down into the aquifer where they can persist and be transported down gradient. Key contaminants of concern for groundwater are *E. coli* and nitrate-nitrogen. As there are no groundwater quality objectives in the NPS-FM 2020 we have used the Drinking Water Standards New Zealand (2018) (DWSNZ) for assessment in this report. These standards are referred to in Objective 8 of the Region-Wide Objective in the proposed Southland Water and Land Plan (pSWLP) as the required standard until such time as any freshwater objectives are established under the Freshwater Management Unit processes.

*E. coli* is present in many of the monitored wells across the region and often does not meet the DWSNZ thresholds as shown in Figure 8 below. This is a human health threshold designed around the requirements for providing safe drinking water, as many rural properties and communities may source their domestic water supply from groundwater.

Nitrate-nitrogen is present in concentrations that strongly indicate nitrate leaching from pastoral land use in all but one of the 30 monitoring bores included in this analysis as shown in Figure 9. Of the remainder there are 6 that have been shown to exceed the DWSNZ threshold more than 25% of the time. These are clustered across the Waimea Plains around the Balfour and Wendonside areas. The trend analysis on LAWA[8] indicates that approximately half of the sites are showing a degrading trend in quality. In cases where there are long aquifer residence times it could take significant time to improve nitrate-nitrogen concentrations.

This interpretation is based on readily available data from a range of bores used in Southland to monitor groundwater quality. There are some limitations in the monitoring that mean our interpretations can only be tentative. For example, it is apparent from our brief primarily desktop review of the bore: type, depth, wellhead protection, and locations, that the reasons for initially establishing the bores varies considerably. Some bores have been located close to known locations of effluent application to endeavour to assess potential local effects. Some bores used historically have had inadequate wellhead protection (See Appendix B) and may have acted as conduits for contaminated surface water to enter groundwater. Some of these bores are not monitored frequently enough to enable full statistical analyses. Very few bores appear to have been established as long-term (i.e., to be used for 50+ years) bores to monitor regional groundwater quality. The ideal would be for long-term strategically located bores to be established on regional council owned land or land with an access easement that provides for groundwater quality monitoring by the regional council.

This data and location-specific investigations by Environment Southland into groundwater quality in various locations strongly indicate that nitrate concentrations in Southland groundwater are a significant issue, both in terms of groundwater used as a source of drinking water and as a source of recharge water for rivers. However, the limitations outlined above make it challenging to draw definitive conclusions about the state and trend of regional groundwater quality in some parts of Southland.

[8] LAWA = Land Air Water Aotearoa, www.lawa.org.nz Regional councils cooperate by uploading surface water and groundwater quality data onto this website. Common sampling, reporting and data analysis methods are used.

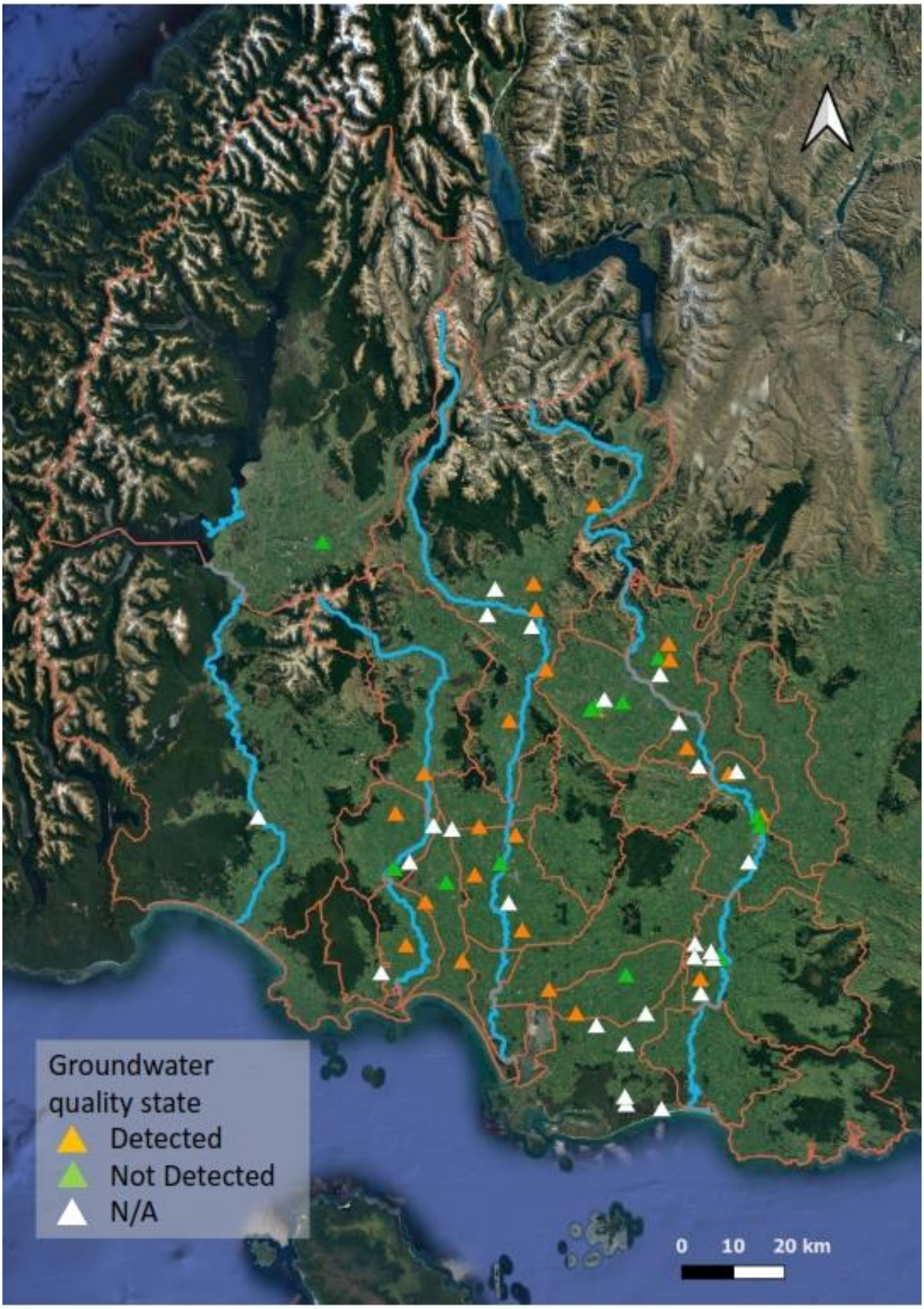



**Figure 8: State of *E. coli* in groundwater in Southland. (Sites where *E. coli* has been detected are not suitable as a source of untreated drinking water.)**

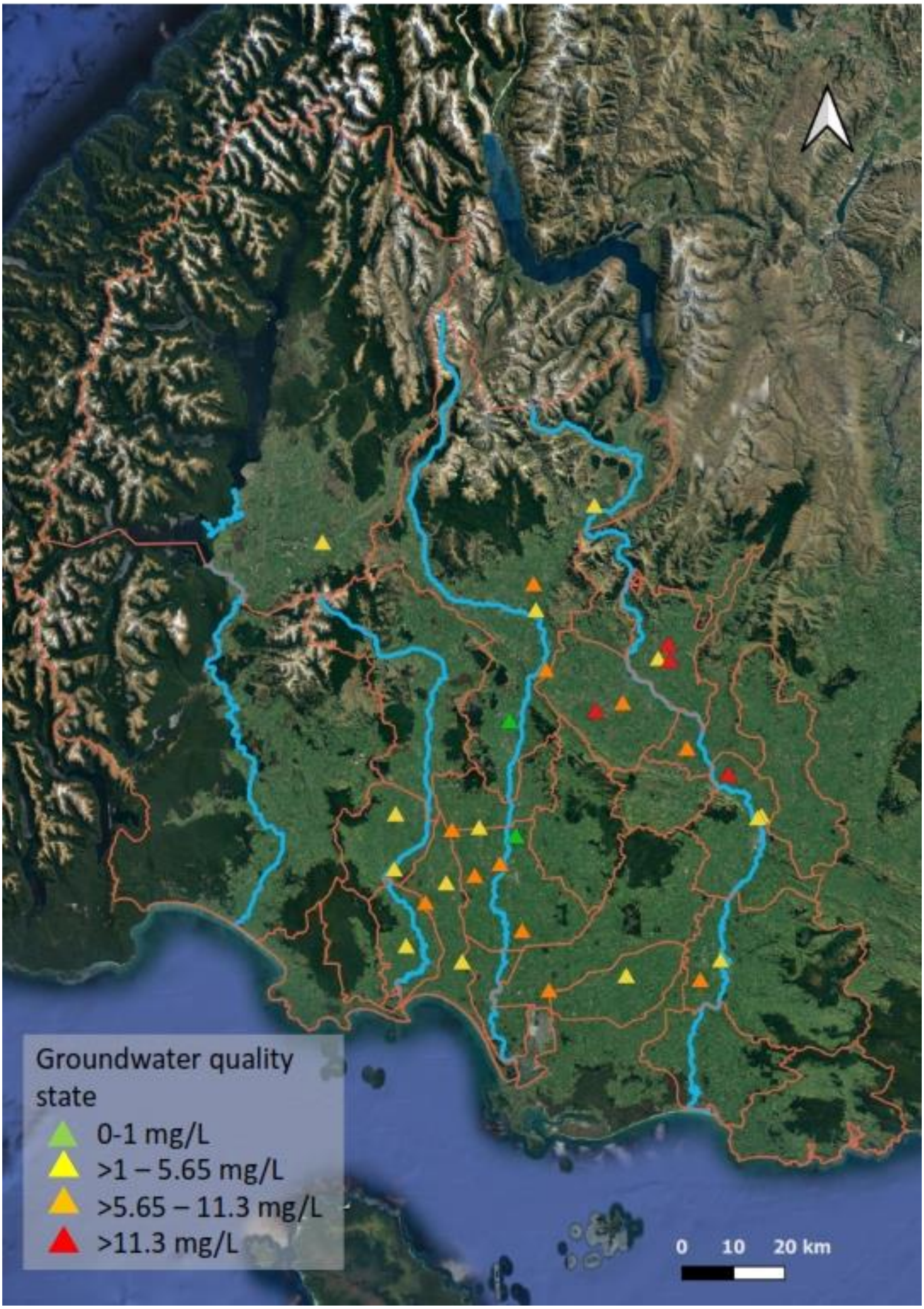



**Figure 9: State of Nitrate-Nitrogen in groundwater in Southland showing median concentrations relative to the DWSNZ maximum acceptable value of 11.3 mg/L**

## 5.3 Wetlands

Wetlands are very important landforms for the protection of biodiversity and their ability to provide ecosystem services (Dare & Ewans, 2018). Southland has in the past had extensive wetland systems of various types but since the arrival of Europeans, and due to their tendency to want to drain land for agriculture, approximately 90% of the wetlands have been lost. With so few wetlands remaining it is not unreasonable to consider all remaining wetlands to be significant with some being considered more important than others based on the extent of the loss of each type (Clarkson *et al*, 2011). However, it has been found that wetlands in Southland are still being lost despite many legislative and policy tools being in place to try to protect them (Dare & Ewans, 2018). Dare & Ewans found that wetland loss was highest in lowland areas where approximately 1,165 ha was lost between 2007 and 2014/15, or a rate of around 1.5% lowland areas as shown in Figure 10. This is a surprising and concerning statistic and possibly is indicative of the misunderstanding by some of both the importance of wetlands and in fact what landforms and vegetation constitute being a wetland.

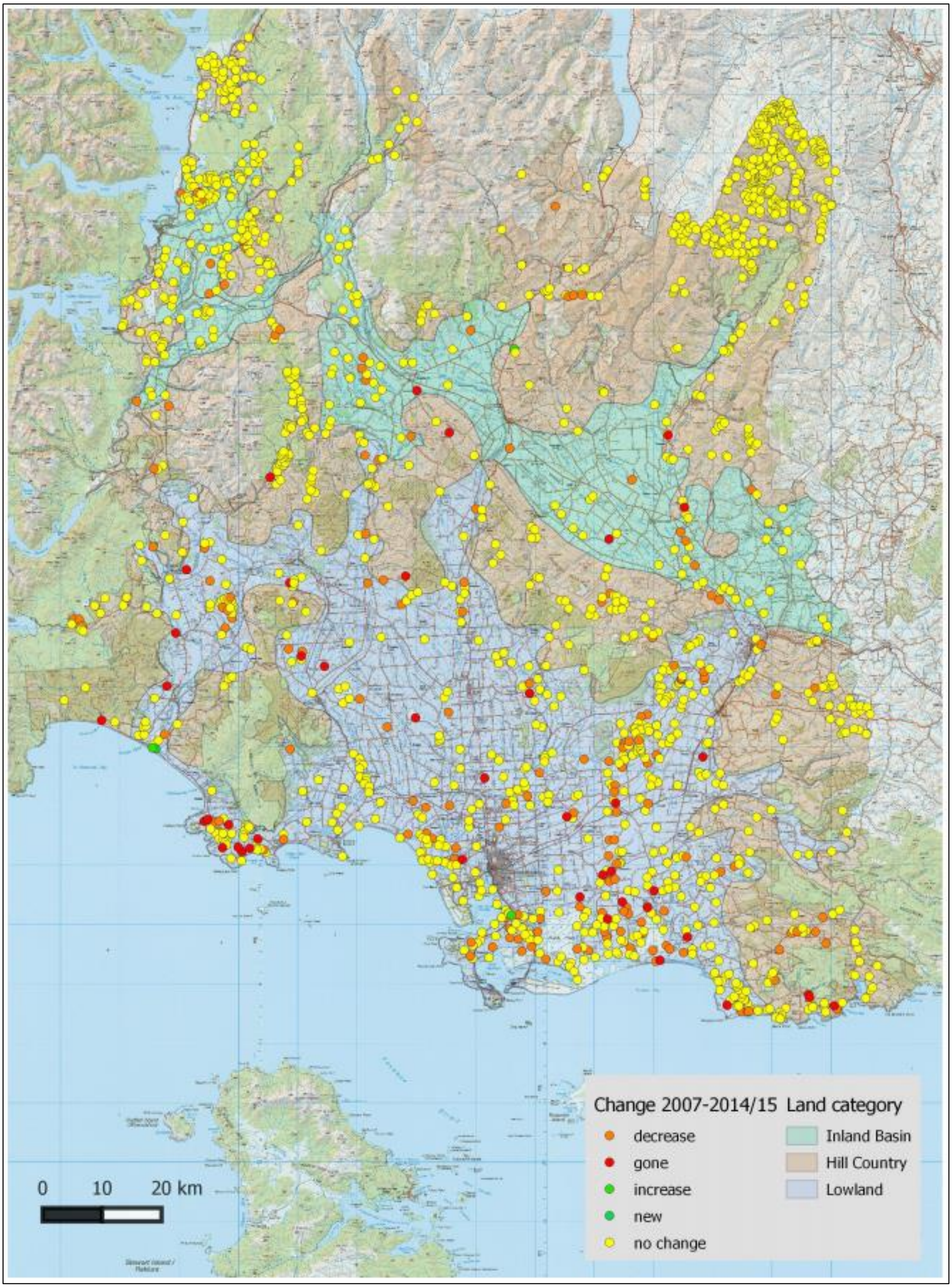



**Figure 10: Change in mapped wetland areas between 2007 and 2014/2015 (from Dare & Ewans, 2018)**

## 5.4 Estuaries

Estuaries are an extremely important part of the overall landscape of Southland. They are the receiving environment of much of the material carried by the rivers so are therefore impacted by activities in the upstream catchment. As such the health of the estuary can be an indicator of potential upstream issues. Estuaries support aquatic and terrestrial ecosystems and there are five important components that work together to do this: water quality, water quantity, habitat, aquatic life, and ecological processes (ES, 2020).

As estuaries are the final receiving environment for sediment and nutrient load from the region's rivers, they are naturally productive environments. Estuaries have developed over millennia to process the natural loads coming off their catchment. However, when this load is changed through introduction of additional nutrients or sediment, there can be significant adverse effects. Some estuary systems are more sensitive than others to these changes (ES, 2020).

Estuaries in Southland have been grouped according to their level of susceptibility, or risk of becoming eutrophic. Some estuaries have a higher risk of eutrophication than others, depending on catchment load, level of river inflow and volume, levels of nutrient accumulation, estuary size, shape and depth, and tidal influence (ES, 2020).

Increases in sediment and nutrient loads to the estuaries that are the result of changes in upstream land use practices are significant drivers of degradation of estuary health (Green, 2015). The influx of nutrients can lead to proliferations of phytoplankton and macroalgae (Green, 2015) which can lead to poor trophic conditions. Shallow estuaries, and especially Intermittently Closed or Open Lakes and Lagoons (ICOLLs), are most susceptible to such changes. Figure 11 below shows Southlands monitored estuaries, all of which are shallow and two of which (Lake Brunton and Waituna Lagoon/Waipārera) are shallow ICOLLS.


**Figure 11: Southland's monitored estuaries (from ES, 2020)**

Table 2 shows that in the most recent assessment of estuary health by Environment Southland (ES, 2019) there are three estuaries that are classed as having high overall eutrophic risk (Waiau Lagoon/Te Wae, Lake Brunton and Waituna Lagoon/Waipārera). The New River Estuary and the Jacobs River Estuary are classed as at moderate risk but are clearly eutrophic and the Waikawa Estuary is showing signs of stress. Once an estuary system has entered a eutrophic state it can be difficult to reverse that due to the complexity of the estuary system itself and the likelihood of significant lag times between land use management practice changes and changes in sediment and nutrient concentrations in the contributing waters.

The results for the low eutrophication risk Toetoes Estuary strongly indicates that despite the well flushed nature of the estuary it is exhibiting signs of eutrophication with low sediment oxygen concentrations and significant reductions in seagrass coverage.

**Table 2: Estuary health monitoring results as at 2018 (from ES (2019))**

| Estuary | Soft Mud | Nutrients in sediment | Oxygen in sediment | Macrophyte cover | Sea grass | GEZ* |
|---|---|---|---|---|---|---|
| High Eutrophication risk | | | | | | |
| Waiau Lagoon/ Te Wae | | | | | | |
| Lake Brunton | | | | | | |
| Waituna Lagoon/ Waipārera | | | | N/A | | |
| Moderate Eutrophication Risk | | | | | | |
| New River Estuary | | | | | | |
| Jacobs River Estuary | | | | | | |
| Waikawa Estuary | | | | | | |
| Haldane Estuary | | | | | None observed | |
| Freshwater Estuary | | | | | | |
| Low Eutrophication Risk | | | | | | |
| Waimatuku Estuary | | | | | | |
| Toetoes Estuary | | | | | | |

Key:

| | |
|---|---|
| | Very Good |
| | Good |
| | Fair |
| | Poor |

* Gross Eutrophic Conditions (GEZ) occur when estuaries have the combined effects of high mud content, a shallow RPD (<1cm) and high macroalgal growth (>50% cover)

## 5.5 Water quality and biodiversity

Freshwater has a critical role in providing for New Zealand's diverse freshwater species and their habitats. Changing land use, introduced invasive species, changes in waterway forms, and reduced flows collectively increase pressure on freshwater bodies. In turn, this affects freshwater fish, invertebrates, plants, and birds reliant on functioning freshwater ecosystems.

The landscape of the Southland region has been significantly modified since the arrival of humans. The least modified area is the mountains of Fiordland and other mountainous areas, though these have still been impacted by introduced fauna and flora. The remainder of Southland including the plains and lower hill country has been significantly changed from a variety of vegetation types that supported a wide range of fauna to what is now almost a monoculture of exotic grassland. This will have had detrimental effects on the biodiversity of the area and resulted in significant species loss over time. It is important that where there are remnants of natural fauna and flora that they be preserved and protected both to maintain the variety of species but also for the ecosystem services values they hold.

One of the most impacted landform types is wetlands, which have been dramatically reduced in extent through land drainage for agriculture. This is particularly significant due to the high level of ecosystem services provided by wetlands for processing of nutrients and sediment.

# 6. Managing freshwater quality in Southland

Environment Southland has obligations under the Local Government Act (LGA) (Local Government Act, 2002) to provide for community needs now and into the future. As a regional council, Environment Southland is responsible for managing the natural and physical resources of Southland, including air, land, water and the coast.

As discussed in the sections above, Southland is characterised by its diverse geological landscapes, climate, soils, and hydrogeology. Therefore, there cannot be a 'one size fits all' approach to managing freshwater quality in the region. In order to help manage freshwater quality across a diverse landscape, Environment Southland has divided the region into:

- Freshwater management units (FMUs)
- Surface water management units
- Groundwater management zones (GMZs)
- Physiographic zones

These are discussed in more detail below.

## 6.1 Freshwater management units (FMUs)

Freshwater management units (FMUs) are used nationally to plan and manage freshwater. The Ministry for the Environment describes a freshwater management unit as `the water body, multiple water bodies or any part of a water body determined by the regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes.' Environment Southland has divided the Southland region into five FMUs: Fiordland and Islands, Waiau, Aparima, Ōreti and Matāura, shown in Figure 13. The Environment Court has recently issued an interim decision[9] on the pSWLP that strongly indicates that the Waituna Lagoon/Waipārera will be made a separate FMU.

Catchment groups are located within different FMUs. Each FMU has a different set of characteristics that influence freshwater quality. Therefore, catchment groups in one FMU may face different challenges to groups located in other FMUs. See Appendix A (section 14) for more detail.

## 6.2 Surface water management units

The pSWLP refers to "surface water management units" (see Figure 16) such as lowland soft bed, lowland hard bed, mountain and hill, and the pSWLP also includes surface water quality standards that are linked to the specified surface water management units. The Environment Southland GIS website (https://maps.es.govt.nz/) also refers to 17 surface water management zones.

## 6.3 Groundwater management zones (GMZs)

Southland's unconfined aquifers have been divided into 30 groundwater management zones (GMZs) based on areas of similar hydrogeological characteristics (see Figure 14). Zones were delineated based on the presence of unconfined (or semi-confined) aquifers hosted in Quaternary alluvium.

The management zones differ in terms of water recharge, water discharge, water availability, storage volumes,

[9] https://www.environmentcourt.govt.nz/assets/Documents/Publications/2019-NZEnvC-208-Aratiatia-Livestock-Limited-v-Southland-Regional-Council.pdf

water quality, and surface connectivity. Combined, these factors affect how Environment Southland manages the use of groundwater resources. Note that separate management criteria apply to unconfined and confined aquifers.

## 6.4 Physiographic zones

Environment Southland uses a physiographic concept to assist in understanding how contaminants build up and move through different soil types, through areas of groundwater and into surface waterways.[10]. This approach involves integrating information particularly on climate, geology, topography and soils to create specific physiographic zones that have common features in terms of how contaminants move to water.

There are nine physiographic zones for Southland (Figure 15):

- Alpine
- Bedrock-hill country
- Central Plains
- Gleyed
- Lignite-marine terraces
- Old Mataura
- Oxidising
- Peat wetlands
- Riverine

Contaminants in some zones may not be such a problem in others. Understanding the key transport pathways for contaminants helps to understand these differences between zones. The four main transport pathways are overland flow, artificial drainage, deep drainage, and lateral drainage. Natural bypass flow also occurs in areas where water can drain vertically through the soil profile via cracks and fissures. Transport pathways also influence contaminant attenuation processes i.e., processes that can reduce the amount of contaminants that eventually enter groundwater and/or surface water.

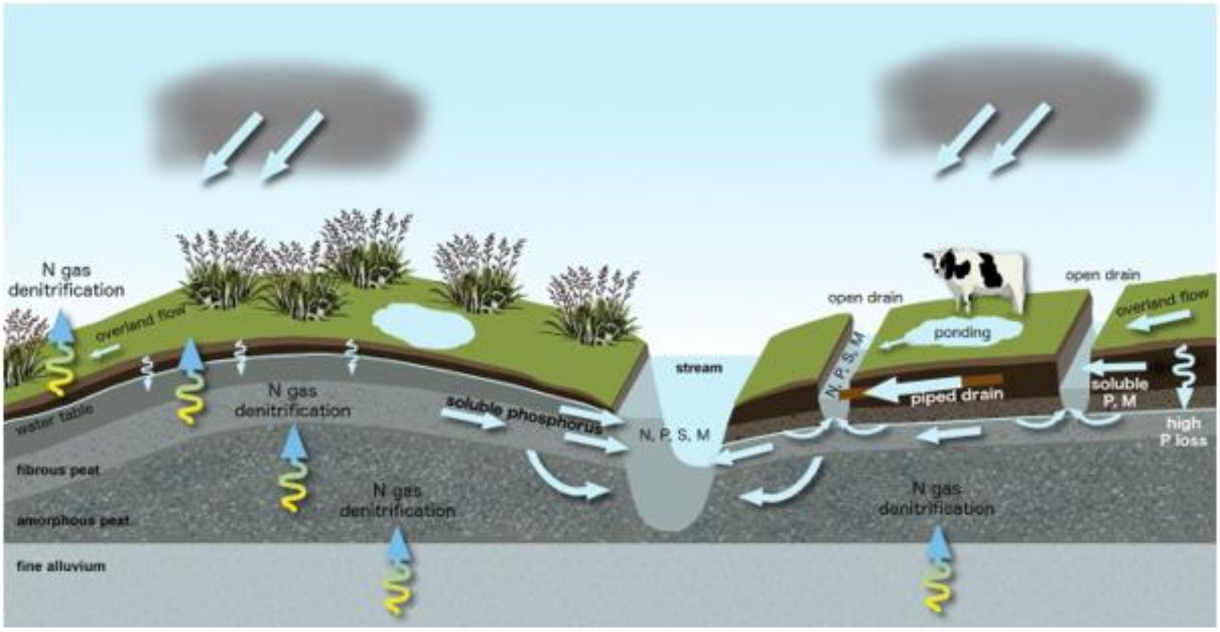



**Figure 12: Example of contaminant pathways and attenuation for the Peat Physiographic Zone. Source: Environment Southland**

10 https://www.es.govt.nz/community/farming/physiographics/introduction-to-physiographics

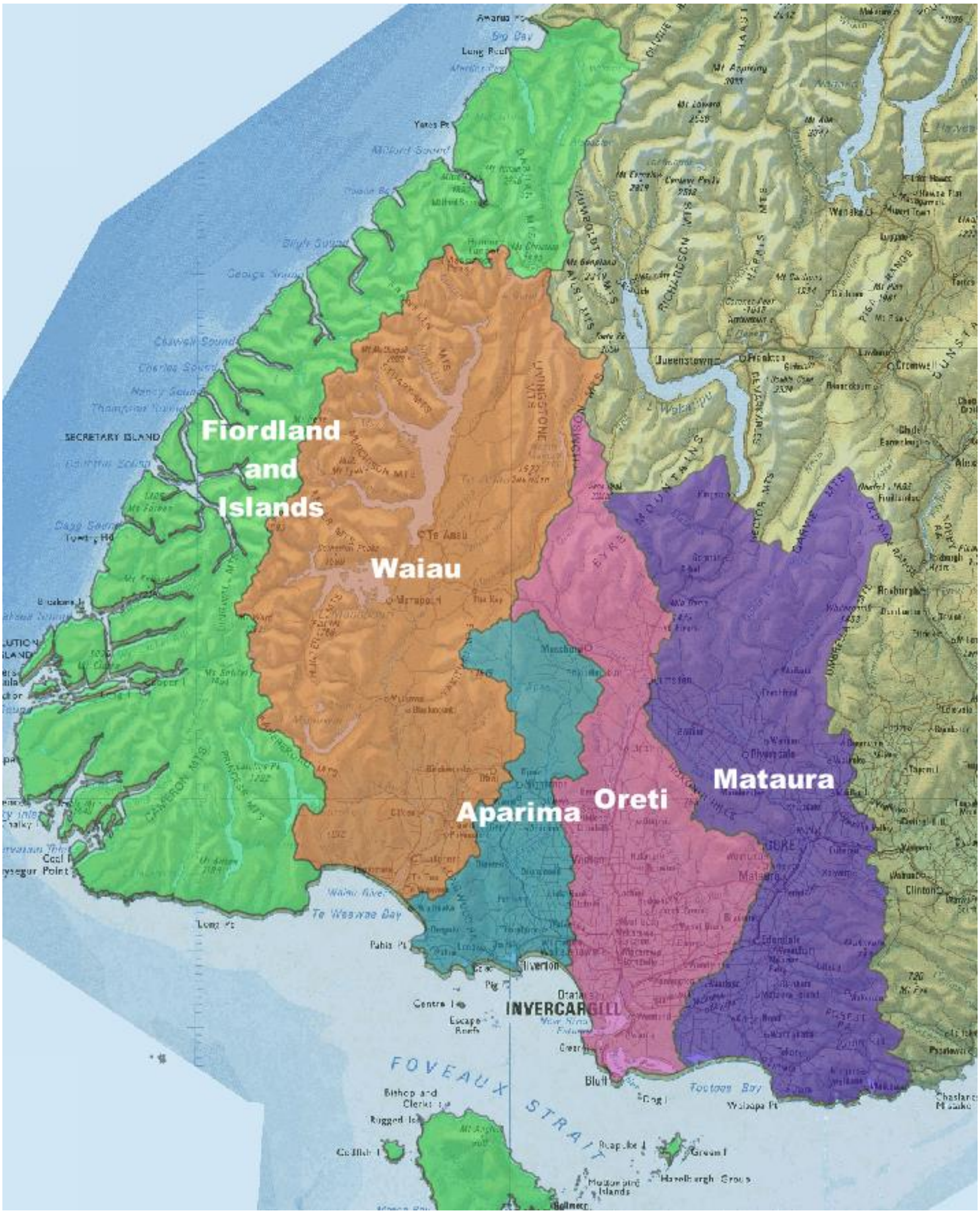


Figure 13: The five freshwater management units (FMUs) in Southland as at November 2020

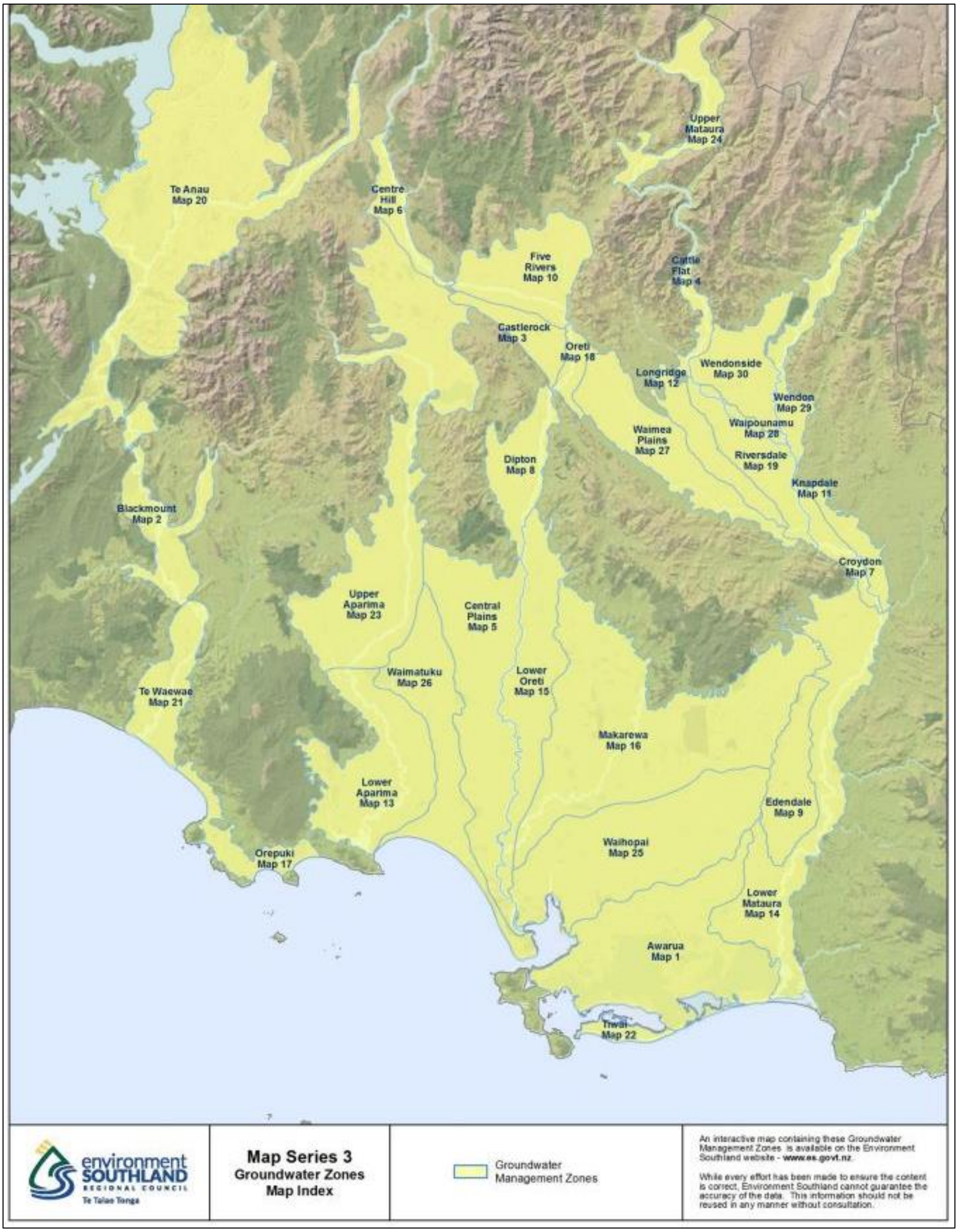



**Figure 14: Environment Southland Groundwater Management Zones from the proposed Southland Water and Land Plan**

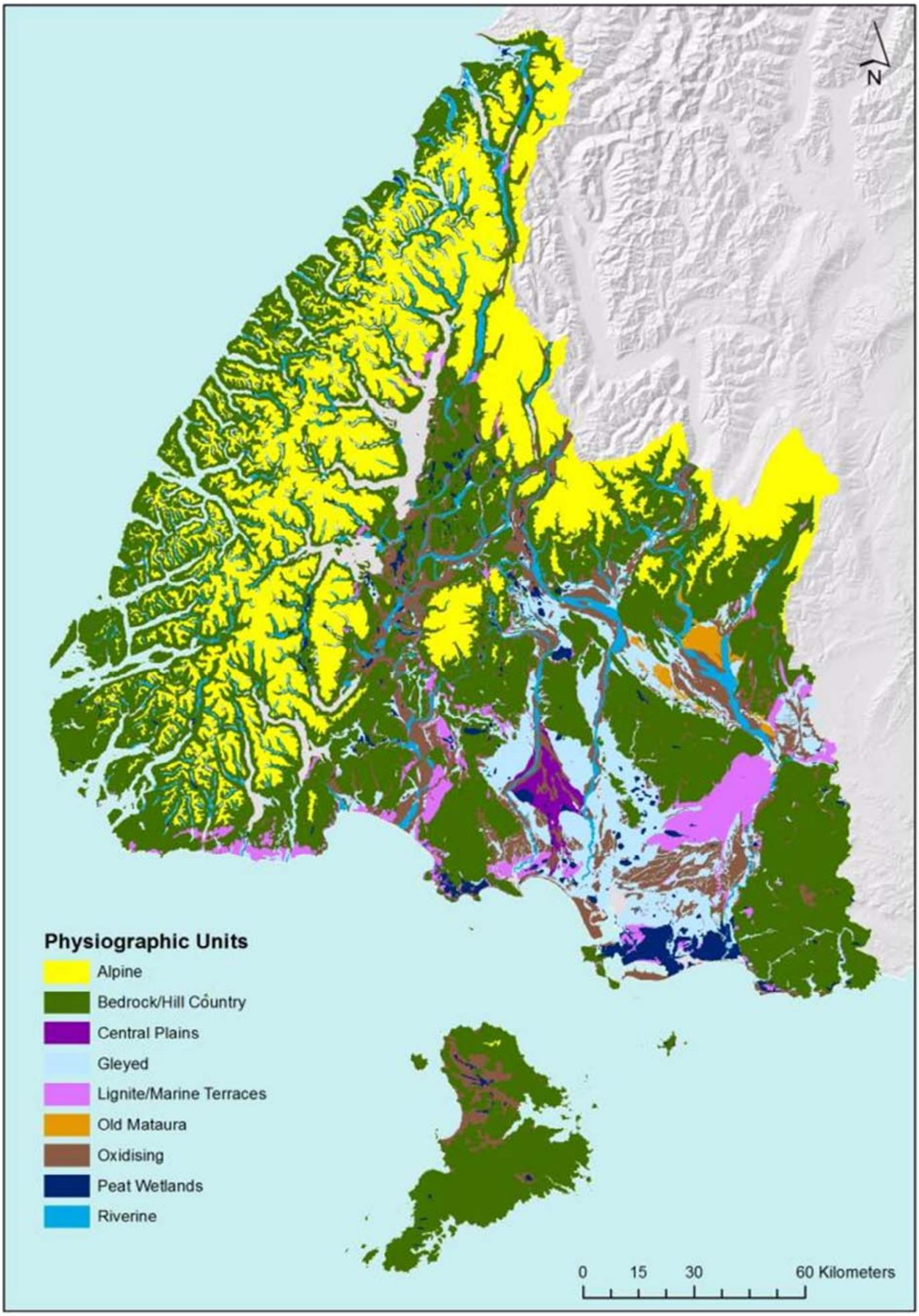



**Figure 15: Environment Southland's physiographic zones from Hughes *et al.* 2016**

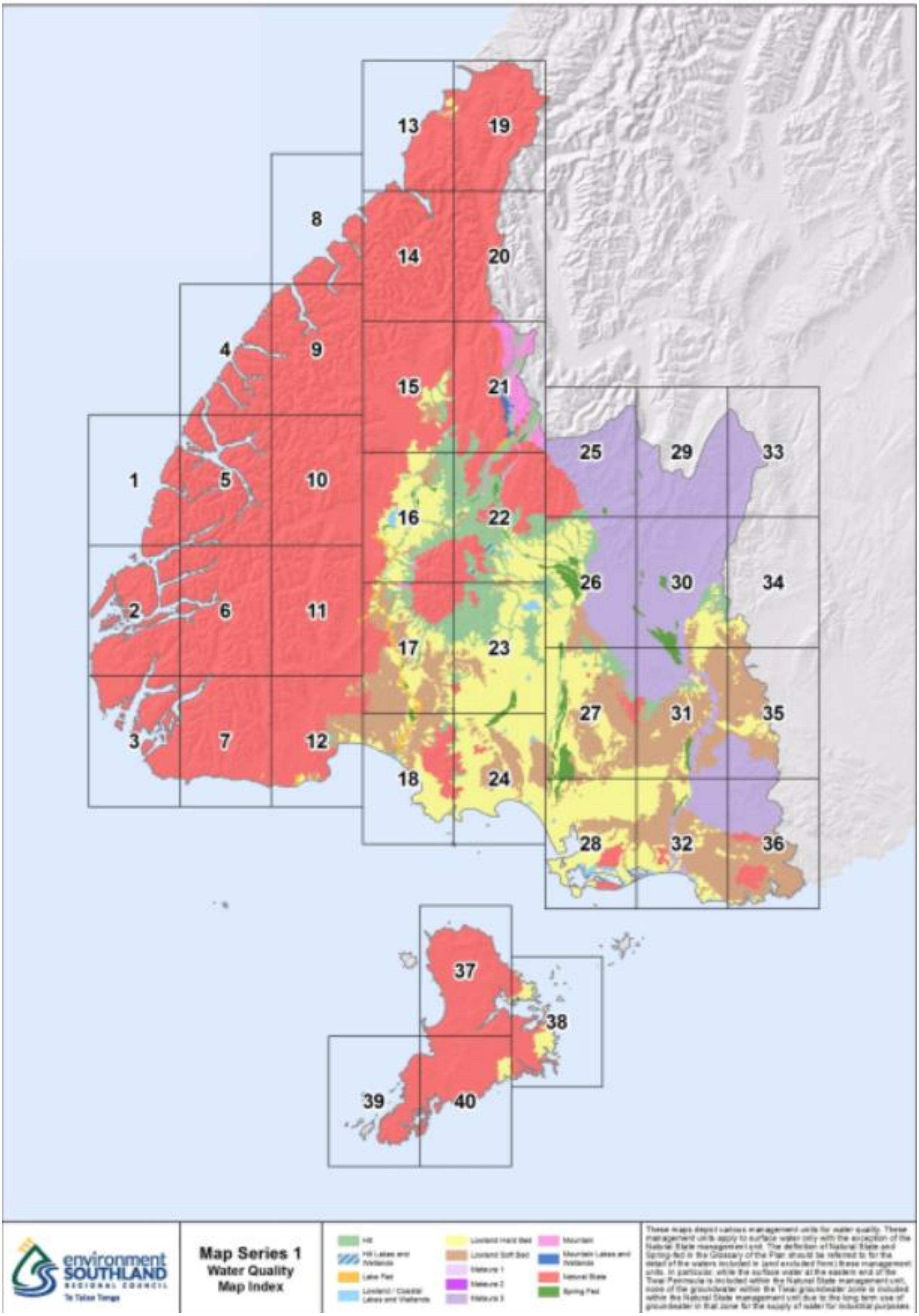



**Figure 16 Surface water management units specified in the pSWLP**

# 7. Policy and Plan Direction

For both national government, and local authorities, there are several tools available to manage freshwater use. In Southland, Environment Southland has the primary responsibility for managing activities that may impact freshwater, through giving effect to both national and regional planning and regulatory tools.

## 7.1 National level

The following section outlines the various tools used by central government to manage freshwater resources. These include legislative tools such as the Resource Management Act 1991 (RMA), National Policy Statement for Freshwater Management 2020; National Environmental Standards for Freshwater 2020; additional regulations; and other relevant statutory requirements.

### 7.1.1 Legislative Tools

At a national level, land use and water quality are primarily managed through the RMA.

The RMA prevents any person using land in a way that contravenes a national environmental standard, a regional rule or a district rule, unless the land use is allowed by a resource consent or an existing use right. Simply put, any land use is permitted, unless controls are included in a planning document. Conversely, discharges and the abstraction/use of water must be specifically authorised by a regional rule, resource consent or National Environmental Standard/regulation.

The use of land is regulated by local government, including both territorial authorities (city and district councils) and regional councils. Territorial authorities and regional councils have different roles and responsibilities, and different policy and planning documents. Southland's territorial authorities are Invercargill City Council, Gore District Council, and the Southland District Council. They are responsible for the control of land use generally. The Southland Regional Council (Environment Southland) is responsible for the control of land relating to soil conservation, freshwater management, natural hazards, hazardous substances, the coastal marine area, and indigenous biodiversity.

In addition to the RMA, there are other laws that have direct or indirect implications for land use and/or water quality management. These include the Hazardous Substances and New Organisms Act 1996, Health Act, and the Ngāi Tahu Claims Settlement Act 1998. The latter is particularly important because it implements settlement provisions recognising the particular cultural, spiritual, historical and traditional associations of Ngāi Tahu with particular sites, These provisions include the identification of taonga species and the establishment of tōpuni (authority over an area), statutory acknowledgements and nohoanga (seasonal occupation) sites, to improve the effectiveness of Ngāi Tahu participation in resource management. Resource Management Act processes such as plan development and resource consent processing must have regard to statutory acknowledgments. See section 8 for an overview of Tangata Whenua perspectives and the Resource Management Act framework.

Under the RMA, there is a hierarchy of policy statements and plans that collectively seek to achieve the RMA's goal of sustainable management.

- **National Policy Statements** – state objectives and policies for matters of national significance relevant to achieving sustainable management, such as freshwater management, renewable electricity generation, and urban development.
- **Water conservation orders** – recognise and sustain outstanding amenity or intrinsic values of water in its natural state.
- **National Environmental Standards** – regulations that provide technical standards, methods or other requirements for environmental matters. They include standards for air quality, drinking water, and soil contaminants.

- **National Planning Standards** – set requirements relating to the structure, format or content of regional policy statements and plans. These standards must give effect to national policy statements and be consistent with national environmental standards.
- **Regional policy statements** – must give effect to national policy statements and empower regional councils to provide broad direction and a framework for resource management within their regions. They must not be inconsistent with water conservation orders. They must take into account any relevant planning document recognised by an iwi authority. In Southland this is "*Te Tangi a Tauira - The Cry of the People Ngāi Tahu ki Murihiku Natural Resource and Environmental Iwi Management Plan 2008*[11]*"*
- **Regional plans** – must give effect to national policy statements and regional policy statements and must not be inconsistent with Water Conservation Orders. They must also take into account "*Te Tangi a Tauira - The Cry of the People".*
- **District plans** – must not be inconsistent with regional plans, and must give effect to national policy statements and regional policy statements. They must also take into account "Te Tangi a Tauira - The Cry of the People".

### 7.1.2 National Policy Statement for Freshwater Management 2020 (NPSFM)

The **National Policy Statement for Freshwater Management 2020** (NPSFM) came into force on 3 September 2020. The NPSFM provides local government with updated direction on how they should manage freshwater under the RMA.

This NPSFM manages freshwater through a framework that considers and recognises Te Mana o te Wai[12] as an integral part of freshwater management. The meaning of Te Mana o te Wai is different for each community, being based on their unique relationship with freshwater in their area or rohe. Te Mana o te Wai directs the content that regional councils must include in their regional plans, in consultation with their communities. In turn, regional plans direct what activities require a resource consent, and set a key framework for considering resource consent applications (see section 7.2.1).

Te Mana o te Wai is an important concept for how water is managed and utilised in New Zealand. It is now the fundamental concept driving the NPSFM 2020 and councils must give regard to this when setting policy for freshwater management. Te Mana o te Wai recognises the fundamental importance of water in that protecting the health of freshwater protects the health and well-being of the wider environment. It is an approach that protects the Mauri (life-force) of the water. Te Mana o te Wai is about restoring and preserving the balance between the water, the wider environment, and the community (MfE, 2020). The framework for implementing Te Mana o te Wai in the NPSFM 2020 is reproduced here:

> *"Te Mana o te Wai encompasses 6 principles relating to the roles of tangata whenua and other New Zealanders in the management of freshwater, and these principles inform this National Policy Statement and its implementation.*
>
> *The 6 principles are:*
>
> *(a) Mana whakahaere: the power, authority, and obligations of tangata whenua to make decisions*

---

[11] Te Tangi a Tauira - The Cry of the People. Ngāi Tahu ki Murihiku Natural Resource and Environmental Iwi Management Plan 2008

[12] Te Mana o te Wai was introduced to the Freshwater NPS in 2014. Te Mana o te Wai is a concept for fresh water that encompasses several different aspects of the integrated and holistic health and well- being of a water body. When Te Mana o te Wai is given effect, the water body will sustain the full range of environmental, social, cultural and economic values held by iwi and the community. The concept is expressed in te reo Maori, but applies to freshwater management for and on behalf of the whole community. (source: Ministry for the Environment)

*that maintain, protect, and sustain the health and well-being of, and their relationship with, freshwater*

*(b) Kaitiakitanga: the obligation of tangata whenua to preserve, restore, enhance, and sustainably use freshwater for the benefit of present and future generations*

*(c) Manaakitanga: the process by which tangata whenua show respect, generosity, and care for freshwater and for others*

*(d) Governance: the responsibility of those with authority for making decisions about freshwater to do so in a way that prioritises the health and well-being of freshwater now and into the future*

*(e) Stewardship: the obligation of all New Zealanders to manage freshwater in a way that ensures it sustains present and future generations*

*(f) Care and respect: the responsibility of all New Zealanders to care for freshwater in providing for the health of the nation.*

*There is a hierarchy of obligations in Te Mana o te Wai that prioritises:*

*(a) first, the health and well-being of water bodies and freshwater ecosystems*

*(b) second, the health needs of people (such as drinking water)*

*(c) third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future. "*

There are several new significant requirements under the NPSFM 2020. The key changes include:

- Managing freshwater in a way that 'gives' effect to Te Mana o te Wai.
- Improving degraded water bodies, and maintaining or improving all others using bottom lines defined in the NPSFM.
- An expanded national objectives framework, including:
  - Threatened species, mahinga kai, ecosystem health, and human health as compulsory values, which council must develop plan objectives describing the environmental outcome sought for each value.
  - Attributes for ecosystem health (e.g. sediment, macroinvertebrates, dissolved oxygen), which councils have to develop action plans and/or set limits on resource use to achieve these attributes.
  - Tougher national bottom lines for ammonia and nitrate toxicity attributes to protect 95% of species from toxic effects.
  - A requirement to manage dissolved inorganic nitrogen and dissolved reactive phosphorus as they relate to periphyton (algae/bacteria) and other ecosystem health attributes, and to provide for the health of downstream ecosystems.
- Avoid any further loss or degradation of wetlands and streams, map existing wetlands and encourage their restoration.
- Identify and work towards target outcomes for fish abundance, diversity and passage.
- Set an aquatic life objective for fish and address in-stream barriers to fish passage over time.
- Monitor and report annually on freshwater; publishing a report every 5 years containing ecosystem health scores and respond to any deterioration.

The change to the national bottom line for nitrate nitrogen in the NPSFM will have significant implications for the management of nitrogen loss from land in some catchments, particularly in a catchment like the Waimatuku

Stream[13] where the five year median nitrate nitrogen concentration of 3.4 g N/$m^3$ at the end of 2019, is significantly higher than the NPSFM national bottom line of an annual median of 2.4 g N/$m^3$.

Other potential changes to river flow regimes, fish passage and broader ecosystem health will need to be considered alongside initiatives to maintain and enhance water quality. This report does not address those wider water management issues.

### 7.1.3 National Environmental Standards for Freshwater 2020

National Environmental Standards are regulations issued under the RMA, prescribing technical standards, methods, or other requirements for environmental matters, which must be enforced by the relevant local authority. The **National Environmental Standards for Freshwater 2020** (NESFM) were released at the same time as the NPSFM 2020. This NESFM regulates the activities that pose risks to the health of freshwater and freshwater ecosystems. These standards are designed to:

- Protect existing inland and coastal wetlands.
- Protect urban and rural streams from in-filling.
- Ensure connectivity of fish habitat (fish passage).
- Set minimum requirements for feedlots and other stockholding areas (to take effect in winter of 2021).
- Improve poor practice intensive winter grazing of forage crops (to take effect in winter of 2021).
- Restrict further agricultural intensification until the end of 2024.
- Limit the discharge of synthetic nitrogen fertiliser to land to no more than 190kg per hectare per year, and require reporting of fertiliser use (to take effect in winter of 2021).

### 7.1.4 Regulations

Two additional regulations were released at the same time as the NPSFM and NESFM. Firstly, the **Resource Management (Stock Exclusion) Regulations 2020** were released. These regulations apply to anyone who owns or controls cattle, deer, or pigs (stock). Under these regulations:

- Stock must be excluded from specified wetlands, lakes, and rivers more than one metre wide.
- Dairy and dairy support cattle, and pigs must be excluded from water bodies.
- Beef cattle and deer must be excluded from water bodies whatever the terrain if they're break feeding, grazing annual forage crops, or irrigated pasture. Otherwise, these Regulations apply to beef cattle and deer only on mapped low slope land.
- Stock must be excluded from the beds of lakes, rivers, and wetlands, and must not be on land closer than three metres to the bed of rivers and lakes. However, stock doesn't need to be excluded from land within three metres of the bed if there is a permanent fence already in place.
- Stock (except deer) have to cross a river or lake by using a dedicated bridge or culvert, unless they cross no more than twice in any month. There are specific circumstances when cattle and pigs can cross without a dedicated culvert or bridge.

Secondly, the **Resource Management (Measurement and Reporting of Water Takes) Regulations 2010** were amended. Consent holders taking between 5 and more than 20 litres of water a second are now required to measure their water use every 15 minutes, store their records, and electronically submit their records to their council every day. These Regulations are applied in a staged approach, applying to consent holders with larger water takes first:

---

[13] We have not assessed all rivers and lakes in Southland against all of the NPSFM provisions. However, in addition to the Waimatuku Stream, the Waihopai River at the Queens Drive monitoring site had a five year nitrate nitrogen median of 2.2 g N/$m^3$ at the end of 2019, just below the NPSFM national bottom line of an annual median of 2.4 g N/$m^3$.

