# Understanding your landscape's resilience: Beyond Regulation

## FINAL REPORT

### APRIL 2024

THRIVING SOUTHLAND
*Tōnui ana te whenua. Tōnui ana te takata.*

LAND & WATER SCIENCE

Understanding your landscape's resilience: BEYOND REGULATION

# Understanding your landscape's resilience: BEYOND REGULATION


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**This has been a complex and collaborative project, and would not have been possible without the support of:** *the Case Study Farmers, Prebble L, Pearson L, Beatson C, Frengley D, Stevenson D, Chakwiziva E and AGMARDT.*

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# Definition of terminology

Physiographic approach – assesses the dominant processes within the landscape in influencing environmental outcomes by combining existing soil, geological, topography and climate data to understand the landscape factors controlling variation in water quality.

Landscape susceptibility mapping – takes a high-resolution physiographic approach and maps it for a property (the resolution is