- Takes of 20L/s or more must comply within two years (by 2 September 2022).
- Takes of more than 10 and less than 20L/s must comply within four years (by 2 September 2024).
- Takes between 5 and 10L/s must comply within six years (by 2 September 2026).

### 7.1.5 Other relevant statutory requirements

Other than the NESFM, there are several other National Environmental Standards that are of relevance for farmers. Relevant National Environmental Standards include:

- **National Environmental Standard for Sources of Human Drinking Water –** This aims to reduce the risk of human drinking water sources becoming contaminated, requiring regional councils to ensure that the effects of activities on drinking water sources are considered in decisions on resource consents and in regional plans.
- **National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health** – This provide planning controls and soil contaminant values, to ensure that land affected by contaminants in soil is appropriately identified and assessed before being developed, and if necessary, remediate soil or contain the contaminants.
- **National Environmental Standards for Plantation Forestry** – This aims to maintain or improve the environmental outcomes associated with plantation forestry activities and to increase the certainty and efficiency in the management of those activities. These regulations permit core forestry activities including afforestation, earthworks and harvesting provided there are no significant adverse environmental effects.

The **New Zealand Coastal Policy Statement** is important. This document sets objectives and policies to achieve to promote the sustainable management of the natural and physical resources of the coastal environment. This document provides Environment Southland with direction how activities should be managed in Southland's range of estuaries, and coastal lagoons and wetlands.

**Water Conservation Orders** are also important. Under Part 9 of the RMA, water conservation orders can be created to recognise and protect outstanding values that a water body provides (such as important fisheries, scientific and ecological values, or recreational, historical, spiritual or cultural values). Regional policy statements, regional plans and district plans must not be inconsistent with any order, and any resource consents granted must not be contrary to an order. In Southland, the Ōreti River and the Matāura River have water conservation orders.

## 7.2 Regional Level

In Southland, Environment Southland (the Southland Regional Council) is the relevant regulatory body that must give effect to national policy statements, national environmental standards, and national planning standards in their own regional plans and regional policy statements. Territorial authorities must ensure that their district plans are not inconsistent with the national and regional policy and planning documents.

### 7.2.2 Proposed Southland Water and Land Plan

The **proposed Southland Water and Land Plan** (pSWLP)[14] is Environment Southland's primary tool for water quality management. This plan was publicly notified in 2016 and brings together and updates the Regional Water Plan for Southland 2010, the Regional Effluent Land Application Pan 1998, and the Transitional Regional Plan

[14] The pSWLP is currently (late 2020) under appeal and the Environment Court has released a series of decisions that is expected to continue in early 2021. Updates on the status of the pSWLP can be found on Environment Southland's website: https://www.es.govt.nz/about-us/plans-and-strategies/regional-plans/proposed-southland-water-and-land-plan The first four interim decisions have focussed on objectives. Subsequent decisions will address policies, rules and other aspects of the plan.

1991 (most of which has already been superseded).

Significant changes from previous plans included:

- The introduction of Te Mana o te Wai.
- An updated set of objectives.
- New objectives and policies setting out the freshwater management unit process to come.
- New controls for activities known to have a significant effect on water quality, such as land use intensification, wintering, cultivation and stock access to waterways.

In summary, the pSWLP provides direction and guidance for the sustainable use, development and protection of water and land resources in Southland, seeking to address activities that are known to have adverse effects on water quality, such as land use intensification, urban discharge, wintering, and stock access to water.

### 7.2.3 Regional Water Plan 2010

The **Regional Water Plan** was created to promote the sustainable management of Southland's rivers, lakes and water resources, as well as enabling the sustainable use and development of water. Once finalised, the proposed Southland and Water Land Plan will replace the Regional Water Plan.

This plan was developed to focus on water quality and quantity, groundwater, river and lake beds, and wetlands. This plan sets the framework for the use, development, and protection of the surface water and groundwater resources, and sets out the information required to deal with relevant matters raised.

### 7.2.4 Southland Regional Policy Statement 2017

The Southland Regional Policy Statement guides resource management policy and practice in Southland. This document provides a framework for Environment Southland to base decisions on the management of Southland's natural and physical resources, gives an overview of the significant resource management issues facing in the region, including issues of significance to Tangata Whenua, and includes objectives, policies and methods to resolve any identified issues. Environment Southland's regional plan must give effect to this policy statement.

### 7.2.5 Regional Coastal Plan for Southland 2013

The Regional Coastal Plan describes Southland's coastal values and identifies management issues. This plan sets out how Environment Southland will carry out its resource management responsibilities in Southland's the coastal area.

### 7.2.6 Regional Effluent Land Application Plan 1998

This plan includes some specific policies and rules that apply to the discharge of effluent. Once finalised, the proposed Southland and Water Land Plan will replace the Regional Effluent Land Application Plan.

### 7.2.7 Te Tangi a Tauira – The Cry of the People, Ngāi Tahu ki Murihiku Natural Resource and Environmental Management Plan 2008

This plan was developed by Ngāi Tahu ki Murihiku[15], consolidating Ngāi Tahu ki Murihiku values, knowledge and perspectives on natural resource and environmental management issues. The purpose of the Plan is to:

- Describe the values underpinning the relationship between Ngāi Tahu ki Murihiku and the natural environment.
- Identify the primary issues associated with natural resource and environmental management in the

[15] Murihiku refers to a large part of the lower South Island and includes the Southland region.

takiwā, from the perspective of Ngāi Tahu ki Murihiku.

- Articulate Ngāi Tahu ki Murihiku policies and management guidelines for natural resource and environmental management, wāhi tapu and wāhi taonga.

In addition, this Plan provides a tool to:

- Enable Ngāi Tahu ki Murihiku to effectively and proactively apply cultural values to the management of natural resources, wāhi tapu and wāhi taonga.
- Assist regional, territorial and national authorities to understand Ngāi Tahu ki Murihiku values and perspectives, and thus fulfill their statutory obligations under the Resource Management Act 1991. Ngāi Tahu Claims Settlement Act 1998, Local Government 2002 and other relevant legislation.
- Recognise the importance of consultation, but does not replace the need for direct consultation with Ngāi Tahu ki Murihiku.

## 7.3 Future Direction

In response to declining freshwater quality in developed parts of New Zealand**,** central government announced changes to the National Policy Statement for Freshwater Management (NPSFM), the National Environmental Standard for Freshwater (NES) and changes to the Resource Management Act in August 2020**.** The following section outlines what changes might be expected over the coming months and years.

### 7.3.1 Resource Management Act Changes

It is expected that there will be significant reform of the RMA within the next five years. This will have flow-on consequences for territorial and regional planning in Southland. In July 2020, the Government released a report following a year-long review of the RMA. The report concluded that the RMA should be repealed and replaced with two new separate Acts:

1. **The Natural and Built Environments Act** – This would carry over appropriate key principles of the RMA, and would aim to enhance the quality of the environment, recognise the concept of Te Mana o te Taiao (to ensure Māori views are recognised, reflecting the fundamental importance of natural resources in sustaining all life), and achieving high-quality outcomes. It would set national standards for environmental outcomes, and would create 14 combined plans (replacing the 100+ regional and territorial policy statements and plans) to cover each region.
2. **The Strategic Planning Act** – This would set long-term strategic goals and facilitate the integration of legislative functions across the resource management system. This would include functions to enable land and resource planning to be better integrated with the provision of infrastructure as well as associated funding and investment. Regional spatial strategies would be a critical part of this legislation, identifying areas suitable for development as well as areas or features for protection.

It is likely that there will be significant changes made to the RMA in the coming years. Any proposed changes will go through a public consultation process, which will provide an opportunity for all stakeholders to submit on any new proposal.

### 7.3.2 Regional Plan Changes

Environment Southland in partnership with Te Ao Marama[16] is in the process of developing a significant plan change (Southland Water and Land Proposed Plan Change, SWLPPC) to meet the NPSFM requirements,

[16] Te Ao Marama is an incorporated society that represents four Papatipu Rūnanga (Oraka/Aparima, Waihopai, Awarua and Hokonui) within the Murihiku (which includes Southland) area of the Ngāi Tahu tribal area. Te Ao Mārama works with local authorities on statutory planning and consenting processes. https://ngaitahu.iwi.nz/te-runanga-o-ngai-tahu/papatipu-runanga/

particularly to set limits and target for water quality.

Environment Southland has indicated that a plan change to achieve this will be publicly notified in 2023 and the RMA requires that this this plan is operative by the end of 2025. Environment Southland and Te Ao Marama Inc have established a community-based Regional Forum to consider and advise on limits, targets, and methods.

This plan change will focus on the five Fresh Water Management Units (FMUs) identified by Environment Southland: Fiordland and islands, Waiau, Aparima, Ōreti and Matāura (Figure 13). However, the Environment Court has recently issued an interim decision[17] on the pSLWP that strongly indicates that the Waituna Lagoon/Waipārera will be made a separate FMU. In addition, as indicated in Section 8 below, the Environment Court has recently made some significant changes[18] to the objectives of the pSLWP and decisions relating to policies and rules are expected in 2021.

Similar plan changes to set limits and targets for water quality have been developed in other regions such as Canterbury and the Waikato. These plan changes have generally proposed significant reductions in nutrient losses to water from land.

Environment Southland is in the process of plan development that will integrate Te Mana o te Wai in its approach to freshwater management. The Environment Court interim decisions on the pSWLP have clarified the roles of ki uta ki tai and Te Mana o te Wai. The pSWLP now states:

"*Interpretation Statement*

*All persons exercising functions and powers under this Plan and all person who use, develop or protect resources to which this Plan applies shall recognise that:*

*Objectives 1 and 2 are fundamental to this plan, providing an overarching statement on the management of water and land, and all objectives are to be read together and considered in that context; and*

*i) The plan embodies ki uta ki tai and upholds Te Mana o te Wai and they are at the forefront of all discussions and decisions about water and land.*

*Objective 1*

*Land and water and associated ecosystems are sustainably managed as integrated natural resources, recognising the connectivity between surface water and groundwater, and between freshwater, land and the coast.*

*Objective 2*

*The mauri of water provide for te hauora o te taiao (health and mauri of the environment), hauora o te wai (health and mauri of the water body), and te hauora o te tangata (health and mauri of the people)."*

# 8. An overview of Tangata Whenua perspectives

Water is a taonga and is held in the highest regard by Ngāi Tahu. The Māori world view (Te Ao Māori) acknowledges the interconnectedness and interrelationship of water and land. Cultural practices and the health and wellbeing of Murihiku rūnanga (tribal council or board) depends on the ability to express Kaitiakitanga (as

[17] https://www.environmentcourt.govt.nz/assets/Documents/Publications/2019-NZEnvC-208-Aratiatia-Livestock-Limited-v-Southland-Regional-Council.pdf

[18] Environment Court Fourth Interim Decision on pSWLP, November 2020

guardian and advocate).

**Ki uta ki tai** is a philosophy that reflects the Ngāi Tahu view of resource management. It is a traditional concept of kaitiakitanga (guardianship) from the mountains and inland lakes, down the rivers to hāpua/lagoons, wahapū/estuaries and to the sea (from the mountains to the sea). Ki uta ki tai recognises the need to manage the interconnectedness of the whole environment.

Three overarching values have been identified by Murihiku iwi[19]:

- "***Te Mana o te Wai****: The role of valuing the living expression of Māori cultural Mauri (energy and flow of life force) of water bodies and taonga species. Te Mana o te Wai is recognised in the National Policy Statement for Freshwater Management as: the health and wellbeing of water bodies; the health and wellbeing of people and the health and wellbeing of the environment. Te Mana o te Wai recognises that values setting within the community needs to underpin all regional authorities' conservation and environmental management work.*
- ***Kaitiakitanga****: The actions of Māori cultural guardianship, advocacy and protection.*
- ***Tino Rangatiratanga****: The exercise of the Treaty of Waitangi, statutory rulings and cultural expression in the protection and restoration of the environment such that the social, health and economic development of the Māori community is integrated*."

Ngāi Tahu ki Murihiku has significant concerns with how water has been managed in Southland. The document "Wai Ngāi Tahu ki Murihiku" (Te Ao Mārama Inc, 2019) provides an overview of Te Runanga o Ngāi Tahu ki Murihiku values with respect to freshwater.

Ngāi Tahu ki Murihiku have an approach of aiming for the highest possible standard of water quality that is characteristic of a place or waterway. This relates back to the way that a place or waterway was used and valued historically. To meet these aspirations Ngāi Tahu ki Murihiku believe that the resource management and in particular, the limit setting framework need to consider cultural values alongside scientific values. This approach is underpinned by the perception held by Māori that water is a "holistic sacred entity within which it holds its own life force or 'Mauri'". Māori world view follows that humans are "one" with the environment (Earth mother - Papatūānuku) and that water and rivers are the lifeblood of Papatūānuku. This also includes the approach of integrated management of the environment that is encompassed by the concept of Ki uta ki Tai (Mountains to the Sea), which includes:

- Integration across agencies and legislation.
- Integration across natural and physical resources (e.g. water, soil, the coast).
- Integration across outcomes for a given waterway.
- Integration of local with regional and national objectives.

Key areas of environmental concerns regarding freshwater management in Southland identified by Te Ao Mārama include:

- **Water drainage.** This is considered to be more of an issue than water abstraction and relates to the significant loss of wetlands and associated biodiversity and cultural values as a result of land development.
- **Water abstraction.** There is concern regarding the limited understanding of groundwater and surface water interactions, particularly where there is uncertainty about the impacts of groundwater abstraction on surface water bodies.
- **Discharge of wastewater (sewage and stormwater) to water.** This should be avoided due to the impact on cultural values and the preference for treatment and then discharge to land via wetlands and riparian areas.

[19] http://waterstory.es.govt.nz/ngai-tahu-ki-murihiku-values.aspx

- **Preservation of mahinga kai and taonga species.** This is the preservation of the biodiversity and availability of traditional mahinga kai sources and the preservation of culturally valuable ecosystems.

Catchment groups need to appreciate and understand the concerns of Ngāi Tahu ki Murihiku, the significant importance of these concerns in RMA processes and the need to work with local rūnanga[20] as land use changes are being considered to maintain and improve catchment water quality.

# 9. Implications for catchment groups

Summary information on water quality demonstrates that no lowland river in Southland fully complies with all the relevant water quality guidelines/standards and some rivers are significantly degraded compared to national guidelines and/or regional water quality standards. This means that the limit and target setting process that Environment Southland is currently working on is almost certain to introduce new policies, rules and other initiatives to reduce losses of contaminants to water that will need some significant land use changes and/or farm system changes.

The purpose of this section is to summarise the background to this, identify the potential options to reduce contaminant losses from land use and suggest how to contribute to, and prepare for, the pending changes.

## 9.1 Land use and practices that result in the greatest loss of contaminants to water

The main contaminants of concern are N, P, sediment, and microorganisms of health significance (monitored using faecal indicator organisms). There is a significant amount of information available on N loss from a range of land uses in New Zealand and Southland. This is summarised below to provide one indication of relative contaminant losses:

- Forestry 1-5 kg N/ha/r,
- Sheep and beef 6-40 kg N/ha/yr,
- Dairying 25-100 kg N/ha/yr,
- Arable 10-140 kg N/ha/yr
- Commercial vegetables 100-300 kg N/ha/yr.

This highlights that some of the relatively minor land uses such as arable and commercial vegetable growing can have relatively high losses of N. It is also important to appreciate that even in one sector the N loss rates can vary significantly.

It is also important to appreciate that while there is a considerable amount of quantitative information available on N losses, there are important water quality issues related to sediment, P and microorganisms that will also have implications for land use.

Catchment and site-specific characteristics are critical to determining the amounts and effects of contaminant losses on water quality, aquatic ecosystems and the uses and values of water.

Land use, catchment and site-specific characteristics will usually determine the most practicable options to reduce contaminant losses. For example, there is more potential to reduce N losses from a typical dairy farm than to reduce N losses for a dryland sheep and beef farm.

A significant amount of research has been undertaken in New Zealand and overseas into identifying effective

[20] https://ngaitahu.iwi.nz/te-runanga-o-ngai-tahu/papatipu-runanga/

measures to reduce contaminant losses from agricultural land. These provide a wide range of options to significantly reduce losses of contaminants.

It is important to appreciate that some contaminant loss mitigation measures will be effective in reducing a range of contaminants while some will be specific to one contaminant.

## 9.2 Trends in land use change over the past 30 years

A key land use change that has occurred in Southland over the past 30 years has been the significant increase in dairying and the concurrent reduction in sheep and beef numbers. Dairy cow numbers started increasing significantly after 1990 and rose from less than 40,000 milking cows in Southland to just under 600,000 in 2019. This rate of increase flattened significantly in the last five years, as illustrated in Figure 17.

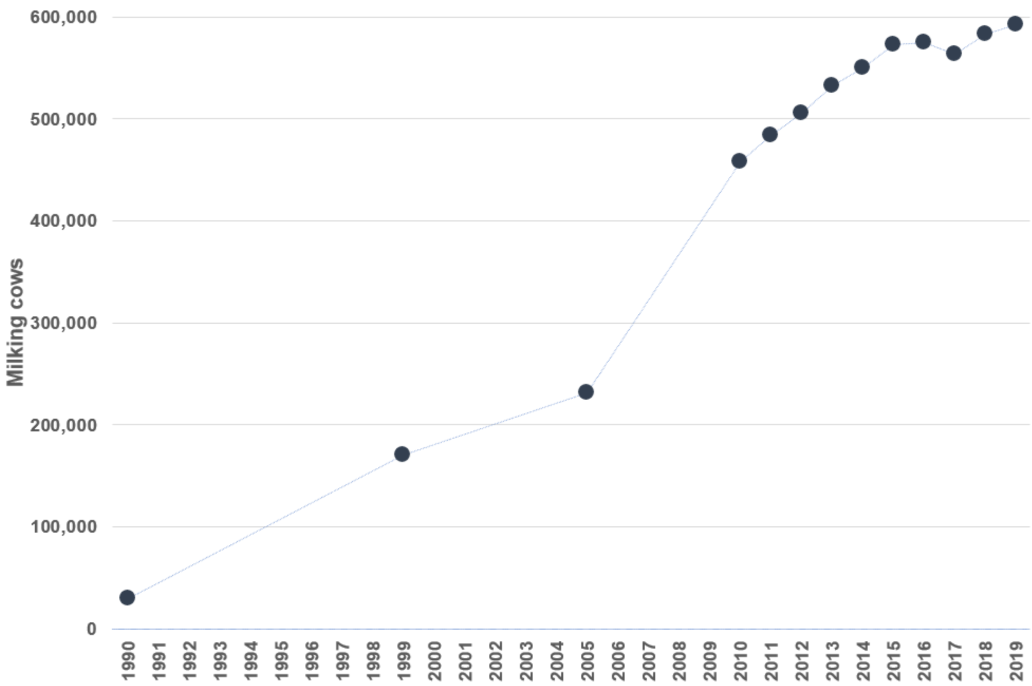



**Figure 17: The number of milking cows in Southland 1990 - 2019**

This change in land use means that there is potential for significant losses of contaminants to enter water. It is possible that in some locations these changes could mean that there is a significant nitrogen "load to come", i.e., a significant lag time between nitrogen draining through to groundwater and that groundwater emerging in a surface water body. However, this possibility has to be critically assessed on a catchment by catchment basis. The water quality data summarised in this report and Southland specific research indicates that shallow groundwater in Southland generally responds relatively quickly to land use change and in general the lag time is years not decades. Catchment specific characteristics will dictate how quickly groundwater moves into surface waters.

Sheep and beef land use is still by far the predominant use of agricultural land on an area basis in Southland, with approximately 700,000 hectares, while dairying land uses approximately 300,000 hectares.

# 10. What Does this Mean for Farmers?

## 10.1 How will land use/system changes be implemented and what does this mean for farmers?

Environment Southland has stated that the proposed 'limits and targets' plan change (SWLPPC) will be notified in 2023. Environment Southland and Te Ao Marama Inc have established a community-based Regional Forum to consider and advise on limits, targets, and methods.

Plan changes will result in additional controls in Southland that will be focussed on reducing the loss of contaminants, specifically N and P, from land to groundwater and surface water. This means that in most parts of Southland there will be new rules that directly or indirectly will set limits on the amounts of N and P that can be lost to water. There are also likely to be new rules aimed at reducing discharges of sediment and microorganisms to water.

It is important to appreciate that groundwater quality and surface water quality vary across Southland. As an example, the Waiau River at Tuatapere, currently has a median nitrate-nitrogen concentration of 0.25 $g/m^3$ while the Waimatuku Stream at Lorneville Riverton, had a five-year median nitrate nitrogen concentration of 3.4 $g/m^3$ for the five years ending December 2019. However, it is also important to appreciate that other factors that may be relevant to a catchment such as the state of the downstream estuary. For example, the relatively poor status of the New River Estuary is highly likely to have implications for nutrient management of the Oreti River.

To obtain an early indication of one important driver for nitrogen loss reduction, concentrations can be compared to the new 'National Bottom Line' (NBL) for nitrate nitrogen in rivers of a median of 2.4 $g/m^3$. For example, the water quality of the Waimatuku Stream does not comply with this NBL. The Waihopai River five-year median nitrate nitrogen concentration as at the end of 2019 was just below the NBL at 2.2 $g/m^3$ . Therefore, it should be clear that new policies and rules for these catchments will be aimed at achieving significant reductions in nitrogen losses to water.

It should also be appreciated that even if there are no significant catchment nitrate toxicity issues it is likely that nitrogen loss reductions will be required in most catchments to address nutrient enrichment issues such as estuary eutrophication.

It is not possible at this stage of the process to be sure about exactly what this will all mean for individual farmers. However, we are certain that to significantly reduce concentrations of contaminants in groundwater and surface waters to achieve the water quality being sought by the community will require major reductions in contaminant losses to water in most Southland catchments.

## 10.2 Planning process for nutrient reduction

Regional councils take the following basic steps when undertaking the planning process for nutrient reduction:

1. Identify the water quality objectives that need to be achieved e.g., periphyton extent on a river bed.
2. Identify the water quality targets needed to support those objectives e.g., dissolved nutrient concentrations.
3. Identify the annual catchment load of N and P that would be consistent with those dissolved nutrient concentrations.
4. Identify the current annual catchment loads of N and P.
5. Identify the catchment reductions required to meet the catchment load targets (where objectives are not being met)

6. Use an allocation method to distribution reductions across resource users and determine a time period to achieve water quality objectives
7. Develop a suite of planning provisions: policies, rules and other implementation methods.

Some key steps in a simple hypothetical scenario are illustrated in Figure 18, which assumes all properties in a catchment would reduce nutrient losses by the same proportion.

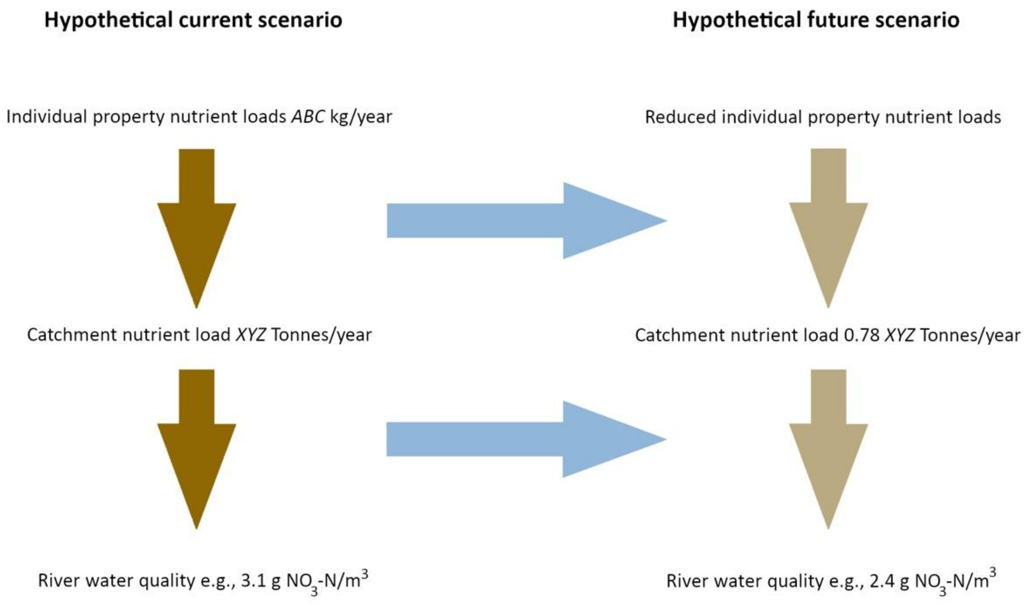



**Figure 18: Diagrammatic representation of a simplistic change in catchment N loads and water quality**

## 10.3 What can you do to help improve water quality?

There are many well established good management practices that clarify the general expectations to minimise contaminant losses to water. The industry specific guidelines are available on the relevant websites:

- Beef + Lamb NZ
- Dairy NZ
- Deer NZ
- Foundation of Arable Research
- Horticulture NZ
- Irrigation New Zealand
- Pork NZ

Environment Southland have published some high level good management practices (GMPs), as well as some contaminant transport route specific guidelines.

The "Industry-agreed Good Management Practices relating to water quality" summarise the high-level general practices that should be adopted. These are summarised under the following headings.

### 10.3.1 Good Management Practices

#### GENERAL PRINCIPLES

1. Identify the physical and biophysical characteristics of the farm system, assess the risk factors to water quality associated with the farm system, and manage appropriately
2. Maintain accurate and auditable records of annual farm inputs, outputs and management practices
3. Manage farming operations to minimise direct and indirect losses of sediment and nutrients to water, and maintain or enhance soil structure, where agronomically appropriate

### NUTRIENTS

4. Monitor soil phosphorus levels and maintain them at or below the agronomic optimum for the farm system
5. Manage the amount and timing of fertiliser inputs, taking account of all sources of nutrients, to match plant requirements and minimise risk of losses
6. Store and load fertiliser to minimise risk of spillage, leaching and loss into waterbodies
7. Ensure equipment for spreading fertilisers is well maintained and calibrated
8. Store, transport and distribute feed to minimise wastage, leachate and soil damage

### WATERWAYS

9. Identify risk of overland flow of sediment and faecal bacteria on the property and implement measures to minimise transport of these to waterbodies
10. Locate and manage farm tracks, gateways, water troughs, self-feeding areas, stock camps, wallows and other sources of run-off to minimise risks to water quality
11. Exclude stock from waterbodies to the extent that is compatible with land form, stock class and stock intensity. Where exclusion is not possible, mitigate impacts on waterways

### LAND AND SOIL

12. Manage periods of exposed soil between crops / pasture to reduce risk of erosion, overland flow and leaching
13. Manage or retire erosion-prone land to minimise soil losses through appropriate measures and practices
14. Select appropriate paddocks for intensive grazing, recognising and mitigating possible nutrient and sediment loss from critical source areas
15. Manage grazing to minimise losses from critical source areas

### EFFLUENT

16. Ensure the effluent system meets industry-specific Code of Practice or equivalent standard
17. Have sufficient suitable storage available for farm effluent and wastewater
18. Ensure equipment for spreading effluent and other organic manures is well maintained and calibrated
19. Apply effluent to pasture and crops at depths, rates and times to match plant requirements and minimise risk to waterbodies

### WATER AND IRRIGATION

20. Manage the amount and timing of irrigation inputs to meet plant demands and minimise risk of leaching and runoff
21. Design, check and operate irrigation systems to minimise the amount of water needed to meet production objectives
22. The following are often identified as key practices that can be modified to manage the loss of contaminants.

**Table 3:** A summary of general farm practices, mitigation measures and the contaminants targeted

| Farm practices and mitigation measures | Contaminant targeted |
|---|---|
| Fertiliser type and timing | N & P |
| Rate and method of fertiliser application | N & P |
| Cultivation practices, including timing | N & P |
| Soil and cover management | Sediment & P |
| Livestock type and stocking rate | N & microorganisms |
| Feed type, pasture choice, forage crop choices | N |
| Grazing practices and regimes | P, N & sediment |
| Soil fertility status | P and N |
| Irrigation practices | N, P, and sediment |
| Effluent practices | N, P, microorganisms, & sediment |
| Use of wetlands | N, P, microorganisms, & sediment |
| Riparian management | P, microorganisms, & sediment |
| Track, and laneway planning and management | N, P, microorganisms, & sediment |
| Reducing/removing point source risks | N, P & microorganisms |

## 10.4 Implications for land use and water quality management

These changes that took effect on 3 September 2020 will have significant implications for land use and water quality management. The key changes and implications are listed in Table 4:

**Table 4:** Implications of new RMA provisions for contaminant loss management

| New controls | Key implications |
|---|---|
| National Policy Statement for Freshwater Management (NPSPW) | Changes the National Bottom Line (NBL) for median nitrate-nitrogen concentration in rivers from 6.9 g/m$^3$ to 2.4 g/m$^3$. This will eventually be implemented via a regional plan and reinforce the need for significant land use change in some catchments e.g., the Waimatuku and Waihopai where water quality currently does not comply with this requirement. |
| Regulations for stock exclusion and freshwater farm plans | Should have limited implications because most farms in Southland comply with stock exclusion requirements and existing farm environmental management plans required already under the pSWLP are equivalent to freshwater farm plans. |
| Freshwater National Environmental Standards (NESFW)<br>• Stock holding area standards<br>• Intensive winter grazing standards<br>• Agricultural intensification restrictions<br>• Limiting the application of synthetic nitrogen fertiliser to a maximum of 190 kg N/ha/yr | These changes will have significant implications for some farms. |

The detailed requirements are set out on the Ministry for the Environment and various industry organisation websites.

Many of these new requirements will over the next few years result in the reduction of some losses of contaminants to water in Southland. However, some of them are similar to initiatives that have been underway for a number of years in Southland. In addition, changes such as reductions in the maximum annual synthetic fertiliser use will take some years before reductions are reflected in water quality. It is also possible that in some situations reductions in fertiliser use will result in substitution, for example feed used to replace a reduction in pasture production.

Taking all these factors into account, we consider that in Southland the effects of the new regulations and NESFW on water quality will be relatively minor, and are most likely to just assist in halting any further deterioration in those locations where water quality is degraded.

The NPSFW will require Environment Southland to develop and implement specific additional measures in those catchments where the current nitrate-nitrogen water quality does not comply with the new NBL. This means that it is likely that the most significant reductions in N losses may be required in these two catchments where water quality currently doesn't comply with the nitrate nitrogen NBL:

- Waimatuku Creek
- Waihopai River

In addition to consideration of nitrate-nitrogen as a potential toxicant it is also a nutrient and as such it is also highly likely that significant nitrogen loss reductions will be required in most catchments to address nutrient enrichment/accelerated plant growth issues.

## 10.5 Will GMP and new regulations/NESFW be enough?

The information summarised in this report strongly indicates that neither Good Management Practice (GMP) measures nor the new regulations/NESFW will be enough to significantly improve receiving water quality.

One of the issues with GMPs is that many of them are frequently not explicitly defined. For example, a wide range of practices for farm tracks management or fertiliser use could be GMPs but still be quite different and result in different levels of contaminant loss to water in different locations. Taking this into account and not knowing to what extent farms in Southland would 'comply' with all GMPs means that it is difficult to be confident about what the effect would be of all farms in Southland 'complying' with all the relevant sector and or physiographic zone GMPs. However, two aspects are clear:

- The majority of farms in Southland are likely to be already generally operating at 'GMP'.
- The water quality improvements that would occur with greater uptake of some 'GMPs' are likely to be relatively small.

We have not seen the detailed Environment Southland technical work that is currently underway but from our summary of the gaps between existing water quality and existing water quality standards including national bottom lines, it is clear that GMPs and new regulations/NESFW alone will not achieve that water quality.

Our very preliminary assessment is that most catchments will need nitrogen loss reductions from farming land of more than 15 % compared to current practices. While we understand that for the dairy sector nitrogen loss reduction of 15 % compared to 'good management practice' is generally considered achievable for most farms, it would still require significant farm system and management changes together with specific nutrient loss mitigation measures. However, our understanding of the scale of the water quality issues in most catchments, particularly in terms of estuary eutrophication, is that 15% reductions won't be enough to achieve the likely water quality targets.

It is also clear that there are differences: in catchment water quality, catchment characteristics and individual farms. This will mean that distinct individual catchment and farm approaches are likely to be needed to take account of these differences.

## 10.6 How accurate are predictions about the effectiveness of contaminant reduction strategies?

It is important to appreciate that all predictions of the effectiveness of contaminant loss predictions have inherent uncertainty. The extent of uncertainty depends on many factors such as the similarity of an individual situation compared to the information used to estimate the effectiveness. The information in the following sections is provided as an indication of the range of likely effectiveness.

The information in the following sections is an initial guide. A Certified Nutrient Management Advisor (CNMA) should be consulted to develop site specific strategies. Environment Southland land sustainability officers may also be available to provide advice.

# 11. Action on the ground

The following section outlines specific strategies for reducing nitrogen, phosphorus, sediment and microorganism loss from farm systems.

## 11.1 Specific strategies for reducing nitrogen losses

The focus of this section is primarily on dairying given the extent of dairying in Southland and the relatively high N loss rates from dairying. Some of the practices also apply to other farm systems.

These strategies are in addition to GMPs and existing requirements as specified in the pSWLP, NESFW and regulations e.g., stock exclusion, effluent management, intensive winter grazing controls, irrigation management, optimum soil nutrient concentrations, etc.

The Waikato Regional Council has a useful detailed guide to the effectiveness and costs of different practices to reduce nutrient losses to water for dairy farms, drystock farms and cropping farms: "Farm Menus". Much of that information will be applicable in Southland.

### 1. Fertiliser practices and tactical use of nitrogen fertiliser

The Fertiliser Associations Code of Practice for Nutrient Management, sets out best practices for N fertiliser use covering N requirements, rate, timing and form of application, soil conditions (moisture and temperature), minimum pasture covers, management of N on an effluent block. Careful control of the amounts and time of year of fertiliser application can significantly reduce N losses to water.

### 2. Feedpads, off paddock structures and restricted grazing

Losses of N from urine patches are responsible for most of the N leaching from grazed pastures. Removing animals from the grazed pasture in the autumn, winter and early spring periods significantly reduces the number of urine patches contributing to N leaching.

The use of feedpads and off paddock structures also reduces or avoids intensive winter grazing that can result in significant losses of N to water.

These are highly effective strategies in reducing N losses to water. Urine collected while the animals are on a feedpad or in an off paddock structure can be returned more evenly, at lower rates and at times of the year when net drainage is unlikely. However, it is critical to design and operate effluent management systems in conjunction with any of these systems to ensure that effluent is collected and stored until soil and weather conditions are suitable.

### 3. Wetlands and riparian attenuation zones

Trapping and retaining nutrients and sediment in wetlands and vegetation buffers alongside water courses has the potential to significantly reduce direct contamination of waterways. Local conditions such as, soil types, slope, rainfall, and land use, will contribute to the potential effectiveness of these systems.

### 4. Low nitrogen feed supplements

Use of feed supplements such as maize silage or barley grain as an alternative to using fertiliser N boosted grass lowers the amount of N in the diet. This translates into lower N concentrations in urine and the amount of N deposited in a urine patch, reducing the amount of N at risk to leaching.

### 5. Nitrification inhibitors

Nitrification inhibitors target the animal urine patch limiting the microbial conversion of urine-N to nitrate, which is the main source of N for leaching. They offer considerable potential. However, none are currently approved for use.

### 6. Management of soil alternatives

Some soils are more free draining than others and provide limited or no opportunities for denitrification (microbial process of reducing nitrate to gaseous forms of nitrogen) of nitrate-nitrogen. Therefore, there can often be opportunities to for example, move high N loss activities to heavier soils that provide greater potential for denitrification to occur.

### 7. Summary of effectiveness and costs of nitrogen loss reduction strategies

The following diagram (McDowell *et al* 2013) summarises the range of effectiveness and costs of some common strategies to reduce N losses to water.

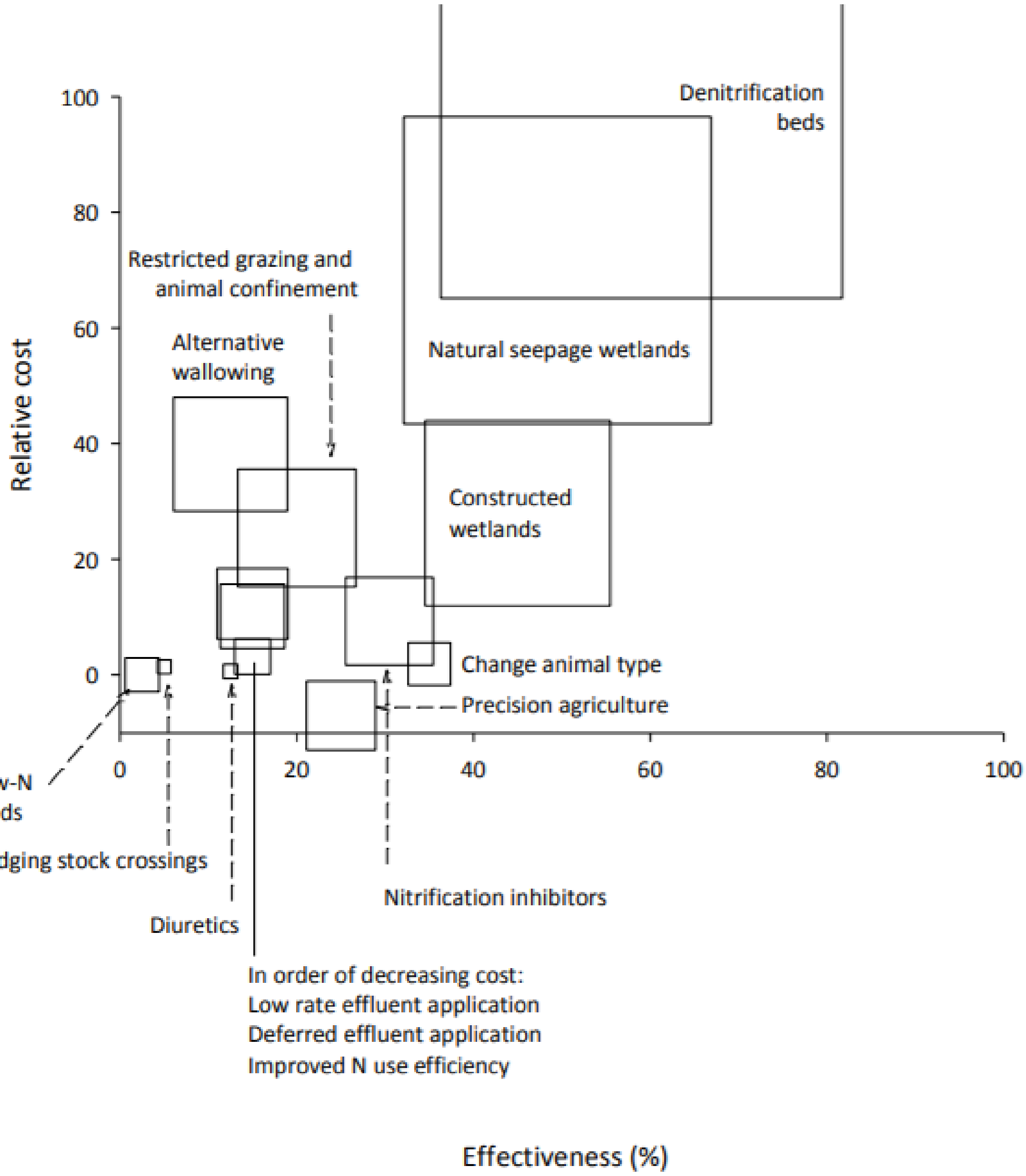



Figure 19: The relative cost and effectiveness of farm strategies to mitigate N losses to water. Cost is shown as the cost per kg of N mitigated relative to the most expensive strategy. The centre of the squares represents the mid-point in the range for each strategy, while the size represents the relative variability of each strategy (Diagram reproduced with permission of AgResearch)

The information on N loss reduction strategies indicate that there appear to be three general options for N loss reduction (Table 5):

**Table 5: Summary of nitrogen loss reduction strategies**

| Extent of N loss reduction | Strategies involved | Approximate % N loss reduction |
|---|---|---|
| Minor | • Compliance with all current requirements, i.e., pSWLP, NESFW & regulations<br>• Tactical use of fertiliser, low N feed, alternative pasture/crops<br>• Enhanced management of tracks, laneways, critical source areas, minor farm system changes, and riparian strips<br>• Some use of feedpads<br>• Careful management of effluent and irrigation<br>• Management of soil alternatives<br>• Strategic grazing of winter crops | 5 - 15 |
| Moderate | • All of the above<br>• Animal genetics<br>• Development and use of off paddock structures for 3 – 5 months of the year<br>• Significant areas of riparian buffer strips | 15 - 25 |
| Major | • All of the above<br>• Reduced farming intensity e.g., reduce stock numbers<br>• Major investment in constructed/modified wetlands<br>• Catchment strategies e.g., aquifer recharge<br>• Land use change | 25 - 50 |

## 11.2 Specific strategies for reducing phosphorus, sediment, and microorganism losses to water

These strategies are in addition to GMPs and existing requirements as specified in the pSWLP, NESFW and regulations. They include stock exclusion, effluent management, intensive winter grazing controls, irrigation management, and optimum soil nutrient concentrations.

One important consideration to keep in mind is that some strategies may provide significant benefits to some contaminant loss pathways, but not others. For example, contaminant loss via surface runoff (overland flow) versus contaminants loss via deep drainage (leaching).

### 1. Reduced soil erosion

Soil erosion processes can result in significant losses of P, sediment, and faecal bacteria to waterways. Some locations are particularly susceptible to soil erosion from overland flow during rainfall events, for example, via slumps, slips, and stream bank erosion. There are established methods to reduce soil erosion such as tree planting, stabilisation, and retirement, to reduce soil erosion that in turn significantly reduce the amounts of these contaminants lost to water.

### 2. Fertiliser type and practices.

The use of slow release P fertiliser products and restricting applications during periods of high risk, for example, when significant rainfall is forecast has potential to significantly reduce P losses to water.

### 3. Soil management, cultivation practices and critical source areas

Minimising soil cultivation, minimising the amount of time that soil is bare, avoiding or reducing grazing of poorly drained soils will all reduce the loss of contaminants in surface run-off events. Identification and management of Critical source areas (CSAs) is an important component.

### 4. Feedpads, off paddock structures and restricted grazing

Restricted grazing, feedpads and off paddock structures can also be effective for reducing the loss of contaminants in surface run-off, particularly in locations with heavy soils that are prone to becoming saturated in winter.

### 5. Wetlands and riparian attenuation zones/systems

Trapping and retaining nutrients and sediment in wetlands, riparian attenuation zones and other systems such as bunds have the potential to significantly reduce losses of sediment phosphorus and faecal bacteria to surface waters. Local conditions such as, soil types, slope, rainfall, and land use, will also contribute to the potential effectiveness of these systems. Riparian plantings around small streams can also provide shade and improve aquatic habitat.

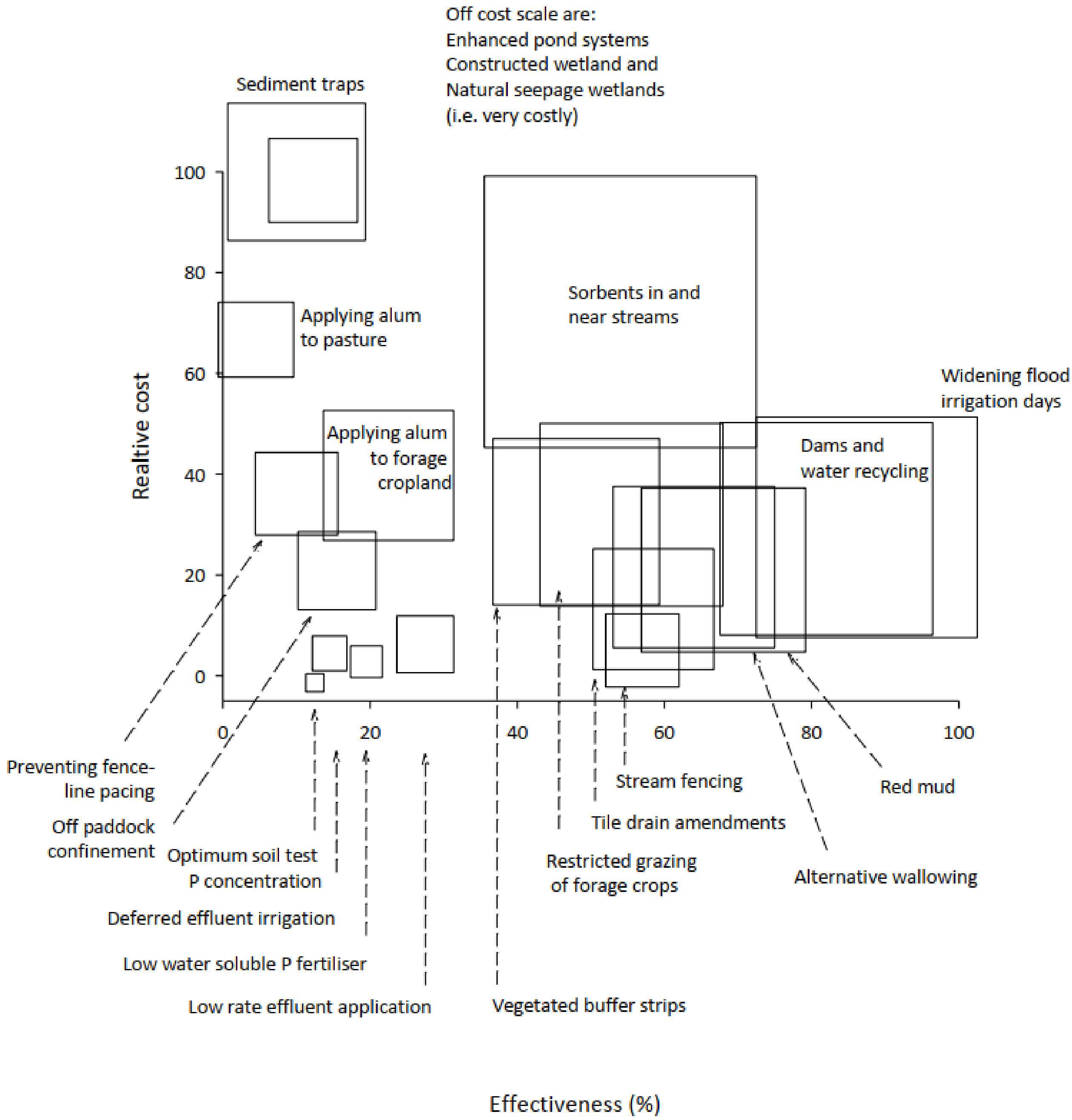



Figure 20: The relative cost and effectiveness of farm strategies to mitigate P losses to water. Cost is shown as the cost per kg of P mitigated relative to the most expensive strategy. The centre of the squares represents the mid-point in the range for each strategy, while the size represents the relative variability of each strategy (Diagram reproduced with permission of AgResearch)

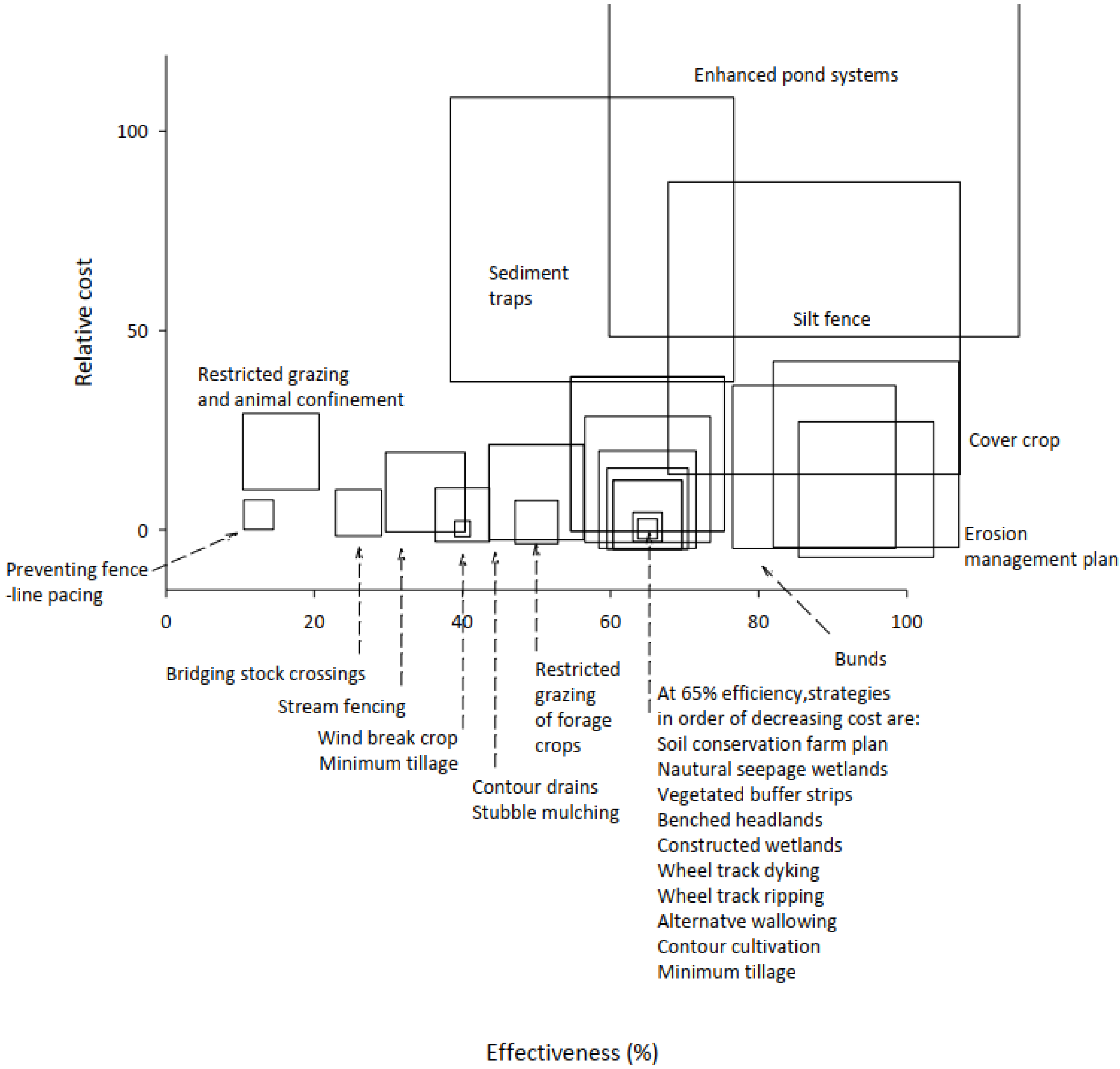



Figure 21: The relative cost and effectiveness of farm strategies to mitigate sediment losses to water. Cost is shown as the cost per kg of sediment mitigated relative to the most expensive strategy. The centre of the squares represents the mid-point in the range for each strategy, while the size represents the relative variability of each strategy (Diagram reproduced with permission of AgResearch)

It is important to appreciate that the Figures 14, 15 and 16 assume a starting point with little or no mitigation of contaminant losses, and therefore the current starting point in Southland is that for example, a significant majority of surface waters have been fenced to exclude dairy cows and cattle.

**Table 6: Summary of phosphorus, sediment and faecal bacteria loss reduction strategies**

| Extent of loss reduction | Strategies involved | Approximate % loss reduction |
|---|---|---|
| Minor | • Compliance with all current requirements, i.e., pSWLP, NESFW & regulations<br>• Tactical use of fertiliser, slow release P fertiliser,<br>• Some use of feedpads<br>• Careful management of effluent and irrigation<br>• Strategic grazing of winter crops | 5 - 15 |
| Moderate | • All of the above<br>• Development and use of off paddock structures for 3 – 5 months of the year<br>• Significant areas of riparian buffer strips<br>• Enhanced management of tracks, laneways, and critical source areas | 15 - 40 |
| Major | • All of the above<br>• Reduced farming intensity e.g., reduce stock numbers<br>• Major investment in constructed/modified wetlands<br>• Major investment in managing all CSAs<br>• Land use change | 40 - 60 |

## 11.3 Catchment group opportunities

Catchment groups are in the ideal position to collectively work together on strategies that can be designed to address specific catchment challenges. While the focus of the general strategies outlined above has been on individual farms, catchment groups will be in the best position to tailor packages that take account of how for example, adjoining land owners can work together to create synergies that may not work as effectively if each farm operated independently. This can particularly be the case when it comes to managing run-off.

## 11.4 Take Action Now or Wait?

There are significant advantages in initiating changes now to start reducing contaminant losses and improve water quality.

Concerns have been expressed that any initiative taken now may make it harder to comply with future rules because most regional councils have approached the issue of setting nutrient limits and targets by requiring nutrient loss reductions compared to a ‘baseline period’.

It is not certain that Environment Southland will use a baseline reference period, but this is the most commonly used method in New Zealand to develop policies and rules for catchment nutrient loss reductions.

It is extremely unlikely that any baseline period for the forthcoming SWLPPC would be set for the period post July 2020. The new National Environmental Standards for Freshwater (NESFW) that took effect on 3 September 2020 include a “reference” period of 1 July 2014 to 30 June 2019. Rule 20 of the pSWLP has a five-year reference period specified for one resource consent activity status. We consider that it is likely that Environment Southland will align with the NESFW period or a subset of that period. A 'most recent five years prior to a resource consent application' may inappropriately encourage some farms to ramp up nutrient loss prior to applying for a resource consent.

A significant amount of technical investigation work has been undertaken recently by and for Environment Southland, which will be used as technical information for the SWLPPC. A significant amount of that work will relate to detailed assessments of water quality, catchment nutrient loads, and modelling the relationships between land use and water quality. As at September 2020 we understand that the primary technical investigations and modelling has finished.

We consider that it is likely that a baseline period will be used in the SWLPPC and it will be for a three to five-year period between 2014 and 2019.

Recent approaches to nutrient loss reduction policies such as those proposed in North Canterbury have been based on percentage reductions below a suite of specific GMPs for a baseline period. A significant advantage of this approach is that it does not penalise anyone who achieves that reduction early. However, we are aware that other approaches have been used in New Zealand such as the allocation on the basis of land use capability that was used in the Manawatu Wanganui region.

Environment Southland will continue to monitor groundwater quality and surface water quality and use that information to assist with developing the SWLPPC and to provide feedback on the effectiveness of the planning framework. The achievement of water quality objectives will be a critical input into the regulatory framework.

We understand that catchment groups are focussed on improving water quality. Therefore, we think that the most appropriate approach would be to gather as much information as practicable on an individual farm basis about land management practices over the last four years to assist in understanding existing long-term annual average N and P losses. This should involve using a Certified Nutrient Management Adviser (CNMA) to model this information in Overseer. This will help to have a context for considering the contaminant loss reduction options that will be available.

We understand that some people have suggested that it may be appropriate to intensify land use to increase nutrient losses on the assumption that this would mean that with a higher baseline it will be easier in the future to comply with a requirement to reduce nutrient losses. We do not recommend this approach; both because it is almost certain that any baseline period will be for a period between 2014 and 2019 and because it could result in additional water quality deterioration. New land use intensification may also require additional resource consents under the pSWLP and/or the NESFM.

## 11.5 What should you do now to be ready for future new regional rules?

There are a range of practices that should be implemented as soon as possible that will contribute to improving water quality, involve minimal costs and should assist in long-term planning for future additional measures. There are also a range of precautionary procedures that should be followed.

**Complete baseline assessments**
Work with a CNMA to develop modelled long-term annual average nutrient losses for the four-year period 2016 – 2019.

**Operational preparation:**

- Make sure that you understand all the relevant current pSWLP rules and the new NESFW/regulations that apply to your farm.
- Ensure that you comply with the relevant provisions by the due dates and/or apply for resource consents if required.

- If you have any questions or need to apply for resource consents consult an experienced professional.
- Ensure that you have systems in place to ensure ongoing compliance with all your relevant resource consents. This includes having 'fail safe' systems in place particularly for effluent infrastructure.
- Ensure that you know when your current resource consents expire and that you prepare to apply to replace them at least 12 months before they expire.
- In consultation with your CNMA, develop at least two to three options for progressively reducing contaminant losses from land on the basis that it is almost certain that nutrient losses from individual farms will need to be reduced.
- Consult and coordinate with others in your catchment group, particularly neighbours to assess how measures could best be coordinated.
- Consult an experienced farm consultant/nutrient management advisor to discuss the best options for your individual farm so you understand what would be involved in implementing the options that are likely to be available to you and which methods would be most cost effective for your specific circumstances.

#### Implementation of additional specific contaminant loss reduction measures

Work with a CNMA to develop a range of strategies that can be quantified, such as:

- Avoid or minimise specific risk issues e.g., reducing/rerouting run-off into water from tracks, culverts, bridges, etc.
- Identify and address any potential point source risks, e.g., old effluent pumps, old 'monitoring bores' with poor well head protection or located too close to a contaminant source such as a laneway.
- Investigate the opportunities for changes to fertiliser use to see if changes or reductions could be achieved that would not adversely affect production.
- Look at farm system changes for dairy farms such as new or additional use of feedpads, increased area for effluent application and or different soil types that would result in reductions in N leaching and or P loss.
- For all farm systems look at the opportunities for increasing the width of riparian margins and opportunities for developing or enhancing wetland areas for treating runoff.
- Identify all significant critical source areas (CSAs) and prioritise measures to reduce contaminant losses from them.

All of these measures can be quantified to a greater or lesser extent and can therefore be counted towards any future nutrient loss reduction that may be required under the SWLPPC

#### Consider all your options

- Do not consider business as usual as an option.
- Carefully consider the potential implications of major investments. Will that potential major investment ensure that you can comply with future rules or will it become an expensive 'albatross'?

## 11.6 Develop a mitigation toolbox for your farm

Every farm in Southland has its own set of unique circumstances and each catchment will have differences. We think that is useful to think about a unique 'mitigation toolbox' that can be developed for each farm that takes account of both catchment and farm circumstances. For example, the key targeted contaminant may change from N to P/sediment/microorganisms depending on the catchment. Similarly, the opportunities for nutrient loss reduction will change from farm to farm depending on the type of farm, soils, slope, underlying hydrogeology, rainfall, etc.

## 11.7 Groundwater specific issues

The primary focus of attention for both national and regional controls has been on surface water quality management. However, groundwater plays a critical role in that in much of Southland groundwater is an important part of the recharge of surface water bodies. This is particularly the case with those catchments where a majority of river recharge comes from low altitude runoff and or drainage from agricultural areas.

Some catchments such as the Waimatuku have very little high-altitude recharge sources and the major proportion of surface water flow is sourced from runoff and groundwater from agricultural land. In contrast, for example the Waiau River has a major portion of its flow sourced from surface waters from mountains and hills in a large and extensive catchment.

This has important implications for both the quality of water in the low altitude source rivers, which is generally significantly degraded, e.g., the Waihopai River and the Waimatuku Stream, and the significant challenges that farmers will have in those catchments to improve water quality.

# 12. Recommendations for further work

We have identified the following opportunities for improvement that we consider warrant investigation. We have not identified a specific organisation for each matter. This is because the suggested initiatives will involve coordination between a number of organisations such as Environment Southland, industry support organisations and Crown Research Institutes and we think it is premature for us to identify exactly how an initiative could be developed and progressed.

## 12.1 Methods to assess the effectiveness of specific mitigation measures

This report has summarised a diverse range of contaminant loss reduction approaches. For many specific mitigation measures there is limited Southland specific information available on their effectiveness. For example, the range of effectiveness of riparian buffer strips in reducing sediment and P loss to water is generally accepted to range from just less than 40% to nearly 60%. Reducing this scale of uncertainty with Southland specific investigations will assist in determining how much mitigation would be needed to contribute to achieving specific water quality.

There would be significant benefits to the Southland community if assessments could be made of the effectiveness of a range of contaminant loss reduction strategies at representative Southland sites, specifically: constructed wetlands; riparian buffer strips; the use of off paddock structures; management of tracks; laneways and critical source areas; and changes to intensive winter grazing systems.

There would also be benefit in assessing the effectiveness of mitigation approaches at a scale beyond the paddock or farm and to look at the effectiveness of multi-property initiatives.

The currently available information has a relatively high level of uncertainty about the effectiveness of each individual strategy and therefore it will be in everyone's interest to achieve a greater level of certainty as the whole community works towards fining cost-effective strategies.

## 12.2 Catchment specific contaminant reduction targets and packages

Each catchment has many unique characteristics and the development of catchment limits and water quality targets will provide direction for farmers on the scale of the challenge for each catchment. However, this process will not necessarily identify potential mitigation packages for each catchment or sub-catchment that would reduce losses to the point that is consistent with the water quality targets.

It will be essential for Environment Southland to work with catchment groups and recognised catchment modellers to develop options about the range of mitigation packages that would reduce contaminant losses sufficiently to meet the target water quality. A catchment mitigation package option could indicate the extent to which potential mitigation strategies would need to be implemented across a catchment e.g., XYZ km of new 5m wide riparian buffer strips from location A to B, at least X ha of new feedpads used for at least Y months of the year for at least Z milking cows, a minimum of X ha of intensive winter grazing of dairy cows/cattle/deer replaced with wintering barns for at least four months of the year, all X km of tracks and laneways within five metres of a surface water to be recontoured to shed runoff away from the surface water, etc.

## 12.3 Establishment of improved water quality monitoring programmes - local and regional

Robust, meaningful, and accurate water quality monitoring is a fundamental component of freshwater management. This is increasingly the case when programmes are being developed, based on modelling that has inherent uncertainties, to identify contaminant loss policy packages to improve water quality.

The NPSFM recently changed the nitrate nitrogen national bottom line from a median of 6.9 g $NO_3$-N/$m^3$ to 2.4 $NO_3$-N/$m^3$. This will have many implications for regional councils and catchment groups. One specific implication is that it will increase the expectations that both groundwater and surface water quality monitoring programmes will need to be fit for this current and future challenges.

Regional groundwater quality monitoring needs to be enhanced to develop a long-term network of groundwater quality monitoring bores that are more focused on obtaining strategic, meaningful and representative groundwater quality data at sites where either land ownership or other contractual arrangements mean that there is a very high level of assurance that long-term (i.e., 50 - 100 years) information is obtained.

Catchment groups could play important roles in supporting Environment Southland to collect water quality samples in accordance with the nationally accepted methodology[21].

The freshwater quality standards in the pSWLP need to be reviewed and the plan made consistent with the appropriate numeric attributes in the NPSFM. In addition, given the importance and significance of groundwater in Southland both as a source of drinking water and recharge to rivers, groundwater quality standards should be developed as part of the pending SWLPPC.

The water quality standards specified in the Water Conservation (Matāura River) Order 1997 could simply be left in place and equivalent modern water quality standards applied alongside them to provide regional consistency while still ensuring that the regional plan is “not inconsistent” with the water conservation order.

## 12.4 Improved information on the causes of areas of high nitrate nitrogen in groundwater

There are many locations in Southland where groundwater nitrate-nitrogen concentrations have been reported as significantly elevated (Environment Southland Beacon GIS information). Many of these results appear to be relatively spatially isolated and may reflect localised contamination such as close proximity of a shallow monitoring bore down-gradient from a known potential source such as an effluent disposal area. However, there are also many more extensive areas with high nitrate nitrogen concentrations and are likely to reflect the effects of wider land use and/or discharges.

Many locations such as the Balfour and Edendale ‘nitrate hotspots’ have been investigated and the most likely

[21] http://www.nems.org.nz/documents/

cause identified. 'Hot spots' appear to exist at or near Dipton, Knapdale, Morton Mains, and Mabel Bush. These nitrate hotspot areas should be investigated to endeavour to understand the significance of the hotspot and the cause(s). The results of these investigations should be made available publicly and to landowners/catchment groups in that area and considered as the SWLPPC policy packages are developed.

Catchment groups would welcome specific feedback from Environment Southland on hotspots in their areas not only to obtain a better understanding of the causes of adverse effects on groundwater, but also on the implications for surface waters that may be recharged by this groundwater.

## 12.5 Information and preparation for the future changes

Catchment groups need to be provided with tailored information and advice as soon as practicable to ensure that as many people in the catchment as possible understand the nature of the changes that are coming, the scale of the likely changes that will be needed, and the measures that can be taken individually and collectively to ensure that communities are moving towards the achievement of agreed objectives.

Profound changes are likely to be needed in many catchments to meet the coming challenge of improving water quality. The responses will need to go well beyond individual farm mitigation measures and are likely to require major investments in collaborative catchment initiatives.

The four Papatipu Rūnanga in Murihiku (Hokonui Rūnanga, Te Rūnaka O Awarua, Oraka/Aparima Rūnaka, and Waihopai Rūnaka) through Te Ao Marama are recognised by organisations like Environment Southland as partners in the management of water resources. Catchment groups need to ensure that all members understand the Māori world view (te ao Māori) particularly the relationships that local rūnanga have with water, their Kaitiakitanga responsibilities and the need to develop strong enduring partnership models with rūnanga for water management.

# 13. References


Clarkson, B. R., Briggs, C., Fitzgerald, N., Rance, B., & Ogilvie, H. (2011). Current and historic wetlands of Southland Region: Stage 2. Landcare Research Contract Report no. LC312. Prepared for Environment Southland, Invercargill.

Dare, J. & Ewans, R. (2018) Wetland inventory and monitoring in Southland: Recent work to advance reporting on wetland state in the region. Environment Southland Science Symposium 2018 poster.

Environment Southland (2018) Proposed Southland Water and Land Plan, Part B – Maps. Decisions version 4th April 2018. Environment Southland Publication number 2018/3.

Environment Southland (2019) Southland Estuaries' health results. https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/environment/water/estuaries/documents/Southland%27s%20estuaries%20health%20results%202018.pdf

Environment Southland (2020a) Beacon: Water monitoring and alerts, accessed July/August 2020 from http://gis.es.govt.nz/

Environment Southland (2020b). Southlands monitored estuaries: A Guide to estuary ecosystem health monitoring.

Grant, D. (2015) Southland region - Geology and landforms. Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/southland-region/page-2 (accessed 25/8/2020)

Green, M. (2015). Drivers of Estuary Ecological Health and Water Quality in the Southland Region. NIWA Client Report HAM2015-017 prepared for DairyNZ and Environment Southland

Hughes, B., Wilson, K., Rissmann, C., and Rodway, E. (2016). Physiographics of Southland: Development and application of a classification system for managing land use effects on water quality in Southland. Environment Southland publication number: 2016/11

LAWA - Land Air Water Aotearoa (2020) Data sets for River Quality, Lake Quality and Groundwater Quality downloaded on 2/7/2020

Ledgard, G. (2013). Land Use Change in the Southland region. Environment Southland Technical Report 2013-13.

Macara, G.R., 2013, The Climate and Weather of Southland, 2nd ed., NIWA Science and Technology Series No. 63

Mager, S. & Horton, S (2018) The Hydrology of Southern New Zealand. Chapter in Strack, M., Wheen, N., Lovelock, B., and Carr, A. (2018) Riverscapes: Research essays on the social context of southern catchments of Aotearoa New Zealand.

McDowell R, Wilcock B & Hamilton D (2013) Assessment of Strategies to Mitigate the Impact or Loss of Contaminants from Agricultural Land to Fresh Waters, AgResearch Report for the Ministry for the Environment, RE500/2013/066

Ministry for the Environment (MfE) (2020) National Policy Statement for Freshwater Management 2020. August 2020.

Ministry of Health. 2018. Drinking-water Standards for New Zealand 2005 (revised 2018). Wellington: Ministry of Health.

Moriarty, E., Pantos, O., and Coxon, S. (2019a). Sources of Pollution in the Aparima Freshwater Management Unit. Institute of Environmental Science and Research Limited report.

Moriarty, E., Pantos, O., and Coxon, S. (2019b). Sources of Pollution in the Mataura Freshwater Management Unit. Institute of Environmental Science and Research Limited report.

Moriarty, E., Pantos, O., and Coxon, S. (2019c). Sources of Pollution in the Oreti Freshwater Management Unit. Institute of Environmental Science and Research Limited report

Moriarty, E., Pantos, O., and Coxon, S. (2019d). Sources of Pollution in the Waiau Freshwater Management Unit. Institute of Environmental Science and Research Limited report

Newson, J. (2000) An introduction to the Southland Region. Proceedings of the New Zealand Grassland Association, 62: 3-5

Pearson, L. (2015) Artificial subsurface drainage in Southland. Technical Report. Publication No. 2015-07. Environment Southland.

Snelder, T., Fraser, C., Hodson, R., Ward, N., Rissman, C., Hicks, A. (2014) Regional Scale Stratification of Southland's Water Quality – Guidance for Water and Land Management. Aqualinc Report No. C13055/02, prepared for Southland Regional Council, March 2014, Christchurch

Stats NZ Tatauranga Aotearoa (2020) Ground Water Quality webpage accessed, and data downloaded 20/8/2020. https://www.stats.govt.nz/indicators/groundwater-quality

Zammit, C., Pearce, P., Mullan, B., Sood, A., Collins, D., Stephens, S., Woolley, J.M., Bell, R., and Wadhwa, S. (2018). Southland climate change impact assessment. NIWA client report No: 2018120CH.

# 14. Bibliography


| Title | Citation | Summary |
|---|---|---|
| **Climate and climate change** | | |
| Effects of weather variability on sheep and beef farming in northern Southland, New Zealand: A modelling analysis | Li, F.Y., Vibart, R., Dynes, R.A., Vogeler, I., and Brown, M. (2012) Effects of weather variability on sheep and beef farming in northern Southland, New Zealand: A modelling analysis. Proceedings of the New Zealand Grassland Association 74: 77-84. | Inter-annual weather variation has profound effects on pasture production and pastoral farm performance. However, the relationship between the variation in herbage and animal production and farm economic and environmental (nitrate leaching and greenhouse gas emission) outcomes are not clearly quantified, especially with varying farm management strategies applied under variable weather scenarios. The authors found that farm economic and environmental outcomes did not respond proportionally to pasture production; compared with the variation range in herbage production, the variation range in animal production was smaller, but the variation range in farm profitability was larger. Environmental efficiency (nitrate leaching and greenhouse gas emissions per unit of animal products) was high in wet years. |
| The Climate and Weather of Southland, 2nd ed. | Macara, G.R., 2013, The Climate and Weather of Southland, 2nd ed., *NIWA Science and Technology Series No. 63* | Regional climatology report for Southland Region. |
| Likely impacts of climate change: how could climate change affect my region | Ministry for the Environment (MfE) (2018); https://www.mfe.govt.nz/climate-change/likely-impacts-of-climate-change/how-could-climate-change-affect-my-region/southland | Summary information on climate change impacts at a regional scale |
| An initial assessment of the potential effects of climate change on New Zealand agriculture | Tait, A., Baisden, T., Wratt, D., Mullan, B., and Stroombergen, A. (2008). An initial assessment of the potential effects of climate change on New Zealand agriculture. New Zealand Science Review. Vol. 65 (3), p.50-56. | Work undertaken recently by NIWA also suggests that, for a range of climate change scenarios, drought risk will increase in some currently drought-prone areas of New Zealand. Agricultural productivity in at least some regions, and hence national gross domestic product (GDP), might be affected by these projected climatic changes. This paper documents an initial assessment of the effect of projected climate changes on New Zealand agriculture. Improvements in production are projected in Southland and the West Coast – regions which are projected to remain moist while warming. |
| Impact of carbon farming on performance, | Vibart, R.E.; Vogeler, I.; Devantier, B.; Dynes, R.; | As New Zealand's agriculture moves steadily towards implementing the Kyoto protocol, a better understanding |

| | | |
|---|---|---|
| environmental, and profitability aspects of sheep and beef farming systems in Southland | Rhodes, T.; Allan, W. 2011. Impact of carbon farming on performance, environmental, and profitability aspects of sheep and beef farming systems in Southland. In: Adding to the knowledge base for the nutrient manager. Eds. Currie, L.D.; Christensen, C.L. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, New Zealand. pp12. http://flrc.massey.ac.nz/ publications.html | of, and methods to reduce or offset, on-farm greenhouse gas (GHG) emissions become increasingly important. This study used the whole-farm system models FARMAX® and OVERSEER® to examine feed flow, nutrient balance, livestock emissions and profitability from sheep and beef farming scenarios in Southland. Increasing level of intensification resulted in greater amounts of sheep meat and beef, and to a lesser extent wool, produced per ha. This was associated with substantial increases in feed conversion efficiency (kg dry matter intake per kg animal product) and farm profit, although these results varied with land-use capability. Intensifying production was also associated with increased methane (CH4) and nitrous oxide (N2O) emissions at a farm level; CO2 equivalents per stocking unit (kg CO2-e/SU), however, was similar among all scenarios, and CO2 equivalents per unit of production (kg CO2-e/kg produced) decreased with intensification. |
| Southland climate change impact assessment. | Zammit, C., Pearce, P., Mullan, B., Sood, A., Collins, D., Stephens, S., Woolley, J.M., Bell, R., and Wadhwa, S. (2018). Southland climate change impact assessment. NIWA Report. Accessed 13 July 2020 from http://www.goredc.govt.nz/ assets/documents/meetings /2019/20190514-southland-climate-change-assessment.pdf | Building on the assessment of future changes in New Zealand's climate (based on six model projections), this report addresses potential impacts of climate change on a range of components of climate, hydrology and coastal processes across Southland. |
| **Ecology and biodiversity** | | |
| Assessment of two drain clearance methods in the Waihopai Catchment | Allibone, R. and Dare, J. (2015) Assessment of two drain clearance methods in the Waihopai Catchment. Accessed 13 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Assessment%20of%20two%20drain%20clearance%20methods%20in%20the%20Waihopai%20Catchment.pdf | The Waihopai River, Southland, is subject to the effect of siltation and prolific macrophyte growth which can reduce water flow and impede the drainage of adjacent land. To address these issues, Environment Southland maintains stream channels within this catchment by clearing sediment and macrophytes on a three-yearly basis. However, drain clearance can also have negative impacts on instream communities. Drainage maintenance was undertaken to assess the ecological effects of two different drain clearance methods, monitor the effects of clearance on downstream water quality, and quantify the difference in costs associated with the two different drain clearing methods. |
| Ecological characterisation, | Biggs, B.J.F., Duncan, M.J., | A programme of research to characterise, classify, and |

| | | |
|---|---|---|
| classification, and modelling of New Zealand rivers: An introduction and synthesis | Jowett, I.G., Quinn, J.M., Hickey, C.W., Davies-Colley, R.J. and Close, M.E. (1990) Ecological characterisation, classification, and modelling of New Zealand rivers: An introduction and synthesis, New Zealand Journal of Marine and Freshwater Research, 24:3, 277-304 | model New Zealand rivers according to hydrological, water quality, and biological properties is introduced. The results are detailed in the accompanying eight research papers. These studies provide a national perspective on water quality and biology in New Zealand's rivers using a consistent methodology. They are also the first step toward providing managers with robust models for predicting the effects on aquatic biota of changes in flow regimes and catchment land use. A synthesis of the results is given in this paper together with recommendations for riverine ecoregions in New Zealand. |
| Aparima River hydraulic and habitat modelling | Bind, J., Hoyle, J., Willsman, A., and Haddadchi, A. (2018). Aparima River hydraulic and habitat modelling. National Institute of Water & Atmospheric Research Ltd report. Accessed 13 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/2018%20Aparima%20River%20hydraulic%20and%20habitat%20modelling%20Stage%201_%20Data%20report.%20NIWA%202018225CH.pdf | This study is a two-dimensional (2d) hydraulic modelling study of a representative reach of the Aparima River, spanning several pool-riffle sequences, to underpin assessment of physical habitat suitability for trout, native fish and benthic invertebrates and net rate of energy intake (NREI) modelling for drift feeding trout. |
| Habitat preferences of giant kokopu, Galaxias argenteus | Bonnett, M.L. and Sykes J.R.E. (2002) Habitat preferences of giant kokopu, Galaxias argenteus, New Zealand Journal of Marine and Freshwater Research, 36:1, 13-24 | The giant kokopu (Galaxias argenteus (Gmelin 1789)) is endemic to New Zealand, and is regarded as threatened. A perceived decline of the species has been attributed mostly to the loss and degradation of its habitat. To determine habitat requirements, information from the New Zealand Freshwater Fisheries Database, and from field surveys in the South Island were analysed. These indicated that five habitat features are important: in-stream cover, deep water, low water velocity, proximity to the sea, and overhead shade/riparian cover. |
| Lamprey (Geotria australis; Agnatha) reddening syndrome in Southland rivers, New Zealand 2011–2013: laboratory findings and epidemiology, including the incidental detection of | Brosnahan, C. L., Pande, A., Keeling, S. E., van Andel, M., & Jones, J. B. (2018). Lamprey (Geotria australis; Agnatha) reddening syndrome in Southland rivers, New Zealand 2011– | From 2011, lamprey (Geotria australis) populations in Southland, New Zealand have been affected by reddening along the length of the body and increased mortalities, termed lamprey reddening syndrome (LRS). Histopathology did not indicate an infectious process was involved, but suggested the reddening may be due to blunt trauma. Epidemiological investigation found the Mokoreta |

| | | |
|---|---|---|
| an atypical Aeromonas salmonicida | 2013: laboratory findings and epidemiology, including the incidental detection of an atypical Aeromonas salmonicida. New Zealand Journal of Marine and Freshwater Research, 1–21. doi:10.1080/00288330.2018.1556167 | River had a significantly higher prevalence of LRS than others in the Southland region, but there was no clear reason why. |
| An empirical test of freshwater vicariance via river capture. | Burridge, C. P., Craw, D., & Waters, J. M. (2007). An empirical test of freshwater vicariance via river capture. Molecular Ecology, 16(9), 1883–1895. | River capture is a geomorphological process through which stream sections are displaced from one catchment to another, and it may represent a dominant facilitator of interdrainage transfer and cladogenesis in freshwater-limited taxa. However, few studies have been conducted in a manner to explicitly test the biological significance of river capture. A multispecies phylogeographical analysis is used to test whether the nonmigratory fish fauna of the Von River (South Island, New Zealand) is the product of a well-documented, Late Quaternary capture of a section of the Ōreti River (Southland drainage). River capture is responsible for the nonmigratory fish fauna of the Von River. In a broader context, river capture has frequently influenced the distribution of genetic lineages among catchments in New Zealand freshwater-limited fish, and its biogeographical significance may have been underestimated in other regions. |
| Assessment of three lowland Southland lakes using LakeSPI: Lake George, Lake Vincent, and The Reservoir | Burton, T., Wells, R., and Taumoepeau, A. (2015). Assessment of three lowland Southland lakes using LakeSPI: Lake George, Lake Vincent, and The Reservoir. National Institute of Water & Atmospheric Research Ltd report. Accessed 16 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/southland_lakespi.pdf | NIWA was contracted by Environment Southland to assess the ecological condition of three lowland coastal lakes: George, Vincent and The Reservoir, using LakeSPI (Submerged Plant Indicators). The LakeSPI method provides a cost-effective bio-assessment tool for monitoring and reporting on the ecological condition of lakes using submerged vegetation characteristics, and compliments other forms of condition monitoring such Trophic Level Index (TLI). Of the three lowland coastal lakes surveyed in November 2014, Lake George is categorised as in 'excellent' condition and The Reservoir and Lake Vincent as in 'high' condition. |
| Contaminants in estuarine and riverine sediments and biota in Southland | Cavanagh, J., and Ward, N. (2014). Contaminants in estuarine and riverine sediments and biota in Southland. Accessed 13 July | Estuarine and riverine sediments and biota in Southland were sampled for a range of contaminants by Environment Southland in May 2013. This report assesses the potential environmental and human health effects arising from the contaminants observed in sediments and biota from the |

| | | |
|---|---|---|
| | 2020 from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/environment/science/science-summary-reports/contaminants_in_estuarine_and_riverine_sediments_and_biota_in_southland_2014.pdf | Jacobs River and New River estuaries and surrounding rivers and provides recommendations for ongoing monitoring. |
| Current and historic wetlands of Southland Region: Stage 2 | Clarkson, B., Briggs, C., Fitzgerald, N., Rance, B., Ogilvie, H. (2011). Current and historic wetlands of Southland Region: Stage 2. Accessed 10 July 2020 from https://envirolink.govt.nz/assets/Envirolink/903-ESRC231-Current-and-historic-wetlands-of-Southland-Region-Stage-2.pdf | Environment Southland contracted Landcare Research to classify and digitally map current and historic wetlands in Southland, excluding the Department of Conservation (DOC)- administered wetlands of Fiordland National Park and Stewart Island. The project incorporates the recently completed detailed vegetation data of the DOC-administered Awarua-Waituna wetland complex on the Southland Plains. The large extent of the loss of wetlands (90%) in the Southland region study area indicates that virtually all remaining wetlands could be considered significant. Some wetland classes could be considered more important than others based on the extent of loss, with the order of significance being swamp>marsh>fen>bog. |
| Measurement of Impacts of Introduced Pest Animals on Indigenous Biodiversity Values in Southland | Coleman, J.D., and Norbury, G. (2006) Measurement of Impacts of Introduced Pest Animals on Indigenous Biodiversity Values in Southland | Methods for monitoring the impact of vertebrate pest animal control on the biodiversity of indigenous flora and fauna were investigated by Landcare Research for Environment Southland. Monitoring the effects of vertebrate pest control undertaken by community groups in Southland's remnant native habitats should be based on techniques that are reasonably robust and cost-efficient, and are easy to use. |
| Faecal indicator bacteria in New Zealand freshwater fish: a pilot study | Coxon, S., Harding, J. S., & Gilpin, B. (2019). Faecal indicator bacteria in New Zealand freshwater fish: a pilot study. New Zealand Journal of Marine and Freshwater Research, 1–10. | Recent studies have suggested that poikilothermic animals, such as fish, may represent a previously overlooked source of the faecal indicator bacteria (FIB) used for the assessment of water quality. However, quantitative studies of FIB in poikilotherms are scarce. This study investigated the presence of FIB in the faeces of five freshwater fish species. The findings suggest that FIB ingested from the environment may be capable of replication within the fish gut, making fish a potential source and transport mechanism for FIB in New Zealand freshwaters. |
| A Directory of Wetlands in New Zealand. | Cromarty, P., and Scott D. (1996). A Directory of Wetlands in New Zealand. Department of Conservation, Wellington, New Zealand. Accessed 13 | This report summarizes the general situation of the wetlands in New Zealand, and provides information on the institutional and legal base for wetland conservation and research. Then follows a series of accounts of those wetlands, grouped according to Department of Conservation Conservancies, which are known or thought |

| | | |
|---|---|---|
| | July 2020 from https://www.doc.govt.nz/globalassets/documents/science-and-technical/nzwetlands13.pdf | to be of greatest importance from the point of view of nature conservation. The site descriptions include basic information on size and location, physical features, ecological features, ownership, degree of protection, land use, threats and conservation values. |
| Late Quaternary river drainage and fish evolution, Southland, New Zealand | Craw, D., Burridge, C., Anderson, L., & Waters, J. M. (2007). Late Quaternary river drainage and fish evolution, Southland, New Zealand. Geomorphology, 84(1-2), 98–110. | Late Quaternary to Holocene landscape evolution in southern New Zealand was dominated by glacial outwash processes. Evolution of the drainage network on a regional scale was punctuated by numerous river capture events associated with outwash transport and deposition. River capture events can be inferred from geological and topographic observations throughout the region. Independent evidence for river capture and drainage reorientation can be obtained from genetic studies of a freshwater-limited fish (*Galaxias* 'southern', informal name). Geological and genetic data in combination provide powerful tools for the elucidation of local and regional geomorphic evolution where river capture is an important process. The potential is strong for genetic data alone to provide information on the relative and absolute timing of river capture events, but must be interpreted in the context of severance of water connections between catchments and subsequent isolation of freshwater-limited populations |
| The Ecological Effects of Bed Relevelling on the Wairio Stream | Dare, J. and Allibone, R. (2016). The Ecological Effects of Bed Relevelling on the Wairio Stream. Accessed 14 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Wairio%20Stream%20Ecological%20Impact%20of%20Stream%20Re-levelling.pdf | Environment Southland carried out a before after control impact (BACI) study prior to lowering the bed of Wairio Stream in western Southland. Fyke net data showed that large brown trout and long fin eels dispersed away from the treatment reaches following re-levelling, and the Trout Habitat Quality Index (THQI) work suggested that re-levelling had a substantial impact on the occurrence of adult brown trout habitat. However, the juvenile THQI was not affected due to juvenile brown trout preferring to reside in shallow water habitat, similar to that created by the re-levelling process. Impacts on spawning habitat were uncertain, but spawning in re-levelled reaches is likely to be reduced as fewer large brown trout are supported following the channel works. |
| Freshwater biodiversity: importance, threats, status and conservation challenges | Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.H., Soto, D., Stiassny, M.L. and Sullivan, C.A., 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. | This article explores the special features of freshwater habitats and the biodiversity they support that makes them especially vulnerable to human activities. Threats to global freshwater biodiversity: overexploitation; water pollution; flow modification; destruction or degradation of habitat; and invasion by exotic species. They advocate continuing attempts to check species loss but, in many situations, urge adoption of a compromise position of management for biodiversity conservation, to provide a viable long-term basis for freshwater conservation. Recognition will require |

| | | |
|---|---|---|
| | *Biological reviews*, *81*(2), pp.163-182. | adoption of a new paradigm for biodiversity protection and freshwater ecosystem management – 'reconciliation ecology'. |
| Conservation status of New Zealand freshwater fishes, 2017. | Dunn, N.R., Allibone, R.M., Closs, G.P., Crow, S.K., David, B.O., Goodman, J.M., Griffiths, M., Jack, D.C., Ling, N., Waters, J.M., Rolfe, J.R. (2018); Conservation status of New Zealand freshwater fishes, 2017. Department of Conservation. *New Zealand Threat Classification Series 24* | DOC report explaining the conservation status of New Zealand freshwater fish. |
| Guide to the way that Environment Southland monitor estuary health. | Environment Southland (2020). Southlands monitored estuaries: A Guide to estuary ecosystem health monitoring. | Description of the classification and monitoring programme for estuaries in Southland. |
| Environment Southland Wetland Inventory and Monitoring Project | Ewans, R. (2018). Environment Southland Wetland Inventory and Monitoring Project. Accessed 13 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/ES%20Wetland%20Inventory%20and%20Monitoring%20Project%20final%20report%202018.pdf | This project expanded on an earlier 2011 wetland inventory in Southland, to monitor wetlands on non-public conservation land and to monitor recent changes in extent. |
| Current and historic wetlands of Southland Region: Stage 1 | Fitzgerald, N., Clarkson, B., Briggs, C., (2010). Current and historic wetlands of Southland Region: Stage 2. Accessed 10 July 2020 from https://envirolink.govt.nz/assets/Envirolink/754-ESRC221-Current-and-historic-wetlands-of-Southland-Region-Stage-1.pdf | Environment Southland contracted Landcare Research to classify and digitally map current and historic wetlands in Southland, excluding the Department of Conservation (DOC)- administered wetlands of Fiordland National Park and Stewart Island. The project incorporates the recently completed detailed vegetation data of the DOC-administered Awarua-Waituna wetland complex on the Southland Plains. Large probability errors in in the extent and type of wetlands predicted by the Wetlands of National Importance maps were identified. |

| | | |
|---|---|---|
| Duckling survival and habitat selection of brood-rearing mallard (Anas platyrhynchos) females in Southland, New Zealand | Garrick, E. (2016). Duckling survival and habitat selection of brood-rearing mallard (Anas platyrhynchos) females in Southland, New Zealand (Thesis, Master of Science). University of Otago. | Southland has been long recognized as a productive area for mallard ducks (Anas platyrhynchos) in New Zealand. Populations have declined in recent years, and these declines have coincided with an increased intensity of conversion of sheep and deer farms into pastoral dairy farms. The results show that duckling survival is low in Southland relative to estimates using similar methods from North America. Further, dense nesting cover is selected for by brood-rearing females, but translated into lower duckling survival. Narrow, linear, small patches of dense nesting cover could support a greater abundance of predators, or enable greater foraging efficiency of predators. Mallard females might be selecting habitat to maximise another aspect of their life history (e.g., adult female survival, nest success) at the expense of duckling survival. |
| Duckling survival of mallards in Southland, New Zealand | Garrick, E.J., Amundson, C.L., Seddon, P.J. (2017) Duckling survival of mallards in Southland, New Zealand. The Journal of Wildlife Management. Vol.81, p.858-867. | The southern portion of New Zealand's South Island is a productive area for mallards (Anas platyrhynchos) despite a notable lack of permanent or semi-permanent wetlands. Most broods are reared in pastures that may or may not be flooded with ephemeral water. In recent years, there has been an increased conversion from continuous to sporadic grazing that has resulted in a functional change in the emergent and upland vegetation available for broods. Duckling survival was unaffected by pasture type but increased with duckling age, the presence of ephemeral water, and with greater distance from the nearest anthropogenic structure. Survival was lower for broods of second year (SY) females than for broods of after-second year (ASY) females, in areas with more dense cover, and when ducklings moved, on average, greater daily distances. Cumulative 30-day duckling survival ranged from 0.11 for ducklings of SY females without ephemeral water present to 0.46 for ducklings of ASY females with ephemeral water present. Therefore, increasing available seasonal water sources may increase duckling survival. Further, narrow, linear patches of dense cover present in the study could support a greater abundance of predators or increase their foraging efficiency. As such, managers could consider increasing patch sizes of dense cover to reduce predator efficiency, and employing predator removal in these areas to improve duckling survival. |
| Habitat for female longfinned eels in the West Coast and Southland, New Zealand | Graynoth E. and Niven, K. (2004). Habitat for female longfinned eels in the West Coast and Southland, New Zealand. Science for Conservation. Vol. 238. | Longfinned eels (Anguilla dieffenbachii) are endemic and widely distributed throughout New Zealand. They used to support significant Maori fisheries and were present in very high numbers in most waters. In recent times, land use changes, dams, and commercial fishing have reduced the stocks of large female longfinned eels and, as a consequence, the level of recruitment of juvenile eels to |

| | | |
|---|---|---|
| | | New Zealand may be declining. The objectives of this study were to estimate the amount of habitat present for adult and large female eels in lakes and rivers; and the amount of habitat in waters exposed to and protected from commercial fishing in the Southland and West Coast Conservancies of the Department of Conservation (DOC). About 7% of riverine habitat and 26% of lake habitat is totally protected in DOC reserves. However, because reserves tend to be concentrated in high-country and inland regions which support low densities of eels, the amount of longfinned eel habitat in New Zealand that is protected within DOC reserves is probably less than 10%. Therefore previous concerns about the adequacy of reserves for longfinned eels are still justified and additional measures may be required to ensure the stock is managed on a sustainable basis. |
| Spawning escapement of female longfin eels. | Graynoth, E.; Jellyman, D.; Bonnett, M. (2008). Spawning escapement of female longfin eels. New Zealand Fisheries Assessment Report 2008/7. 57p. | The objective of this study was to determine the adequacy of reserve areas closed to commercial fishing for the survival and escapement of female longfin eels (Anguilla dieffenbachii). About 7% of the present tonnage of longfin eels is in waters that are closed to commercial fishing and have safe egress for migrant females. Another 17% is in waters that are protected in their upper reaches but where migrant females could be fished downstream, and a further 25% is located in small streams that are rarely fished. Therefore about 49% of the total tonnage of eels either in reserves or in streams that are rarely fished. Hydro dams have reduced eel access to waters that could support over 6000 tonnes of longfin eels. Both computer models and field studies indicate that relatively few large female eels are left in fished areas and female escapement is derived mainly (80%) from reserves and unfished small streams. Current escapement is probably less than 20% of historical levels that existed in the 1930s before the start of hydro dam construction and commercial eel fishing. If there is no compensatory improvement in survival rates, persistent declines in recruitment could rapidly reduce eel stocks and escapement to low levels. |
| Drivers of Estuary Ecological Health and Water Quality in the Southland Region | Green, M. (2015). Drivers of Estuary Ecological Health and Water Quality in the Southland Region. National Institute of Water & Atmospheric Research Ltd report. Accessed 16 July 2020 from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/doc | This report reviews the way nutrients and fine sediments cause adverse effects in estuaries in Southland, and then review the drivers. |

| | | |
|---|---|---|
| | ument-library/reports/science-reports/Drivers%20of%20Estuary%20Ecological%20Health%20and%20Water%20Quality%20in%20the%20southland%20Region.pdf | |
| The effects of macrophyte control on freshwater fish communities and water quality in New Zealand streams | Greer, M. J. C. (2014). The effects of macrophyte control on freshwater fish communities and water quality in New Zealand streams (Thesis, Doctor of Philosophy). University of Otago. Retrieved from http://hdl.handle.net/10523/4869 | The ecological effects of macrophyte removal on New Zealand's stream ecosystems are not well understood. This thesis investigated how native fish abundance and diversity are impacted by mechanical excavation of macrophytes, and examined the role suspended sediment and dissolved oxygen play in driving changes in community structure following macrophyte removal. The results of this study indicate that mechanical macrophyte removal is likely to cause significant adverse impacts on fish communities in New Zealand waterways. |
| Southland Protection Strategy. | Harding, M.A. (1999). Southland Protection Strategy. A Report to the Natural Heritage Fund Committee. Accessed 09 July 2020 from https://www.doc.govt.nz/Documents/getting-involved/landowners/nature-heritage-fund/nhf-southland-protection-strategy.pdf | This report assesses the original extent of terrestrial indigenous ecosystems in the Southland Conservancy, the present extent of those ecosystems, and the extent to which they are protected. It identifies opportunities for further protection or restoration of indigenous ecosystems, and identifies relative priorities for the protection of representative ecosystems. |
| Microhabitat Models of Large Drift-Feeding Brown Trout in Three New Zealand Rivers | Hayes, J. W. & Jowett, I. G. (1994) Microhabitat Models of Large Drift-Feeding Brown Trout in Three New Zealand Rivers, North American Journal of Fisheries Management, 14:4, 710-725 | This study examined summer habitat use by 189 drift-feeding brown trout Salmo trutta, 45–65 cm long (fork length), by measuring substrate, depth, mean velocity, focal point velocity use, and adjacent velocity into which fish were feeding in three New Zealand rivers. The authors compared habitat used with habitat available (simulated by hydraulic modeling), and derived habitat use, habitat preference, and logistic regression models of habitat selection. Logistic regression and joint habitat preference models were better predictors of suitable habitat in the rivers for which they were developed than were joint habitat use models. However, joint habitat use models may be more general, because, unlike logistic regression and joint habitat preference models, the predictive success of transferred joint habitat use models was similar to that of models tested on the river for which they were developed. Combined-river habitat use, habitat preference, and logistic regression models are presented for general habitat management applications when habitat criteria are |

| | | |
|---|---|---|
| | | not available for specific rivers. |
| Status of Weed Biological Control Agents in Southland. | Hayes L. (2007), Status of Weed Biological Control Agents in Southland. Landcare Research. Accessed 10 July 2020 from https://envirolink.govt.nz/assets/Envirolink/319-ESRC118.pdf | This report checked the status of weed biocontrol agents in Southland. The establishment success of these follow similar trends to the rest of New Zealand. Climate conditions have not been a major obstacle to establish agents. A considerable number of release sites being destroyed has affected establishment success. More investment will be required to complete biocontrol programmes and reap the benefits. |
| Can Weighted Useable Area Predict Flow Requirements of Drift-Feeding Salmonids? Comparison with a Net Rate of Energy Intake Model Incorporating Drift–Flow Processes | Hayes, J.W., Goodwin, E., Shearer, K.A., Hay, J., and Kelly, L. (2016) Can Weighted Useable Area Predict Flow Requirements of Drift-Feeding Salmonids? Comparison with a Net Rate of Energy Intake Model Incorporating Drift–Flow Processes, Transactions of the American Fisheries Society, 145:3, 589-609 | This study compared a process-based invertebrate drift and drift-feeding net rate of energy intake (NREI) model and a traditional hydraulic-habitat model (using the RHYHABSIM [River Hydraulics and Habitat Simulation] software program) for predicting the flow requirements of 52-cm Brown Trout Salmo trutta in a New Zealand river. Predictions for the relationship between weighted useable area (WUA) and flow were made for three sets of drift-feeding habitat suitability criteria (HSC) developed on three midsized and one large New Zealand river (flow at sampling was 2.8–4.6 m3/s and ~100 m3/s, respectively) and the South Platte River, Colorado (flow at sampling, 7–18 m3/s). Overall, WUA appears to underestimate the flow needs of drift-feeding salmonids. The NREI model showed that assessing flow needs of drift-feeding fish is more complex than interpreting a WUA–flow relationship based only on physical habitat suitability. The relationship between predicted fish abundance and flow is an emergent property of flow-dependent drift-foraging dynamics interacting with flow-dependent drift concentration and drift flux, local depletion of drift by feeding fish, and flow-related replenishment of drift from the bed and dispersion. |
| Habitat use by southern forest geckos (Mokopirirakau 'Southern Forest') in the Catlins, Southland | Hoare, J.M., Melgren, P., & Chavel, E.E. (2013) Habitat use by southern forest geckos (Mokopirirakau 'Southern Forest') in the Catlins, Southland, New Zealand Journal of Zoology, 40:2, 129-136 | Basic biological information is critical to evaluating conservation requirements for native taxa, but is lacking for many cryptic New Zealand lizard species. Southern forest geckos (Mokopirirakau 'Southern Forest') are known only from anecdotes, museum specimens and discoveries of an individual at each of three sites during recent surveys in the Catlins. Most geckos were found by searching a boulder used as a diurnal retreat site or in mānuka (Leptospermum scoparium). Two geckos were radio-tracked; both remained within 5 m of capture and exhibited primarily nocturnal behaviour. We recommend further survey work to identify populations and monitoring to evaluate the need for conservation intervention. |
| Riparian and tuna habitat quality in the tributaries of | Holmes R, Goodwin E, Allen C 2015. Riparian and tuna habitat quality in the | This report applied a broad-scale stream habitat-mapping protocol (BSHMP) to the tributaries of Waituna Lagoon/Waipārera. Overall, riparian habitat in most of the |

| | | |
|---|---|---|
| Waituna Lagoon, Southland. | tributaries of Waituna Lagoon, Southland. Prepared for Department of Conservation/ Fonterra partnership: Living Water programme. Cawthron Report No. 2587. 44 p. plus appendices | catchment can be considered to be in average– good condition. In general, in-stream habitat condition for tuna in the catchment can be considered poor–average. Banks in reaches where stock have access to the stream edge are significantly less stable than reaches that have full stock-exclusion fencing. |
| Longfin tuna and brown trout habitat quality indices for interpreting habitat quality score data | Holmes, R 2016. Longfin tuna and brown trout habitat quality indices for interpreting habitat quality score data. Prepared for Environment Southland. Envirolink No.1632-ESRC161. Cawthron Report No. 2843. 7 p. plus appendices. | This report adds value to the Habitat Quality Score (HQS) method by providing a technique to calculate fish habitat quality indices based on data collected using the HQS protocol. The HQS tuna and trout habitat parameter scores are derived from existing literature reviews and fish habitat quality indices which are documented in the Broad-scale Stream Habitat Mapping Protocol report series. |
| Mechanically reshaping stream banks alters fish community composition. | Holmes, R. J., Hayes, J. W., Closs, G. P., Beech, M., Jary, M., & Matthaei, C. D. (2019). Mechanically reshaping stream banks alters fish community composition. River Research and Applications. doi:10.1002/rra.3407 | Mechanically reshaping stream banks is a common practice to mitigate bank erosion in streams that have been extensively channelised and lowered for land drainage. A common perception regarding this activity is that fish populations will be largely unaffected, at least in the short term, because the low-flow wetted channel remains undisturbed. However, the response of fish populations to this practice has rarely been quantitatively evaluated. The results suggest that, even in highly modified stream channels, further bank modification can reduce instream habitat quality and displace eels for at least 1 year. Managers should endeavour to use bank erosion control measures that conserve bank-edge cover, especially in streams with populations of anguillid eels, because these fish are declining globally. |
| Fire in wetlands and scrub vegetation: studies in Southland, Otago, and Westland. | Johnson, P.N. (2005). Fire in wetlands and scrub vegetation: studies in Southland, Otago, and Westland. Department of Conservation Research and Development Series 215. Accessed 13 July, 2020 from https://www.doc.govt.nz/globalassets/documents/science-and-technical/drds215.pdf | Increased fire frequency since human arrival in New Zealand has led to impacts on wetlands and scrub vegetation that are an issue for conservation management. This report describes studies in a selection of South Island sites, documenting patterns of vegetation recovery after fire, the roles and growth characteristics of manuka (Leptospermum scoparium) in fire-prone vegetation, fire-induced changes to wetland communities, and the role of fire in encouraging invasion by weeds. Management of fire and vegetation are discussed, and comments made on avenues for future research. |
| Models of the Abundance of Large Brown Trout in New | Jowett, I.G. (1992) Models of the Abundance of Large Brown Trout in New Zealand | Multiple-regression models of the abundance of brown trout Salmo trutta larger than 200 mm total length were developed from combinations of hydrological, catchment |

| | | |
|---|---|---|
| Zealand Rivers | Rivers, North American Journal of Fisheries Management, 12:3, 417-432, | (89 sites), physical (59 sites), water quality, and benthic invertebrate biomass (43 sites) variables in New Zealand rivers. Three hydrological and catchment variables explained 44.4% of the variation in trout abundance, and benthic invertebrate biomass alone explained almost 45%. Together, invertebrate biomass and weighted usable area (WUA) for adult brown trout drift-feeding habitat explained 64.4% of the variation in trout abundance. The model best suited to the application of the instream flow incremental methodology (IFIM) explained 87.7% of the variation in brown trout abundance at 59 sites. Two variables were calculated with flow data: WUA for food production at median flow and WUA for adult brown trout drift-feeding habitat at mean annual low flow. This study demonstrates that WUA is an important determinant of adult brown trout abundance, refuting one of the major criticisms of IFIM. |
| Flow regime requirements and the biological effectiveness of habitat-based minimum flow assessments for six rivers. | Jowett, I.G. and Biggs, B.J.F. (2006) Flow regime requirements and the biological effectiveness of habitat-based minimum flow assessments for six rivers, International Journal of River Basin Management, 4:3, 179-189 | Sustaining instream values when there is demand for out-of-stream water use is challenging for water resource managers and often there is considerable debate about the methods used to assess flow requirements. Recommendations for flow regime requirements for benthic invertebrates, trout and indigenous fish were made using instream habitat analyses in six New Zealand rivers. We review the results of studies that were carried out to examine the response of aquatic communities to the flow changes. Although the biological data may not be scientifically rigorous in all cases, the weight of evidence from the various sources indicates that in 5 out of the 6 cases, the biological response and the retention of desired instream values, was achieved using the habitat-based methods for setting flows. |
| A calibrated ecological health assessment for Southland lakes | Kelly D, Schallenberg M, Waters S, Shearer K, Peacock L 2016. A calibrated ecological health assessment for Southland lakes. Prepared for Environment Southland. Cawthron Report No. 2832. 56 p. plus appendices. | This study aimed to review existing frameworks for assessing ecological conditions in lakes and select a framework which may be developed to use for assessing lakes in the Southland region, to develop the selected framework into a robust system which is calibrated nationally using lake typology and which spans the range of anthropogenic pressures, and to assess the ecological condition of Southland's lakes relative to the developed framework. The Southland shallow lakes scores ranged from Excellent to Fair depending on the type of aggregation used. The Ecological Integrity metric scores for the Southland deep lakes Te Anau and Manapouri were scored in the Excellent to Good range. |
| Data and literature review on South Island rivers affected by the invasive non-indigenous alga | Kilroy, C. (2008); Data and literature review on South Island rivers affected by the invasive non-indigenous alga | Review of information available on *Didymosphenia geminate.* |

| | | |
|---|---|---|
| Didymosphenia geminate | Didymosphenia geminate. *NIWA Client Report:* CHC2008-078 | |
| Didymo in New Zealand ten years on | Kilroy, C. (2014); Didymo in New Zealand ten years on. NIWA Newsletter: https://www.niwa.co.nz/freshwater-and-estuaries/freshwater-and-estuaries-update/freshwater-update-62-september-2014/didymo-in-new-zealand-ten-years-on | Review of status of *Didymosphenia geminate* 10 years on from initial discovery. |
| Wild ungulate impacts and management in lowland sites in Southland Region | Latham, A.D.M., Cradock-Henry, N., Nugent, G., Warburton, B., and Byrom, A. (2012) Wild ungulate impacts and management in lowland sites in Southland Region. Accessed 10 July 2020 from https://envirolink.govt.nz/assets/Envirolink/1033-ESRC242-Wild-ungulate-impacts-and-management-in-lowland-sites-in-Southland.pdf | This report summarises the state of knowledge about the current ecological status of wild ungulates (wild deer, feral pigs, and feral goats) in lowland areas in the Southland Region, the impacts that these species can have on native biodiversity, and options for managing expanding wild ungulate populations. |
| A review of the damage caused by invasive wild mammalian herbivores to primary production in New Zealand | Latham, A.D.M., M., Latham, M.C., Norbury, G.L., Forsyth, D.M. & Warburton, B. (2020) A review of the damage caused by invasive wild mammalian herbivores to primary production in New Zealand, New Zealand Journal of Zoology, 47:1, 20-52 | Wild mammalian herbivores can compete with domestic livestock and damage other types of production systems. This paper reviewed damage by wild mammalian herbivores, excluding rodents, to primary production in New Zealand and assessed whether primary producers alter stocking rates in response to changes in forage availability following pest control. The process that primary producers use to decide whether to control wild mammalian herbivores includes complex social and economic factors, but quantitative information is important for weighing up the expected costs and benefits of pest control. However, it is unclear how primary producers manage livestock in response to increases in forage availability following pest control. |
| An ecological survey of the central part of the Eyre Ecological District, northern Southland, New Zealand | Mark, A.F., Dickinson, K.J.M., Patrick, B.H. Barratt, B.I.P., Loh, G., McSweeney, G.D., Meurk, C.D., Timmins, S.M., Simpson, N.C., & Wilson, J.B. (1989) An ecological survey | A Protected Natural Areas (PNA) type multidisciplinary survey of c. 30,000 ha in the central part of the c. 197,500 ha Eyre Ecological District (Mavora Ecological Region) in January 1987 provided data from samples of indigenous beech forest, shrubland, grassland, herbfield, fellfield, bluff, scree and snowbank. The study revealed a wide |

| | | |
|---|---|---|
| | of the central part of the Eyre Ecological District, northern Southland, New Zealand, Journal of the Royal Society of New Zealand, 19:4, 349-384 | spectrum of biological features that are currently unrepresented in reserves and not duplicated in other Crown-owned parts of the District. A Recommended Area for Protection (RAP) of c. 33,000 ha was identified and is documented. It embraces an extensive upland and mountainous area with very high biological, ecological, geomorphological, scenic and recreational values. Completion of the Eyre Ecological District PNA survey is recommended. |
| Description and redescription of Galaxias species (Teleostei: Galaxiidae) from Otago and Southland | McDowall, R. M. & Wallis, G.P. (1996) Description and redescription of Galaxias species (Teleostei: Galaxiidae) from Otago and Southland, Journal of the Royal Society of New Zealand, 26:3, 401-427 | There are two distinct genotypes and morphotypes of fish belonging to Galaxias vulgaris Stokell (sensu lato) in narrow sympatry in Healy Stream, a tributary of the Kye Burn in the Taieri River system, northeastern Otago. Therefore the present taxonomy of the species misrepresents the diversity of these fish. Three species are recognised and described or redescribed, on the basis of morphological and genetic evidence. |
| Effects of riparian grazing and channelisation on streams in Southland, New Zealand. 2. Benthic invertebrates | Quinn, J.M., Williamson, R.B., Smith, R.K., & Vickers, M.L., (1992) Effects of riparian grazing and channelisation on streams in Southland, New Zealand. 2. Benthic invertebrates, New Zealand Journal of Marine and Freshwater Research, 26:2, 259-273 | A survey of benthic invertebrate faunas in riparian-protected, riparian-grazed, and channelised reaches of five Southland streams with catchment sizes of 3–37 km2 was carried out. In small streams (catchment areas 3–10 km2 ; widths 1–4 m), channelisation or intensive grazing by cattle greatly reduced shading by riparian vegetation, resulting in substantial increases in daily maximum temperatures during summer. Channelisation also caused gross changes in channel morphology and intensive grazing of a reach with moist streamside soils was associated with increased bed sedimentation and bank damage. Marked changes in invertebrate communities were associated with these habitat modifications. These results indicate that in small streams, with median natural channel widths below c. 6 m, the effects on benthic invertebrates decrease in the following order, channelisation > intensive grazing by cattle > extensive grazing by cattle and/or sheep. Shade provided by riparian vegetation appears to play a vital role in maintaining cool, headwater, stream habitats for benthic invertebrate communities in these streams. |
| Satellite tracking of kereru (Hemiphaga novaeseelandiae) in Southland, New Zealand: impacts, movements and home range | Powlesland, R.G., Moran, L.R., and Wotton, D.M. Satellite tracking of kereru (Hemiphaga novaeseelandiae) in Southland, New Zealand: impacts, movements and home range. New Zealand Journal of Ecology (2011) | Satellite transmitters (PTTs) were attached to four kereru (New Zealand pigeon, Hemiphaga novaeseelandiae) in Invercargill, Southland, New Zealand, during 2005–06. The transmitters were used to monitor the birds' locations, movements and home ranges. Given the long-distance movements kereru make, often to locations distant from roads and tracks, satellite telemetry is probably the most reliable and cost-effective method of determining their locations. |

| | | |
|---|---|---|
| | 35(3): 229- 235 | |
| Broad Scale Intertidal Habitat Mapping of Awarua Bay | Robertson, B., Stevens, L., Thompson, S., and Robertson, B. (2004). Broad Scale Intertidal Habitat Mapping of Awarua Bay. Cawthron Report No. 941. Accessed 16 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Broad%20Scale%20Intertidal%20Habitat%20Mapping%20of%20Awarua%20Bay%202004.pdf | This report summarises the results of a detailed point-in-time, spatial survey of major habitats in the intertidal regions of Awarua Bay, the estuary arm that extends east from Bluff Harbour. |
| Broad Scale Intertidal Habitat Mapping of Bluff Harbour. | Robertson, B., Stevens, L., Thompson, S., and Robertson, B. (2004). Broad Scale Intertidal Habitat Mapping of Bluff Harbour. Cawthron Report No. 940. Accessed 16 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Broad%20Scale%20Intertidal%20Habitat%20Mapping%20of%20Bluff%20Harbour%202004.pdf | This report summarises the results of a detailed point-in-time, spatial survey of major habitats in the intertidal regions of Bluff Harbour. |
| Loss of wetlands since 1990 in Southland, New Zealand. | Robertson, H.A., Ausseil, A., Rance, B., Betts, H., and Pomeroy, E. (2019) Loss of wetlands since 1990 in Southland, New Zealand. New Zealand Journal of Ecology (2019) 43(1): 3355 | This study investigated recent (post 1990) changes in wetland extent to determine if current rates of wetland loss remain a concern for natural resources management. Of the 32,814 ha of wetlands assessed across Southland 3,452 ha were no longer present in the landscape and a further 3,943 ha were at risk. |
| Development Guidelines for a Biological Resources Database for Environment Southland's High Values Area Programme | Rutledge, D. and Spencer, N. (2007) Development Guidelines for a Biological Resources Database for Environment Southland's High Values Area | The High Values Area (HVA) programme is a voluntary programme in which landowners nominate their sites for inclusion. This report asseses Environment Southland’s information needs for HVA programme and recommends development guidelines for a regional biological resources database to meet, first, the needs of the HVA programme |

| | | |
|---|---|---|
| | Programme. Accessed 10 July 2020 from https://envirolink.govt.nz/assets/Envirolink/153-ESRC206.pdf | while considering, second, broader and longer term council needs related to policy development, resource management, and reporting. |
| Diet of feral ferrets (Mustela furo) from pastoral habitats in Otago and Southland, New Zealand | Smith, G.P., Ragg, J.R., Moller, H. & Waldrup, K.A. (1995) Diet of feral ferrets (Mustela furo) from pastoral habitats in Otago and Southland, New Zealand, New Zealand Journal of Zoology, 22:4, 363-369 | In New Zealand, the ferret (Mustela furo) preys upon, and therefore could be threatening, some endemic species and may be involved in the transmission of bovine tuberculosis (Mycobacterium bovis) to domestic stock. The diet of the ferret was studied from prey remains in the digestive tracts of 277 live-trapped animals from Otago and Southland. Lagomorphs constituted 77% of the diet by weight and were identified in 65% of the ferrets sampled. As lagomorphs are such important prey, rabbit control operations may result in short-term increased predation on endemic species; and/or increased consumption of species that serve as a source of infection of Tb (i.e., possums and possibly hedgehogs); and/or a long-term decline in the density of ferrets. |
| A survey of macroinvertebrate communities in seventeen South Island lakes | Stark, J.D. (1993). A survey of macroinvertebrate communities in seventeen South Island lakes. Prepared for the Electricity Corporation of New Zealand. Cawthron Report No. 229. 36 p. | Survey of macroinvertebrate communities in South Island lakes |
| Broad Scale Subtidal Habitat Mapping of Bluff Harbour | Stevens, L and Clarke, M. (2004). Broad Scale Subtidal Habitat Mapping of Bluff Harbour. Cawthron Report No. 916. Accessed 16 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Bluff%20Harbour%20subtidal%20report%20%28Broad%20Scale%20Subtidal%20Habitat%20Mapping%20of%20Bluff%20Harbour%20June%202004%29.pdf | The broadscale habitat mapping approach provides a description of the subtidal environment according to dominant habitat types based on substrate characteristics (mud, sand, cobble, rock, etc) and plants and animals present (e.g. eelgrass, seaweed, shellfish, etc), in order to develop a baseline map. |
| Fortrose (Toetoes) Estuary 2016: Broad Scale Substrate, Macroalgae and Seagrass | Stevens, L.M., and Robertson, B.P. 2017. Fortrose (Toetoes) Estuary | This report provides a brief summary of the results of the 2016 broad scale intertidal habitat mapping of substrate, |

| | | |
|---|---|---|
| Mapping | 2016: Broad Scale Substrate, Macroalgae and Seagrass Mapping. Report prepared by Wriggle Coastal Management for Environment Southland. 28p | macroalgae and seagrass in Fortrose (Toetoes) Estuary. |
| A review of the ecological health and water quality in four Southland estuaries | Townsend, M., and Lohrer, D. (2015). A review of the ecological health and water quality in four Southland estuaries. National Institute of Water & Atmospheric Research Ltd report. Accessed 16 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/A%20review%20of%20the%20ecological%20health%2C%20water%20quality%20and%20drivers%20of%20change%20in%20four%20Southland%20estuaries%20-%20NIWA.pdf | The report includes a relatively detailed review of the methods, analyses and interpretations of data that have been collected in Southland estuaries over a number of years, and an evaluation of the relative status of the four most comprehensively monitored estuaries (Waikawa, Fortrose, Jacobs River, and New River). |
| Multiple-stressor effects on stream health in Southland streams and rivers. | Wagenhoff, A., Matthaei C.D., and Townsend, C.R. (2009). Multiple-stressor effects on stream health in Southland streams and rivers. A report provided to Environment Southland in fulfilment of Envirolink medium advice grant. | The aims of this report were (i) to present analyses of multiple-stressor effects of nutrients and deposited fine sediment on macroinvertebrate community indices commonly used as indicators of stream health by regional councils, in particular to determine whether cause-effect relationships are simple or complex and (ii) to compare different methods and measures of deposited fine sediment in terms of their ability to predict macroinvertebrate community indices but also their cost- and time-efficiency. The report found the change in community structure is the outcome of a combined multiple-stressor effect. Macroinvertebrate community indices (MCI, EPT richness and % EPT) are a function of land-use-related deposited fine sediment on the bed and nutrient status of the water in streams routinely measured by Environment Southland. the measurement of suspended inorganic sediment (SIS) using the Quorer was best at accounting for variation in the macroinvertebrate community indices. |
| A review of benthic macroinvertebrate metrics for assessing stream | Wagenhoff A, Shearer K, Clapcott J 2016. A review of benthic macroinvertebrate | Benthic macroinvertebrates have been used for decades as biological indicators of river and stream health. If macroinvertebrate indicators are to be included in the |

| | | |
|---|---|---|
| ecosystem health | metrics for assessing stream ecosystem health. Prepared for Environment Southland. Cawthron Report No. 2852. 49 p. plus appendices | NPS-FM framework then they need to have connection to defined values. Indicators also need to be quantitatively linked to management options. The currently-used invertebrate indicators in New Zealand do not have these links. At present this is the major constraint for use of macroinvertebrate information in NPS-FM limit-setting framework, particularly when managing the effects of multiple stressors. |
| Consequences to threatened plants and insects of fragmentation of Southland floodplain forests | Walker, S., Rogers, G., Lee, W., Rance, B. Ward, D., Rufaut, C., Conn, A., Simpson, N., Hall, G. and Lariviere, M. (2006). Consequences to threatened plants and insects of fragmentation of Southland floodplain forests. Science for Conservation. 265. | The processes of ecosystem fragmentation and their effects on persistence of key plant and invertebrate groups were investigated within remnants of alluvial podocarp forests in Southland, New Zealand. The ecological integrity of the floodplain ecosystem depends largely on the maintenance of natural hydrological regimes, and their alteration by drainage and flood control works is likely to have profound effects on community composition of remaining floodplain remnants, and adverse consequences for the persistence of its rare plant components. |
| Potential for using a generalised random tessellation stratified (GRTS) survey design to monitor rabbits in Southland | Warburton, B., Williams, M. (2012) Potential for using a generalised random tessellation stratified (GRTS) survey design to monitor rabbits in Southland | Environment Southland (ES) has monitored rabbit abundance and population trends across its region since 1997 using a survey design based on fixed transects allocated to three strata of rabbit proneness. This paper reviewed the council's current methodology for carrying out rabbit monitoring surveys and assessed the potential of a new sampling methodology – based on a spatially balanced, generalised random tessellation stratified (GRTS) design – to address any deficiences identified in the current methodology. Conducting the survey within a GRTS framework is unlikely to cost more than the current survey methodology, and the advantages provided by GRTS outweigh any minimal establishment costs. |
| Scientific approach for Southland Estuaries: in accordance with the National policy statement for Freshwater Management & New Zealand coastal Policy statement. | Ward, N (2016). Scientific approach for Southland Estuaries: in accordance with the National policy statement for Freshwater Management & New Zealand coastal Policy statement. Accessed 14 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Scientific%20approach%20for%20Southland%20 | This document provides clarity around the estuary health programme and collates the review work done to date to achieve lucidity on the further development needed. |

| | | |
|---|---|---|
| | Estuaries.pdf | |
| Mitochondrial DNA phylogenetics of the Galaxias vulgaris complex from South Island, New Zealand: rapid radiation of a species flock | Waters, J. M., & Wallis, G. P. (2001). Mitochondrial DNA phylogenetics of the Galaxias vulgaris complex from South Island, New Zealand: rapid radiation of a species flock. Journal of Fish Biology, 58(4), 1166–1180. | Mitochondrial control region sequence variation was examined in the Galaxias vulgaris complex, a group of freshwater-limited galaxiid fishes endemic to South Island, New Zealand. Molecular clock calibrations suggest that migratory and non-migratory forms, separated by a maximum of 6·4% sequence divergence, diverged no earlier than the mid-late Pliocene. Biogeographical implications of high diversity (eight lineages) in the south (Otago-Southland) and low diversity (one lineage) in central South Island (Canterbury) are discussed. |
| Fine-scale habitat preferences influence within-river population connectivity: a case-study using two sympatric New Zealand Galaxias fish species. | Waters, J. M., & Burridge, C. P. (2015). Fine-scale habitat preferences influence within-river population connectivity: a case-study using two sympatric New Zealand Galaxias fish species. Freshwater Biology, 61(1), 51–56. doi:10.1111/fwb.12675 | Understanding the ecological factors governing population connectivity in freshwater systems represents an ongoing challenge for aquatic biologists. Genetic analysis was used to test the hypothesis that fine-scale habitat preferences can influence within-river connectivity patterns in freshwater-limited fishes. The findings suggest that a combination of main-channel habitat continuity and high water velocity facilitates relatively high connectivity in G. 'southern', whereas G. gollumoides populations are genetically isolated in fragmented low-velocity habitats. Population connectivity can be strongly influenced by habitat preference, leading to profound differences in the phylogeography, diversity and conservation status of freshwater fish lineages. |
| **Environmental Data** | | |
| NZ River Maps: An interactive online tool for mapping predicted freshwater variables across New Zealand | Booker, D.J. and Whitehead, A.L., 2017, NZ River Maps: An interactive online tool for mapping predicted freshwater variables across New Zealand, NIWA: Christchurch, accessed July 2020 from https://shiny.niwa.co.nz/nzrivermaps/ | Online tool displaying modelled freshwater variables. |
| Land and Water Aotearoa | Land and Water Aotearoa (LAWA) (2020); https://www.lawa.org.nz/explore-data/otago-region/ | Summary of environmental monitoring information from regional councils and other sources. |
| Stats NZ Environmental indicators – Groundwater webpage with data download portal | Stats NZ Tataurangа Aotearoa (2020) Ground Water Quality webpage accessed, and data downloaded 20/8/2020. | Summary of groundwater quality across New Zealand compared to Drinking Water Standards New Zealand and other and portal for downloading data. |

| | | |
|---|---|---|
| | https://www.stats.govt.nz/indicators/groundwater-quality | |
| New Zealand Soils Maps | Manaaki Whenua Landcare Research (2020); https://soils-maps.landcareresearch.co.nz/#maps | Online maps of soils in New Zealand |
| Beacon | Environment Southland, 2020, Water monitoring and alerts, accessed July 2020 from http://gis.es.govt.nz/ | Live environmental monitoring data from Environment Southland |
| **Environmental management** | | |
| Improving waterway management through collaborative research: insights from the Melbourne Waterway Research-Practice Partnership | Coleman, R.A., Bathgate, R., Bond, N., Bos, D., Fletcher, T.D., Lovell, B., Morison, P. and Walsh, C.J., 2016. Improving waterway management outcomes through collaborative research: insights. *Melbourne Waterway Research-Practice Partnership. New South Wales*. | The Melbourne Waterway Research-Practice Partnership (MWRPPP) is a new model of waterway management research, focussing on applied research and knowledge exchange. It emphasises active knowledge exchange ensuring shared understanding of management problems and opportunities. The MWRPP has a dual focus of 1) applied research to underpin the improved management of urban and rural waterways and 2) knowledge exchange that integrates research findings and broader science with Melbourne water activities. Knowledge exchange is incorporated early in the research project development and implementation process and planned and delivered with strategic oversight and coordination by the two knowledge brokers, who are responsible for developing a Knowledge Exchange Plan (KEP) that guides key activities on an annual basis. Success depends on commitment of the researchers in communicating outcomes and the commitment of stakeholders to work with the researchers to adopt and use the research outcomes. |
| Managing freshwater quality: Challenges for regional councils. | Controller and Auditor-General (2011). Managing freshwater quality: Challenges for regional councils. Office of the Auditor-General, Wellington. | Report on audit of regional councils' (including Environment Southland) management and control of land use for the purpose of maintaining and enhancing frershwater quality. |
| Managing freshwater quality: challenges and opportunities. | Controller and Auditor-General (2019). Managing freshwater quality: challenges and opportunities. Office of the Auditor-General, | Report on how regional councils (including Environment Southland) manage freshwater quality in their regions. |

| | | |
|---|---|---|
| | Wellington. | |
| Proposed Southland Water and Land Plan | Environment Southland (ES) (2018); Proposed Southland Water and Land Plan. *Regional Plan Document* | Regional Water Plan document |
| Regional Water Plan | Environment Southland (ES) (2010); Regional Water Plan. *Regional Plan Document* | Regional Water Plan document |
| Decision Framework for the Management of Lake Taupo | Howard -Williams, C. (2013). Lake Wānaka – For better or worse? Planning for the future. *Guardians of Lake Wānaka (2013); Seminar Proceedings* | The first early scientific warning trends for Lake Taupo were algal blooms and the greater depletion rate of oxygen. Lake Wanaka currently has low oxygen depletion rate, indicating a healthy state, however because of the long residence time, it is too late for action once effects are clear at surface level. The key thing which came out of the Taupo 2020 consultation was an agreed set of values, which could be relevant to the Lake Wanaka situation. A focus of effort was concentrated on the regulation and controls required to maintain clear water, particularly minimising nitrogen levels. The current process caps nutrient loads and to reduce N loads by 20% through purchasing dairy farms, converting farms etc. Nitrogen trading is still allowed to encourage changes in land use. Lake Taupo serves as an example of the costs needed to install controls once problems are recognised. |
| Intensification of New Zealand agriculture: Implications for biodiversity | Henrik Moller, Catriona J. MacLeod, Julia Haggerty, Chris Rosin, Grant Blackwell, Chris Perley, Sarah Meadows, Florian Weller & Markus Gradwohl (2008) Intensification of New Zealand agriculture: Implications for biodiversity, New Zealand Journal of Agricultural Research, 51:3, 253-263, DOI: 10.1080/00288230809510453. | Working with intensification to identify environmental and social gains at the same time as capturing economic efficiencies is more likely to support biodiversity than simply attempting to stem or reverse intensification. |
| The political economy of a productivist agriculture: New Zealand dairy discourses | Jay, M. (2007). "The political economy of a productivist agriculture: New Zealand dairy discourses". Food Policy. Vol.32, p.266-279. | This paper explores the productivist constructions of environmental management by the New Zealand dairy industry in the context of global economic competition and suggests that despite global pressures of economic competition, it is possible to incorporate non-material values into farm management provided these are recognised and rewarded. |
| Water quality in New | Parliamentary | This report is focused on how current changes in land use |

| | | |
|---|---|---|
| Zealand: Land use and nutrient pollution. | Commissioner for the Environment (2013), Water quality in New Zealand: Land use and nutrient pollution. Accessed 21/11/13, from http://www.pce.parliament.nz/assets/Uploads/PCE-Water-quality-land-use-website.pdf. | are affecting the amounts of nitrogen and phosphorus that end up in fresh water. |
| Regional Effluent Land Application Plan | Southland Regional Council, Regional Effluent Land Application Plan. *Regional Plan Document.* | Regional effluent plan document. |
| **Geomorphology/ Geology** | | |
| Online encyclopedia of New Zealand including description and history of Southland | Grant, D. (2015) Southland region - Geology and landforms. Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/southland-region/page-2 | Brief general introduction to the geology and landforms of Southland |
| Geological Map of New Zealand 1:250,000. GNS Science Geological Map 1 (2nd ed.) | Heron D.W., (custodian), 2018, Geological Map of New Zealand 1:250,000. GNS Science Geological Map 1 (2nd ed.). Lower Hutt, New Zealand.: Institute of Geological and Nuclear Sciences. | Geological Map of New Zealand |
| Low-grade metamorphism of the Takitimu Group, western Southland, New Zealand | Houghton, B.F. (1982) Low-grade metamorphism of the Takitimu Group, western Southland, New Zealand, New Zealand Journal of Geology and Geophysics, 25:1, 1-19 | A 14000 m homoclinal sequence of Lower Permian rhyodacitic to basaltic volcanic, pyroclastic, and epiclastic horizons and shallow intrusives in the Takitimu Mountains, New Zealand, is described. |
| Sedimentology and stratigraphy of Prospect Formation, Te Anau Basin, western Southland, New Zealand | Manville, V. (1996) Sedimentology and stratigraphy of Prospect Formation, Te Anau Basin, western Southland, New Zealand, New Zealand Journal of Geology and | The syntectonic late Miocene—Pliocene Prospect Formation, comprising over 3000 m of gravels and sands, forms the uppermost preglacial unit in the central Te Anau Basin, western Southland, New Zealand. Its inferred distal correlatives, the marine Rowallan Sandstone and Te Waewae Formation, lie to the south in the Waiau Basin. These two units are removed from the Waiau Group and, together with the previously ungrouped Prospect |

| | | |
|---|---|---|
| | Geophysics, 39:3, 429-444, | Formation, are placed in a newly proposed lithostratigraphic unit, the Wilderness Group. |
| **History** | | |
| Landforms chapter in Darby et al. eds., *The Natural History of Southern New Zealand* | Craw, D. and Norris, R.J., 2003, 'Landforms', chapter in Darby et al. eds., *The Natural History of Southern New Zealand*, Dunedin: University of Otago Press. | Description of landforms in Southern New Zealand |
| Introductory paper for NZ Grasslands conference in Invercargill, 2000. | Newson, J. (2000) An introduction to the Southland Region. Proceedings of the New Zealand Grassland Association, 62: 3-5 | Introduction to Southland landscape for conference. |
| Eyre Creek Mélange: an accretionary prism shear-zone mélange in Caples Terrane rocks, Eyre Creek, northern Southland, New Zealand | Pound, K.S., Norris, R.J., and Landis, C.A. (2014). Eyre Creek Mélange: an accretionary prism shear-zone mélange in Caples Terrane rocks, Eyre Creek, northern Southland, New Zealand, New Zealand Journal of Geology and Geophysics, 57:1, 1-20. | The Eyre Creek Mélange, a north–northwest trending 0.5–1 km-wide zone within Caples Terrane rocks in northern Southland, New Zealand, is composed of phyllonite and mylonitic rocks, and includes lenses of spilite, chert and altered microgabbro. This shear-zone mélange (SZM) is enclosed within undifferentiated textural zone IIA Caples Terrane sandstones (Q10F14L76) that are metamorphosed to pumpellyite–actinolite grade. The SZM provides an example of the product of accretionary prism processes that record both sedimentation and deformation during subduction accretion. |
| Geology chapter in Darby et al. eds., *The Natural History of Southern New Zealand* | Reay, T., 2003, 'Geology', chapter in Darby et al. eds., *The Natural History of Southern New Zealand*, Dunedin: University of Otago Press. | Description of geology in Southern New Zealand |
| **Hydrology and hydrogeology** | | |
| Generalized models of riverine fish hydraulic habitat | Booker D.J. (2016) Generalized models of riverine fish hydraulic habitat, Journal of Ecohydraulics, 1:1-2, 31-49 | Physical habitat models are used to relate the availability of suitable habitat to river flows by describing the combined availability of depths, velocities and substrates deemed suitable for a species. Field data are often used to calibrate hydraulic models and therefore calculate availability of suitable physical habitat over a range of flows at a site. This paper describes and tests a parameterize-then-cluster-then-predict strategy that extends physical habitat models across New Zealand. Of the 17 sets of habitat suitability criteria, 12 had predicted habitat–flow |

| | | |
|---|---|---|
| | | patterns that exceeded a set of a priori defined performance criteria, providing evidence that predictions were able to distinguish between-site patterns in relationships between availability of suitable physical habitat and flow at unvisited sites. |
| Hydrochemistry of the Southland Region | Daughney, C.; Rissmann, C.; Friedel, M.; Morgenstern, U.; Hodson, R.; van der Raaij; R.; Rodway, E.; Martindale, H.; Pearson, L.; Townsend, D.; Kees, L.; Moreau, M.; Millar, R.; Horton, T. 2015. Hydrochemistry of the Southland Region, GNS Science Report 2015/24. 217 p. | This study characterises the chemistry of the groundwater and surface water resources of the Southland region. This characterisation of hydrochemistry is intended to assist with the conceptualisation of the regional groundwater-surface water system and inform development of groundwater flow and transport models. |
| Characterising the surface and groundwater interactions in the Waimatuku Stream, Southland | Hitchcock, M. (2014). Characterising the surface and groundwater interactions in the Waimatuku Stream, Southland (Thesis, Master of Science). University of Otago. Retrieved from http://hdl.handle.net/10523/5087 | Surface water and groundwater interactions are inherently complex, include multiple variables, and occur across time and spatial scales. Understanding the connections and interactions of water resources is critical to sustainable water management in New Zealand and mandated under the National Objectives Framework. The aim of this study was to characterise the groundwater and surface water contribution to the Waimatuku Stream, and identifying the spatial and temporal hydrological pathways to streamflow. In particular, this project investigated whether the Aparima River provided a source of water to the Waimatuku via subsurface flow pathways.<br><br>Under normal flow conditions the Waimatuku Stream appears to be fed via groundwater flow derived from precipitation on the land surface, which infiltrates to the water table and then percolates to the stream as suggested by the groundwater flow lines, stable baseflow, geochemical and δ13CDIC signature. The Waimatuku Catchment is groundwater fed from a regional system recharged through the land surface and Bayswater bog. There was no evidence for inter-catchment transfers of water between the Aparima River and the Waimatuku Stream. |
| Flow variability in New Zealand rivers and its relationship to in-stream habitat and biota | Jowett, I.G. and Duncan, M.J. (1990). Flow variability in New Zealand rivers and its relationship to in-stream habitat and biota, New Zealand Journal of Marine and Freshwater Research, 24:3, 305-317 | How variability indices were determined for 130 sites on New Zealand rivers and the sites were divided into groups based on these indices. Flow variability decreased with catchment size and area of lake and, to a lesser degree, with catchment slope. Relationships were found between flow variability, and morphological and hydraulic characteristics. The longitudinal variability of water depth and velocity increased with flow variability, indicating a more pronounced pool/riffle structure in rivers with high |

| | | |
|---|---|---|
| | | flow variability. Mean water velocity at mean annual low, median, and mean flow was higher in rivers of low flow variability than in rivers of high flow variability. There were strong associations with periphyton communities and trout distribution and abundance and a weak association with benthic invertebrate communities. Water velocity was the most important hydraulic variable; it could be linked to changes in water temperature, benthic invertebrate and periphyton community structure, and trout distribution and abundance. |
| Potential evapotranspiration method influence on climate change impacts on river flow: a mid-latitude case study | Koedyk, L. P., & Kingston, D. G. (2016). Potential evapotranspiration method influence on climate change impacts on river flow: a mid-latitude case study. Hydrology Research, 47(5), 951–963. doi:10.2166/nh.2016.152 | Projected changes in 21st century climate are likely to impact water resources substantially, although much uncertainty remains as to the nature of such impacts. A relatively under-explored source of uncertainty is the method by which current and scenario evapotranspiration (ET) are estimated. Using the Waikaia River (New Zealand) as a case study, the influence of a potential ET (PET) method is investigated for a scenario of a 2 W C increase in global mean temperature (the presumed threshold of 'dangerous' climate change). Uncertainty in scenario PET between methods is generally greater than between GCMs, but the reverse is found for runoff. The cause of the reduction in uncertainty from PET to runoff is unclear: the catchment is not water-limited during the summer half-year, indicating that it is not because of actual ET failing to reach the potential rate. |
| General description of history of major catchments in Southern New Zealand | Mager, S. & Horton, S (2018) The Hydrology of Southern New Zealand. Chapter in Strack, M., Wheen, N., Lovelock, B., and Carr, A. (2018) Riverscapes: Research essays on the social context of southern catchments of Aotearoa New Zealand. | Research essay on the characteristics and history of the catchment in the southern part of New Zealand including Otago and Southland. |
| Synthesising water convergent zones for optimised farm contaminant mitigation | Marapara, T., and Jackson, B. (2017). Synthesising water convergent zones for optimised farm contaminant mitigation. Accessed 14 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/ | This project evaluates whether Convergent Zone Mapping can be developed reliably through integrating existing information (high resolution Digital Elevation Models (DEMs), the River Environment Classification, soil data) to provide a hierarchy of place-based priorities for applying mitigation strategies. Areas of water convergence were identified to be widespread around the Waituna catchment. However, at large scale, priority should be placed where the cumulative flow is high, and this coincides with the fifth Strahler order. At farm scale |

| | | |
|---|---|---|
| | document-library/reports/science-reports/2017%2008%20Marapara%20Synthesising%20Water%20Convergence%20Zones%20for%20Optimised%20Farm%20Contaminant%20Mitigation.pdf | priority should focus on all areas of flow convergence. |
| Potential for controlled drainage to decrease nitrogen and phosphorus losses to Waituna Lagoon | McDowell RW, Gongol C, Woodward B. (2012). Potential for controlled drainage to decrease nitrogen and phosphorus losses to Waituna Lagoon. | A brief review of traditional controlled drainage systems highlighted their potential to decrease the load of nitrogen and phosphorus via a combination of decreased flow rates and increased sedimentation and denitrification rates. |
| Shifts in flood and low-flow regimes in New Zealand due to interdecadal climate variations | McKerchar, A.I., and Henderson, R.D. (2003). Shifts in flood and low-flow regimes in New Zealand due to interdecadal climate variations, Hydrological Sciences Journal, 48:4, 637-654 | Thirty-one of the longest available streamflow records for New Zealand were analysed to see whether shifts in flood and low-flow regime occurred in 1977/1978 corresponding to a shift in phase of the Interdecadal Pacific Oscillation. The plots and the tests show that a decrease of flood size has occurred since 1978 in the Bay of Plenty region of the North Island, and that increases in flood size and low-flow magnitude have occurred in the South Island for most rivers with headwaters draining from the main divide of the Southern Alps and Southland. |
| New River Estuary Hydrodynamic Modelling | Measures, R. (2016). New River Estuary Hydrodynamic Modelling. National Institute of Water & Atmospheric Research Ltd report. Accessed 14 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/NewRiverEstuaryModellingReport%202016.pdf | A Delft3D hydrodynamic model was constructed for the New River Estuary in Southland in order to better understand the fate of riverine nutrients and sediments, and inform the limit setting process being undertaken for freshwater management. |
| Groundwater – Surface water investigation of the Waimea Stream, Southland using radon, FODTS and hydrochemistry. | Moreau, M., Rodway, E., Lovett, A.P., Martindale, H. (2018). Groundwater – Surface water investigation of the Waimea Stream, Southland using radon, FODTS and hydrochemistry. Wairakei (NZ): GNS Science. 29 p. | A study on the Waimea Stream to test the effectiveness of an integrated approach combining three techniques to improve understanding of groundwater-surface interaction processes. |

| | | |
|---|---|---|
| Artificial subsurface drainage in Southland | Pearson, L. (2015). Artificial subsurface drainage in Southland. Accessed 15 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Report%20-%20Artificial%20subsurface%20drainage%20in%20Southland.pdf | A framework was developed for estimating where artificial subsurface drainage systems are likely to be present in Southland. Soil permeability and drainage class attributes provided an indication of the density of drainage required to make land suitable for agriculture. Artificial subsurface density classes ranged from none to very high and included categories for non-agricultural areas and the influence of slope on drainage type. |
| Overland flow risk in Southland | Pearson, L. (2017). Overland flow risk in Southland. Accessed 15 July 2020, from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Report%20-%20Overland%20Flow%20Risk%20in%20Southland.pdf | Overland flow, along with deep drainage and subsurface (including artificial) drainage are the three main pathways for the transport of contaminants from land to water. This report assesses the likelihood of overland flow occurring from land surfaces across Southland. |
| Identifying Pollutant Sources within the Waimea Catchment: Applying hydrochemical tracers to surface water time series data. | Rissmann, C. and Pearson, L. (2018). Identifying Pollutant Sources within the Waimea Catchment: Applying hydrochemical tracers to surface water time series data. Land and Water Science Report 2018/15. p54 | This report aimed to increase temporal resolution and understanding of water source and contaminant supply to the Waimea Stream. |
| Ecological Condition of Six Shallow Southland Lakes. | Schallenberg, M., and Kelly, D. (2012). Ecological Condition of Six Shallow Southland Lakes. Cawthron Institute, Report No. 2198. Accessed 10 July 2020 from https://envirolink.govt.nz/assets/Envirolink/1097-ESRC248-Ecological-condition-of-six-shallow-Southland-lakes.pdf | This report was commissioned by Environment Southland (ES) to assess the water quality and ecological condition of six shallow Southland lakes. Overall, the mainland Southland lakes were of moderate to good water quality compared to other shallow lakes around New Zealand. It must be emphasised however, that such lakes in New Zealand have generally been heavily impacted by agricultural land use and introductions of numerous noxious invasive fish and macrophyte species. Overall, the submerged macrophyte communities of the Southland lakes have low taxonomic diversity and two of the lakes contain a non-indigenous species. |
| **Land use** | | |

| | | |
|---|---|---|
| Controlled drainage systems to reduce contaminant losses and optimize productivity from New Zealand pastoral systems | DJ Ballantine & CC Tanner (2013) Controlled drainage systems to reduce contaminant losses and optimize productivity from New Zealand pastoral systems, New Zealand Journal of Agricultural Research, 56:2, 171-185 | Drainage systems are essential for managing soil water levels, thereby ensuring optimal plant productivity while protecting soil quality. Although beneficial, drainage systems are also known to be a significant loss route for dissolved nutrients. A potential way of reducing nutrient loss through drainage systems is to use weirs to strategically control drainage of excess water from the soil profile. This review evaluates the scientific literature to ascertain whether controlled drainage could be a useful crop productivity and nutrient loss mitigation tool for New Zealand pastoral farming systems. While a range of risks and potential disadvantages have been identified, evidence from studies of cropped systems with controlled drainage in Europe, Canada and the US suggests that suitably managed controlled drainage offers significant benefits for water quality, agricultural productivity and nutrient- and water-use efficiency. |
| The profitability and risk of dairy cow wintering strategies in the Southland region of New Zealand. | Beukes, P., Gregorini, P., Romera, A., and Dalley, D.E.. (2011). The profitability and risk of dairy cow wintering strategies in the Southland region of New Zealand. Agricultural Systems. 104. 541-550. | A survey amongst stakeholders in 2007 identified wintering systems with less environmental impact and a reliable supply of high quality feed, which are cost effective and simple to implement, as one of the top three issues requiring research and demonstration in the Southland region of New Zealand. This study used a modelling approach to examine the cost effectiveness, exposure to climate-induced risk and major economic drivers of four selected wintering strategies, i.e. (1) grazing a forage brassica crop on support land (Brassica system), (2) grazing pasture on support land (All pasture system), (3) cows fed grass silage, made on the support land, on a loafing pad where effluent is captured (Standoff system), and (4) cows fed grass silage, made on the support land, in a housed facility where effluent is captured (Housed system). The four systems demonstrated different financial strengths and weaknesses that largely balanced out in the end. The Brassica system is a high-risk system from an environmental perspective and the All pasture system an unlikely alternative because of scarcity of suitable land. Both the Housed and Standoff systems appear to be cost effective alternatives that allow high control over cow feeding, body condition and comfort over winter. Furthermore, both systems have the potential to provide high control over the storage and release of animal effluent onto land, thus saving fertiliser costs and reducing environmental footprint. |
| The changing face of southern New Zealand farming: opportunities of land use change | Copland, R.J. & Stevens, D. (2012). The changing face of southern New Zealand farming: opportunities of land use change. | Southern New Zealand has seen major changes in land use in the past 20 years with the rise in dairy cows in milk from 149 000 in 1994 to 682 000 in 2010, while breeding ewe numbers have declined from 11.2 million to 7.3 million over the same period. The development of milking |

| | | |
|---|---|---|
| | Proceedings of the New Zealand Grassland Association. 1-6. 10.33584/jnzg.2012.74.2876. | platforms with a significant need for winter dairy grazing has opened up many opportunities for sheep, beef and deer farmers in the region. The need to remain profitable, displacement of sheep to more marginal land, and social influences such as retaining family ownership have encouraged farmers to make the most of potential land-use change opportunities. Three case studies outline the changes made and potential profitability increases in dairy conversion, flexible sheep and beef operations and improved deer production, with cash surplus after expenses being more than doubled in each case. |
| Opportunities to decrease the water quality impact of spring forage crops on dairy farms | Dennis, S.J., Mcdowell, R.W., Stevens, D.R., & Dalley, D. (2012). Opportunities to decrease the water quality impact of spring forage crops on dairy farms. Proceedings of the New Zealand Grassland Association 74: 45-50 | Currently spring forage crops are used to manage late calving cows on the dairy platform, protect spring pasture from pugging damage, and allow the animals to feed on a mix of brassica and pasture to transition to a pasture-based diet. In addition, like winter forage crops, they could contribute considerable water quality contaminants via surface runoff. However, it may be possible to manage farms without spring forage crops. Two Southland dairy farms were used to show: 1) flowweighted mean concentrations of many water quality contaminants in surface runoff from a spring-grazed forage crop were similar to those found in studies of winter-grazed forage crops; and 2) that, using growth rate data for 2007–2012, in no year was the modelled forage crop beneficial from a feed supply perspective, and in all years the farms had similar financial performances and fewer feed deficits under all-grass management. Hence, good pasture management (e.g. avoiding treading damage using a stand-off pad and short grazing times) may negate the need for a spring forage crop, decreasing contaminant losses while not impairing farm profitability. |
| Effect of sheep stocking intensity on soil physical properties and dry matter production on a Pallic Soil in Southland | Drewry, J.J., Lowe, J.A.H. & Paton, R.J. (1999) Effect of sheep stocking intensity on soil physical properties and dry matter production on a Pallic Soil in Southland, New Zealand Journal of Agricultural Research, 42:4, 493-499 | This 3-year study examined the extent of damage to soil physical properties of a Pukemutu silt loam (Pallic Soil) and the loss of ryegrass-white clover pasture production caused by intensive winter grazing at 1800 sheep $ha^{-1}$. Macroporosity, pore size distribution, bulk density, and hydraulic conductivity were measured at 5-cm incremental soil depths to 15 cm to assess changes in soil compaction. Soil smearing on intensively winter-grazed plots suggested that soil structural damage had occurred. Soil physical tests, three weeks after winter grazing, in August 1994 and 1995, however, showed only slight compaction at the surface. Macroporosity in the 0–5 cm soil depth was significantly reduced from 16.4% to 12.1% by the intensive winter grazing treatment. Soil pores were water-filled leading to plastic deformation rather than compaction. Spring pasture production was also significantly decreased (21%) following the 1994 winter grazing, but growth |

| | | |
|---|---|---|
| | | recovered the following summer. Macroporosity was generally greater than 10% so was unlikely to limit production for long at this site. |
| Effects of cattle treading and natural amelioration on soil physical properties and pasture under dairy farming in Southland, New Zealand | Drewry, J.J., and Paton, R.J. (2000). Effects of cattle treading and natural amelioration on soil physical properties and pasture under dairy farming in Southland, New Zealand, New Zealand Journal of Agricultural Research, 43:3, 377-386 | The effects of current dairy cow grazing practice, reduced levels of grazing, and stock exclusion on soil physical properties and pasture dry matter production were investigated under dairy farming in Southland. Current grazing practice involves rotational grazing with dairy cows from September to May each year, with no grazing during winter. For the reduced grazing treatments, cattle were excluded during the 3rd, or combined 3rd, 4th, and 5th grazing cycles, or for half-day grazing intervals to reduce grazing intensity. Macroporosity increased by 70% in the ungrazed treatment compared with current grazing practice (control) within four months of dairy cow exclusion. Air permeability was increased by over two orders of magnitude 18 months after trial commencement, and saturated hydraulic conductivity increased by 200% to the 10-cm soil depth. Macroporosity, air permeability, and hydraulic conductivity for the reduced grazing treatments were intermediate between the control and ungrazed treatments. |
| Spatially explicit modelling of the impacts of landuse and land-cover change on nutrient inputs to an oligotrophic lake | Fuentes, R., León-Muñoz, J. and Echeverría, C., 2017. Spatially explicit modelling of the impacts of land-use and land-cover change on nutrient inputs to an oligotrophic lake. *International Journal of Remote Sensing*, *38*(24), pp.7531-7550. | This study aims to gain further understanding of the influence of land-use and land-cover changes on aquatic systems characterised by high quality standards. In this study, a spatially explicit model (N-SPECT) was applied to assess whether, in southern-central Chile, the recent land use change could alter the nutrient input to oligotrophic lakes (total nitrogen (TN) and total phosphorus (TP)). The results indicate that to preserve and/or restore the quality of aquatic south-central Chilean ecosystems, it is necessary to modify the current land use: (1) to fundamentally stop the temperate forest degradation and (2) to regulate the expansion of agricultural land in steeper and higher areas. |
| An analysis of the physical condition of two intensively grazed Southland soils | Greenwood, P.R., and McNamara, R.M. (1992). An analysis of the physical condition of two intensively grazed Southland soils. Proceedings of the New Zealand Grassland Association. 54, p.71-75. | The treading effects of high-density winter grazing of sheep associated with all-grass wintering systems in Southland were studied for evidence of resultant soil physical degradation. The results showed that intensive winter grazing in this environment resulted in significant losses of large soil macropores. As a result, the transmission of water through the root-zone was significantly restricted. After rain, this can lead to waterlogging and soil oxygen deficiencies. Probably as a result of cumulative soil damage over several winters, soil had become more compacted to nearly the full depth of the A horizon. Natural ameliorative processes may therefore be too slow to overcome fully the effects of treading. |
| A review of literature on the | Houlbrooke, D. J., Horne, D. | Dairy farming is the largest agricultural industry in New |

| | | |
|---|---|---|
| land treatment of farm-dairy effluent in New Zealand and its impact on water quality | J., Hedley, M. J., Hanly, J. A. and Snow, V. O. (2004). A review of literature on the land treatment of farm-dairy effluent in New Zealand and its impact on water quality, New Zealand Journal of Agricultural Research, 47:4, 499-511 | Zealand, contributing 20% of export earnings but providing a challenge for the environmentally acceptable treatment of wastes from dairy farms. Nutrient-rich farm-dairy effluent (FDE), which consists of cattle excreta diluted with wash-down water, is a by-product of dairy cattle spending time in yards, feed-pads, and the farm dairy. Research on the effects of land treating FDE, and its effects on water quality, has shown that between 2 and 20% of the nitrogen (N) and phosphorus (P) applied in FDE is leached through the soil profile. In all studies, the measured concentration of N and P in drainage water was higher than the ecological limits considered likely to stimulate unwanted aquatic weed growth. Gaps in the current research have been identified with respect to the application of FDE to artificially drained soils, and the lack of research that has taken place with long term application of FDE to land and at appropriate farm scale with realistic rates of application. Whilst the land treatment of FDE represents a huge improvement on the loss of nutrients discharged to fresh water compared with standard two-pond systems, there is room for improvement in the management of FDE land-treatment systems. In particular, it is necessary to prevent the direct discharge of partially treated FDE by taking into account soil physical properties and soil moisture status. Scheduling effluent irrigations based on soil moisture deficits results in a considerable decrease in nutrient loss and may result in a zero loss of raw or partially treated effluent due to direct drainage. |
| Grazing strategies to protect soil physical properties and maximise pasture yield on a Southland dairy farm | Houlbrooke, D.J., Drewry, J.J., Monaghan, R.M., Paton, R.J., Smith L.C., and Littlejohn, R.P. (2009). Grazing strategies to protect soil physical properties and maximise pasture yield on a Southland dairy farm, New Zealand Journal of Agricultural Research, 52:3, 323-336, DOI: 10.1080/00288230909510517 | Intensive dairy cattle grazing on wet soil can have a detrimental effect on soil physical quality and consequently on pasture production. Soil physical properties (porosity, bulk density, saturated hydraulic conductivity) of a Pallic soil (Pukemutu silt loam) and pasture production were assessed on a dairy farm in Southland, New Zealand, under a number of different cattle grazing strategies: (i) normal grazing management on undrained land, (ii) normal grazing practice on drained land, (iii) restricted autumn grazing, (iv) restricted grazing when soil conditions were wet, (v) never pugged, and (vi) never grazed. There were no significant differences in any soil physical properties measured on cattle grazed treatments. Spring pasture yield from the never grazed treatment was greater ($P < 0.05$) than the drained and undrained standard practice grazing treatments for one of the three seasons. The lack of treatment differences in soil physical properties and pasture yield from grazing treatments suggests that the never pugged grazing strategy failed to prevent soil compaction by dairy cows. |
| The influence of soil | Houlbrooke, D.J., | It is widely believed that intensive dairy farming is |

| | | |
|---|---|---|
| drainage characteristics on contaminant leakage risk associated with the land application of farm dairy effluent. | Monaghan, R.M., (2009) The influence of soil drainage characteristics on contaminant leakage risk associated with the land application of farm dairy effluent. | responsible for accelerated contamination of waterways by nutrients, sediment and faecal microorganisms. In particular, farm dairy effluent (FDE) is frequently implicated as a major contributor to the degradation of surface water quality. Soils that exhibit matrix flow (the relatively uniform migration of water through and around soil aggregates) show a very low risk of direct contamination loss of FDE under wet soil moisture conditions. The effectiveness of current effluent best management practices (deferred irrigation and low application rate tools) varies between soil types depending on their inherent risk of direct contamination from land applied FDE. |
| Drainage management in New Zealand | Hudson, H. and Harding, J. (2020). Drainage management in New Zealand. | The literature on drainage maintenance activities, both within and outside New Zealand, was reviewed. Gaps were identified in New Zealand knowledge of how best to manage drains. There was a basic lack of understanding of the effects of current practices on the hydrology and ecology of drains. While much is still to be learned about specific applications, and the cost-effectiveness of best-management practices in New Zealand, several management principles and practices can be tested and implemented immediately |
| River water quality changes in New Zealand over 26 years: response to land use intensity | Julian, J.P., Beurs, K.M.D., Owsley, B., Davies-Colley, R.J. and Ausseil, A.G.E., 2017. River water quality changes in New Zealand over 26 years: response to land use intensity. *Hydrology and Earth System Sciences*, *21*(2), pp.1149-1171. | In this work they test whether land use intensity – the inputs (fertilizer, livestock) and activities (vegetation removal) of land use – is a better predictor of environmental impact. They use New Zealand as a case study and interpreted water quality state and trends for the 26 years from 1989 to 2014 in the National Rivers Water Quality Network (NRWQN) – consisting of 77 sites on 35 mostly large river systems. Using simple multivariate statistical analyses across the 77 catchments, they found that median visual water clarity was best predicted inversely by areal coverage of intensively managed pastures. The primary predictor for all four nutrient variables (TN, NOx , TP, DRP), however, was cattle density, with plantation forest coverage as the secondary predictor variable. While land disturbance was not itself a strong predictor of water quality, it did help explain outliers of land use–water quality relationships. |
| Dynamic simulation of crop rotations to evaluate the impact of different nitrogen management strategies on water quality in Southland, New Zealand. | Khaembah, E., Cichota, R., Zyskowski, R., and Vogeler, I. (2019). Dynamic simulation of crop rotations to evaluate the impact of different nitrogen management strategies on water quality in Southland, New Zealand. | Nitrogen lost from agricultural fields is one of the main causes of water pollution. The evaluation of environmental impacts from agricultural activities at a catchment scale requires integration of modelling tools designed to work at different levels. A dynamic farm systems model is needed in this context, to capture the impacts of land use changes and management decisions on water and nitrogen fluxes in the soil-plant interface. Generated information from this level can then be scaled up by hydrological models to |

| | | |
|---|---|---|
| | | determine the impact of farming activities at the catchment and regional scales. In this work, we used the Agricultural Production Systems sIMulator (APSIM), a process-based farm systems model, to evaluate the effect of fertiliser nitrogen management on crop production and nitrogen leaching from cropping rotations in the Southland region of New Zealand. These results fundamentally show that soil-test based fertiliser application has the potential to increase fertiliser nitrogen use efficiency and reduce the risk of nitrogen loss to the Southland catchment water systems. These results also demonstrate the capability of the APSIM setup to produce realistic crop production levels and account for intra- and inter-season variability in soil nitrogen and weather conditions. |
| Restricted autumn grazing to reduce nitrous oxide emissions from dairy pastures in Southland, New Zealand | de Klein, C.A.M., Smith, L.C., Monaghan, R.M. (2006). Restricted autumn grazing to reduce nitrous oxide emissions from dairy pastures in Southland, New Zealand. Agriculture, Ecosystems and Environment 112 192–199. | Animal excreta deposited on pasture during grazing represent the single largest source of N2O emissions in New Zealand. These emissions are highest when pastures are grazed during the wet autumn/winter season. The strategic use of a feed pad on dairy farms could restrict the amount of excreta N returned to pasture during this time of year, and thus reduce N2O emissions and other environmental losses. Restricted autumn grazing reduced both N2O emissions and NO3 leaching losses from grazed pasture by about 40%. These calculations indicated that restricted autumn grazing could reduce direct and indirect on-farm N2O emissions by 7–11%, and could thus be an effective tool for reducing N2O emissions, while also reducing NO3 leaching losses, and preventing soil and sward damage. The study further highlighted that the currently used IPCC inventory methodology cannot easily account for reductions in national N2O emission following adoption of N2O mitigation strategies. It also reinforced the need for assessing the impact of mitigation strategies at a whole farm level. |
| Land-use impacts on freshwater and marine environments in New Zealand | Larned, S., Booker, D., Dudley, B., Moores, J., Monaghan, R., Baillie, B., Schallenberg, M., Moriarty, E., Zeldis, J., Short, K. (2018); Land-use impacts on freshwater and marine environments in New Zealand. *NIWA Client Report* 2018127CH | Report prepared by NIWA for MfE that outlines the Pressure-State-Impact concept and its application to monitoring environmental state in New Zealand. Highlights the need to better understand the complex relationships between environmental pressures and the resulting impacts. |
| Evidence for the effects of land use on freshwater ecosystems in New Zealand | Larned, S.T., Moores, J., Gadd, J., Baillie, B. & Schallenberg, M. (2019) Evidence for the effects of land use on | To meet the challenges of preventing and reversing adverse effects of land use on ecosystems, management actions need to be founded on strong evidence. We used the pressure-state-impact (PSI) framework to assess evidence of land-use effects on New Zealand freshwater |

| | | |
|---|---|---|
| | freshwater ecosystems in New Zealand, New Zealand Journal of Marine and Freshwater Research | ecosystems. The evidence consisted of published quantitative and categorical associations linking land-use pressures to state changes and ecological impacts in rivers, lakes and aquifers. There was substantial evidence of land-use effects, particularly where land use/land cover (LULC) classes were used as pressure variables. Proportions of catchment area in urban and pastoral LULC were consistently, positively correlated with contaminant levels in water bodies and negatively correlated with ecological-health indicators. |
| Land Use Change in the Southland region. | Ledgard, G. (2013). Land Use Change in the Southland region. Environment Southland Technical Report 2013-13. Accessed 13 July, 2020 from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/environment/science/science-summary-reports/land_use_change_in_the_southland_region.pdf | The purpose of the report is to investigate land use change and intensification across the Southland region, with a focus on change within the agricultural and forestry sectors, particularly since 1995, to meet State of the Environment (SOE) reporting timeframes. The pressures from these land use changes on the environment can be severe. The large-scale loss of indigenous vegetation across the region has accelerated erosion processes, reduced biodiversity and led to the increased sedimentation of the region's water bodies. The recent shift to high nutrient loss, intensive land uses such as dairying and winter cropping has increased pressures on the region's soil, water and air resources to the extent that we are seeing significant declines in soil and water quality across the region. However, this cannot solely be attributable to the expansion in dairying. The pan-agricultural sector intensification and expansion of intensive pastoralism into parts of the landscape previously considered unsuitable for intensive agriculture, due to productive or development expense limitations, is also placing further stress on these resources. |
| The combined impact of land use change and aquaculture on sediment and water quality in oligotrophic Lake Rupanco (North Patagonia, Chile, 40.8S) | León-Muñoz, J., Echeverría, C., Marcé, R., Riss, W., Sherman, B. and Iriarte, J.L., 2013. The combined impact of land use change and aquaculture on sediment and water quality in oligotrophic Lake Rupanco (North Patagonia, Chile, 40.8 S). *Journal of environmental management*, *128*, pp.283-291. | This study looked at the combined influences of land use change and salmon farming on the nutrient concentrations in an oligotrophic, temperate lake in North Patagonian, Lake Rupanco. Four sub-watersheds were examined ranging in disturbance from near pristine forest, to 53% converted, to cropping, to pasture. Nitrogen exports from the tributary subwatersheds increased from 33 kg TN/km2/y to 621 kg TN/km2/y as the proportion of crop and pastureland increased. |
| Soil phosphorus concentrations to minimise potential P loss to surface waters in Southland | McDowell, R.W. Monaghan, R.M., & Morton, J. (2003) Soil phosphorus concentrations to minimise potential P loss to surface waters in Southland, New | Losses of soil-derived P in overland flow induced by artificial rainfall were measured from six pastoral soils under a range of soil Olsen P concentrations. These soils were selected as being typical of the major soil groups that cover much of lowland Southland. Objectives were to establish the magnitude and patterns of soil P release to |

| | | |
|---|---|---|
| | Zealand Journal of Agricultural Research, 46:3, 239-253 | overland flow under a wide range of soil Olsen P concentrations, established by amendment with either P fertiliser or dairy manure. The incorporation of superphosphate or manure into soils increased the soil Olsen P concentration as well as the concentration of P fractions in overland flow. There appeared to be no difference in the trend of P loss relative to Olsen P regardless of the form of P amendment. The magnitude of P loss appeared to be influenced by soil pedological origin, with lower dissolved reactive P (DRP) concentrations measured in overland flow from the Brown soils, compared to the less weathered Recent and Pallic soils. |
| Establishment of a split grass-clover system to improve water quality and profitability | McDowell, R.W., Knowler, K., and Cosgrove, G.P. (2010) Establishment of a split grass-clover system to improve water quality and profitability. Proceedings of the New Zealand Grassland Association 72: 171-176. | Surface water quality can be impaired by phosphorus (P) loss from land. The lower Olsen P requirement of ryegrass compared with clover can, when growing them separately, allow for more targeted application of nutrients and better profitability than is possible for a mixture. Creating areas of low P (e.g. near streams) can improve water quality. Modelled results of a split white clover-ryegrass system for a dairy farmed paddock in Southland, indicated that it would improve profitability by $46/ha, compared with a mixed pasture receiving 150 kg N/ha. The results suggests that in areas such as near streams where runoff is likely to move nutrients such as P to waterways, ryegrass established by cultivation to 15 cm, and the application of P to maintain an Olsen P concentration no greater than agronomically optimum, is a quick method of maintaining pasture production while minimising the loss of P to surface waters. |
| Potential water quality impact and agronomic effectiveness of different phosphorus fertilisers under grazed dairying in Southland | McDowell, R.W. and Smith, L.C. (2012). Potential water quality impact and agronomic effectiveness of different phosphorus fertilisers under grazed dairying in Southland. Proceedings of the New Zealand Grassland Association. 74, p.225-230. | Phosphorus (P) loss from land is a central factor in poor surface water quality in Southland. Much loss of P can occur if surface runoff occurs soon after the application of highly water soluble P fertilisers (e.g. superphosphate). Three P fertilisers (superphosphate, serpentine super, and a Ca-phosphate) of different water solubilities were applied (30 kg P/ha in spring) to a grazed dairy pasture, and the relative agronomic effectiveness and P losses determined. To decrease P losses associated with fertiliser, applications should be timed when runoff events are unlikely for at least 3 weeks following application. If this runoff cannot be avoided, or to ensure P losses are as low as possible, the use of a low water soluble P product may be of benefit. |
| Nutrient losses in drainage and surface runoff from a cattle-grazed pasture in Southland | Monaghan, R.M., Paton, R.J., Smith, L.C., and Binet, C. (2000). Nutrient losses in drainage and surface runoff from a cattle-grazed pasture in Southland. Proceedings of | In response to local concerns about the expanding Southland dairy herd, a 4-year study was initiated in 1995 with the primary objective of quantifying nitrate-N losses to waterways from intensively grazed cattle pastures. Extrapolating the results to a 'typical' dairy pasture in Eastern Southland would suggest that the safe upper limit |

| | | |
|---|---|---|
| | the New Zealand Grassland Association. 62: 99-104. | for annual fertiliser N additions to this site to achieve nitrate in drainage water below the drinking water standard is approximately 170 kg N/ha. |
| Nitrogen and phosphorus losses in mole and tile drainage from a cattle-grazed pasture in eastern Southland, New Zealand | Monaghan, R.M., Paton, R.J., and Drewry, J.J. (2002). Nitrogen and phosphorus losses in mole and tile drainage from a cattle-grazed pasture in eastern Southland, New Zealand Journal of Agricultural Research, 45:3, 197-205. | An experimental system for monitoring drainage outflows from mole- and tile-drained plots is described, and nitrogen (N) and phosphorus (P) losses in drainage are reported for Year 1 of a 4-year study examining nutrient losses in drainage from a pasture in Southland. Twelve plots (0.09 ha), grazed by non-lactating dairy stock, were artificially drained by installing a mole and tile drainage network. The amount of nitrate-N lost in drainage water in this first year of study was 25 kg N/ ha, resulting in a volume-averaged nitrate-N concentration of 6.9 mg N/L. Although this is a significant loss of potentially plant available N, the average nitrate-N concentration of the drainage water was below the 11.3 mg N/L standard adopted by the New Zealand Ministry of Health for acceptable nitrate levels in drinking water. Mean dissolved reactive P and total P concentrations in drainage waters were 23 and 74 µg P/L, respectively. Analysis of forms of P showed 61 % of the total P lost in the drainage was in the form of particulate P, which may reflect the recent introduction of mole and tile drainage to this site. |
| Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand | Monaghan, R.M., Wilcock, R.J., Smith, L.C., Tikkisetty, B., Thorrold, B.S., Costallf, D. (2006). Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand. *Agriculture, Ecosystems & Environment.* 118, p. 211-222 | Linkages between land management activities and stream water quality are reported for a 2480 ha catchment used for dairy farming, sheep–beef farming and forestry in Southland, New Zealand. The approach was to reconcile measured loads of nutrients exported from the catchment with those estimated based on characterisation of farming practices within the catchment. Some land management practices that appear to be key sources of many of these pollutants, including subsurface drainage systems (including the preferential flow of irrigated effluent through these soils), overland flow from the heavy soils used for dairy farming in the catchment and the practice of intensively wintering cows on forage crops. Modeling suggests that a significant improvement in catchment water quality could be achieved through the implementation of targeted best management practices (BMPs) on dairy farms in the catchment. |
| Land use and land management risks to water quality in Southland | Monaghan, R.M., Semadeni-Davies, A., Muirhead, R.W., Elliott, S., and Shankar, U. (2010). Land use and land management risks to water quality in Southland | This review documents some of the effects of agricultural land use practices on water quality in Southland., This report's key conclusions are: (i) the type of farming operation (e.g. sheep v. dairy etc) practised is an important determinant of contaminant losses from land to water, (ii) some landscapes have greater risks of loss (e.g. sloping or poorly drained land) than others, and (iii) these losses can be significantly modified according to land management, and (iv) there remain a considerable number of knowledge |

| | | |
|---|---|---|
| | | gaps in our understanding of land-water transfers of stream contaminants. |
| The impacts of animal wintering on water and soil quality | Monaghan, R.M. (2012). The impacts of animal wintering on water and soil quality | Preliminary research has indicated that areas used for forage crop grazing during winter can potentially make a particularly large contribution to N, P and sediment loss from the total farm system. The concentrations of nitrate-N in drainage from grazed winter forage crops are relatively high. Evidence suggests that much of the sediment lost originates from within the gullies where soil disturbance and overland flow generation is relatively high, and that grazing management can have a very large influence on these yields. Soil damage associated with winter grazing of forage crops can be a particular challenge for paddocks subjected to repeated use for winter forage cropping and grazing, as is sometimes the case on runoff blocks. |
| Management practices and mitigation options for reducing contaminant losses from land to water | Monaghan, R.M. (2016). Management practices and mitigation options for reducing contaminant losses from land to water. Accessed 14 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Mitigation%20Summary_Monaghan_Final.pdf | This document provides a brief description of a range of good agricultural management practices and mitigation measures that are relevant to managing water quality in Southland. |
| Pathways of contaminant transfers to water from an artificially-drained soil under intensive grazing by dairy cows | Monaghan, R.M., Smith, L.C., Muirhead, R.W. (2016) Pathways of contaminant transfers to water from an artificially-drained soil under intensive grazing by dairy cows. Agriculture, Ecosystems and Environment 220, 76-88. | There is limited quantitative understanding of the pathways and temporal patterns involved in the transfer of nitrogen (N), phosphorus (P), faecal bacteria and sediment from grazed temperate pastoral land to water. Because these transfers have the potential to significantly impair water quality, many catchment and community groups want to identify farming systems and management strategies that minimise the risks that farming activities pose for their water quality goals. The concentrations and loads of N, P, sediment and the faecal indicator bacteria *E. coli* (*E. coli*) were measured in mole-pipe drainage (3-year monitoring period) and surface runoff (2-year monitoring period) collected from hydrologically-isolated plots grazed by dairy cattle in southern New Zealand. We also evaluate the effectiveness of restricted autumn grazing management as a strategy that could potentially reduce these losses. Temporal patterns of loss suggest that the management of urinary N deposited in the months preceding winter drainage events is key for reducing |

| | | |
|---|---|---|
| | | potential N losses in drainage. A restricted autumn grazing strategy reduced losses of dissolved N in subsurface drainage by 43% on average, although statistically significant reductions were only observed for 2 of the 3 measurement years. Temporal patterns of P, sediment and *E. coli* fluxes suggest that management strategies which can reduce surface runoff generated during spring on these poorly-drained soil types may be the most effective approach for reducing the impacts of these contaminants on surface water quality. |
| Discussion Paper: A potential methodology for assessing farm dairy effluent systems | Monaghan, R.M., Larenson, S. (2019). Discussion Paper: A potential methodology for assessing farm dairy effluent systems | This report documents the requirements for assessing Farm Dairy Effluent (FDE) systems in a consenting process. A review of research literature suggests that there are 3 key aspects of any proposed FDE system that need particular consideration to ensure the FDE resource is utilised efficiently and risks to the environment are minimised. These are: Ensuring that the proposed FDE system contributes to balanced pasture nutrition and maintenance of soil quality. The use of an assessment process that ensures the hydraulic loading attributes of the proposed FDE system are appropriate for the landscape where FDE is to be applied. Identification of key contaminant pathways and key contaminants of concern are important considerations in this process. Consideration of the nitrogen (N) loss risk (to water) that any FDE system could pose. |
| Spatial analysis of winter forage cropping in Southland and the implications for water quality management | Pearson, L., Couldrey, M., Rodway, E. (2016). Spatial analysis of winter forage cropping in Southland and the implications for water quality management. Accessed 16 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Technical%20Report%20-%20Spatial%20analysis%20of%20winter%20forage%20cropping%20in%20Southland%20%28PDF%29.pdf | This report documents recent work by Landcare Research and Environment Southland to understand the extent of winter forage crops in Southland, and collates advice and technical information on risks to water quality. |
| Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill- | Quinn, J.M., Cooper, A.B., Davies-Colley, R.J., Rutherford, J.C. and Williamson, R.B., 1997. Land | Water quality, habitat, and biota were compared during spring amongst 100 m reaches on 11 streams draining pasture, native (podocarp broadleaf) forest, and exotic pine forest. Differences were greatest between the pasture |

| | | |
|---|---|---|
| country streams | use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill-country streams. *New Zealand journal of marine and freshwater research*, *31*(5), pp.579-597. | and native forest streams. Only 1-3% of incident light reached native and pine forest streams whereas 30% reached pasture streams. Pasture streams had 2.2°C higher mean temperature than the native streams, and 5-fold higher nitrate, 30-fold higher algal biomass, and 11-fold higher gross photosynthesis. Native streams were 60% wider than pasture, with pine streams intermediate. Pine and pasture streams had 3-fold higher suspended solids and fine sediment stored in the streambed than native streams. Woody debris volume was 17-fold greater in pine than pasture streams, with native streams intermediate. Invertebrate taxa richness did not differ between land uses. |
| Grassland farming and water quality in New Zealand | Quinn, J.M., Wilcock, R.J., Monaghan, R.M., McDowell, R.W., Journeaux, P.R. Tearmann, the Irish journal of agri-environmental research, Vol. 7, 69-88. | Pastoral agriculture is the dominant land use in New Zealand and accounted for 49% of merchanised export earnings in 2007. Agriculture has intensified in the last 20 years, with dairy expanding at the expense of sheep and beef farming. Although water quality in New Zealand is relatively good compared with Europe, North America and Asia, many lowland agricultural streams and rivers do not meet guideline values for contact recreational activities (e.g., swimming and water-sports) and the proportion of pastoral land cover with catchments has also been associated with trends in river and lake degradation. Agricultural and water researchers are working with industry to develop a toolbox of mitigation measures to control agricultural impacts on water values. Application of these tools to catchments with sheep and beef, deer or dairy farms has shown water quality benefits. |
| Loss of wetlands since 1990 in Southland, New Zealand | Robertson, H., Ausseil, A., Rance, B., Betts, H. and Pomeroy, E. (2018). Loss of wetlands since 1990 in Southland, New Zealand. New Zealand Journal of Ecology. 43. 10.20417/nzjecol.43.3. | Reports of wetland loss in New Zealand are typically related to the historical, pre-European coverage of wetland ecosystems. It is widely accepted that large areas of wetlands were converted to other land uses prior to the 1990s before comprehensive national and regional environmental legislation was established. This study sought to investigate recent (post 1990) changes in wetland extent to determine if current rates of wetland loss remain a concern for natural resources management. Of the 32 814 ha of wetlands assessed across Southland 3452 ha were no longer present in the landscape and a further 3943 ha were at risk. The predominant cause of the loss of wetlands is conversion to other land use, typically to pasture used for agriculture. |
| Nitrogen and phosphorus losses in overland flow from a cattle-grazed pasture in Southland | Smith, L.C. and Monaghan, R.M. (2003). Nitrogen and phosphorus losses in overland flow from a cattle-grazed pasture in | A field study was conducted to quantify N and P losses in overland flow from a cattle-grazed pasture in eastern Southland. Results indicated that total overland flow was between two to seven times greater from the undrained than from the drained soil. Losses of N and P in overland flow from drained soils were low relative to that measured |

| | | |
|---|---|---|
| | Southland, New Zealand Journal of Agricultural Research, 46:3, 225-237, DOI: 10.1080/00288233.2003.9513549 | in subsurface drainage from these soils. Much of the overland flow, and overland N and P loss, occurred during winter and spring, rather than summer and autumn when annual P fertiliser applications were made. Overland flow and losses of N and P were greatest from the undrained soil receiving 400 kg N ha−1 year−1 and stocked at the equivalent of 3.1 cows ha−1. |
| The effectiveness of different nitrification inhibitor formulations in limiting nitrate accumulation in a Southland pastoral soil | Smith, L.C., Monaghan, R.M., Ledgard S.F., Catto, W.D. (2005) The effectiveness of different nitrification inhibitor formulations in limiting nitrate accumulation in a Southland pastoral soil, *New Zealand Journal of Agricultural Research*, 48:4, 517-529, DOI: 10.1080/00288233.2005.9513685 | In pastoral dairy grazing systems, the high localised nitrogen (N) concentration in urine patches has been identified as a major source of nitrate nitrogen (NO3-N) available for leaching. This study was initiated to investigate the effectiveness of different formulations of a nitrification inhibitor, dicyandiamide (DCD), in limiting NO3-N accumulation in a typical Southland pastoral soil. Applying DCD in a granular form or in conjunction with granular fertiliser was found to be an effective way to limit NO3-N build-up in the soil profile. |
| Long term pasture growth patterns for Southland New Zealand: 1978 to 2012 | Smith, L.C. (2012). Long term pasture growth patterns for Southland New Zealand: 1978 to 2012. Proceedings of the New Zealand Grassland Association. 74: p. 147-152 | Pasture growth rates for Southland were reported by several researchers in the late 1970s and early 1980s. However, pasture species and farm management systems have changed somewhat since then. This paper presents data from measurements at Woodlands, near Invercargill, that have been ongoing since 1977, and discusses some of the variability that has occurred over the years. Measurement of pasture growth was done using a standardised cutting method known as "rate of growth" or moving cages, with measurements every 3 weeks. Annual yields were calculated from 1 June to 31 May of the next year. The pasture growth at Woodlands is characterised by a spring-summer peak of growth followed by a deep winter trough where growth is minimal. Long-term average annual growth was 11.8 t DM/ha for older 'Ruanui' based pasture and 12.7 t DM/ ha for newer 'Nui'/'Supreme'/'Greenstone' ryegrass-based pasture. However the newer pasture produced considerably more (ca.14.2 t DM/ha/year) for an initial period of 3 years, after which time the production dropped back to be similar to the old pasture (ca.12.0 t DM/ha/year). |
| Assessment of Farm Mitigation Options and Land Use Change on Catchment Nutrient Contaminant Loads in the Southland Region | Snelder, T., and Legard, G. (2014). Assessment of Farm Mitigation Options and Land Use Change on Catchment Nutrient Contaminant Loads in the Southland Region. Aqualinc Research Ltd report. Accessed 13 July, 2020 from | This study investigated how nutrient loads in eight large Southland catchments would be changed by on-farm mitigation measures, and the extent to which on-farm mitigation measures could offset the effects of land use change and increasing production on dairy farms on catchment water quality. The key findings of this study are that mitigation measures on farms could result in reductions in nutrient loads discharged in Southland. However, these reductions could be eroded in the future |

| | | |
|---|---|---|
| | https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/environment/science/science-summary-reports/regionalloadslandusemitigationreport_final.pdf | due to ongoing conversion of sheep & beef to dairy farms and production increases on dairy farms. It is concluded that under the status quo of ongoing conversions and increasing production on dairy farms, water quality will not be maintained in the long term even if very stringent mitigation requirements (i.e. M3 on all farms) were to be adopted. Setting limits for catchment nutrient loads and then managing discharges to meet these limits appears to be the most appropriate method for ensuring that the goal of maintaining and improving water quality in Southland will be achieved. |
| Application of a Three-Dimensional Water Quality Model as a Decision Support Tool for the Management of Land-Use Changes in the Catchment of an Oligotrophic Lake | Trolle, D., Spigel, B., Hamilton, D.P., Norton, N., Sutherland, D., Plew, D. and Allan, M.G., 2014. Application of a three-dimensional water quality model as a decision support tool for the management of land-use changes in the catchment of an oligotrophic lake. *Environmental management*, *54*(3), pp.479-493. | We undertook a modelling study to demonstrate science-based options for consideration of agricultural intensification in the catchment of Lake Benmore. Based on model simulations of a range of potential future nutrient loadings, it is clear that different areas within Lake Benmore may respond differently to increased nutrient loadings. This study provides a basis for use of model results in a decision-making process by outlining the environmental consequences of a series of land-use management options and quantifying nutrient load limits needed to achieve defined trophic state objectives. |
| Potential for land use change to dairy in Southland, New Zealand: Impact on profitability and emissions to air and water | Vibart, R.E., Vogeler, I., Dennis, S.B., Burggraaf, V., Beautrais, J., & Mackay, A.D. (2013). Potential for land use change to dairy in Southland, New Zealand: Impact on profitability and emissions to air and water. | Southland has witnessed a pronounced change in its agricultural landscape in recent years. Greater profitability of dairy relative to sheep farming has led to a large number of dairy conversions over the last 20 years, with the scope for further substantive conversions into the future. The economic and social benefits have been extensively reported, but less is understood about the environmental impacts associated with this land use change. To investigate the potential effect of land use change from sheep and beef to dairy on economic and environmental outcomes in the Southland region of New Zealand, farm-scale enterprise simulation models were linked with spatially explicit land resource information. A shift in land use from the current 15% of land area under dairying to a potential 46% led to a large increase in regional profit (76%). The environmental impact from this land use change, however, became substantial, with regional nitrate leaching increasing by 34% and GHG emissions by 24%. Conversion of more farms into dairying increased farm profit, N leaching and GHG emissions in the region compared with the current situation. |
| Cost and effectiveness of mitigation measures for reducing emissions to water and air from pastoral farms | Vibart, R. & Vogeler, I., Dennis, S., Kaye-Blake, W., Monaghan, R., Burggraaf, V., Beautrais, J., and Mackay, | Using a novel approach that links geospatial land resource information with individual farmscale simulation, we conducted a regional assessment of nitrogen (N) and phosphorous (P) losses to water from the predominant mix |

| | | |
|---|---|---|
| in Southland, New Zealand. | Alec. (2015). Cost and effectiveness of mitigation measures for reducing emissions to water and air from pastoral farms in Southland, New Zealand. Conference paper. | of pastoral industries in Southland, New Zealand. An evaluation of the cost and effectiveness of several nutrient loss mitigation strategies applied at the farm-scale, set primarily for reducing N losses and grouped by capital cost and potential ease of adoption, followed an initial baseline assessment. Grouped nutrient loss mitigation strategies were applied on an additive basis on the assumption of full adoption, and were broadly identified as 'improved nutrient management' (M1), 'improved animal productivity' (M2), and 'restricted grazing' (M3). Overall, M1 provided for high levels of regional scale N- and P loss abatement at a low cost per farm without affecting overall farm production, M2 provided additional N-loss abatement but only marginal P-loss abatement, whereas M3 provided the greatest N-loss abatement, but came at a large financial cost to farmers, sheep and beef farmers in particular. The modeling approach provides a farm-scale framework that can be extended to other regions, capturing the interactions between farm types, land use capabilities and production levels, as these influence nutrient losses and the effectiveness of mitigation measures. |
| Land-water interactions in five contrasting dairying catchments: issues and solutions | Wilcock, R.J., Monaghan, R.M., Thorrold, B.S., Meredith, A.S., Betteridge, K. and Duncan, M.J. (2007). Land Use and Water Resources Research, University of Newcastle upon Tyne, Centre for Land Use and Water Resources Research, vol. 7, pages 1-10. | Monitoring of five dairy farming catchment streams in New Zealand shows they have high concentrations of N and P forms and faecal indicator bacteria. Suspended solids (SS) concentrations are sometimes high because of poor riparian management. Trend analysis and specific yields of N, P and SS for two streams that have been monitored for five years indicates that little change has occurred in water quality. However, improved water quality has been detected in the trends for two streams that have been monitored for 10 years, as a result of reductions in point sources and improved stock management (less intensive grazing and better stream bank fencing) that have taken place over the longer period. Surveys of farm management practices have been conducted at two-yearly intervals and best management practices are recommended for farming in each catchment, based on identified linkages between land use and water quality. |
| The Effects of Riparian Protection on Channel Form and Stability of 6 Grazed Streams, Southland, New Zealand. | Williamson, R.B., Smith R.K., and Quinn, J.M. (1990). The Effects of Riparian Protection on Channel Form and Stability of 6 Grazed Streams, Southland, New Zealand. Water Quality Centre Publication No.19. | The effects of grazing animals on stream margins and the benefits of riparian retirement to streambank erosion and aquatic habitat were assessed through the survey of 6 streams and rivers in Southland, New Zealand. Grazing was found to have little effect on channel morphology and bank stability of most streams. |
| Effects of riparian grazing and channelisation on | Williamson, R.B., Smith R.K., and Quinn, J.M. (1991). | The effects of mixed sheep and cattle grazing of stream margins, channelisation, and the benefits of riparian |

| | | |
|---|---|---|
| streams in Southland, New Zealand. 1. Channel form and stability | Effects of riparian grazing and channelisation on streams in Southland, New Zealand. 1. Channel form and stability. New Zealand Journal of Marine and Freshwater Research, 26:2, 241-258 | retirement were assessed through a survey of five streams in Southland, New Zealand. Morphological and vegetation data affecting erosion processes and aquatic habitat were compared among grazed, channelised, and retired reaches. There is no evidence that grazing streambanks in floodplain streams of northern Southland will lead to rapid and severe deterioration of channel form, except in small streams (< 2 m wide) under intensive grazing of wet streamside soils. Generally, the dominant erosion mechanism—the undercutting of banks—is largely unaffected by grazing stream margins. In contrast, channelisation has led to severe streambank and streambed erosion in two of the three streams examined. The major factor in this degradation appears to be straightening and deepening the channel so that underlying uncohesive shingle is exposed to high flows. Riparian retirement had variable effects depending on the stability of the stream channel. On smaller, relatively inactive channels, it reduced localised bank erosion from livestock trampling, especially at cattle crossings. However, this damage (which sometimes can be quite visible) did not lead to significant change in average channel form or width in the 7–15 years since the land has been converted to intensive agriculture from extensively grazed tussock. Retirement also increased vegetation overhang. On the larger channels that were more actively meandering, retirement had comparatively little benefit because any retirement or grazing effects were rapidly overtaken by channel migration. |
| An alternative wintering system for Southland: a comparison of wintering cows outside, on brassica crops versus inside, in a free stall barn in Southland, New Zealand | De Wolde, A. (2006). An alternative wintering system for Southland: a comparison of wintering cows outside, on brassica crops versus inside, in a free stall barn in Southland, New Zealand: a dissertation submitted in partial fulfillment of the requirements for the degree of Master of Professional Studies at Lincoln University. Lincoln University, Lincoln. | In New Zealand, dairy cows generally calve in the spring and produce milk through spring, summer and autumn. This is arranged this way to ensure that there is ample good quality grass available when the cows require it most - in early lactation. In the winter most farmers dry all their cows off to let them gain strength and condition in anticipation of the next calving and lactation. The feeding and tending of the cows during the winter period is generally called "wintering". Cows in the Southern parts of New Zealand are mainly wintered on brassica crops. A common practice is to plough up enough area for winter feed, use the ground for wintering for two years, put the paddocks back into grass and plough up the next lot. This first crop rotation can take up to eight or ten years, but at some stage the first cropping round will run out and paddocks that have had brassica crops in them before will have to be used again. This is when the negative effects are felt in regard to soil structure damage and weed infestation. The viability and sustainability of this system is now in question. This report describes an investigation into the physical, environmental, animal health/ welfare and |

| | | |
|---|---|---|
| | | financial implications of an alternative to this system |
| Remediation Options for Southland Estuaries | Zeldis, J., Measures, R., Stevens, L., Matheson, F., and Dudley, B. (2019). Remediation Options for Southland Estuaries. National Institute of Water & Atmospheric Research Ltd Report. Accessed 13 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Remediation%20Options%20for%20Southland%20Estuaries%202019.pdf | Several estuaries across Southland are in a degraded or threatened state as a result of intensive land use, reclamation of land, contaminants and habitat loss. This investigates eight remediation options that cover a range of potential actions for Southland's estuaries and their marginal habitats. For each remediation option, it identifies the environmental issues addressed, the benefits and feasibility of applying the option, and the likelihood of success with respect to restorative targets. It identifies knowledge gaps, potential ecological side-effects and qualitative costs involved. |
| **Social** | | |
| Survey of Rural Decision Makers in Canterbury, Southland and Waikato. | Brown, P., Small, B., Morgan, F., Lynch, C. Burton, R., de Oca Munguia, O.M., Brown, M. (2013). Survey of Rural Decision Makers in Canterbury, Southland and Waikato. Accessed 10 July 2020 from https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/survey-rural-decision-makers-canterbury-southland-waikato.pdf | This report presents the results of the research project that looks into understanding farmers' responses to policies setting limits on the use of freshwater resources. The purpose of the study is to use the resulting knowledge to improve current quantitative methods used for policy evaluation. Obtaining farmer behavioural data will strengthen the analysis of land-use change and adoption of farm practices, which will provide more realistic predictions for land users' responses to economic instruments. |
| Perceptions of the environment: What New Zealanders think | Colmar Brunton, 2018, Perceptions of the environment: What New Zealanders think, *Research report for Fish and Game NZ* | Fish and Game commissioned report on perceptions of NZ environment. |
| Non-Market Water Values in Southland | Denne, T., Hoskins, S., Webster, G, Jowett, I. (2013) Non-Market Water Values in Southland | This report provides an analysis and discussion of the non-market values that individuals and communities hold for freshwater in Southland. |
| Beyond the Tanker Track: the social influence of dairying in Southland, 1992 | Greenhalgh, J. and Rawlinson, Ph. (2013). Beyond the Tanker Track: | The aim of this study was to investigate the social influence that the recent growth of dairying has had in Southland. Over 60 semi-structured and informal interviews were |

| | | |
|---|---|---|
| to 2012. | the social influence of dairying in Southland, 1992 to 2012. Conference Paper presented at the New Zealand Agricultural and Resource Economics Society. | undertaken with a wide cross-section of organisations and individuals. The overall finding is that dairying has revitalised an ailing Southland economy by creating a wider range of employment opportunities, drawing in a more youthful population, and generating a more diversified economic base. |
| Lake Tourism in New Zealand: An Overview | Hall, C. M., & Stoeffels, M. (2003, July). Lake tourism in New Zealand: an overview. In International Lake Tourism Conference (pp. 2-5). | The notion of 'clean and green' is inextricably linked to the international perception and imaging of New Zealand tourism (Hall and Kearsley 2001). Crystal clear water, green mountains and valleys, and pure white snow, along with the portrayal of traditional elements of Maori culture are all elements of the development of New Zealand tourism as '100% Pure'. For example, a 2003 presentation from Tourism New Zealand, the country's international tourism marketing organisation, noted that what brings tourists to New Zealand was 'fiords and mountain ranges' among other natural and cultural products (Tourism New Zealand 2003a). In addition to '100% Pure' the promotional campaigns developed by Tourism New Zealand in recent years have used the slogans such as '100% Pure Adventure', '100% Pure Solitude' and '100% Pure Adrenaline' and have featured images of 'iconic freshwater bodies including the Southern Lakes, the thermal waters of Rotorua and most recently, Lake Rotorua' (Ministry of Tourism 2004: 2). |
| "I'm not a greenie but…": Environmentality, eco-populism and governance in New Zealand Experiences from the Southland whitebait fishery. | Haggerty, J. H. (2007). "I'm not a greenie but…": Environmentality, eco-populism and governance in New Zealand Experiences from the Southland whitebait fishery. Journal of Rural Studies, 23(2), 222–237. | The experiences of nascent local institutions in regional resource management issues in New Zealand can help to inform the important analytical projects of considering the impacts of neoliberalism on environmental management as well as the meanings of governance as the new order in rural and natural resource management. This study considers how devolved governance shapes individual subject positions relative to the environment in a neoliberal context, deploying Agrawal's optics of ''environmentality'' to analyze a case study of the political ecology of the whitebait fishery in Southland, New Zealand. This research demonstrates that the devolution of resource governance in New Zealand has cultivated empowered, 'accidental environmentalists' and related environmental subjectivities. The extent and quality of individual involvement in governance influences whitebaiters' perceptions of environmental change and resource management priorities. At the same time, a strong 'eco-populist' conceptualization of resource management infuses the fishers' environmental subjectivities and potentially constrains the depth and degree of fishers' opposition to environmental degradation. |
| Conversion of family farms | Forney, J. and Stock, | Deregulation of New Zealand agriculture prompted the |

| | | |
|---|---|---|
| and resilience in Southland, New Zealand | P.V. (2014). Conversion of family farms and resilience in Southland, New Zealand. International Journal of Sociology of Agriculture and Food, 21(1), pp. 7-29. T | growth of dairy farming, particularly in the region of Southland. The formation of the giant cooperative Fonterra only exacerbated the conversion of sheep farms into dairy farms that challenged both farmers' and the region's traditional identity as a sheep country. Interviews with converted farmers show that farming families convert to dairy primarily in an attempt to preserve what is important for them: farm succession and a professional identity. At the community level, conversions to dairy prompted economic revival and a reversal of population loss. This article engages the literature on resilience and rural communities to explore Southland's adaptation to new economic and farming realities while exploring potential shocks in the future around financialization and environmental well-being. |
| Why do good? Understanding the role of farmers' norms and beliefs as predictors of adoption of good management practice in Southland | Luoni, S. (2018). Why do good? Understanding the role of farmers' norms and beliefs as predictors of adoption of good management practice in Southland. Masterate Thesis. Lincoln University. Lincoln. | This research investigates how farmers' norms and beliefs predict adoption of 10 farm specific good management practices (GMPs) for improved water quality in Southland. These GMPs are components of Environment Southland's Water and Land 2020 & Beyond Project. Based on these GMPs, a survey was conducted which was informed by a modified version of Stern's Values-Beliefs-Norms model (mBN). The modification excluded Stern's values and new ecological paradigm components, in order to focus on beliefs and norms as the most proximal determinants of GMP adoption. The mBN assumes a causal linear chain whereas the results suggest that beliefs and norms can independently effect adoption of GMPs. Parts of the model display significance for predicting GMP adoption but overall, the results show the hypothesised mBN model was a poor fit to the observed data. The discussion identifies the potential role of the individual beliefs and norm components as targeted intervention points for desired behaviour change and considers alternative models and their merits for future research |
| National Policy Statement for Freshwater Management Implementation Review Southland – Murihiku | Ministry for the Environment (2017. National Policy Statement for Freshwater Management Implementation. Review Southland – Murihiku. Accessed 13 July 2020 from https://www.mfe.govt.nz/sites/default/files/media/npsfw-implementation-review-regional-chapter-southland.pdf | The information and analysis contained in this report are based on evidence collected from a questionnaire completed by Environment Southland (the Council), a series of interviews and panel discussions with relevant parties, planning documents and associated reports, and the Ministry's ongoing relationships and projects across the region. |
| The Southland Economic Project: Agriculture and | Moran, E., Pearson, L., Couldrey, M., and Eyre, K. | This report brings together a large amount of research on the agriculture sector that industry groups have done as |

| | | |
|---|---|---|
| Forestry. Technical Report | (2017). The Southland Economic Project: Agriculture and Forestry. Technical Report. Publication no. 2019-04. Environment Southland, Invercargill, New Zealand. 340pp | part of The Southland Economic Project. Agriculture occupies 87 percent of the developed land in Southland, and the aim of this research was to develop information on the effectiveness and impacts on profitability of managing nutrient losses within farm production systems. This report highlights Southland's reliance on agriculture, compared to other regions, and it develops a number of themes. One is the role of Southland's environment in the development of agriculture and forestry and, in turn, how this development has modified the environment over the years. Southland's water and land is highly connected, in comparison to many other regions. Water now flows more rapidly through the landscape than in the past, and there are fewer opportunities for the natural processing of nutrients carried in it. Other themes are the complexity and diversity within agriculture, and the connections (and integration) between its different industries, both on-farm and between farms, which were all important considerations in this research. |
| The Southland Economic Project: Urban and Industry. Technical Report | Moran, E., McKay D., Bennett, S., West, S., and Wilson, K. (2018). The Southland Economic Project: Urban and Industry. Technical Report. Publication no. 2018-17. Environment Southland, Invercargill, New Zealand. 383pp | This report brings together a large amount of research on the agriculture sector that industry groups have done as part of The Southland Economic Project. Agriculture occupies 87 percent of the developed land in Southland, and the aim of this research was to develop information on the effectiveness and impacts on profitability of managing nutrient losses within farm production systems. This report brings together research on municipal wastewater that Southland's four councils (Gore District Council, Invercargill City Council, Southland District Council, and Environment Southland) have done within The Southland Economic Project, and aimed to develop information on the financial costs of further managing contaminants in discharges of treated wastewater from municipal schemes. |
| Potential impacts of water related policies in Southland | Kaye-Blake, B., Schilling, C., Monaghan, R., Vibart, R., Dennis, S., and Post, E. (2013). Potential impacts of water related policies in Southland. Accessed 10 July 2020 from https://www.mfe.govt.nz/sites/default/files/potential-impacts-water-related-policies-southland.pdf | This report investigates the impacts of nutrient caps and mandated farm practices in the Southland region on its economy and environment. |
| Southland Region: Economic Impacts of Water Policy Decisions Workstream | McIlrath, L., McDonald, G., Bell, B. (2013). Southland Region: Economic Impacts of Water Policy Decisions | This report provides a regional profile of Southland and highlights current water use trends and implications, and presents an overview of the significant water issues in Southland. |

| | | |
|---|---|---|
| | Workstream | |
| Overview of Studies Assessing the Potential Impact of Scenarios for Setting Water Quality Objectives | Ministry for the Environment, 2013, Overview of Studies Assessing the Potential Impact of Scenarios for Setting Water Quality Objectives, Wellington | The purpose of this study is to help inform community discussions and support policy making by regional councils on the potential economic, environmental, social and cultural impacts of freshwater management options. The study also informs national policy development on the potential impacts of setting freshwater objectives and limits, including proposed national bottom lines, under the National Policy Statement for Freshwater Management 2011. |
| Regional Aspects of Tourism in New Zealand | Oppermann, M. (1994). Regional aspects of tourism in New Zealand. *Regional Studies*, 28(2), 155-167. | Study of regional tourism in New Zealand |
| Determining Community Values for the Waituna Catchment and Lagoon | Wedderburn, L (2015). Determining Community Values for the Waituna Catchment and Lagoon. Accessed 16 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/determining_the_values_for_the_waituna_catchment_and_lagoon_report_-_2015_09_-_agresearch.pdf | This report identifies community values of the Waituna catchment and lagoon, for people at the individual, community, local and regional levels. |
| "They Changed the Rules": Farm Family Responses to Agricultural Deregulation in Southland, New Zealand | Wilson, O. (1994). "They Changed the Rules": Farm Family Responses to Agricultural Deregulation in Southland, New Zealand. New Zealand Geographer, 50(1), 3–13. | Agricultural deregulation in the mid-1980s altered the economic and political climate in which farm families in New Zealand operate. The results of a survey of sheep/beef farmers in Southland shows that the main response to the new conditions and the rural downturn was to 'self-exploit'. Impacts varied, depending on farm finances at the start of the downturn. Farming practices and farmers' attitudes changed but only partly because of deregulation. |
| **Water quality and chemistry** | | |
| Drivers of *Phormidium* Blooms in Southland Rivers and the Development of a Predictive Model. | Atalah, J., Rabel, H. Thomson-Laing, G., Wood, S. (2018). Drivers of *Phormidium* Blooms in Southland Rivers and the Development of a Predictive Model. Cawthron Institute, | The prevalence of toxic benthic cyanobacteria blooms has increased in New Zealand rivers over the last decade. These blooms are most commonly formed by the genus Phormidium. The analysis of environmental drivers revealed a marked seasonal pattern with peak Phormidium cover at the end of the summer and strong site-to-site variability. The relationships with physico-chemical |

| | | |
|---|---|---|
| | Report No. 3196. Accessed 10 July, 2020 from https://envirolink.govt.nz/assets/Envirolink/Reports/1782-ESRC280-Drivers-of-Phormidium-blooms-in-Southland-rivers-and-the-development-of-a-predictive-model.pdf | variables was in general very weak. In general, these findings aligned with patterns described for other rivers nationwide. |
| Analysis of national river water quality data for the period 1998-2007 | Ballantine, D., Booker, D., Unwin, M., Snelder, T. (2010). Analysis of national river water quality data for the period 1998-2007 | This report provides an updated assessment of national river water quality in New Zealand. Analysis of water quality data shows that water quality is highly variable across the country. The trend analyses indicate that trend strength and direction is highly variable across the country. The results suggest that water quality decreased over the 1998 to 2007 period in low-elevation areas and in catchments dominated by pastoral land cover. Over the same period however, NH4-N showed decreasing trends in the same categories. |
| The effects of drain clearing on water quality of receiving environments | Ballantine, D., Hughes, A. (2012). The effects of drain clearing on water quality of receiving environments. NIWA Report. Accessed 10 July, 2020 from https://envirolink.govt.nz/assets/Envirolink/1104-ESRC251-The-effects-of-drain-clearing-on-water-quality-of-receiving-environments.pdf | This study was undertaken to understand the potential water quality impacts of drain clearing, and the effects of the associated release of nutrients and sediments to downstream ecologically sensitive environments. Through drain clearing, total suspended solids concentrations and concentrations of some water variables increased sharply. Total phosphorus concentrations increased. As well as water quality effects, drain clearing significantly affects the morphology of the drain channel, bank vegetation and structure, instream ecology and instream physical conditions. |
| Water quality trends in New Zealand rivers: 1989–2009 | Ballantine, D.J., Davies-Colley, R.J. (2014). Water quality trends in New Zealand rivers: 1989 - 2009. Environmental Monitoring and Assessment 186, 1939–1950 | Recent assessments of water quality in New Zealand have indicated declining trends, particularly in the 40 % of the country's area under pasture. The most comprehensive long-term and consistent water quality dataset is the National Rivers Water Quality Network (NRWQN). Since 1989, monthly samples have been collected at 77 NRWQN sites on 35 major river systems that, together, drain about 50 % of New Zealand's land area. Trend analysis of the NRWQN data shows increasing nutrient concentrations, particularly nitrogen (total nitrogen and nitrate), over 21 years (1989–2009). Total nitrogen and nitrate concentrations were increasing significantly over the first 11 years (1989–2000), but for the more recent 10-year period, only nitrate concentrations continued to increase sharply. Also, the increasing phosphorus trends over the first 11 years (1989–2000) levelled off over the later 10-year period (2000–2009). Conductivity has also increased over the 21 years (1989–2009). Visual clarity has increased |

| | | |
|---|---|---|
| | | over the full time period which may be the positive result of soil conservation measures and riparian fencing. NRWQN data shows that concentrations of nutrients increase, and visual clarity decreases (i.e. water quality declines), with increasing proportions of pastoral land in catchments. As such, the increasing nutrient trends may reflect increasing intensification of pastoral agriculture. |
| Water quality trends in selected shallow lakes in the Waikato region: 1995-2001 | Barnes G. (2002). Water quality trends in selected shallow lakes in the Waikato region: 1995-2001. *Environment Waikato Technical Report No. 2002/11.* | Scientific technical report on water quality trends in Waikato region. |
| Mataura Quantitative Microbial Risk Assessment (QMRA) | Cressey, P., Hodson, R., Ward, N., and Humphries, B. (2017). Mataura Quantitative Microbial Risk Assessment (QMRA). Institute of Environmental Science and Research Limited. Accessed 14 July 2020 from | Available information has been used to estimate the risk of Campylobacter infection associated with children swimming in the Matāura River in the environs of Matāura township using quantitative microbial risk assessment (QMRA). |
| Groundwater Well and/or Bore Assessment – Heddon Bush; Central Southland | Dairy Green (2019). Groundwater Well and/or Bore Assessment – Heddon Bush; Central Southland | Assessment of shallow groundwater wells in Central Southland. Groundwater monitoring wells were identified as a source of groundwater nitrate contamination. |
| Effects of agricultural and urban land cover on New Zealand's estuarine water quality | Dudley, B. D., R. Burge, O., Plew, D., & Zeldis, J. (2020). Effects of agricultural and urban land cover on New Zealand's estuarine water quality. New Zealand Journal of Marine and Freshwater Research, 1–21. doi:10.1080/00288330.2020.1729819 | National-scale analyses of land cover effects on water quality can aid in directing environmental policy. For this study, a coastal water quality database for New Zealand comprising 320 estuarine and coastal sites with records between 2013 and 2018 was compiled. Sites with greater freshwater influence had higher nutrient and faecal indicator bacteria concentrations, and turbidity, indicating that open coast and estuarine water quality is reduced predominantly via flows from the land. Nitrate, ammonium, total and dissolved reactive phosphorus, and water column chlorophyll-a concentrations were greater in estuaries with higher urban land cover and total phosphorus concentrations were greater with higher agricultural land cover. |
| New River Estuary Reclaimed Land Desktop Assessment | e3Scientific Limited (2019). New River Estuary Reclaimed Land Desktop Assessment. e3Scientific Limited report. Accessed 13 July 2020 from | This report collates, summarises and reviews all the information available regarding the contaminated reclaimed land along the eastern Waihopai arm of the New River Estuary in Invercargill, Southland. Understanding the risks associated with the contamination within the study area requires an understanding of the sources, processes |

| | | |
|---|---|---|
| | https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/New%20River%20Estuary%20Reclaimed%20Land%20Desktop%20Assessment%202019.pdf | and sinks in and around the estuary. All available literature pertaining to the environmental setting, history and contamination of the New River Estuary was collated and reviewed to develop a conceptual site model. |
| Stream bank erosion in Murihiku/Southland and why we should think differently about sediment | Ellis, T., Hodgetts, J., and McMecking, J. (2018). Stream bank erosion in Murihiku/Southland and why we should think differently about sediment. Accessed 13 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Stream%20bank%20erosion%20in%20Southland.pdf | This report addresses the problem of understanding, simulating and mitigating problem sediment mobilised from stream bank erosion in Murihiku/Southland, Aotearoa/New Zealand. The main purpose of this report was to determine methods for better-informing stream bank erosion algorithms in the erosion and sedimentation model SedNetNZ. Popular methods for on-site stream bank erosion mitigation, address symptoms, not causes and may ultimately fail, or make matters worse, unless the main drivers are simultaneously addressed. |
| Lake Brunton Broad Scale Habitat Mapping 2019 | Forrest, B., and Stevens, L. (2019). Lake Brunton Broad Scale Habitat Mapping 2019. Salt Ecology Report. Accessed 13 July 2020, from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Lake%20Brunton%20%282019%29%20Broad%20Scale%20Habitat%20Mapping.pdf | This report summarises the results of broad scale habitat mapping of Lake Brunton conducted on 9 March 2019. Based on surveys conducted in 2008, 2009 and 2013, Lake Brunton was identified as being in an early eutrophic state, characterised by poor water clarity and declining macrophytes, a variable presence of algal slime, and areas of anoxic, sulphide rich sediments. These same features persist in 2019. |
| Lake George Broad Scale Habitat Mapping 2019 | Forrest, B., and Stevens, L. (2019). Lake George Broad Scale Habitat Mapping 2019. Salt Ecology Report. Accessed 13 July 2020, from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9 | This report summarises the results of broad scale habitat mapping of Lake George (Uruwera) conducted on 12 March 2019. The 2019 survey revealed no substantive change in macrophyte cover since the last broad scale survey was undertaken in 2013. |

| | | |
|---|---|---|
| | ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Lake%20George%20%282019%29%20Broad%20Scale%20Habitat%20Mapping.pdf | |
| Lake Vincent Broad Scale Habitat Mapping 2019 | Forrest, B., and Stevens, L. (2019). Lake Vincent Broad Scale Habitat Mapping 2019. Salt Ecology Report. Accessed 13 July 2020, from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Lake%20Vincent%20%282019%29%20Broad%20Scale%20Habitat%20Mapping.pdf | This report summarises the results of broad scale habitat mapping of Lake Vincent conducted on 1 March 2019. There have been no substantive changes in the condition of Lake Vincent since the last broad scale survey in 2013. |
| Te WaeWae (Waiau) Lagoon Broad Scale Habitat Mapping 2019 | Forrest, B., and Stevens, L. (2019). Te WaeWae (Waiau) Lagoon Broad Scale Habitat Mapping 2019. Salt Ecology Report. Accessed 13 July 2020, from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Waiau%20Lagoon%20%282019%29%20Broad%20Scale%20Habitat%20Mapping.pdf | This report summarises the results of broad scale habitat mapping of Te WaeWae (Waiau) Lagoon conducted on 6 March 2019. The macrophyte assemblage was more species-rich in 2019 (12 species) than in four earlier surveys conducted annually from 2009-2012 (5-8 species). More significantly, compared with the earlier surveys there was a substantial increase in the percentage cover of macrophytes in the lagoon in 2019. |
| The Reservoir Lagoon Broad Scale Habitat Mapping 2019 | Forrest, B., and Stevens, L. (2019). The Reservoir Lagoon Broad Scale Habitat Mapping 2019. Salt Ecology Report. Accessed 13 July 2020, from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document- | This report summarises the results of broad scale habitat mapping of The Reservoir conducted on 8 March 2019. There have been no substantive changes in marginal vegetation or lake macrophytes since the last broad scale survey in 2013. |

| | | |
|---|---|---|
| | library/reports/science-reports/Waiau%20Lagoon%20%282019%29%20Broad%20Scale%20Habitat%20Mapping.pdf | |
| Human health risks associated with contaminants in Southland waters | Gadd, J. (2019). Human health risks associated with contaminants in Southland waters. National Institute of Water & Atmospheric Research Ltd. | Human health is affected by pathogenic organisms and toxic contaminants: for the latter there is little information on potential human health risks. This report provides a high-level overview of the human health risk of toxic contaminants in waterways, estuaries and their potential sources in Southland that will be relevant in the objective setting process, highlights key sources of toxic contaminants in Southland that should be considered in the objective setting process, ranks the risk of different toxic contaminant sources and activities, and identifies key knowledge gaps with respect to toxic contaminants in Southland and human health risk. |
| New River Estuary sediment sources tracking pilot study | Gibbs, M., Olsen, G., and Stewart, M. (2015). New River Estuary sediment sources tracking pilot study. National Institute of Water & Atmospheric Research Ltd report. Accessed 16 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/New%20River%20Estuary%20sediment%20tracking%20pilot%20study.pdf | This report assesses the sources of sediment accumulating in the New River Estuary and the possible factors that may be exacerbating soil erosion in the estuary catchment. The results show that the major source of the terrigenous sediment in the New River Estuary is associated with bank erosion. |
| Effects of mechanical macrophyte control on suspended sediment concentrations in streams | Greer, M., Hicks, A., Crow, S., & Closs, G. (2016). Effects of mechanical macrophyte control on suspended sediment concentrations in streams. New Zealand Journal of Marine and Freshwater Research, 51(2), 254–278. doi:10.1080/00288330.2016.1210174 | Suspended sediment (SS) is an important pollutant in freshwater ecosystems and can be detrimental to fish communities. Although macrophytes mediate sediment deposition, little effort has been put into determining how their removal affects sediment resuspension. The present study examined the immediate and long-term impacts of mechanical macrophyte removal on SS concentrations in streams. These results demonstrate that macrophyte removal can result in SS levels that have previously been shown to harm fish, and indicate that this activity may be more detrimental to fish than previously thought. |
| River water quality trends and increased dairying in | Hamill, K.D. & McBride, G.B. (2003) River water quality trends and increased | Results indicate that increased dairy farming has been associated with increasing concentrations of dissolved reactive phosphorus. There has been a worsening in other |

| | | |
|---|---|---|
| Southland, New Zealand | dairying in Southland, New Zealand, 37:2, 323-332, DOI: 10.1080/00288330.2003.9517170 | water quality variables (oxidised nitrogen, dissolved oxygen) but these also occurred in non-dairying catchments. |
| Snapshot of Lake Water Quality in New Zealand | Hamill, K., (2006). Snapshot of Lake Water Quality in New Zealand. Ministry for the Environment. | Summarises which lakes in NZ are surveyed over what period and which indicators are used |
| Assessing the State of Periphyton in Southland Streams and Rivers | Hodson, R. and De Silva, N. (2018). Assessing the State of Periphyton in Southland Streams and Rivers. Accessed 13 July, 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Technical%20Report%20-%20Periphyton%20state%20in%20Southland%20-%20September%202018.pdf | This report provides a revised assessment of the state of benthic periphyton commonly referred to as slime algae in the Southland region (expressed as benthic chlorophyll a (chl-a, mg m -2 ), ash-free dry mass (AFDM, g m-2 ), or percentage cover). |
| Water Quality in Southland: Current State and Trends | Hodson, R., Dare, J. Merg, M., and Couldrey, M. (2017) Water Quality in Southland: Current State and Trends. Environment Southland Publication No 2017-04. Accessed 14 July, 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Water%20Quality%20in%20Southland%20-%20Current%20State%20and%20Trends%20-%20April%202017.pdf | The report provides an assessment of the state and trends of water quality in Southland rivers, lakes and groundwater. |
| Monitoring soil quality in intensive dairy-farmed catchments of New Zealand: implications for farm management and | Houlbrooke, D.J., Monaghan, R.M., Drewry, J.J., Smith, C., and McGowan, A. Monitoring soil quality in intensive dairy-farmed catchments of New Zealand: | Soil physical and chemical quality assessments were performed for the predominant soil types within four intensively grazed dairy catchments in New Zealand during the winters of 2001, 2003, 2005 and 2007. The four catchments monitored were in the following regions: Waikato (Toenepi stream), Taranaki (Waiokura stream), |

| | | |
|---|---|---|
| environmental quality | implications for farm management and environmental quality. Accessed 08 July 2020 from https://www.iuss.org/19th%20WCSS/Symposium/pdf/0583.pdf | Canterbury (Waikakahi stream) and Southland (Bog Burn stream). The surveys suggest that, in general, soil quality was good. Mean soil macroporosity was initially low in the Toenepi catchment but is now within the recommended range for good pasture production. All catchments, except the Bog Burn, have showed that soil macroporosity values have increased since the study began. A considerable proportion (76%) of farms within all catchments has higher than optimum concentrations of soil Olsen P. These P concentrations have been maintained despite evidence from farm surveys which suggest that P fertilization rates have decreased. However, changes in soil test status following a change in fertilization policy can be slow to manifest themselves. These high levels are likely to be uneconomic and pose increased risk of P loss to waterways. |
| Physiographics of Southland: Development and application of a classification system for managing land use effects on water quality in Southland | Hughes, B., Wilson, K., Rissmann, C., and Rodway, E. (2016). Physiographics of Southland: Development and application of a classification system for managing land use effects on water quality in Southland. Environment Southland publication number: 2016/11. | Water quality risk for each physiographic zone and variant was identified using assessments of their drainage pathways, and the potential for attenuation or dilution processes to occur along each pathway. This water quality risk assessment was then used to identify appropriate mitigation measures to reduce the effects of land use on water quality to support implementation of the proposed Southland Water and Land Plan. |
| Recreational Waters of Southland 2012/13. | Larkin, G., (2013). Recreational Waters of Southland 2012/13. | This report summarises the results of Environment Southland's 2012/13 microbial monitoring programme. The programme monitors the public health risk from contact recreation at 11 marine beaches, 13 rivers and lakes, and 8 shellfish gathering sites in the region. The report also presents the latest Ministry for the Environment Suitability for Recreation Grades (SFRGs) for Southland marine and freshwater bathing sites. The report also summarised the results of the eight shellfish monitoring sites. |
| Water quality in low-elevation streams and rivers of New Zealand: Recent state and trends in contrasting land-cover classes | Larned, S.T., Scarsbrook M.R., Snelder T.H., Norton, N.J. and Biggs, B.J.F. (2004). Water quality in low-elevation streams and rivers of New Zealand: Recent state and trends in contrasting land-cover classes, New Zealand Journal of Marine and Freshwater Research, 38:2, 347-366, DOI: | River water quality in New Zealand is at great risk of impairment in low elevation catchments because of pervasive land-use changes, yet there has been no nationwide assessment of the state of these rivers. Data from the surface-water monitoring programmes of 15 regional councils and unitary authorities, and the National River Water Quality Network were used to assess the recent state (1998–2002) and trends (1996–2002) in water quality in low-elevation rivers across New Zealand. Assessments were made at the national level, and within four land-cover classes (native forest, plantation forest, |

| | | |
|---|---|---|
| | 10.1080/00288330.2004.9517243 | pastoral, and urban). |
| Colour Classification of 1486 Lakes across a Wide Range of Optical Water Types | Lehmann, M., Nguyen, U., Allan, M., & van der Woerd, H. (2018). Colour classification of 1486 lakes across a wide range of optical water types. *Remote Sensing*, 10(8), 1273. | Remote sensing by satellite-borne sensors presents a significant opportunity to enhance the spatio-temporal coverage of environmental monitoring programmes for lakes, but the estimation of classic water quality attributes from inland waterbodies has not reached operational status due to the difficulty of discerning the spectral signatures of optically active water constituents. Determination of water colour, as perceived by the human eye, does not require knowledge of inherent optical properties and therefore represents a generally applicable remotely sensed water quality attribute. |
| Jacobs River Estuary: Summary of the Ecological Health of the Estuary, Drivers and Issues | Leonard, M. (2019). Jacobs River Estuary: Summary of the Ecological Health of the Estuary, Drivers and Issues. | The purpose of this report is to summarise the ecological state of health of the Jacobs River Estuary, the drivers which affect its health and the issues around setting policy and management objectives to improve Jacobs River Estuary ecological health. |
| Monitoring the impact of farm practices on water quality in the Otago and Southland deer focus farms. | Mcdowell, R.W., Mcgrouther, N., Morgan, G., Srinivasan, M.S., Stevens, D.R., Johnson, M., Copland, R. (2006). Monitoring the impact of farm practices on water quality in the Otago and Southland deer focus farms. Journal of New Zealand Grasslands. 68, 183-188. | Two deer focus farms (1 each in Otago and Southland) were established to showcase how productivity and environmental objectives can coincide. Water quality in the unfenced and partially fenced tributaries was poor with no water quality parameters meeting ANZECC guidelines, whereas water quality in the fenced-off and planted tributary was better. Water exiting the retired area met ANZECC guidelines. Although water quality on parts of both deer farms did not meet ANZECC guidelines, when management practices such as fencing off and the creation of a pond were used water quality improved. More importantly, an area retired from grazing and further development on the Southland DFF showed that water quality could be significantly improved and could be better than that entering the farm. |
| Water quality and the effects of different pastoral animals | McDowell, R.W., & Wilcock, R.J. (2008) Water quality and the effects of different pastoral animals, New Zealand Veterinary Journal, 56:6, 289-296, | Water quality in agricultural catchments tends to be worse than in forested (native or exotic) catchments. Reduced water quality tends to have significant effects on the ecosystem of streams, including increased nuisance algal and plant growth (eutrophication) associated with nutrient input, toxicity to aquatic life due to ammonia, faecal contamination, and loss of habitat or spawning areas due to sedimentation. An analysis of catchment contaminant loads from 38 studies conducted since 1975 was carried out to determine if there were differences in loads between land uses under different livestock (dairy, sheep, sheep-and-beef (mixed), deer) and non-agricultural. Significantly more N was lost from dairy catchments than catchments with other land uses, and more sediment lost |

| | | |
|---|---|---|
| | | from deer catchments than other catchments. |
| Trends in Southland's water quality: a comparison between regional and national monitoring sites for groundwater and rivers. | Moreau, M., Hodson, R. (2015) Trends in Southland's water quality: a comparison between regional and national monitoring sites for groundwater and rivers. GNS Science Consultancy Report. 2014/61. 110p. | This report consists of trend analysis on equivalent time windows for ground and river water systems, compares these systems, as well as comparing trends in water quality between Southland and other regions. |
| Sheep as a Potential Source of Faecal Pollution in Southland Waterways | Moriarty, E. (2017) Sheep as a Potential Source of Faecal Pollution in Southland Waterways. Institute of Environmental Science and Research Limited report. Accessed 14 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Sheep%20as%20a%20potential%20source%20of%20microbial%20contamination%20in%20Southland.pdf | Due to the large number of sheep in Southland (4.1 million), the prolonged survival of E. coli in ovine faeces during the warmer seasons and their daily faecal output (approximately 1 kg per day), a potentially large reservoir of contamination exists in Southland. During rainfall or irrigation generated overland flow could result in considerable contamination of the waterways. |
| Sources of Pollution in the Aparima Freshwater Management Unit | Moriarty, E., Pantos, O., and Coxon, S. (2019). Sources of Pollution in the Aparima Freshwater Management Unit. Institute of Environmental Science and Research Limited report. Accessed 13 July 2020 from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Environment%20Southland%20-%20Aparima%20FMU.pdf | Environmental waters may be impacted by faecal contamination from human and animal sources, including the discharge of municipal sewage or animal effluents, seepage from septic tanks, stormwater and urban run-off, agricultural run-off, and direct deposition by animals, including birds, wildlife, and livestock (where access permits). This report details the results of a study of sources of faecal pollution at 9 freshwater sites within the Aparima Freshwater Management Unit (FMU) in Southland, between December 2014 and September 2015. |
| Sources of Pollution in the Mataura Freshwater Management Unit | Moriarty, E., Pantos, O., and Coxon, S. (2019). Sources of Pollution in the Mataura Freshwater Management Unit. Institute of | Environmental waters may be impacted by faecal contamination from human and animal sources, including the discharge of municipal sewage or animal effluents, seepage from septic tanks, stormwater and urban run-off, agricultural run-off, and direct deposition by animals, |

| | | |
|---|---|---|
| | Environmental Science and Research Limited report. Accessed 13 July 2020 from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Environment%20Southland%20-%20Mataura%20FMU.pdf | including birds, wildlife, and livestock (where access permits). This report details the results of a study of faecal pollution sources at 15 freshwater sites within the Matāura Freshwater Management Unit (FMU) in Southland. |
| Sources of Pollution in the Oreti Freshwater Management Unit | Moriarty, E., Pantos, O., and Coxon, S. (2019). Sources of Pollution in the Oreti Freshwater Management Unit. Institute of Environmental Science and Research Limited report. Accessed 13 July 2020 from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Environment%20Southland%20-%20Oreti%20FMU.pdf | Environmental waters may be impacted by faecal contamination from human and animal sources, including the discharge of municipal sewage or animal effluents, seepage from septic tanks, stormwater and urban run-off, agricultural run-off, and direct deposition by animals, including birds, wildlife, and livestock (where access permits). This report details the results of a study of faecal pollution sources at 13 freshwater sites within the Ōreti Freshwater Management Unit (FMU) in Southland. |
| Sources of Pollution in the Waiau Freshwater Management Unit | Moriarty, E., Pantos, O., and Coxon, S. (2019). Sources of Pollution in the Waiau Freshwater Management Unit. Institute of Environmental Science and Research Limited report. Accessed 13 July 2020 from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Environment%20Southland%20-%20Waiau%20FMU.pdfpdf | Environmental waters may be impacted by faecal contamination from human and animal sources, including the discharge of municipal sewage or animal effluents, seepage from septic tanks, stormwater and urban run-off, agricultural run-off, and direct deposition by animals, including birds, wildlife, and livestock (where access permits). This report details the results of a study of faecal pollution sources at five freshwater sites within the Waiau Freshwater Management Unit (FMU) in Southland. |
| Water Quality Modelling for the Southland Region | Palliser, C and Elliot, S. (2013). Water Quality Modelling for the Southland Region. NIWA Report. Accessed 10 July 2020 from https://www.mfe.govt.nz/si | This report describes the catchment model used to predict median concentrations of TN (total nitrogen), TP (total phosphorus) and E. coli at monitored sites in the Southland region and the loads of these contaminants to estuaries in this region. |

| | | |
|---|---|---|
| | tes/default/files/water-quality-modelling-southland-region.pdf | |
| New River Estuary - CLUES Estuary analysis | Plew, D. (2016). New River Estuary - CLUES Estuary analysis. National Institute of Water & Atmospheric Research Ltd report. Accessed 14 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/New%20River%20Estuary%20CLUES%20-%20Estuaries%202017%20final.pdf | Total nitrogen (TN) concentrations in the New River Estuary are predicted using the CLUES-Estuary approach. CLUES-Estuary is a GIS-based tool that predicts nutrient concentrations in an estuary using a combination of land-use models to predict nutrient loads, and analytical estuary models to calculate the dilution between sea-water and riverine water in the estuary. The model returns a single estimate of time and volume averaged potential total nitrogen (TN) concentration in the estuary for a given nutrient load, tidal prism and freshwater inflow. |
| Waituna Catchment Water Quality Review | Rekker, J., and Wilson, S. (2016). Waituna Catchment Water Quality Review. Lincoln Agritech Limited report. Accessed 1 July 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Waituna%20Catchment%20Water%20Quality%20Review.pdf | This report examined the Mokotua Infiltration Zone (MIZ) concept which was proposed in a recent groundwater technical report on the Waituna catchment, and assesses the catchment boundaries assigned by Environment Southland on the basis of land surface gradient. |
| Physiographics of Southland Part 1: Delineation of key drivers of regional hydrochemistry and water quality | Rissmann, C., Rodway, E., Beyer, M., Hodgetts, J., R., Snelder, T., Pearson, L., Killick, M., Marapara, T. R., Akbaripasand, A., Hodson, R., Dare, J., Millar, R., Ellis, T., Lawton, M., Ward, N., Hughes B., Wilson K., McMecking, J., Horton, T., May, D., Kees, L. (2016). Physiographics of Southland Part 1: Delineation of key drivers of regional hydrochemistry and water quality. Publication No. | The key aim of this work was to better understand and estimate spatial variation in freshwater hydrochemistry at a regional scale in Southland, New Zealand using a physiographic approach. The authors developed a semi-quantitative, mechanistic conceptual model to estimate the hydrochemical variation in ground and surface waters and shallow, soil influenced groundwater. |

| | | |
|---|---|---|
| | 2016/3. | |
| Identifying Pollutant Sources within the Waimea Catchment: Applying Hydrochemical Tracers to Surface Water Time Series Data | Rissmann, C. and Pearson, L. (2018). Identifying Pollutant Sources within the Waimea Catchment: Applying hydrochemical tracers to surface water time series data. Land and Water Science Report 2018/15. p54. | This report aimed to increase temporal resolution and understanding of water source and contaminant supply to the Waimea Stream, using a novel hydrogrpagh separation method to time series water quality data for surface water sites within the Waimea Valley, Southland, New Zealand. |
| A hydrochemically guided landscape classification system for modelling spatial variation in multiple water quality indices: Process-attribute mapping | Rissmann, C.W.F., Pearson, L.K., Beyer, M., Couldrey, M.A., Lindsay, J.L., Martin, A.P., Baisden, W.T., Clough, T.J., Horton, T.W., and Webster-Brown J.G. (2019). A hydrochemically guided landscape classification system for modelling spatial variation in multiple water quality indices: Process-attribute mapping. | Spatial variation in landscape attributes can account for much of the variability in water quality relative to land use on its own. Such variation results from the coupling between the dominant *processes* governing water quality, namely hydrological, redox, and weathering and gradients in key landscape *attributes*, such as topography, geology, and soil drainage. Despite the importance of '*process-attribute'* gradients (PAG), few water quality models explicitly account for their influence. Here a processes-based water quality modelling framework is presented that more completely accounts for the role of landscape variability over water quality – Process-Attribute Mapping (PoAM). Critically, hydrochemical measures form the basis for the identification and mapping of effective landscape attributes, producing PAG maps that attempt to replicate the natural landscape gradients governing each dominant process. Application to the province of Southland (31,824 km2), New Zealand, utilised 12 existing geospatial datasets and a total of 28,626 surface water, groundwater, spring, soil water, and precipitation analyses to guide the identification and mapping of 11 individual PAG. Cross-validated R2 values ranged between 0.81 and 0.92 for median total nitrogen, total oxidised nitrogen, total phosphorus and dissolved reactive phosphorus. |
| Condition of Southland's Shallow, Intertidal Dominated Estuaries in Relation to Eutrophication and Sedimentation: Output 1: Data Analysis and Technical Assessment | Robertson, B.M., Stevens, L.M., Ward, N., and Robertson, B.P., 2017. Condition of Southland's Shallow, Intertidal Dominated Estuaries in Relation to Eutrophication and Sedimentation: Output 1: Data Analysis and Technical Assessment - Habitat Mapping, Vulnerability Assessment and Monitoring Recommendations Related to Issues of Eutrophication | This report summarises and analyses relevant existing Southland SIDE data in order to assess estuary trophic state and fine sediment condition, undertakes an initial assessment of the relationship between catchment nutrient and sediment loads and ecological state, ("proof of concept" assessment), and makes science recommendations. In addition, this includes a review of available water quality data in New River Estuary, estuary bathymetry studies, hydrodynamic modelling of New River Estuary, macroalgal nutrient uptake studies, catchment land use mapping, and catchment sediment and nutrient and load estimates (representing current and historical inputs). |

| | | |
|---|---|---|
| | and Sedimentation. Report prepared by Wriggle Coastal Management for Environment Southland. 172p. | |
| Faecal Source Investigations in Selected Southland Waterways | Rusinol, M., and Moriarty, E. (2014). Faecal Source Investigations in Selected Southland Waterways. Institute of Environmental Science and Research Limited report. | Animal-specific viruses, mainly from the Adenoviridae and Polyomaviridae families have been suggested as faecal source tracking (FST) tools due to their host-specificity, resistance to many inactivation processes, high prevalence and common excretion in faeces or urine. In our current study, based in Southland, FST analysis was carried out on 11 rivers, targeting a variety of dairying, sheep and urban catchments to demonstrate the ability of the assay to detect ovine pollution in NZ waters. We also determined the rivers' sediment particle size and E. coli concentration of the water and sediment to determine if correlations existed between the E. coli concentration of the water and sediment and virus particles and sediment particle size. |
| Nutrient Loads to Protect Environmental Values in Waituna Lagoon, Southland | Scanes, P. (2012). Nutrient Loads to Protect Environmental Values in Waituna Lagoon, Southland NZ.Accessed 8 July 2020 from https://www.researchgate.net/publication/268036506_Nutrient_Loads_to_Protect_Environmental_Values_in_Waituna_Lagoon_Southland_NZ | Waituna Lagoon is a brackish, intermittently closed open lake/lagoon (ICOLL) in Southland (New Zealand; 46.5º latitude) approx. 20 km to the east of Bluff. ICOLLs are recognised as the most sensitive type of estuary to inputs of nutrients and sediments, due to long water residence times and limited interaction with the ocean (Haines et al. 2006, Scanes et al. 2007, Robertson et al. 2011). The objective of this report was to recommend interim nutrient load targets to protect the environmental values of Waituna Lagoon, based on analyses of loads to similar NSW lagoons. In order to prevent a drastic and potentially irreversible change to the ecological character of Waituna Lagoon, it was recommended that, as an interim step, the mean nutrient loads of both N and P associated with NSW estuaries that have moderately disturbed catchments be adopted as interim load targets while a more detailed assessment is made of the ecological condition of Waituna Lagoon and it's response to stressors such as catchment derived nutrients, entrance manipulation and salinity stress. |
| Multiple lines of evidence determine robust nutrient load limits required to safeguard a threatened lake/lagoon system, New Zealand | Schallenberg, M., Hamilton, D.P., Hicks, A.S., Robertson, H.A., Scarsbrook, M., Robertson, B., Wilson, K., Whaanga, D., Jones H.F.E. & Hamill, K. (2017) Multiple lines of evidence determine robust nutrient load limits required to safeguard a threatened lake / lagoon system, New Zealand | Three independent scientific lines of evidence were sought to determine the nutrient load limits to safeguard the macrophyte community of an intermittently closed and open lake/lagoon (ICOLL): (1) a literature review identified nitrogen load thresholds related to the collapse of macrophytes in similar systems in Australia, Europe and elsewhere, (2) an ICOLL expert carried out an assessment based on current local data and on data from 57 Australian coastal lakes and lagoons, and (3) a deterministic coupled hydrodynamic-ecological model was developed and applied to simulate the ecological outcomes of several |

| | | |
|---|---|---|
| | Journal of Marine and Freshwater Research, 51:1, 78-95 | nutrient loading scenarios. Multiple lines of evidence helped derive robust nutrient load limits for managing the ICOLL to safeguard values associated with a healthy macrophyte community. |
| Environmental Assessment of Farm Mitigation Scenarios in Southland | Snelder, T. and Fraser, C. (2013) Environmental Assessment of Farm Mitigation Scenarios in Southland. Accessed 10 July, 2020 from https://www.mfe.govt.nz/sites/default/files/environmental-assessment-farm-mitigation-scenarios-southland_0.pdf | This report provides an assessment of the water quality outcomes associated with different farm-level mitigation scenarios and evaluates the results in terms of levels of acceptability proposed by the National Objectives Framework (NOF). Existing river quality in Southland achieves a high level of attainment against the proposed NOF attributes. The results indicate that the current level of water quality would be maintained or improved in the future under nearly all the mitigation scenarios, with improvements increasing as mitigation becomes more stringent. However, at the regional level these improvements are not large, as mitigation measures mainly impact dairy farming, which currently makes up only 17% of the region's agricultural land use and is only projected to increase to 28% by 2037. Southland's estuaries are likely to be more sensitive receiving environments than rivers and that contaminant loss from all farming activities in the region (not just dairy farming) has its most marked effect on estuaries. |
| Identification of priority areas for actions to address land and water issues. | Snelder, T., Fraser, C., Hodson, R., Ward, N., Rissman, C., Hicks, A. (2014) Regional Scale Stratification of Southland's Water Quality – Guidance for Water and Land Management. *Aqualinc Report* No. C13055/02, prepared for Southland Regional Council, March 2014, Christchurch | This report details the development of the Water and Land Management Stratification (WLMS). The purpose of the WLMS is to identify the highest priority areas for actions to address specific land and water management issues and, conversely, areas where land and water management risks are low. |
| Nitrogen loads to New Zealand aquatic receiving environments: comparison with regulatory criteria | Snelder, T. H., Whitehead, A. L., Fraser, C., Larned, S. T., & Schallenberg, M. (2020). Nitrogen loads to New Zealand aquatic receiving environments: comparison with regulatory criteria. New Zealand Journal of Marine and Freshwater Research, 1–24. doi:10.1080/00288330.2020 | There is concern about the deteriorating nutrient status of aquatic receiving environments in New Zealand. This study estimated the amount by which current nitrogen (N) concentrations and loads exceed criteria in rivers, lakes and estuaries nationally. Non-compliance with N criteria was broadly distributed nationally particularly in low-elevation catchments. Catchments with unacceptable N status constituted at least 31% of New Zealand's land area, which corresponds to at least 43% of the country's agricultural land. |

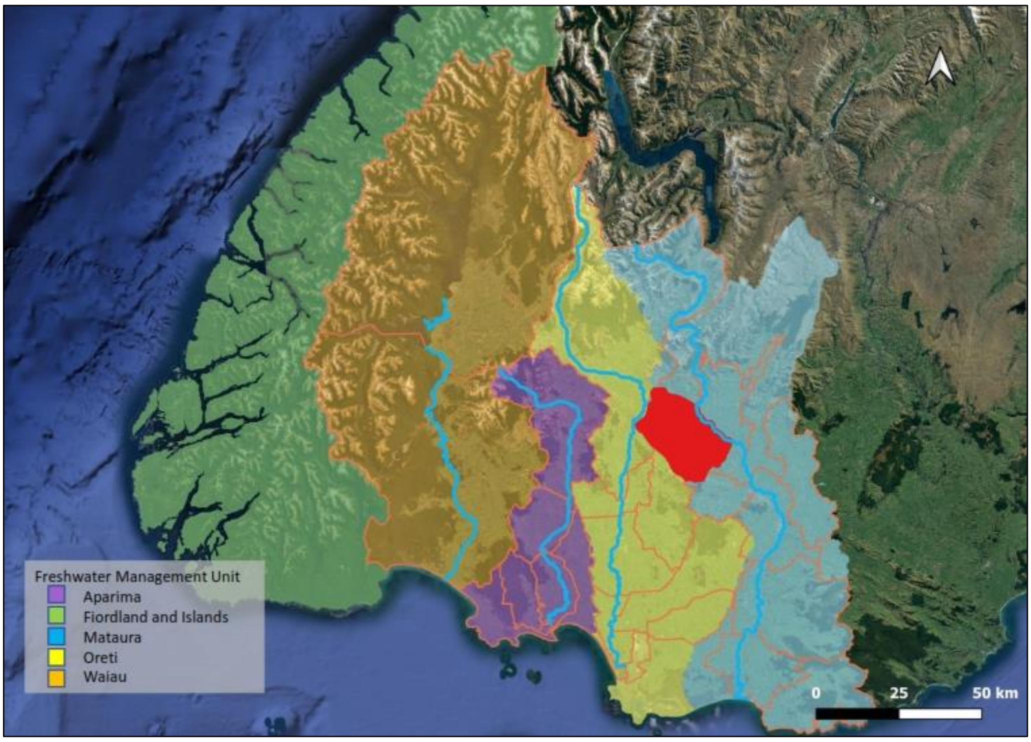
| | | |
|---|---|---|
| | .1758168 | |
| Review of the risks from emerging organic contaminants in waterbodies to human and environmental health in Southland. | Stewart, M. and Tremblay, L. (2020) Review of the risks from emerging organic contaminants in waterbodies to human and environmental health in Southland. Report ESO1901–Final 24-04-20, Streamlined Environmental, Hamilton, 63 pp. | This report outlines the risks from emerging contaminants potentially in Southland's water bodies pose to human health and ecosystem health of the receiving environment. |
| Soil quality targets for Olsen P for the protection of environmental values | Taylor, M.D. Drewry, J.J, Curran-Cournane F, Pearson L, McDowell RW, Lynch B , (2016). Soil quality targets for Olsen P for the protection of environmental values. In: Integrated nutrient and water management for sustainable farming. (Eds L.D. Currie and R.Singh). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 29. 12 pages. | Regional councils need tools to assess potential risks to the environment, including those associated with phosphorus (P). Currently, soil quality monitoring (SQM) is used to assess soil health. In this paper, they estimate potential P loss from different soils and demonstrate two risk assessment models that use SQM data collected from 4 regions of NZ. The upper Olsen P target for SQM is discussed in the light of the model results. Both risk assessment models can be used with regional council soil quality monitoring data to identify the relative risk of P loss in overland /subsurface flow. These models estimated the relative risk of P loss for different soil orders at various P saturation factors. Results showed there were substantial soil type effects on P loss risk and losses from flat land, while less than losses from slopes of the same soil type, can still be considerable. The risk of P transport may be low, due to the slope and less likely to cause overland flow, yet, if concentrations of Olsen P are excessive and P retention low, the risk from a flat high fertility area may be ultimately much higher than that for steeper, lower fertility areas. It may be that protecting all environmental values will be impracticable if the goal of enhancing primary production is to be achieved and there will need to be a tradeoff between production and water quality |
| The Influence of Groundwater Nitrate on the Waimea Stream, Southland, New Zealand | Thornton, J.M. (2016) The Influence of Groundwater Nitrate on the Waimea Stream, Southland, New Zealand. Thesis. University of Canterbury, Christchurch. | It has long been understood that groundwater and surface water interact, and thus cannot be studied separately. Gaining an understanding of the relationship and connectivity between the two is critical for water management in New Zealand. However, interactions between surface and groundwater are naturally complex, varying both spatially and seasonally due to a multitude of different factors. The aim of this study was to characterise the connectivity between the groundwater of the Waimea Plains in Southland, which has highly elevated nitrate concentrations near the small town of Balfour, and the Waimea Stream, which has also been shown to have elevated nitrate concentrations. As overland flow is a significant contributor to flow during winter, the winter |

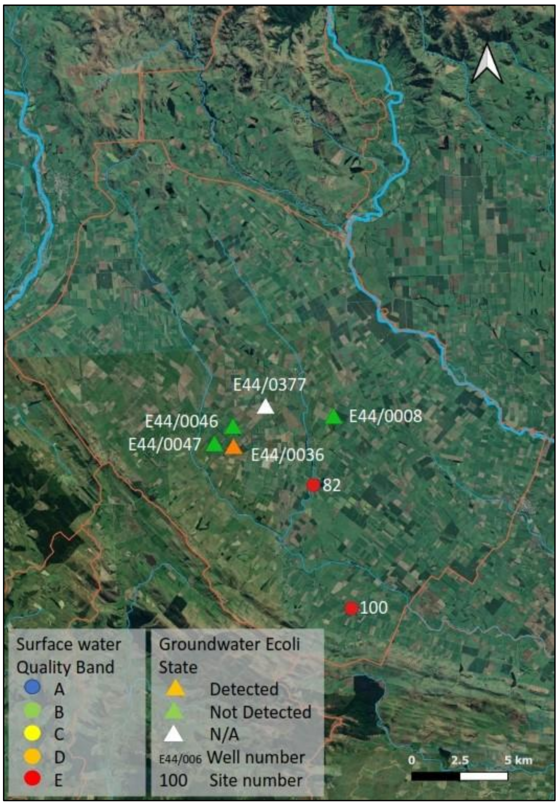
| | | |
|---|---|---|
| | | increase of nitrate and DRP is expected to stem from increased farm run off. Future management of nutrient inputs into the Waimea Stream should therefore focus on limiting winter surface runoff inputs of both DRP and nitrate. Groundwater inputs of nitrate will be much more difficult to ameliorate, although the use of on farm nutrient budgets should help limit the vertical loss of nitrate down into the Waimea Plains aquifer. |
| Summary of review and further estuarine management considerations for Environment Southland. | Ward, N. & Roberts, K., 2018. Summary of review and further estuarine management considerations for Environment Southland. Report prepared by Environment Southland. 54p. | This report explores the relationship between catchment nutrient/sediment loads and ecological state in a particular hydrological estuary type across Southland. This estuary type includes some of Southland's larger estuaries, including New River, Jacobs River, Waikawa and Haldane estuaries. |
| Estimating Time Lags for Nitrate Response in Shallow Southland Groundwater | Wilson, S., Chanut, P., Rissmann, C., and Ledgard, G. (2014). Estimating Time Lags for Nitrate Response in Shallow Southland Groundwater. Accessed 13 July 2020 from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/environment/science/science-summary-reports/estimating_time_lags_for_nitrate_response_in_shallow_southland_groundwater.pdf | This report presents a region-wide study to estimate the length of time it will take for changes in land practices to reach the groundwater table. The results of the modelling indicate that shallow groundwater beneath properties in most of Southland will respond rapidly to a reduction in leaching rates. Most of Southland's shallow groundwater (close to the water table) is expected to show some response to a change in farming practices within five years. Large future increases in nitrate concentrations are only expected in discrete areas beneath older more elevated outwash gravel deposits. |
| Predicting Groundwater Redox Status in the Southland Region | Wilson, S., Close, M., Abraham, P. (2016). Predicting Groundwater Redox Status in the Southland Region. Lincoln Agritech Limited. | This report presents a methodology and results for predicting the redox status of groundwater for the Southland region. Reducing conditions are necessary for denitrification to occur. We can therefore use maps of predicted redox status to identify areas where potentially significant nitrate reduction could occur in the subsurface. Groundwater chemistry sample data from the Environment Southland database were classified into redox categories: oxic, mixed, or reduced. These categories were then related to spatial parameter datasets, such as geology, topography and soil characteristics using discriminant analysis. Models were incorporated into GIS and the prediction of redox status was extended over the whole region, excluding mountainous land. This knowledge improves spatial prediction of reduced groundwater zones, and therefore, when combined with groundwater flow paths, improves estimates of denitrification. |

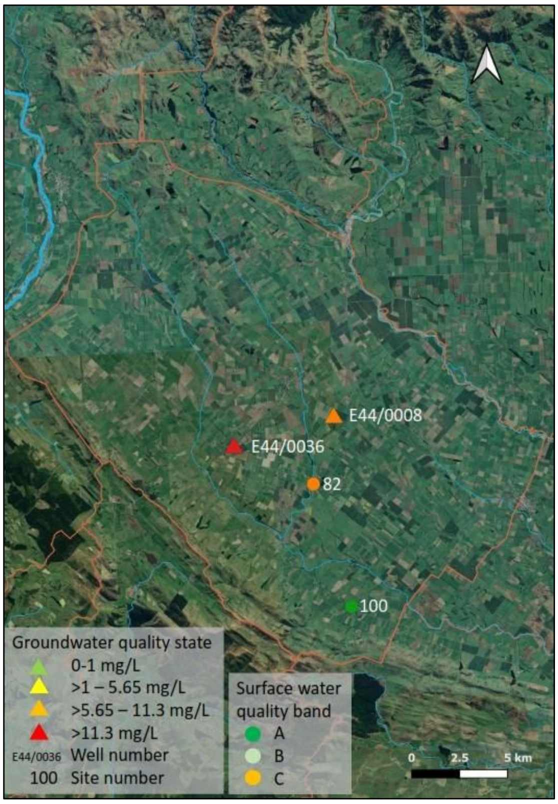
| | | |
|---|---|---|
| | | Groundwaters to the north of the Hokonui and Takitimu ranges are predicted to be dominantly oxic in nature. To the south of these ranges, the prevailing redox condition is reduced, and mixed redox status is seen along the riparian terraces of the major rivers. |
| Science Preparedness for Limit-Setting | Wilson, K. and Norton, N. (2018). Science Preparedness for Limit-Setting. Accessed 13 July, 2020 from https://contentapi.datacomsphere.com.au/v1/h%3Aes/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Science%20Preparedness%20for%20Limit%20Setting%20Report.pdf | The purpose of this report was to identify the types of scientific information and skills which have provided the greatest value to limit setting processes elsewhere in New Zealand, and to use this as a basis for assessing Environment Southland's preparedness (e.g. identifying current strengths, gaps and opportunities) for its next stage of limit-setting. |
| Advice on Benthic Cyanobacteria Health Risks and Communication Strategies in the Southland Region | Wood, S. (2017) Advice on Benthic Cyanobacteria Health Risks and Communication Strategies in the Southland Region. Cawthron Institute, Report No. 3075. Accessed 10 July 20202 from https://envirolink.govt.nz/assets/Envirolink/Reports/1781-ESRC169-ADVICE-ON-BENTHIC-CYANOBACTERIA-HEALTH-RISKS-AND-COMMUNICATION-STRATEGIES-IN-THE-SOUTHLAND-REGION.pdf | Benthic cyanobacteria that produce toxins and form blooms have increased in prevalence in New Zealand rivers in the last decade. It is important the public is educated about the risks Phormidium poses, but that this is done in a manner that does not scare them away from using rivers. Potentially toxic Phormidium are present at a number of sites in the Southland region. The concentrations of toxins at some sites are extremely high (i.e. the highest detected in New Zealand to date), and preliminary studies have shown that anatoxins accumulate in aquatic organisms at one site. |
| Lake water quality in New Zealand 2010: status and trends | Verburg, P., Hamill, K., Unwin, M., J. Abell, J. (2010) Lake water quality in New Zealand 2010: status and trends. New Zealand Ministry for the Environment. NIWA Client Report HAM2010-107. | Study at a national scale of Lake water quality in New Zealand 2010: status and trends |

# Appendix A: Individual catchment group area state and trend information

## Balfour Waimea Upper Mataura Catchment Group




| | |
|---|---|
| **Left:** | ***E. coli* surface and groundwater monitoring sites current state** |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** |
| **Site key:** | **Groundwater △ as labelled** |
| | **Surface water ○ refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Longridge Stream at Sandstone | E | Likely improving | Indeterminate | Very likely improving |
| North Peak Stream at Waimea Valley Rd | E | Indeterminate | Very likely improving | Very likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Longridge Stream at Sandstone | C | Very likely degrading | Very likely degrading | Not assessed |
| North Peak Stream at Waimea Valley Rd | A | Likely improving | Very likely improving | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $N0_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| E44/0008 | Not detected | 0% |
| E44/0036 | Detected | 0-10% |
| E44/0046 | Not Detected | N/A |
| E44/0047 | Not Detected | N/A |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

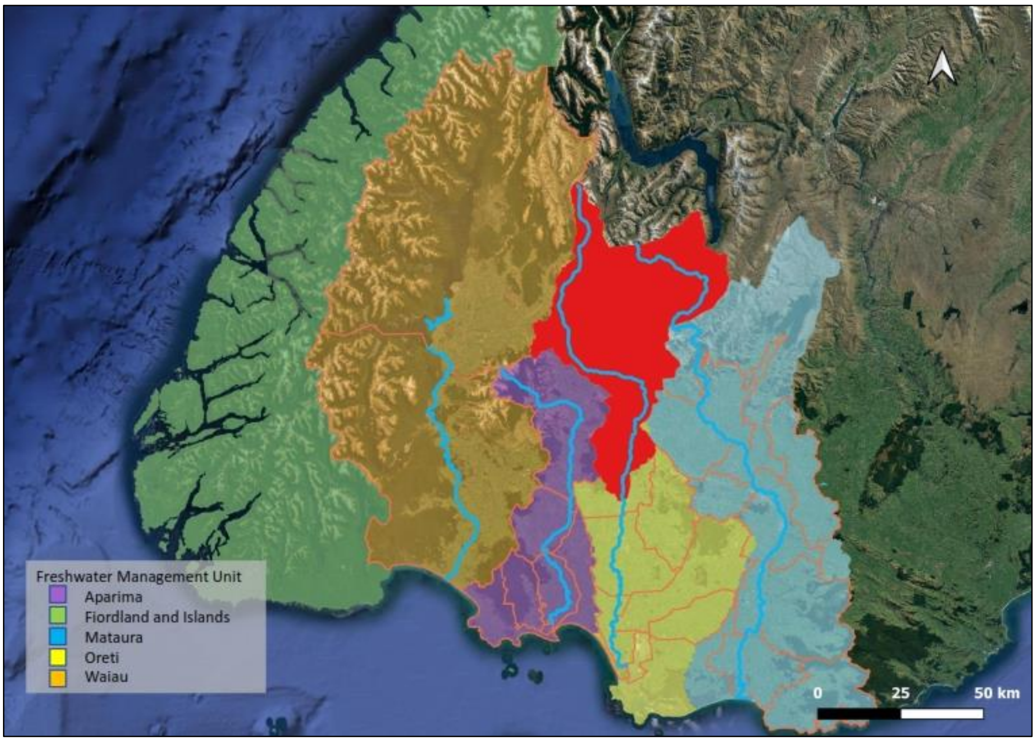
**Summary of Nitrate-Nitrogen state and trends in groundwater**

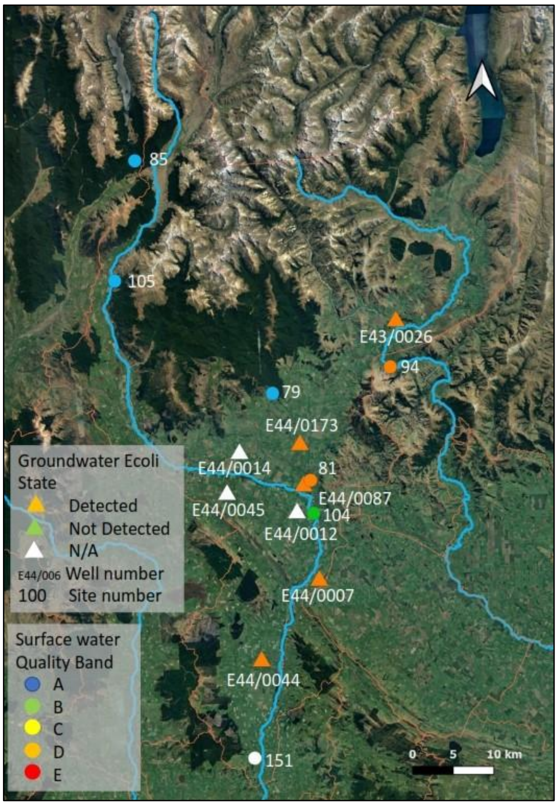
| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| E44/0008 | 7.20 | 0% |
| E44/0036 | 13.90 | >25% |

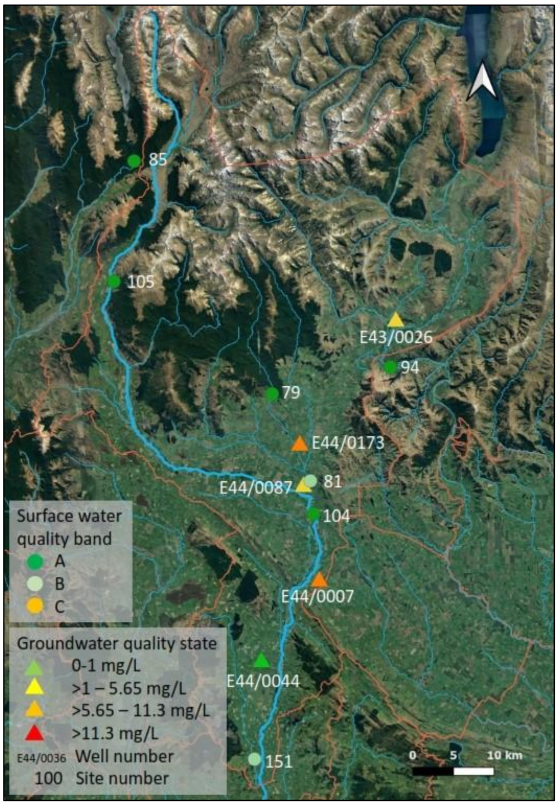
* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

## Between the Domes Catchment Group




| | |
|---|---|
| **Left:** | ***E. coli* surface and groundwater monitoring sites current state** |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** |
| **Site key:** | **Groundwater △ as labelled** |
| | **Surface water ○ refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Cromel Stream at Selbie Rd | A | Likely improving | Not assessed | Not assessed |
| Irthing Stream at Ellis Rd | D | Likely improving | Indeterminate | Very likely improving |
| Oreti River at Lumsden Bridge | B | Very likely improving | Likely improving | Indeterminate |
| Oreti River at Three Kings | A | Likely improving | Likely improving | Not assessed |
| Dipton Stream at South Hillend-Dipton Rd | N/A | Very likely improving | Not assessed | Not assessed |
| Mataura River at Parawa | D | Very likely improving | Likely degrading | Likely degrading |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Cromel Stream at Selbie Rd | A | Likely degrading | Very likely degrading | Not assessed |
| Irthing Stream at Ellis Rd | B | Very likely degrading | Very likely degrading | Not assessed |
| Oreti River at Lumsden Bridge | A | Very likely degrading | Not assessed | Not assessed |
| Oreti River at Three Kings | A | Likely improving | Very likely improving | Not assessed |
| Dipton Stream at South Hillend-Dipton Rd | B | Very likely degrading | Not assessed | Not assessed |
| Mataura River at Parawa | A | Very likely degrading | Not assessed | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| **Monitoring sites in catchment** | **State (2014-18)** | **Exceedance category^** |
| E44/0173 | Detected | 0-10% |
| E44/0044 | Detected | 0-10% |
| E44/0007 | Detected | 0-10% |
| E43/0026 | Detected | 10-25% |
| E44/0087 | Detected | 10-25% |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

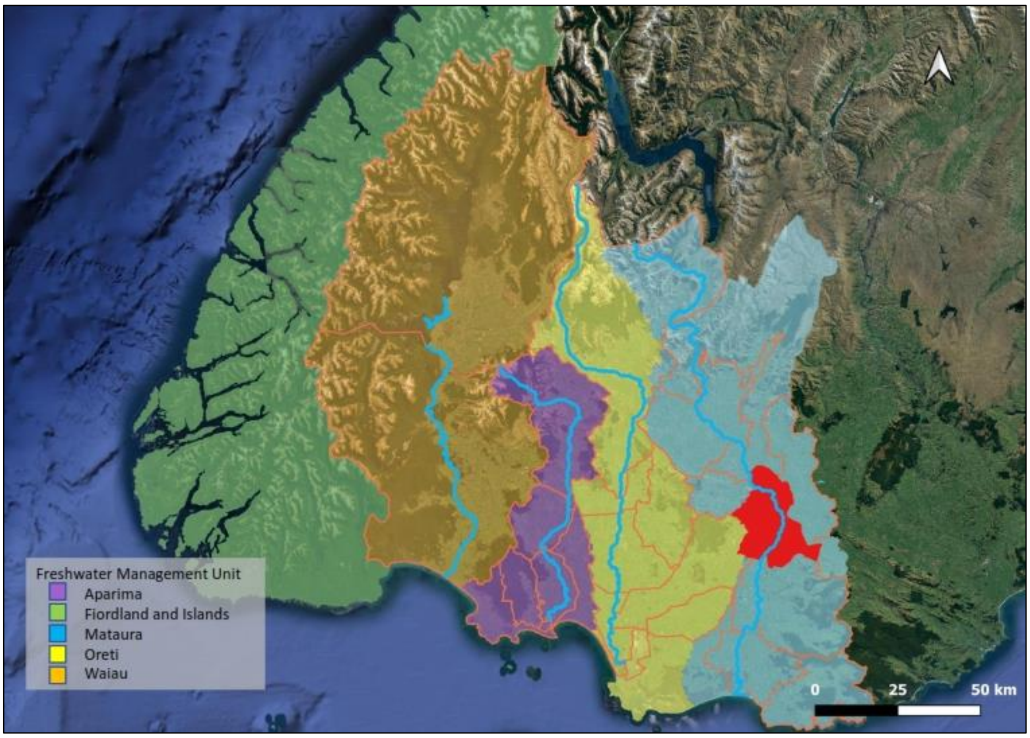
**Summary of Nitrate-Nitrogen state and trends in groundwater**

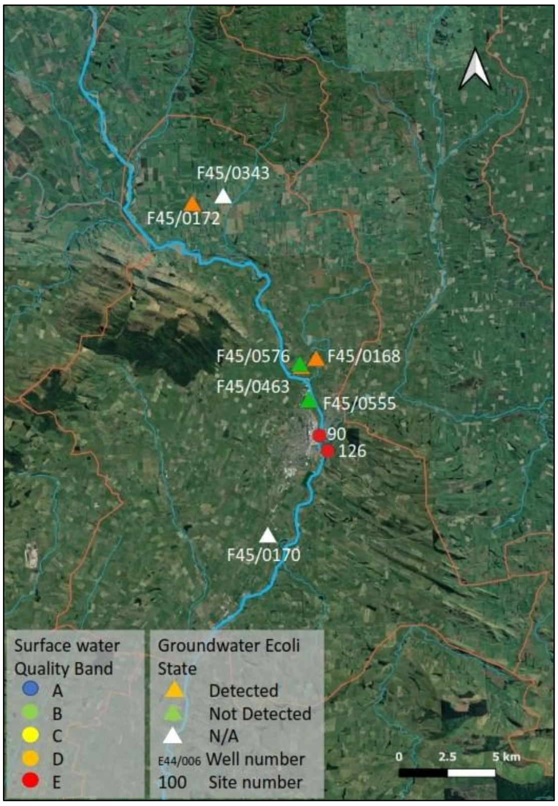
| | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| **Monitoring sites in catchment** | **State (2014-18), $NO_3$-N mg/L** | **Exceedance category^** |
| E44/0173 | 7.20 | 0% |
| E44/0044 | 0.02 | 0% |
| E44/0007 | 7.30 | 0% |
| E43/0026 | 4.20 | 0% |
| E44/0087 | 1.35 | 0% |

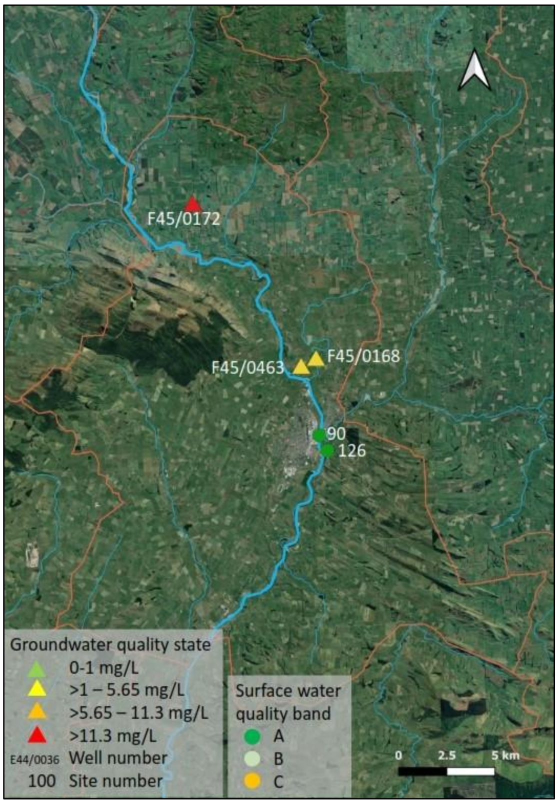
* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

# Gore Waimumu Catchment Group




| | | |
|---|---|---|
| **Left:** | ***E. coli* surface and groundwater monitoring sites current state** | |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** | |
| **Site key:** | **Groundwater △** | **as labelled** |
| | **Surface water ○** | **refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Mataura River at Gore | E | Indeterminate | Indeterminate | Likely degrading |
| Waikaka Stream at Gore | E | Very likely improving | Very likely improving | Very likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Mataura River at Gore | A | Very likely degrading | Likely degrading | Not assessed |
| Waikaka Stream at Gore | A | Very likely improving | Likely improving | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

.

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| F45/0168 | Detected | >25% |
| F45/0463 | Detected | 0-10% |
| F45/0172 | Detected | 10-25% |
| F45/0170 | N/A | |
| F45/0343 | N/A | |
| F45/0576 | Not Detected | Not assessed |
| F45/0555 | Not Detected | Not assessed |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

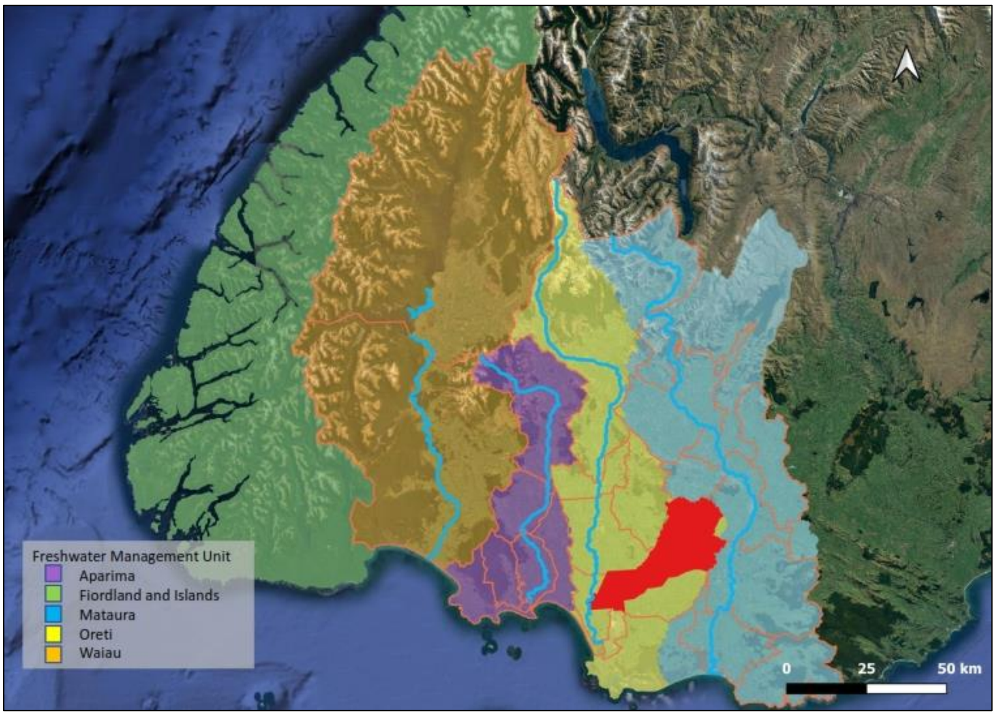
**Summary of Nitrate-Nitrogen state and trends in groundwater**

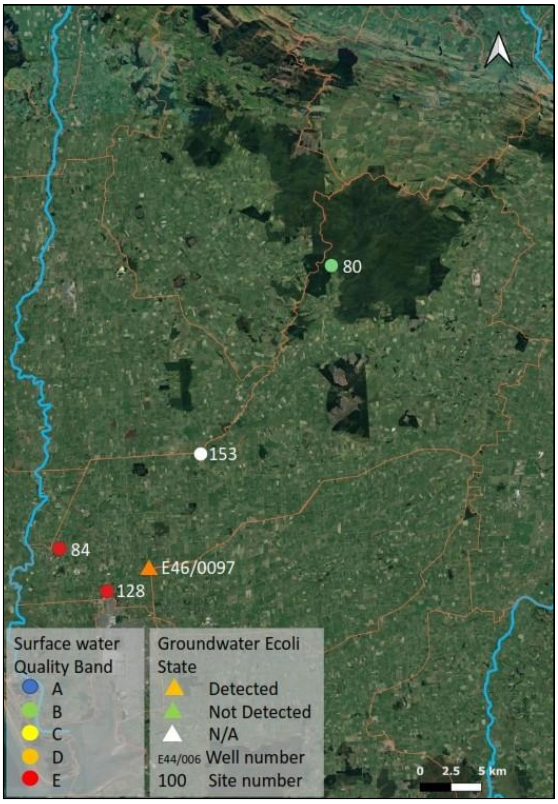
| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| F45/0168 | 3.2 | 0% |
| F45/0463 | 4.8 | 0% |
| F45/0172 | 17.6 | >25% |

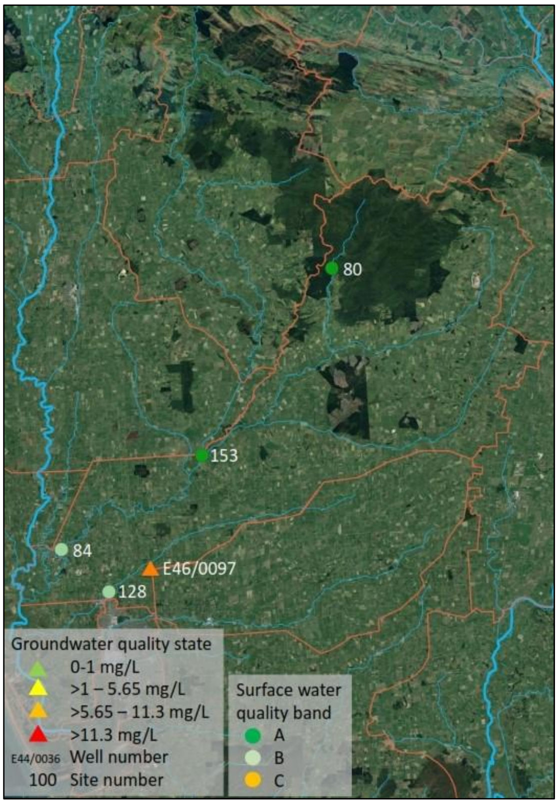
* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

## Hedgehope Makarewa Catchment Group




| | | |
|---|---|---|
| **Left:** | ***E. coli*** **surface and groundwater monitoring sites current state** | |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** | |
| **Site key:** | **Groundwater △** | **as labelled** |
| | **Surface water ○** | **refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Dunsdale Stream at Dunsdale reserve | B | Likely improving | Likely degrading | Likely degrading |
| Makarewa river at Wallacetown | E | Very likely improving | Likely improving | Likely improving |
| Waikiwi Stream at North Road | E | Very likely improving | Likely improving | Very likely improving |
| Hedgehope Stm 20m u/s Makarewa Confl | NA | Not assessed | Not assessed | Not assessed |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Dunsdale Stream at Dunsdale reserve | A | Indeterminate | Very likely degrading | Not assessed |
| Makarewa river at Wallacetown | B | Likely degrading | Very likely improving | Not assessed |
| Waikiwi Stream at North Road | B | Very likely degrading | Likely degrading | Not assessed |
| Hedgehope Stm 20m u/s Makarewa Confl | A | Indeterminate | Not assessed | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N.

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| E46/0097 | Detected | >25% |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

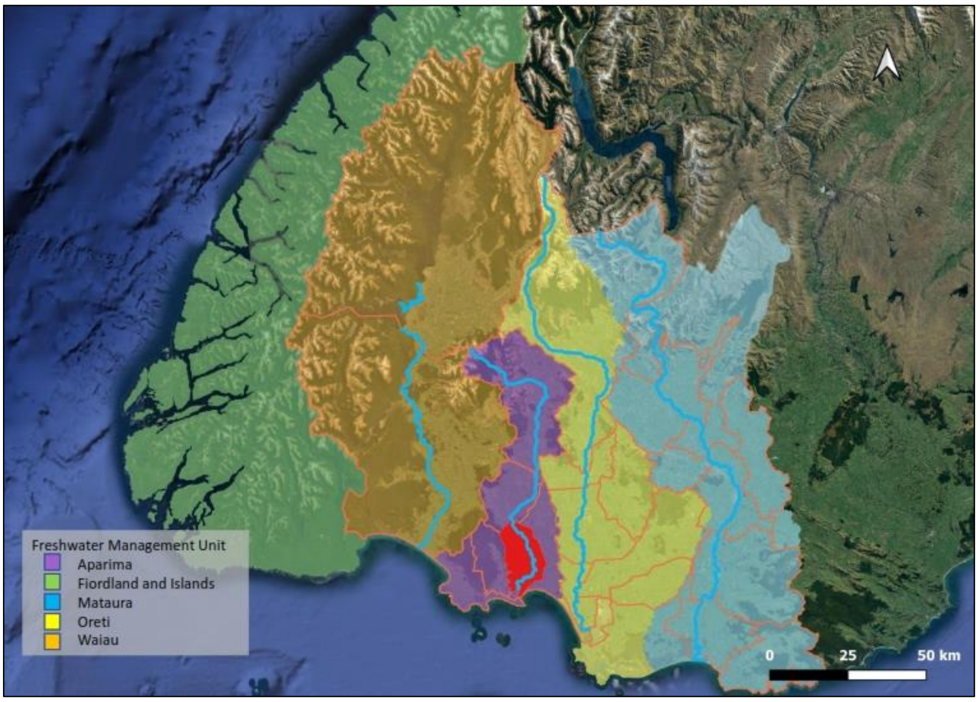
**Summary of Nitrate-Nitrogen state and trends in groundwater**

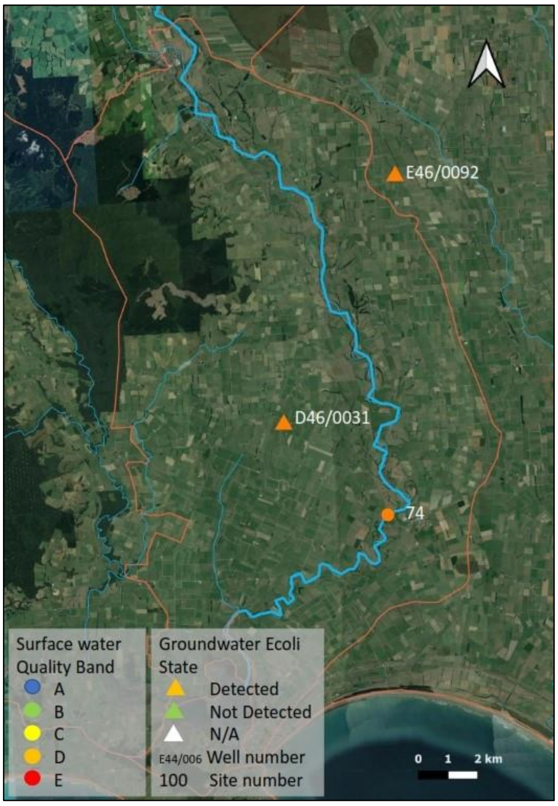
| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| E46/0097 | 5.70 | 0% |

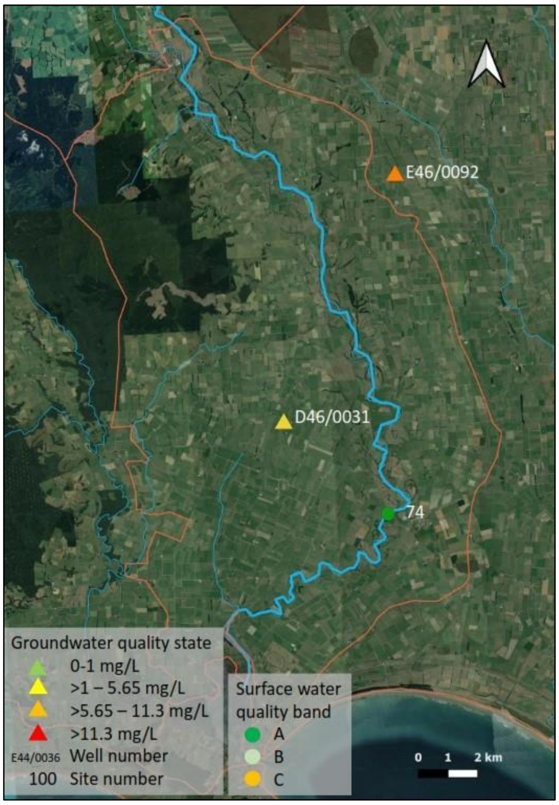
* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

## Lower Aparima Catchment Group




**Left:** ***E. coli*** **surface and groundwater monitoring sites current state**
**Right:** **TON (surface water) and NO3-N (groundwater) monitoring sites current state**
**Site key:** **Groundwater △ as labelled**
**Surface water ○ refer to Appendix B for site names**

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Aparima River at Thornbury | D | Very likely improving | Very likely improving | Very likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Aparima River at Thornbury | A | Likely improving | Very likely improving | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $N0_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| D46/0031 | Detected | 10-25% |
| E46/0092 | Detected | >25% |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

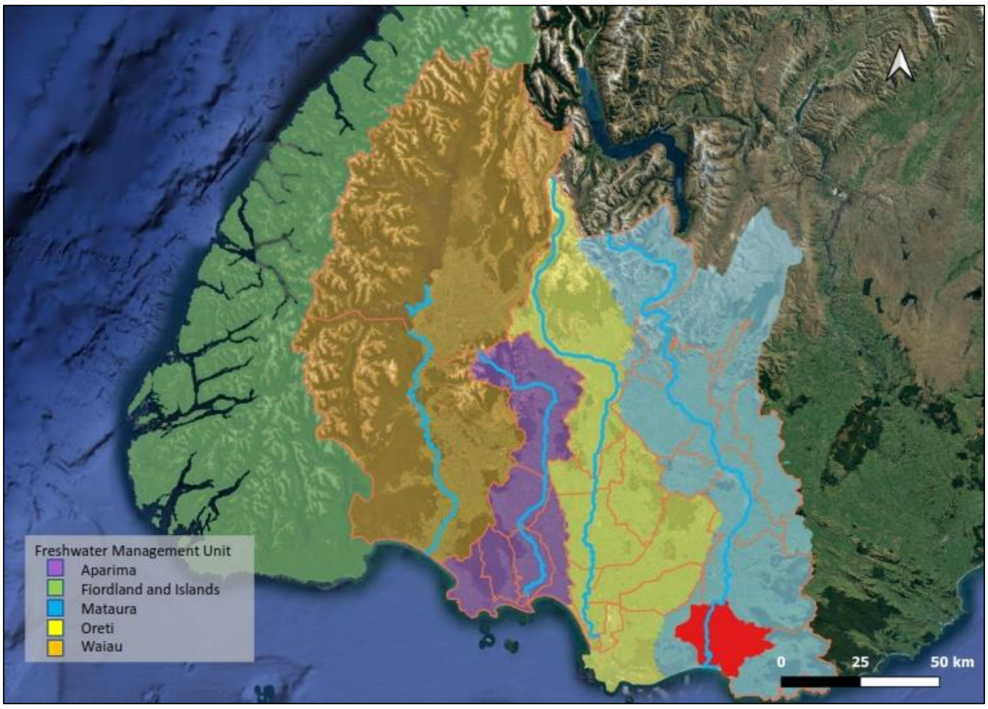
**Summary of Nitrate-Nitrogen state and trends in groundwater**

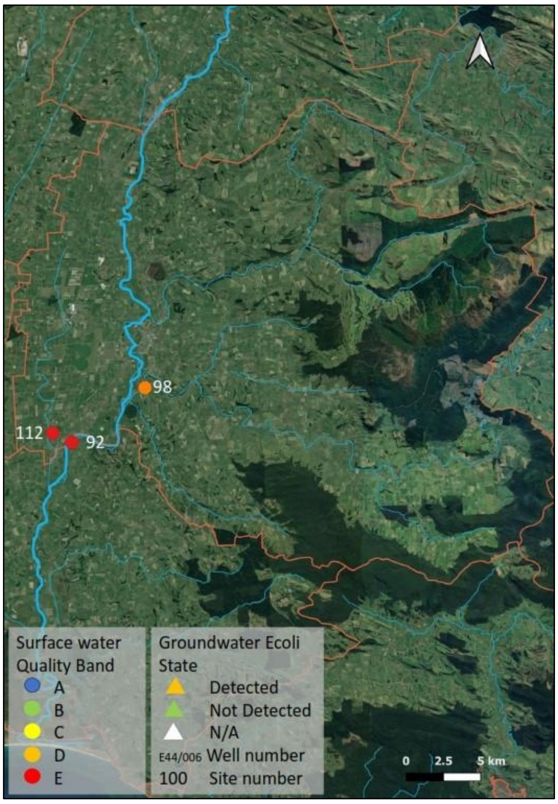
| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| D46/0031 | 1.79 | 0% |
| E46/0092 | 7.85 | 0% |

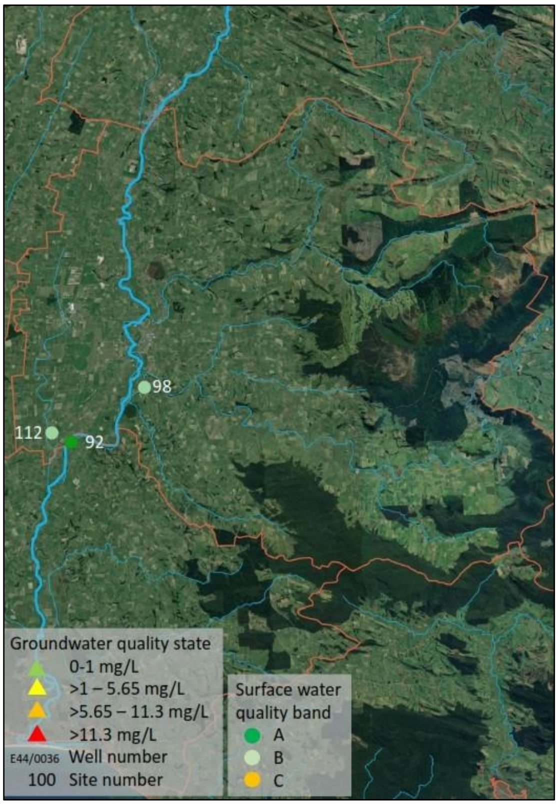
* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

## Lower Mataura Catchment Group




| | |
|---|---|
| **Left:** | ***E. coli* surface and groundwater monitoring sites current state** |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** |
| **Site key:** | **Groundwater △ as labelled** |
| | **Surface water ○ refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Mataura river at Mataura Island Bridge | E | Likely improving | Indeterminate | Very likely improving |
| Mokoreta River at Wyndham River Road | D | Likely improving | Very likely improving | Very likely improving |
| Oteramika Stream at Seaward Downs | E | Likely degrading | Indeterminate | Likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Mataura river at Mataura Island Bridge | A | Indeterminate | Not assessed | Not assessed |
| Mokoreta River at Wyndham River Road | B | Likely improving | Indeterminate | Not assessed |
| Oteramika Stream at Seaward Downs | B | Likely degrading | Very likely degrading | Not assessed |

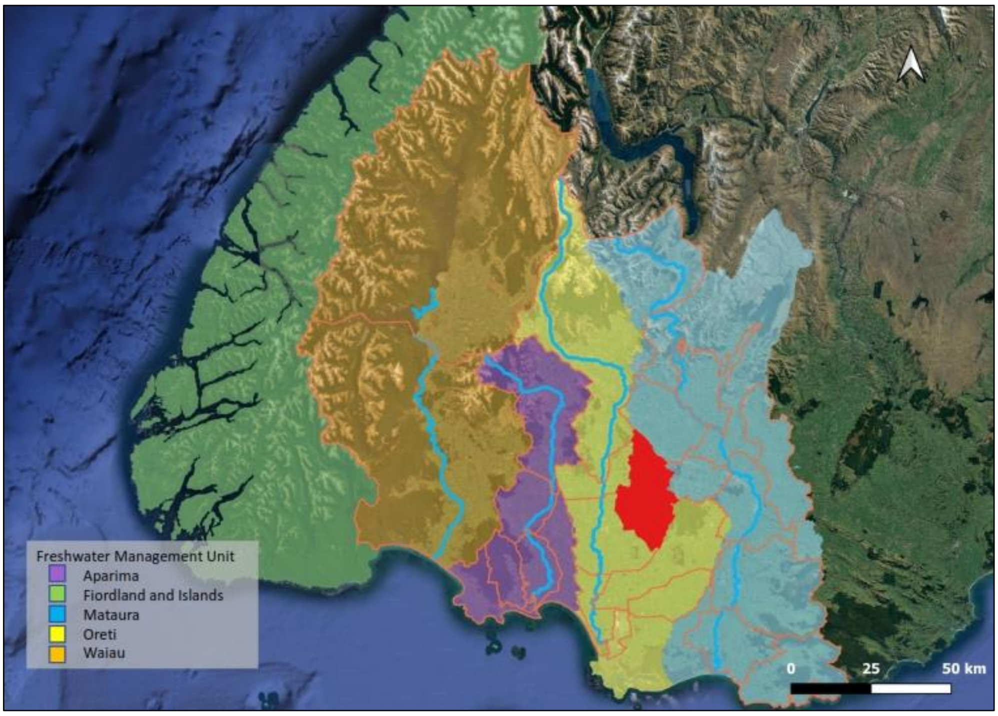
^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

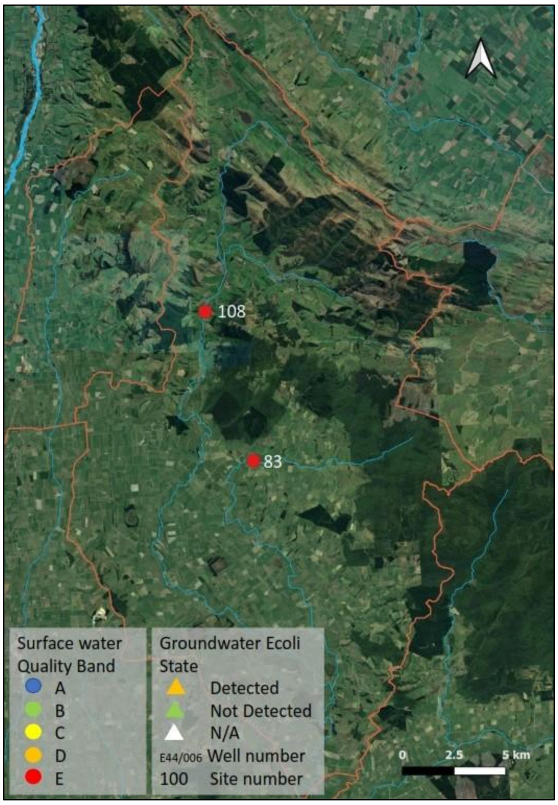
* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $N0_3$-N.

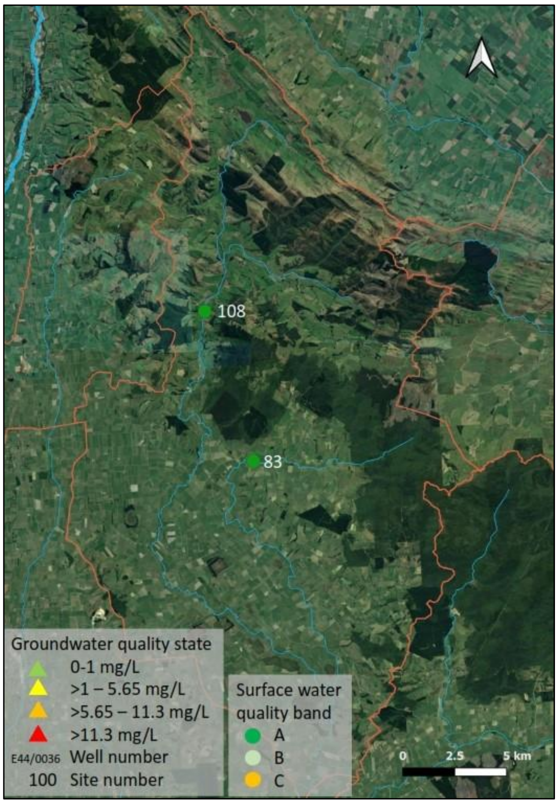
## Groundwater Quality State and Trends

There are no groundwater quality monitoring sites in this catchment area on the LAWA website and as such no state or trend information has been presented.  Additional information may be held by ES.

## Makarewa Headwaters Catchment Group




**Left:** *E. coli* **surface and groundwater monitoring sites current state**
**Right:** **TON (surface water) and NO3-N (groundwater) monitoring sites current state**
**Site key:** **Groundwater △ as labelled**
**Surface water ○ refer to Appendix B for site names**

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Otapiri Stream at Otapiri Gorge | E | Indeterminate | Indeterminate | Indeterminate |
| Makarewa River at Lora Gorge Road | E | Very likely improving | Very likely improving | Likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

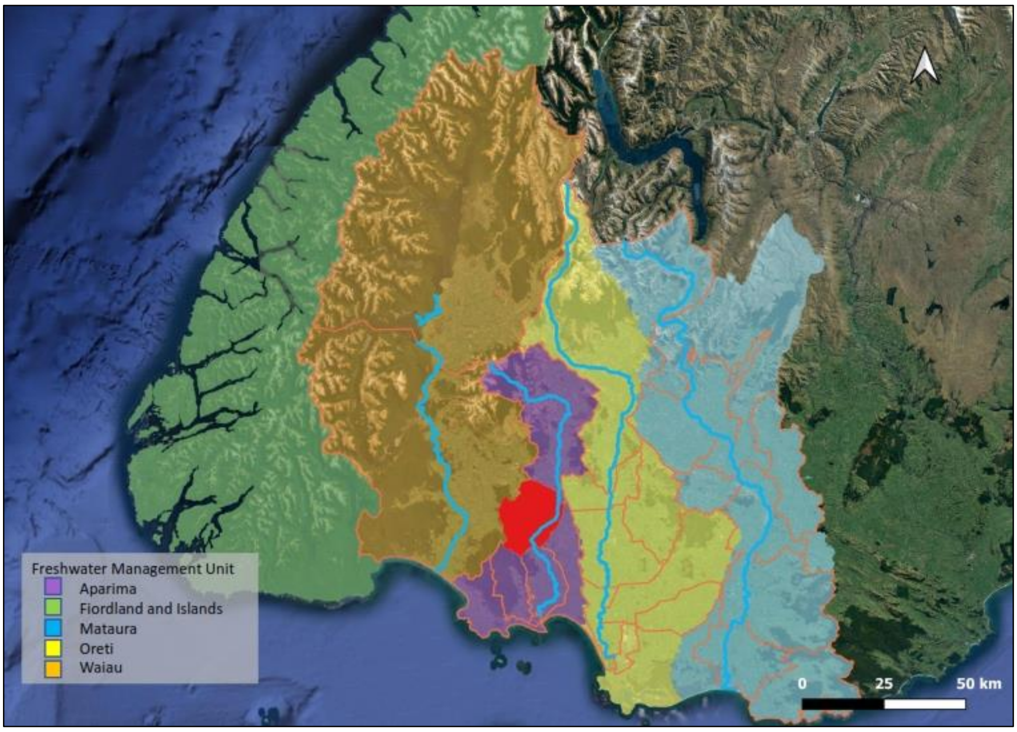
| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Otapiri Stream at Otapiri Gorge | A | Likely degrading | Very likely degrading | Not assessed |
| Makarewa River at Lora Gorge Road | A | Indeterminate | Very likely degrading | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration
* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N.

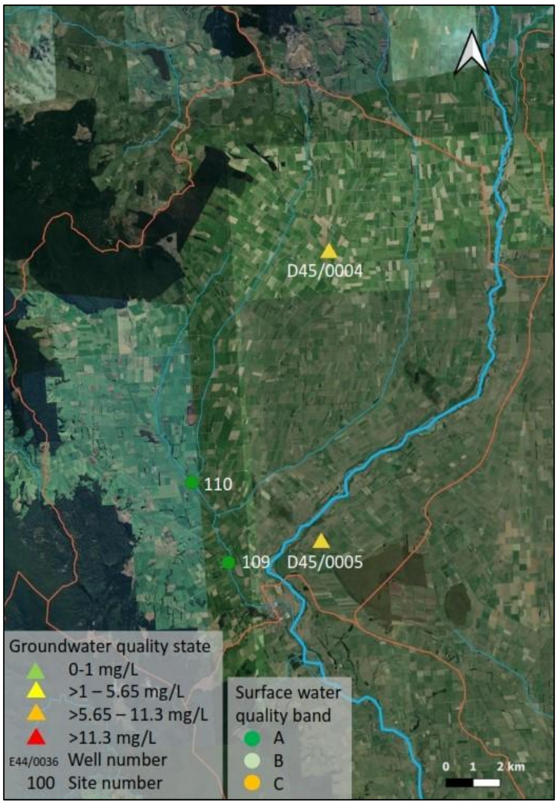
## Groundwater Quality State and Trends

There are no groundwater quality monitoring sites in this catchment area on the LAWA website and as such no state or trend information has been presented. Additional information may be held by ES.

## Mid-Aparima Catchment Group








**Left:** ***E. coli*** **surface and groundwater monitoring sites current state**
**Right:** **TON (surface water) and NO3-N (groundwater) monitoring sites current state**
**Site key:** **Groundwater △ as labelled**
**Surface water ○ refer to Appendix B for site names**

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Otautau Stream at Otautau-Tuatapere Rd | E | Likely improving | Likely improving | Indeterminate |
| Otautau Stream at Waikouro | E | Indeterminate | Likely improving | Indeterminate |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Otautau Stream at Otautau-Tuatapere Rd | A | Very likely degrading | Likely degrading | Not assessed |
| Otautau Stream at Waikouro | A | Very likely degrading | Likely degrading | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| D45/0004 | Detected | 10-25% |
| D45/0005 | Not detected | 0% |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

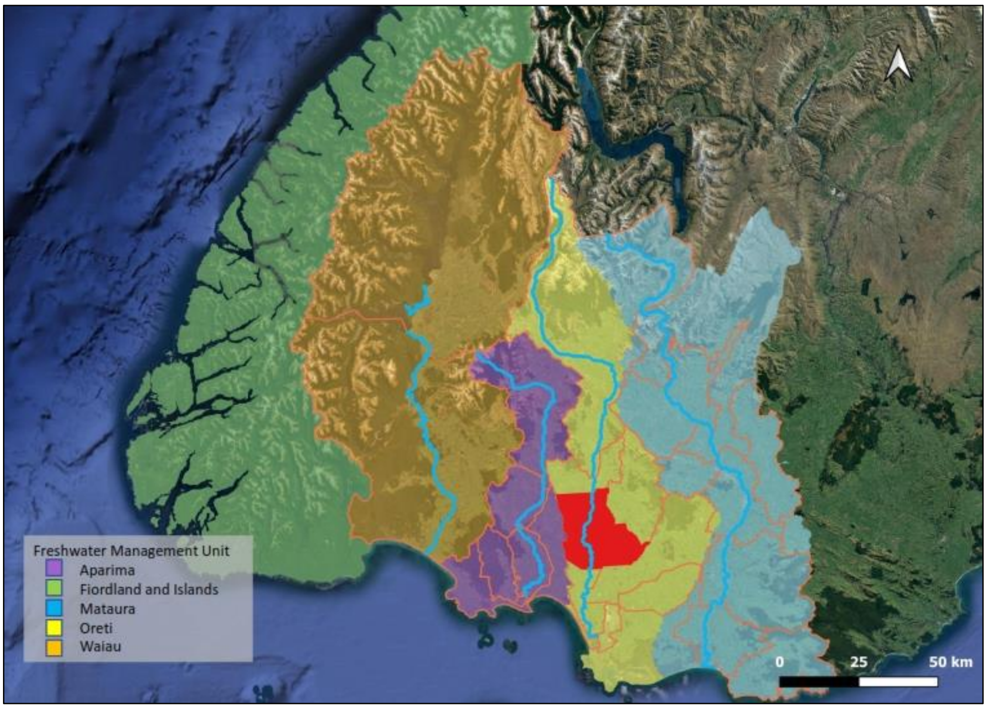
**Summary of Nitrate-Nitrogen state and trends in groundwater**

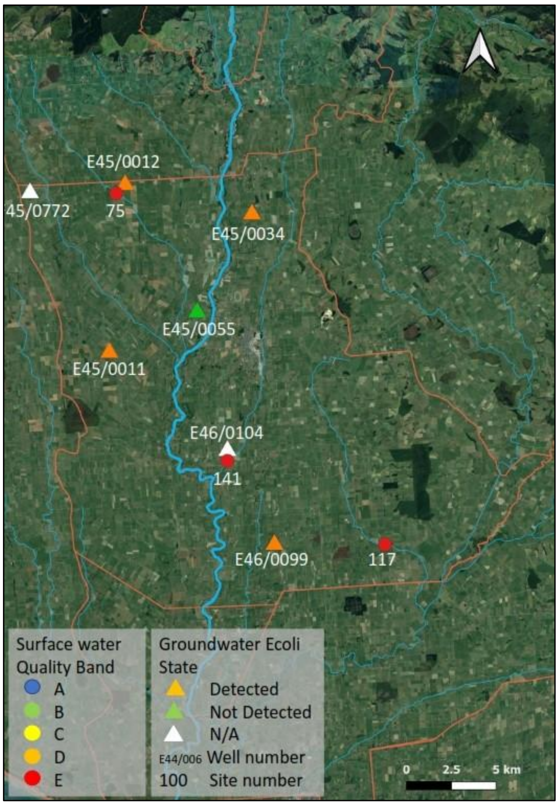
| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| D45/0004 | 1.03 | 0% |
| D45/0005 | 3.40 | 0% |

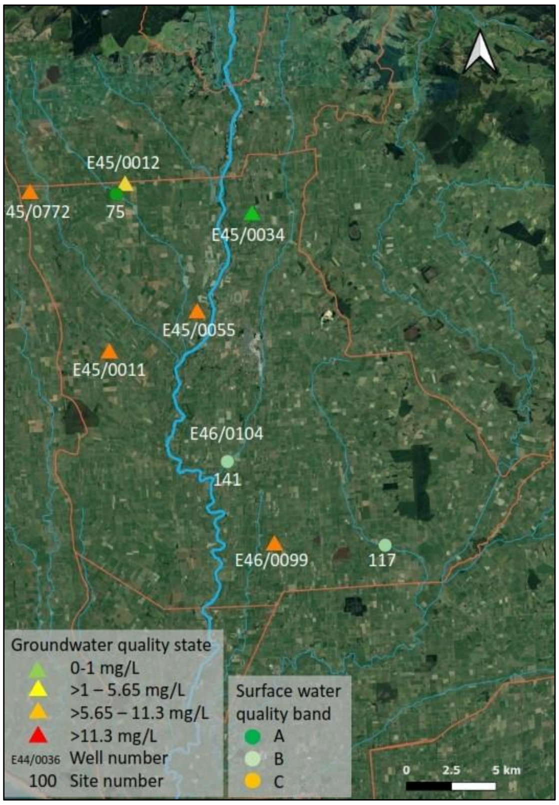
* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

## Mid-Oreti Catchment Group




**Left:** ***E. coli*** **surface and groundwater monitoring sites current state**
**Right:** **TON (surface water) and NO3-N (groundwater) monitoring sites current state**
**Site key:** **Groundwater △ as labelled**
**Surface water ○ refer to Appendix B for site names**

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Tussock Creek at Cooper Rd | E | Very likely improving | Likely improving | Indeterminate |
| Winton Stream at Lochiel | E | Likely improving | Very likely improving | Likely improving |
| Bog Burn d/s Hundred Line Rd | E | Likely improving | Very likely improving | Indeterminate |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Tussock Creek at Cooper Rd | B | Likely degrading | Very likely improving | Not assessed |
| Winton Stream at Lochiel | B | Likely degrading | Very likely improving | Not assessed |
| Bog Burn d/s Hundred Line Rd | A | Likely improving | Very likely improving | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| **Monitoring sites in catchment** | **State (2014-18)** | **Exceedance category^** |
| E45/0011 | Detected | 10-25% |
| E45/0012 | Detected | 0-10% |
| E46/0099 | Detected | 0-10% |
| E45/0055 | Not Detected | 0% |
| E45/0034 | Detected | 10-25% |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

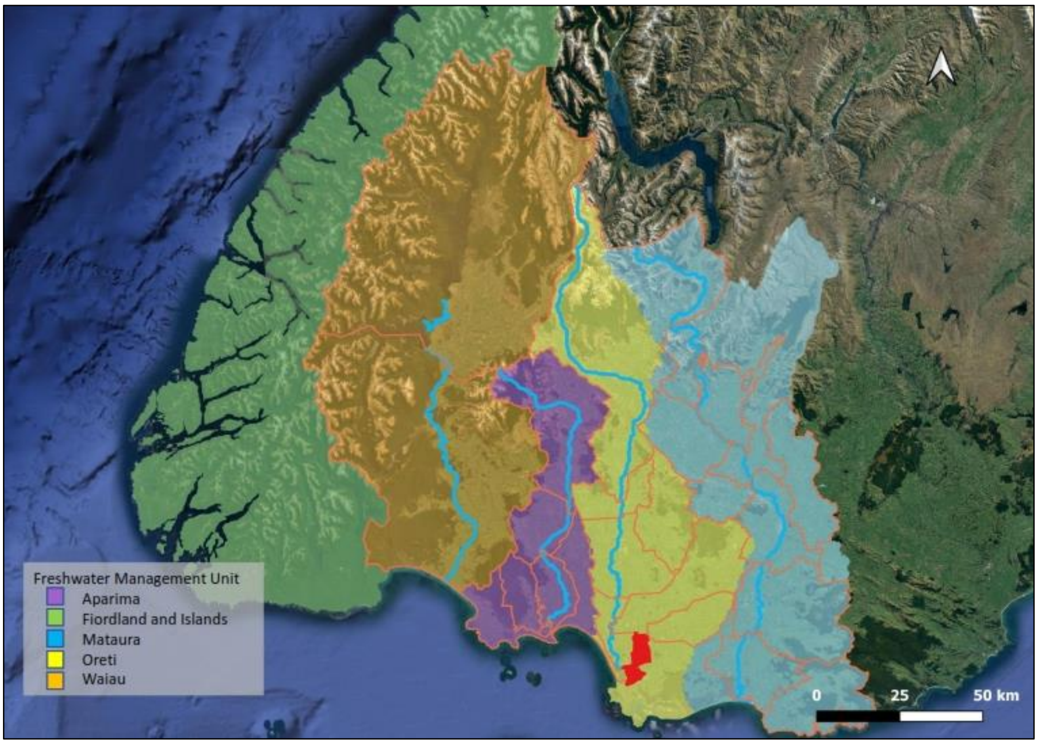
**Summary of Nitrate-Nitrogen state and trends in groundwater**

| Nitrate-Nitrogen | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| **Monitoring sites in catchment** | **State (2014-18), $NO_3$-N (mg/L)** | **Exceedance category^** |
| E45/0011 | 10.65 | >25% |
| E45/0012 | 4.30 | 0% |
| E46/0099 | 6.10 | 0% |
| E45/0055 | 6.90 | 0% |
| E45/0034 | 0.00 | 0% |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

# New River Estuary Forum






| | |
|---|---|
| **Left:** | ***E. coli*** **surface and groundwater monitoring sites current state** |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** |
| **Site key:** | **Groundwater △ as labelled** |
| | **Surface water ○ refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Otepuni Creek at Nith Street | E | Indeterminate | Indeterminate | Likely degrading |
| Waihopai River u/s Queens Drive | E | Likely improving | Very likely improving | Very likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Otepuni Creek at Nith Street | B | Indeterminate | Very likely improving | Not assessed |
| Waihopai River u/s Queens Drive | B | Indeterminate | Indeterminate | Not assessed |

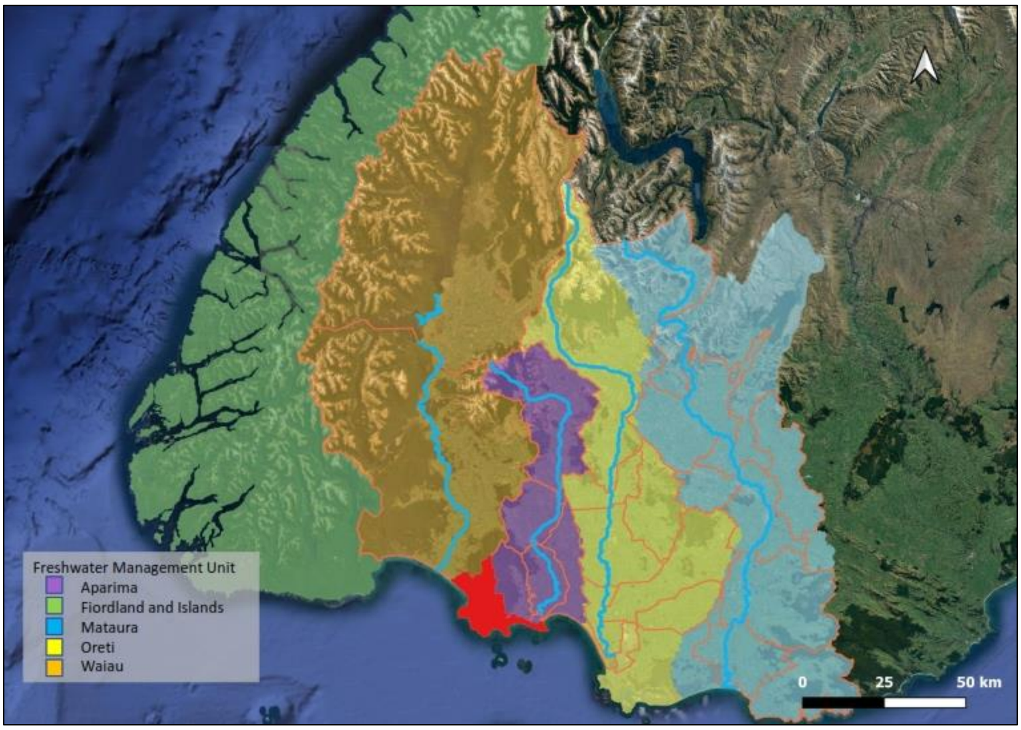
^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N.

## Groundwater Quality State and Trends

There are no groundwater quality monitoring sites in this catchment area on the LAWA website and as such no state or trend information has been presented. Additional information may be held by ES.

## Orepuki Catchment Group



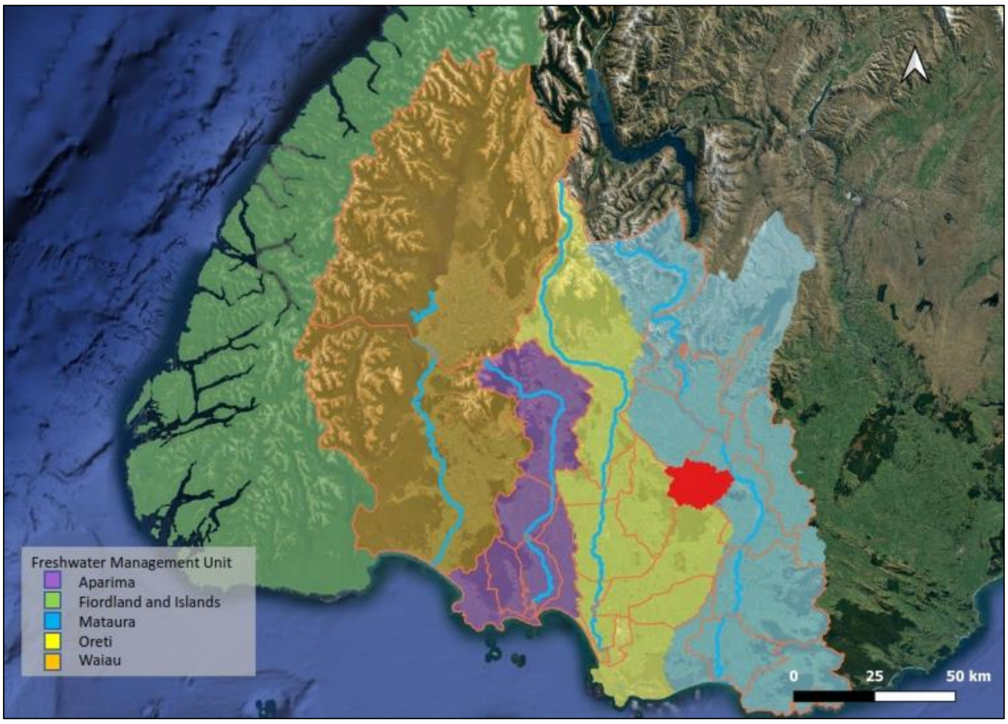

### Surface Water Quality State and Trends

There are no river or stream quality monitoring sites in this catchment area on the LAWA website and as such no state or trend information has been presented. Additional information may be held by ES.

### Groundwater Quality State and Trends

There are no groundwater quality monitoring sites in this catchment area on the LAWA website and as such no state or trend information has been presented. Additional information may be held by ES.

## Otamita Catchment Group






**Left:** ***E. coli*** **surface and groundwater monitoring sites current state**
**Right:** **TON (surface water) and NO3-N (groundwater) monitoring sites current state**
**Site key:** **Groundwater △ as labelled**
**Surface water ○ refer to Appendix B for site names**

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Otamita Stream at Mandeville | D | Likely improving | Likely improving | Indeterminate |
| Waimea Stream at Mandeville | D | Indeterminate | Likely improving | Indeterminate |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Otamita Stream at Mandeville | A | Likely improving | Indeterminate | Not assessed |
| Waimea Stream at Mandeville | C | Very likely degrading | Very likely degrading | Not assessed |

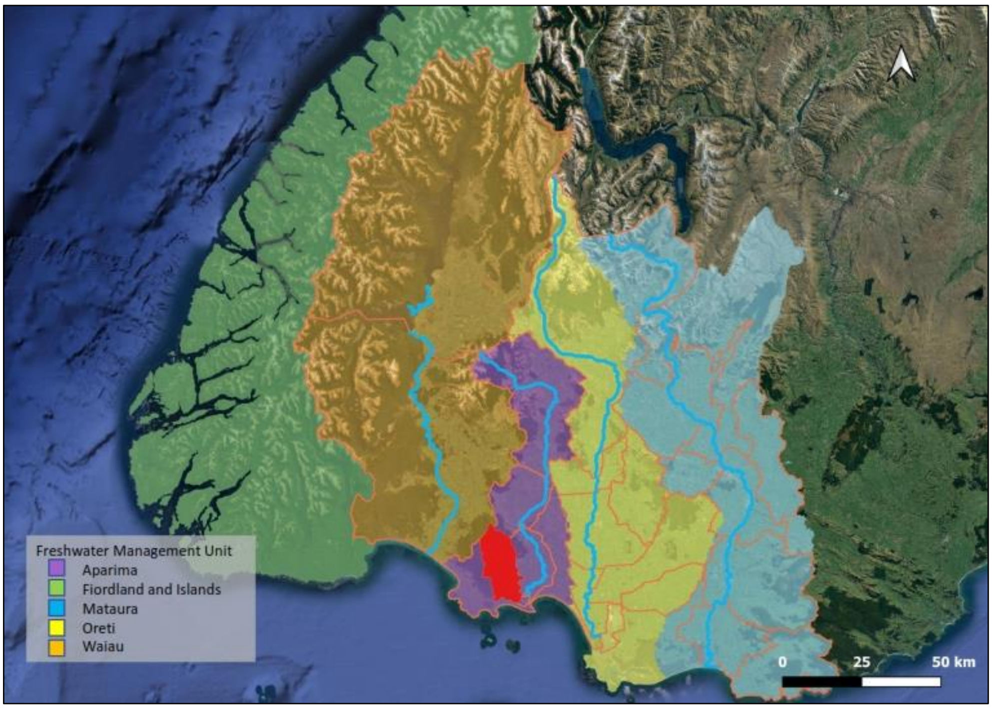
^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

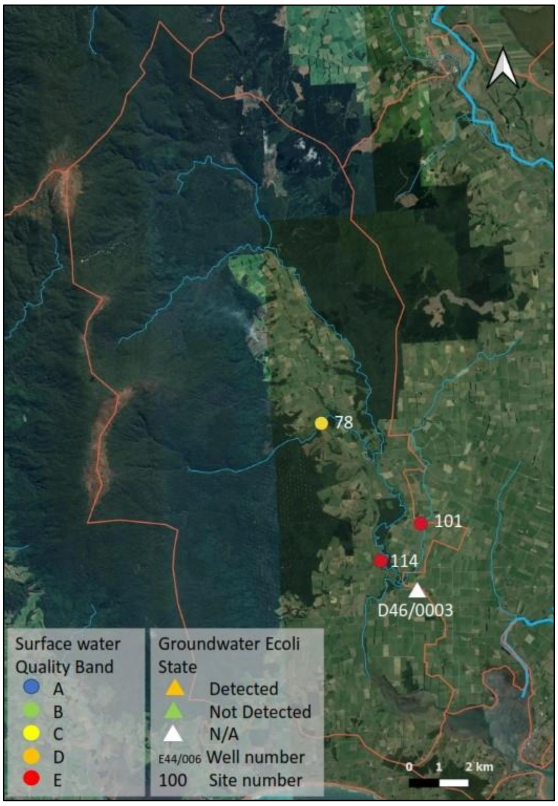
* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $N0_3$-N.

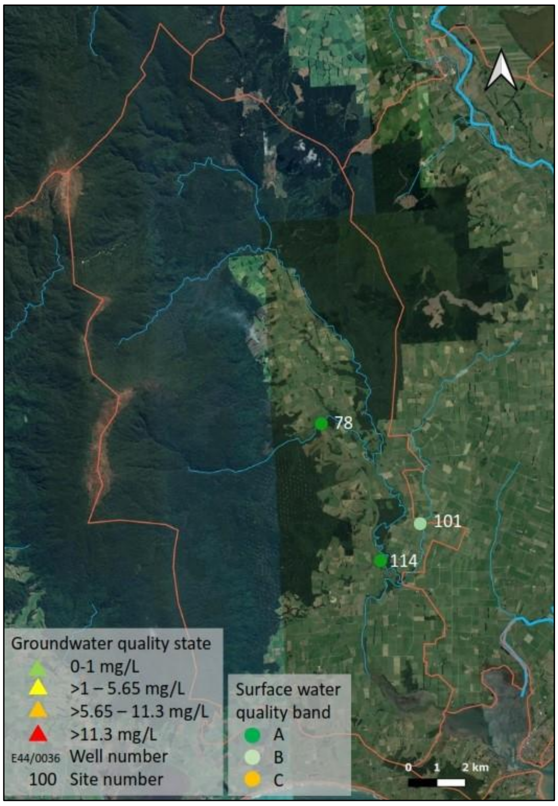
## Groundwater Quality State and Trends

There are no groundwater quality monitoring sites in this catchment area on the LAWA website and as such no state or trend information has been presented. Additional information may be held by ES.

## Pourakino Catchment Group




**Left:** ***E. coli*** **surface and groundwater monitoring sites current state**
**Right:** **TON (surface water) and NO3-N (groundwater) monitoring sites current state**
**Site key:** **Groundwater △ as labelled**
**Surface water ○ refer to Appendix B for site names**

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Cascade Stream at Pourakino Valley Rd | C | Likely improving | Likely degrading | Very likely degrading |
| Opouriki Stream at Tweedie Rd | E | Indeterminate | Very likely improving | Indeterminate |
| Pourakino River at Traill road | E | Indeterminate | Likely degrading | Very likely degrading |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Cascade Stream at Pourakino Valley Rd | A | Not assessed | Not assessed | Not assessed |
| Opouriki Stream at Tweedie Rd | B | Likely improving | Very likely degrading | Not assessed |
| Pourakino River at Traill road | A | Very likely degrading | Very likely degrading | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration
* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N.

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| **Monitoring sites in catchment** | **State (2014-18)** | **Exceedance category^** |
| D46/0031 | Detected | 10-25% |

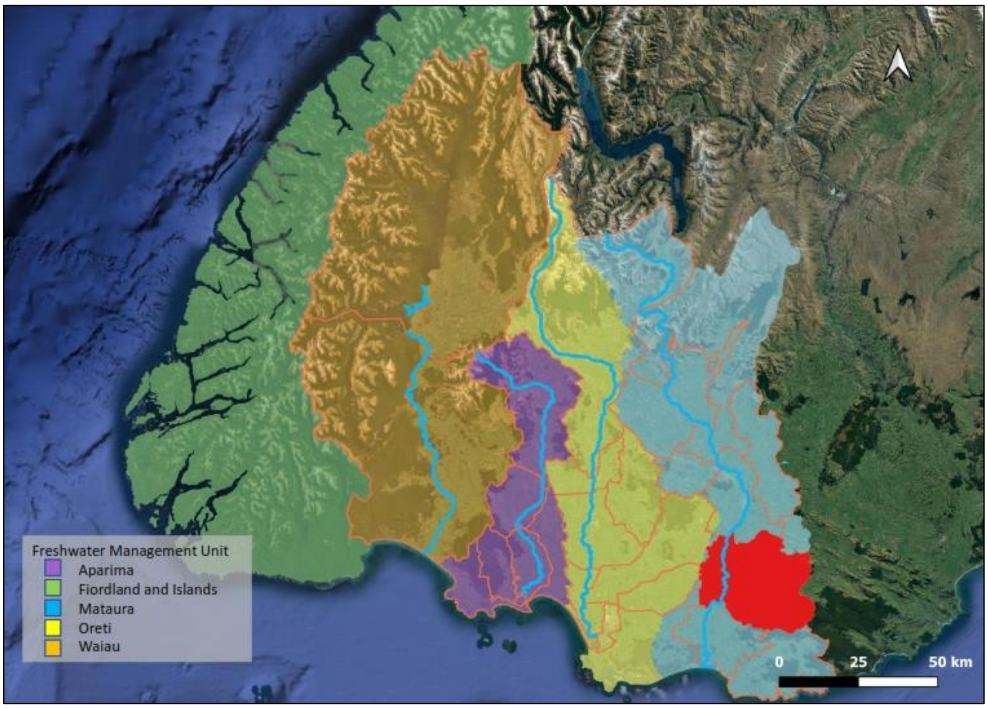
* https://www.stats.govt.nz/indicators/groundwater-quality
^ Grades categorised as per Stats NZ (2014-2018)

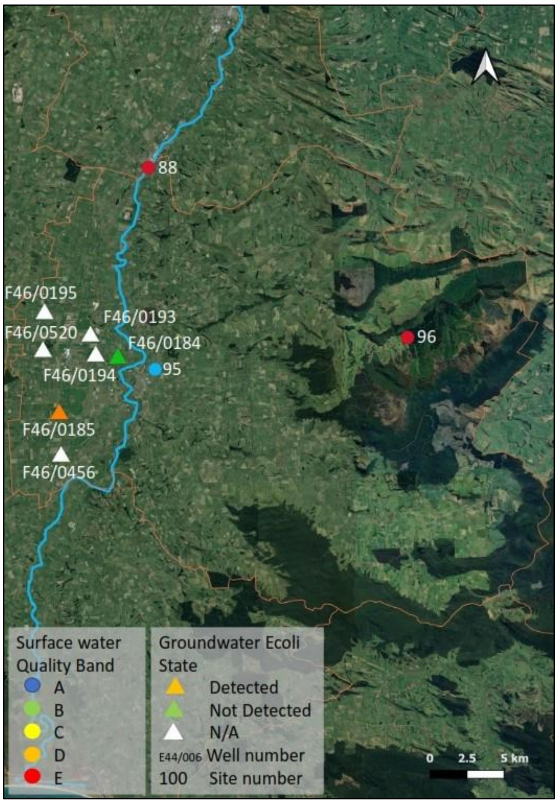
**Summary of Nitrate-Nitrogen state and trends in groundwater**

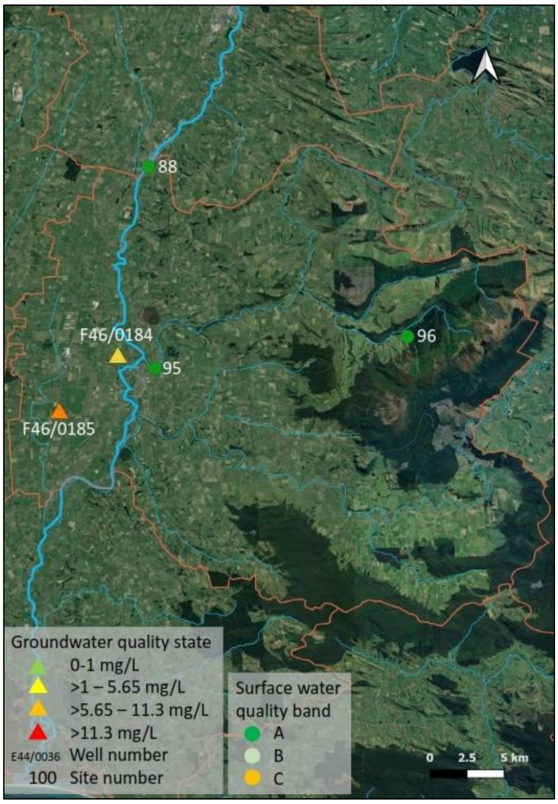
| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| **Monitoring sites in catchment** | **State (2014-18)** | **Exceedance category^** |
| D46/0031 | 1.79 | 0% |

* https://www.stats.govt.nz/indicators/groundwater-quality
^ Grades categorised as per Stats NZ (2014-2018)

## +Three Rivers Catchment Group




| | |
|---|---|
| **Left:** | ***E. coli*** **surface and groundwater monitoring sites current state** |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** |
| **Site key:** | **Groundwater △ as labelled** |
| | **Surface water ○ refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Mataura River 200m d/s Mataura Bridge | E | Not assessed | Indeterminate | Very likely degrading |
| Mimihau Stream at Wyndham | E | Very likely improving | Very likely improving | Very likely improving |
| Mimihau Stream Tributary at Venlaw Forest | A | Not assessed | Not assessed | Not assessed |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Mataura River 200m d/s Mataura Bridge | A | Likely degrading | Indeterminate | Not assessed |
| Mimihau Stream at Wyndham | A | Very likely improving | Indeterminate | Not assessed |
| Mimihau Stream Tributary at Venlaw Forest | A | Likely improving | Very likely improving | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N.

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| F46/0185 | Detected | >25% |
| F46/0184 | Not Detected | 0% |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

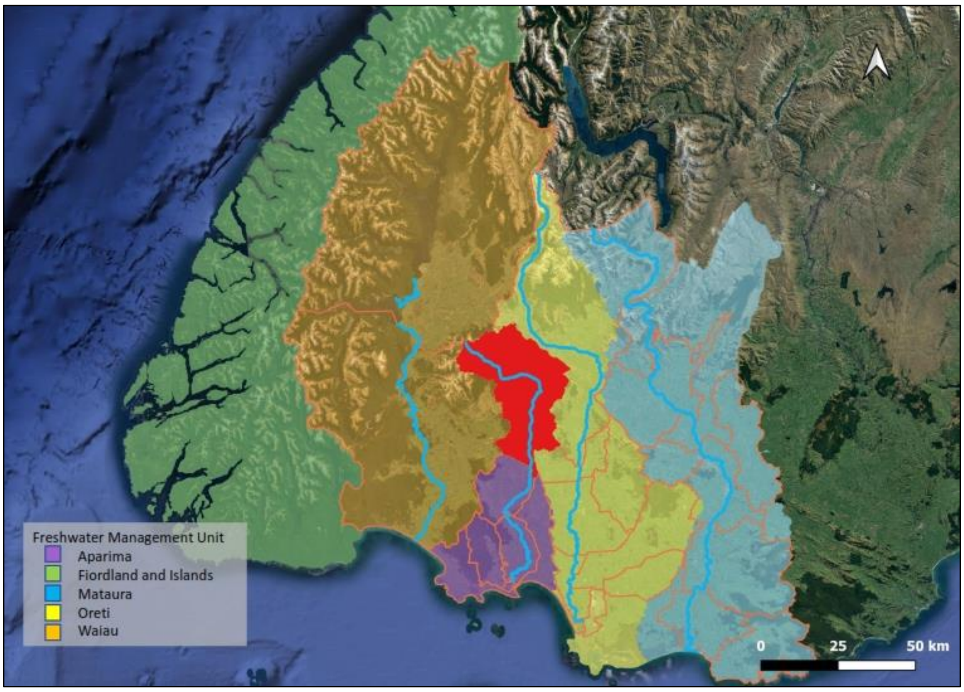
**Summary of Nitrate-Nitrogen state and trends in groundwater**

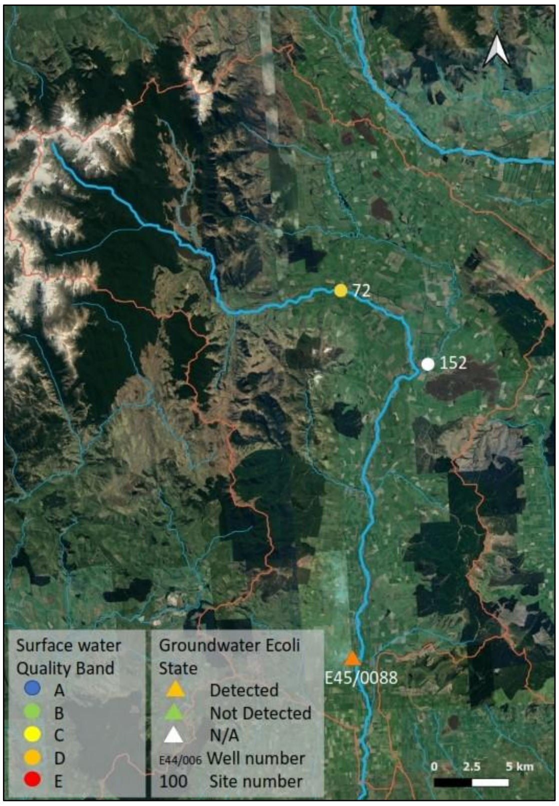
| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| F46/0185 | 7.4 | 0% |
| F46/0184 | 4.2 | 0% |

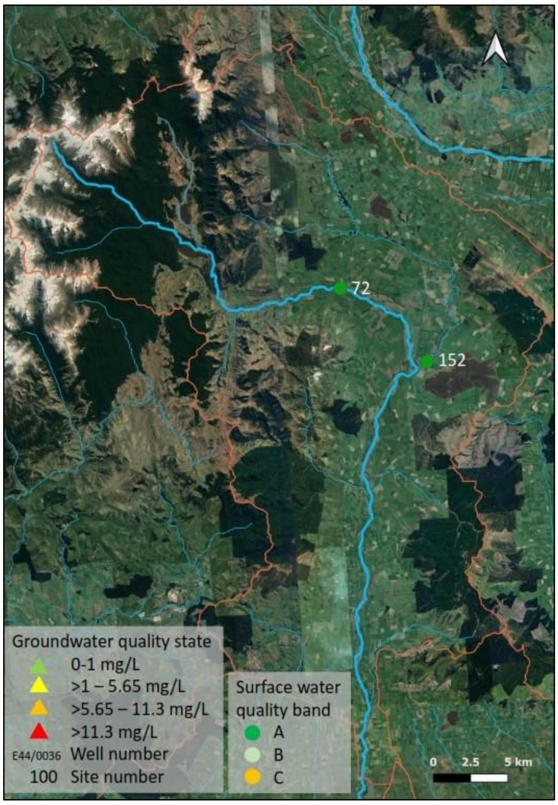
* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

## Upper Aparima Catchment Group




| | | |
|---|---|---|
| **Left:** | ***E. coli* surface and groundwater monitoring sites current state** | |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** | |
| **Site key:** | **Groundwater △** | **as labelled** |
| | **Surface water ○** | **refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Aparima River at Dunrobin | C | Likely degrading | Likely improving | Likely improving |
| Hamilton Burn at Affleck Road | N/A | Likely improving | Not assessed | Not assessed |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Aparima River at Dunrobin | A | Likely improving | Indeterminate | Not assessed |
| Hamilton Burn at Affleck Road | A | Indeterminate | Not assessed | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| E45/0088 | Detected | N/A |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

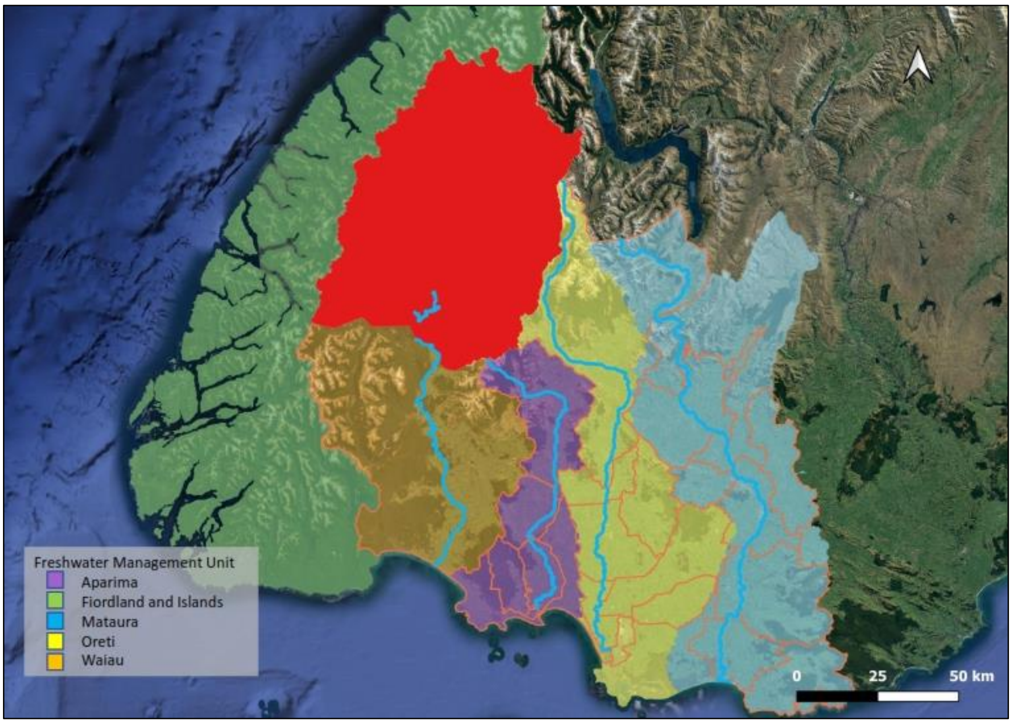
**Summary of Nitrate-Nitrogen state and trends in groundwater**

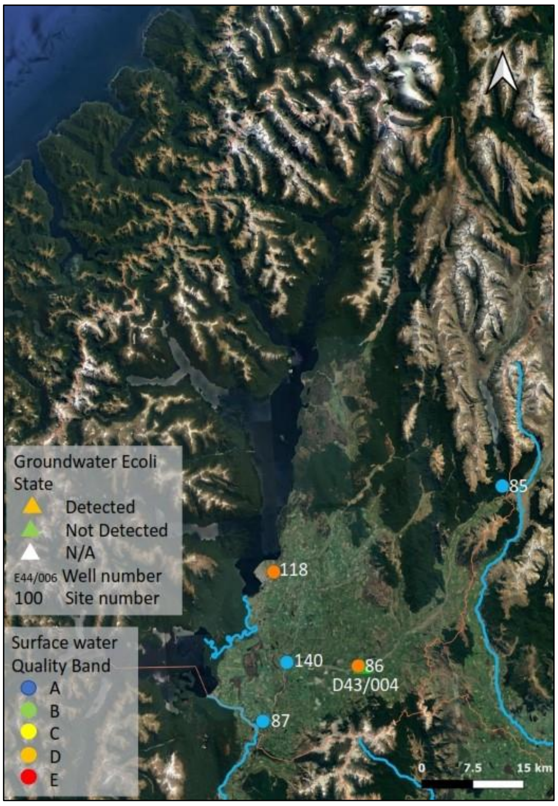
| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| E45/0088 | 3.5 | N/A |

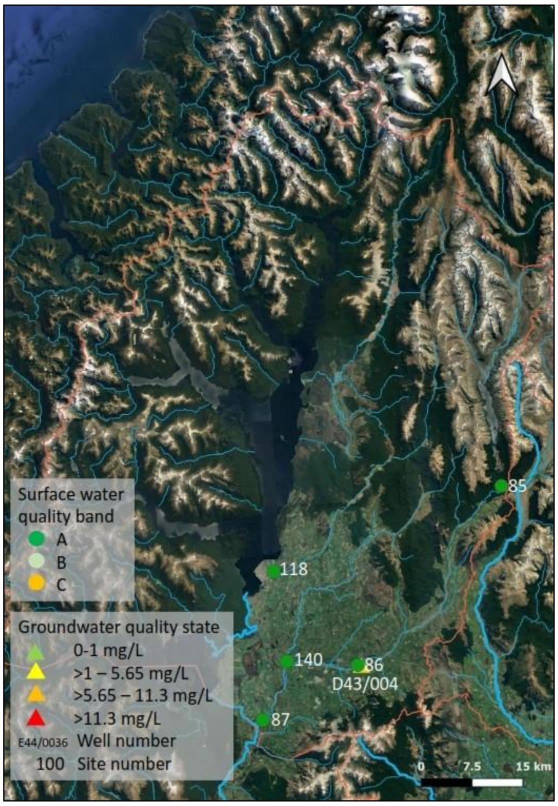
* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

## Upper Waiau – Te Anau Catchment Group




| | | |
|---|---|---|
| **Left:** | ***E. coli*** **surface and groundwater monitoring sites current state** | |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** | |
| **Site key:** | **Groundwater △** | **as labelled** |
| | **Surface water ○** | **refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Mararoa River at South Mavora Lake | A | Not assessed | Indeterminate | Indeterminate |
| Mararoa River at The Key | D | Indeterminate | Likely improving | Very likely improving |
| Mararoa River at Weir Road | A | Indeterminate | Very likely improving | Very likely improving |
| Upukerora River at Te Anau Milford Road | D | Indeterminate | Indeterminate | Very likely improving |
| Whitestone River d/s Manapouri-Hillside | A | Likely improving | Very likely improving | Very likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Mararoa River at South Mavora Lake | A | Not assessed | Not assessed | Not assessed |
| Mararoa River at The Key | A | Very likely degrading | Indeterminate | Not assessed |
| Mararoa River at Weir Road | A | Likely degrading | Likely degrading | Not assessed |
| Upukerora River at Te Anau Milford Road | A | Indeterminate | Indeterminate | Not assessed |
| Whitestone River d/s Manapouri-Hillside | A | Likely improving | Likely degrading | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | Median (2014-18) | Exceedance category^ |
| D43/0004 | Not detected | 0% |

* https://www.stats.govt.nz/indicators/groundwater-quality

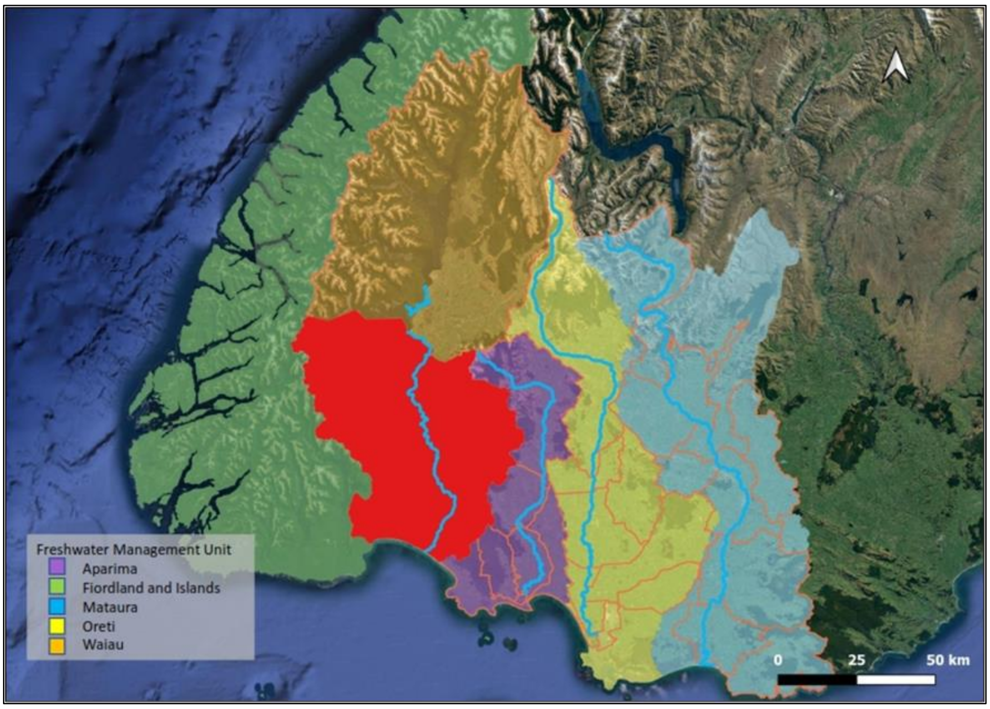
^ Grades Stats NZ (2014-2018)

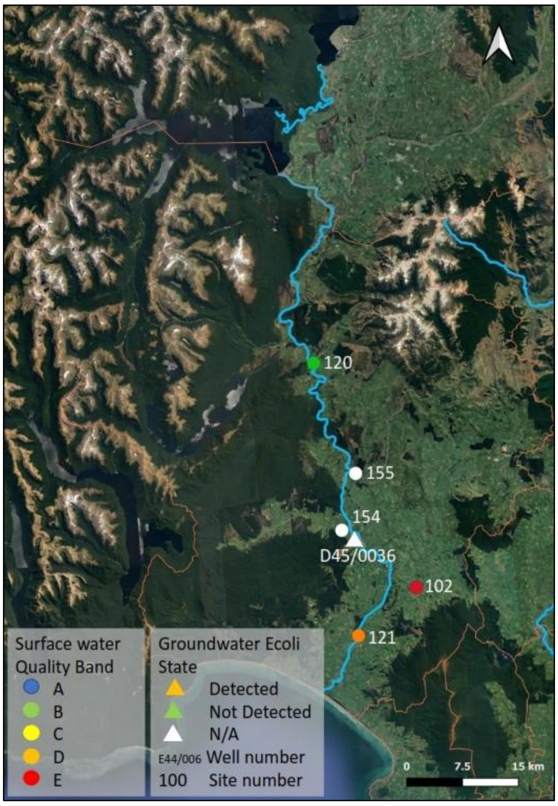
**Summary of Nitrate-Nitrogen state and trends in groundwater**

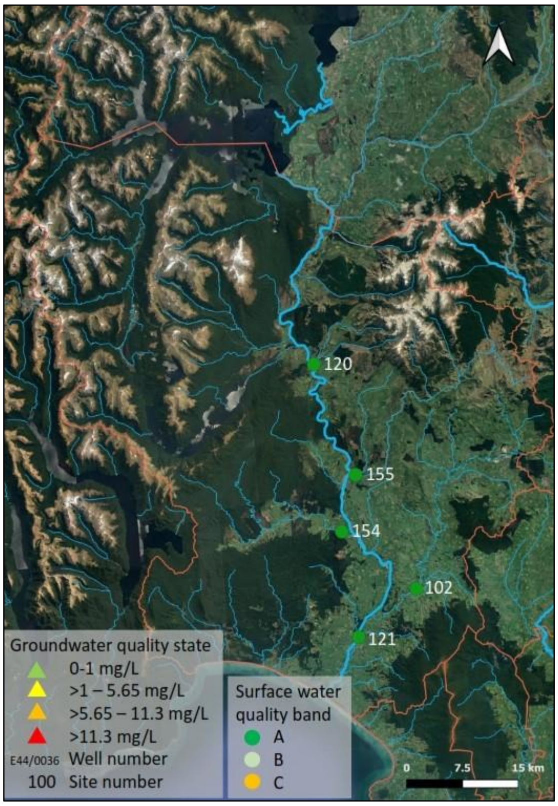
| Nitrate-Nitrogen | Statistics NZ comparison to DWSNZ* | |
|---|---|---|
| Monitoring sites in catchment | Median (2014-18) | Exceedance category^ |
| D43/0004 | 2.6 | 0% |

*Grades as published by Statistics NZ (2014-2018)

## Waiau River Care Group




| | |
|---|---|
| **Left:** | ***E. coli*** **surface and groundwater monitoring sites current state** |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** |
| **Site key:** | **Groundwater △ as labelled** |
| | **Surface water ○ refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Orauea River at Orawia Pukemaori Rd | E | Likely improving | Likely improving | Very likely improving |
| Waiau River at Sunnyside | B | Very likely degrading | Likely degrading | Likely degrading |
| Waiau River at Tuatapere | D | Indeterminate | Very likely improving | Very likely improving |
| Wairaki River D/S Blackmount Rd | NA | Indeterminate | Not assessed | Not assessed |
| Lill Burn at Lill Burn-Monowai Rd | NA | Indeterminate | Not assessed | Not assessed |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Orauea River at Orawia Pukemaori Rd | A | Indeterminate | Likely degrading | Not assessed |
| Waiau River at Sunnyside | A | Very likely degrading | Very likely degrading | Not assessed |
| Waiau River at Tuatapere | A | Very likely degrading | Not assessed | Not assessed |
| Wairaki River D/S Blackmount Rd | A | Indeterminate | Not assessed | Not assessed |
| Lill Burn at Lill Burn-Monowai Rd | A | Not assessed | Not assessed | Not assessed |

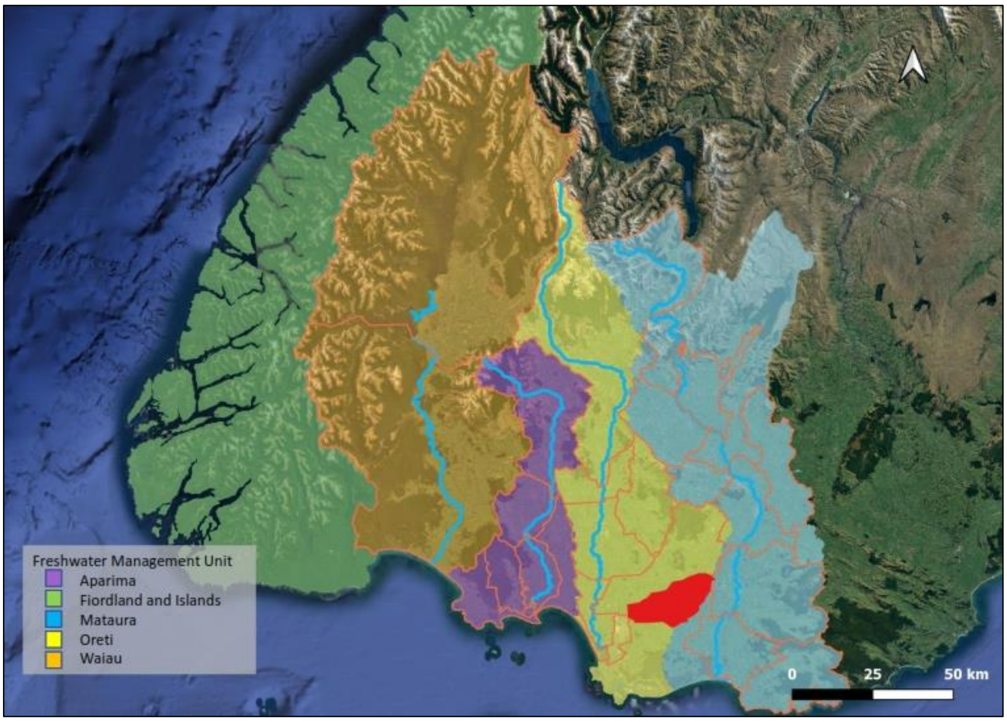
^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

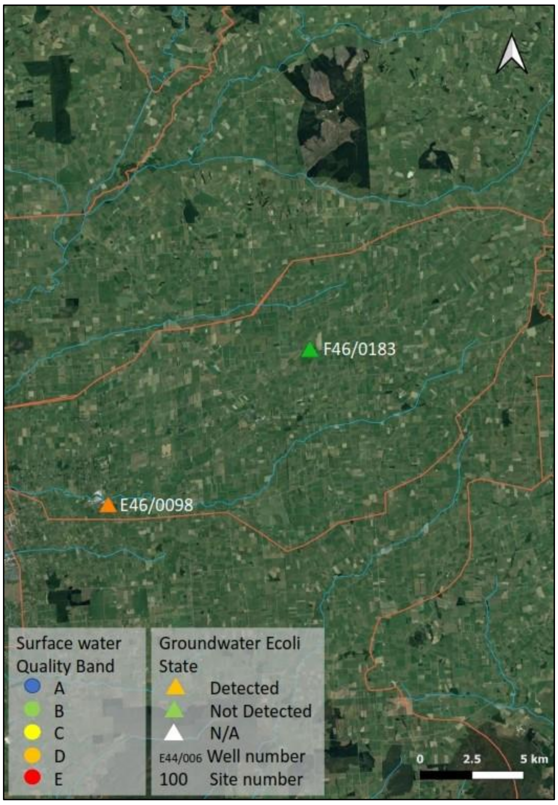
* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

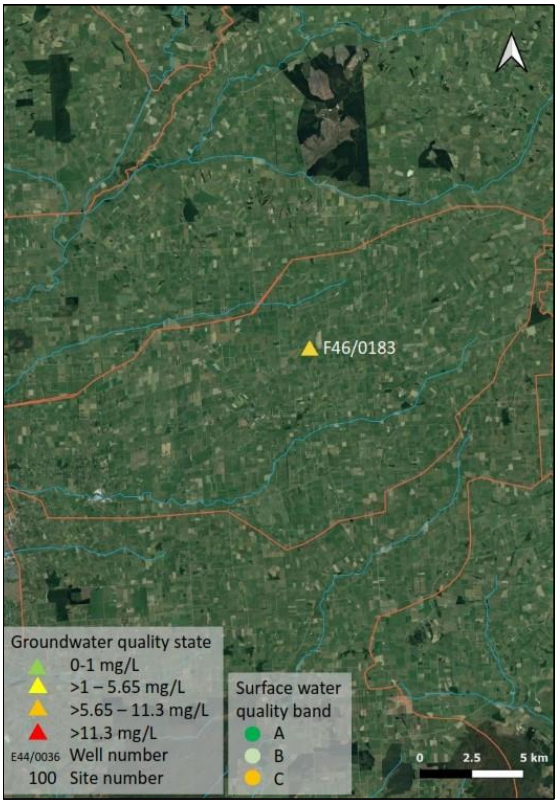
## Groundwater Quality State and Trends

There is one groundwater site in this catchment on the LAWA website that has a history of water quality monitoring but there is no data available since December 2010. As such no state or trend information has been presented. Additional information may be held by ES.

## Waihopai Catchment Group




| | |
|---|---|
| **Left:** | ***E. coli*** **surface and groundwater monitoring sites current state** |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** |
| **Site key:** | **Groundwater △ as labelled** |
| | **Surface water ○ refer to Appendix B for site names** |

## Surface Water Quality State and Trends.

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Waihopai River U/S Queens Drive | E | Likely improving | Very likely improving | Very likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| Monitoring sites in catchment | NOF band | 5-year | 10-year | 15-year |
| Waihopai River U/S Queens Drive | B | Very likely degrading | Likely degrading | Very likely degrading |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| F46/0183 | Not Detected | 0% |
| E46/0098 | N/A | |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

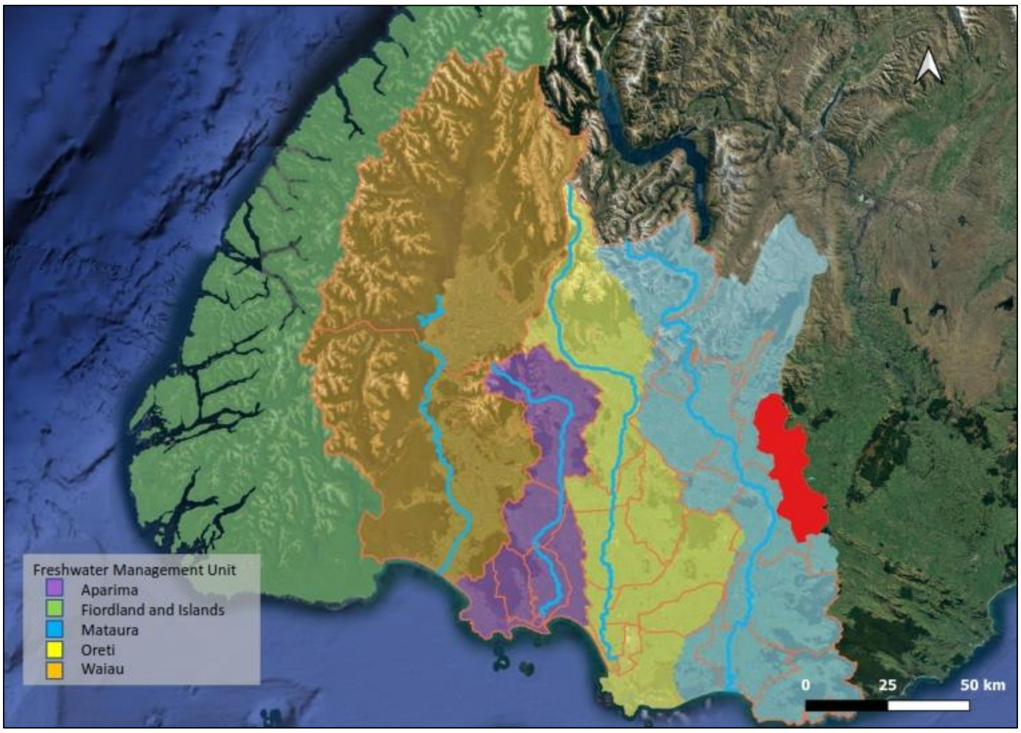
**Summary of Nitrate-Nitrogen state and trends in groundwater**

| *E. Coli* | Statistics NZ comparison to DWSNZ* and/or LAWA data | |
|---|---|---|
| Monitoring sites in catchment | State (2014-18) | Exceedance category^ |
| F46/0183 | 1.80 | 0% |

* https://www.stats.govt.nz/indicators/groundwater-quality

^ Grades categorised as per Stats NZ (2014-2018)

## Waikaka Stream Catchment Group




### Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Waikaka Stream at Gore | D | Likely improving | Very likely improving | Very likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Waikaka Stream at Gore | A | Likely improving | Very likely improving | Indeterminate |

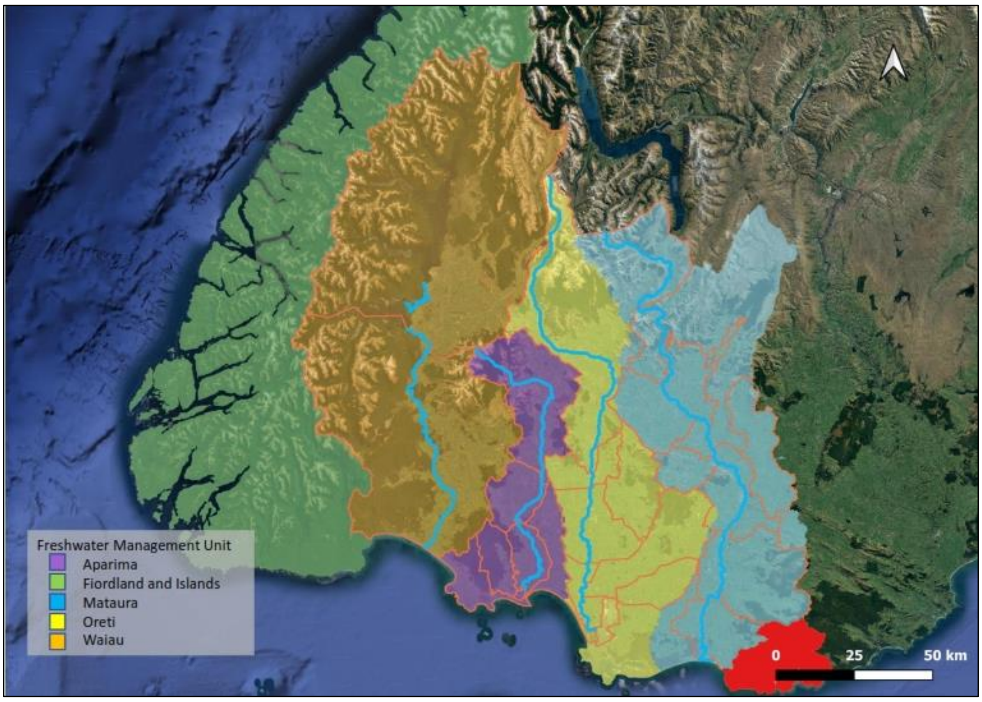
^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration

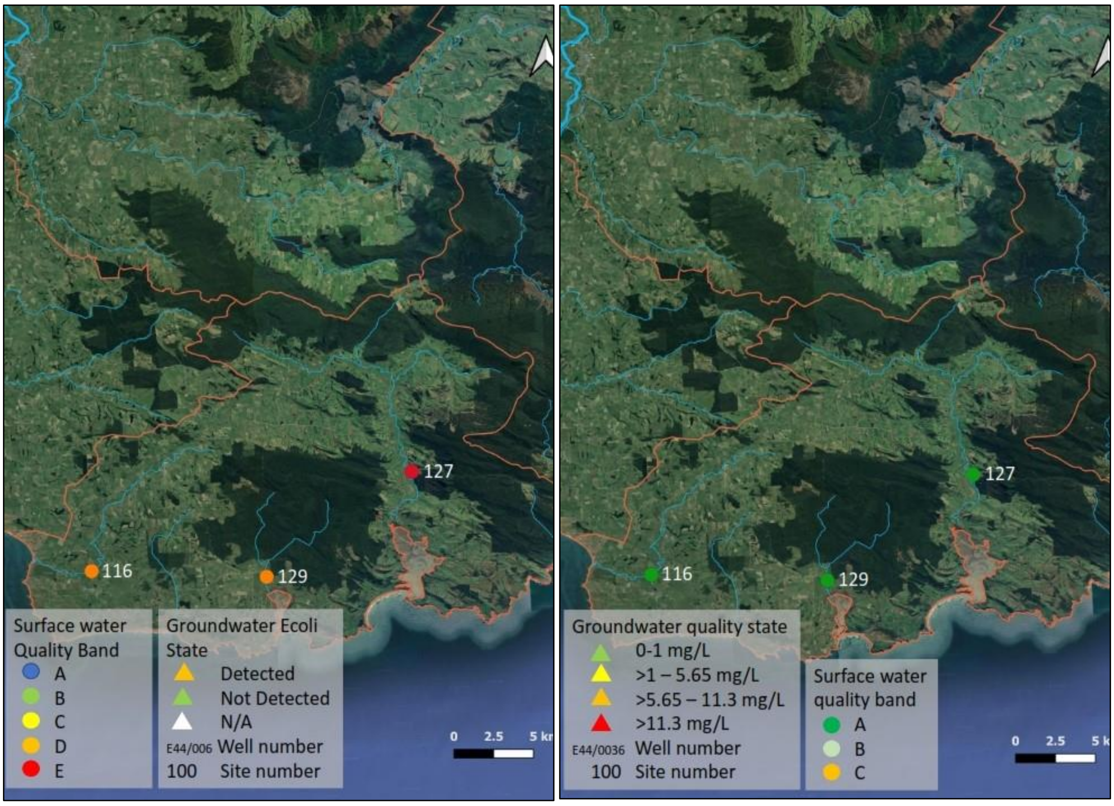
* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

### Groundwater Quality State and Trends

There are no groundwater quality monitoring sites in this catchment area on the LAWA website and as such no state or trend information has been presented. Additional information may be held by ES.

# Waikawa Catchment Group




**Left:** ***E. coli*** **surface and groundwater monitoring sites current state**
**Right:** **TON (surface water) and NO3-N (groundwater) monitoring sites current state**
**Site key:** **Groundwater △ as labelled**
**Surface water ○ refer to Appendix B for site names**

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| *E. Coli* | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Tokanui River at Fortrose Otara Road | D | Likely degrading | Indeterminate | Likely degrading |
| Waikawa River at Progress Valley | E | Likely improving | Indeterminate | Likely improving |
| Waikopikopiko Stream at Haldane Curio Bay | D | Indeterminate | Very likely improving | Likely improving |

* 2014-2018 median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

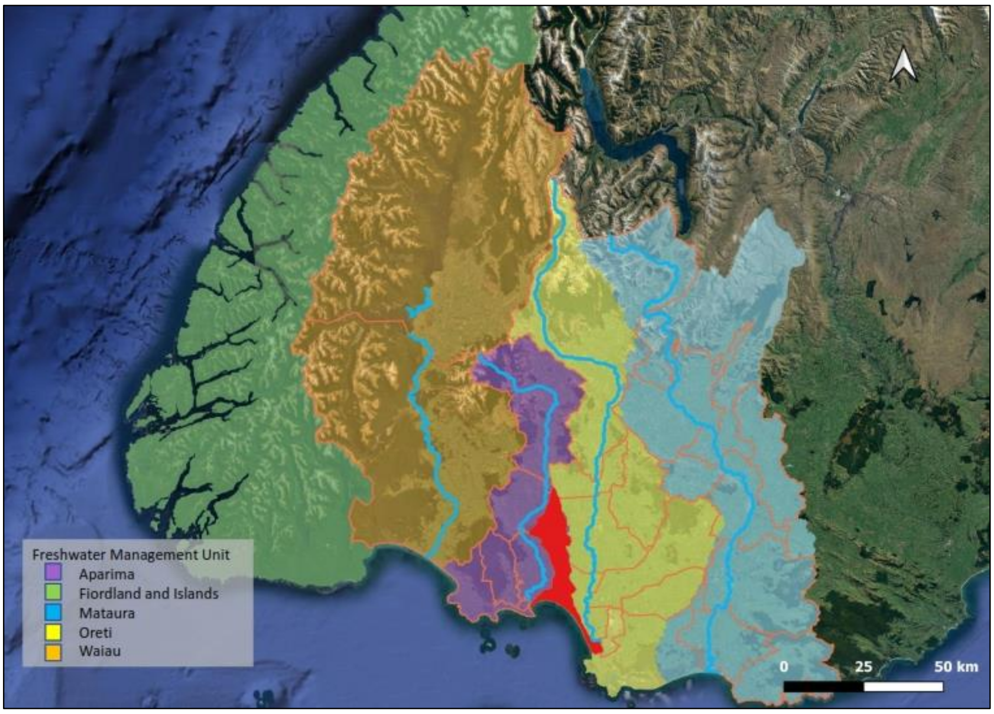
| Total Oxidised Nitrogen (TON)^ | State* | Trend | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Tokanui River at Fortrose Otara Road | A | Very likely improving | Very likely improving | Not assessed |
| Waikawa River at Progress Valley | A | Very likely improving | Very likely improving | Not assessed |
| Waikopikopiko Stream at Haldane Curio Bay | A | Indeterminate | Very likely improving | Not assessed |

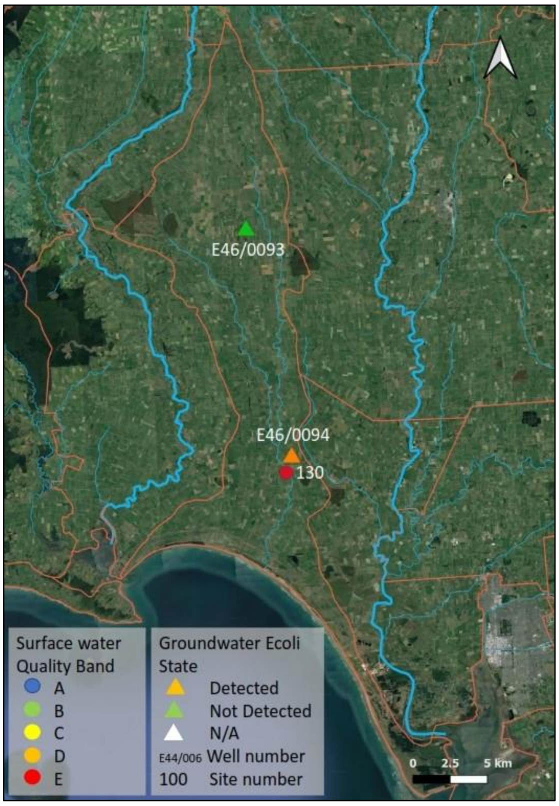
^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration
* 2014-2018 median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N.

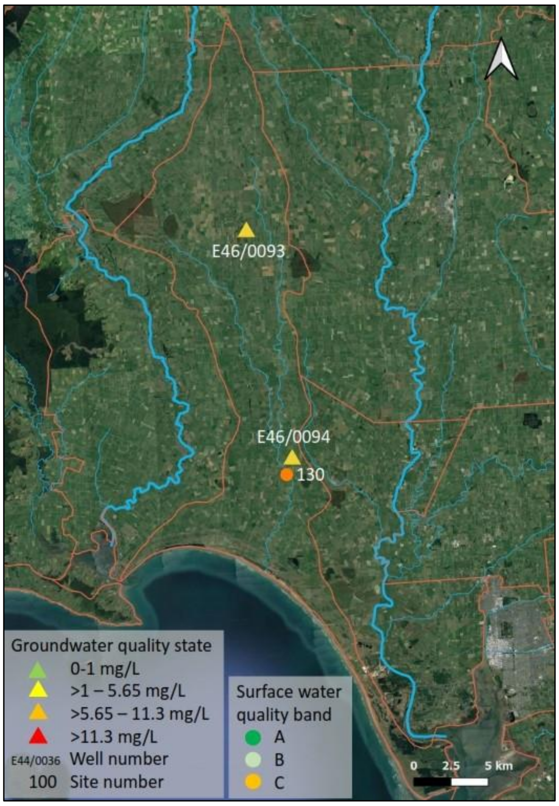
## 14.20.2 Groundwater Quality State and Trends

There are no groundwater quality monitoring sites in this catchment area on the LAWA website and as such no state or trend information has been presented. Additional information may be held by ES.

## Waimatuku Catchment Group




| | |
|---|---|
| **Left:** | ***E. coli*** **surface and groundwater monitoring sites current state** |
| **Right:** | **TON (surface water) and NO3-N (groundwater) monitoring sites current state** |
| **Site key:** | **Groundwater △ as labelled** |
| | **Surface water ○ refer to Appendix B for site names** |

## Surface Water Quality State and Trends

**Summary of *E. Coli* state and trends in surface water**

| ***E. Coli*** | **State*** | **Trend** | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Waimatuku Stm at Lorneville Riverton Hwy | E | Very likely improving | Very likely improving | Very likely improving |

* 2014-2018 LAWA median graded as per NPS-FM 2020

**Summary of Total Oxidised Nitrogen (TON) state and trends in surface water**

| **Total Oxidised Nitrogen (TON)^** | **State*** | **Trend** | | |
|---|---|---|---|---|
| **Monitoring sites in catchment** | **NOF band** | **5-year** | **10-year** | **15-year** |
| Waimatuku Stm at Lorneville Riverton Hwy | C | Indeterminate | Very likely improving | Not assessed |

^ Total Oxidized Nitrogen (TON) is the sum of nitrate and nitrite. Nitrite is generally a very small fraction of the TON concentration in rivers, TON is taken to be equivalent to the nitrate concentration
* 2014-2018 LAWA median graded per NPS-FM 2020 using TON as surrogate for $NO_3$-N

## Groundwater Quality State and Trends

**Summary of *E. Coli* state and trends in groundwater**

| ***E. Coli*** | **Statistics NZ comparison to DWSNZ* or LAWA data** | |
|---|---|---|
| **Monitoring sites in catchment** | **Median (2014-18)** | **Exceedance category^** |
| E46/0094 | Detected | 10-25% |
| E46/0093 | Not Detected | Not assessed |

* https://www.stats.govt.nz/indicators/groundwater-quality
^ Grades Stats NZ (2014-2018)

**Summary of Nitrate-Nitrogen state and trends in groundwater**

| **Nitrate-Nitrogen** | **Statistics NZ comparison to DWSNZ*** | |
|---|---|---|
| **Monitoring sites in catchment** | **Median (2014-18)** | **Exceedance category^** |
| E46/0094 | 1.67 | 0% |
| E46/0093 | 4.5 | |

* https://www.stats.govt.nz/indicators/groundwater-quality
^ Grades categorised as per Stats NZ (2014-2018)

# Appendix B: Surface water monitoring sites

| Site number | Site |
|---|---|
| 72 | Aparima River at Dunrobin |
| 74 | Aparima River at Thornbury |
| 75 | Bog Burn d/s Hundred Line Road |
| 76 | Carran Creek at Waituna Lagoon Road |
| 78 | Cascade Stream at Pourakino Valley Road |
| 79 | Cromwell Stream at Selbie Road |
| 80 | Dunsdale Stream at Dunsdale Reserve |
| 81 | Irthing Stream at Ellis Road |
| 82 | Longridge Stream at Sandstone |
| 83 | Makarewa River at Lora Gorge Road |
| 84 | Makarewa River at Wallacetown |
| 85 | Mararoa River at South Mavora Lake |
| 86 | Mararoa River at The Key |
| 87 | Mararoa River at Weir Road |
| 88 | Matāura River 200m d/s Mataura Bridge |
| 90 | Matāura River at Gore |
| 92 | Matāura River at Mataura Island Bridge |
| 94 | Matāura River at Parawa |
| 95 | Mimihau Stream at Wyndham |
| 96 | Mimihau Stream Tributary at Venlaw Forest |
| 97 | Moffat Creek at Moffat Road |
| 98 | Mokoreta River at Wyndham River Road |
| 99 | Mokotua Stream at Awarua |

| | |
|---|---|
| 100 | North Peak Stream at Waimea Valley Road |
| 101 | Opouriki Stream at Tweedie Road |
| 102 | Orauea River at Orawia Pukemaori Road |
| 104 | Ōreti River at Lumsden Bridge |
| 105 | Ōreti River at Three Kings |
| 106 | Ōreti River at Wallacetown |
| 107 | Otamita Stream at Mandeville |
| 108 | Otapiri Stream at Otapiri Gorge |
| 109 | Otautau Stream at Otautau – Tuatapere Road |
| 110 | Otautau Stream at Waikouro |
| 111 | Otepuni Creek at Nith Street |
| 112 | Oteramika Stream at Seaward Downs |
| 114 | Pourakino River at Traill Road |
| 115 | Sandstone Stream at Kingston Crossing Rd |
| 116 | Tokanui River at Fortrose Otara Road |
| 117 | Tussock Creek at Cooper Road |
| 118 | Upukerora River at Te Anau Milford Road |
| 120 | Waiau River at Sunnyside |
| 121 | Waiau River at Tuatapere |
| 122 | Waihopai River u/s Queens Drive |
| 123 | Waikaia River at Waikaia |
| 124 | Waikaia River at Waipounamu Bridge Road |
| 125 | Waikaia River u/s Piano Flat |
| 126 | Waikaka Stream at Gore |
| 127 | Waikawa River at Progress Valley |
| 128 | Waikawa Stream at North Road |

| | |
|---|---|
| 129 | Waikopikopiko Stream at Haldane Curio Bay |
| 130 | Waimatuku Stream at Lorneville Riverton Hwy |
| 132 | Waimea Stream at Mandeville |
| 139 | Waituna Creek at Marshall Road |
| 140 | Whitestone River d/s Manapouri- Hillside |
| 141 | Winton Stream at Lochiel |
| 151 | Dipton Stream at South Hillend-Dipton Road |
| 152 | Hamilton Burn at Affleck Road |
| 153 | Hedgehope stream 20m u/s Makarewa Confluence |
| 154 | Lill Burn at Lill Burn-Monowai Road |
| 155 | Wairaki River d/s Blackmount Road |

## Appendix C: Illustration of a securely protected well head (Courtesy Hawkes Bay Regional Council)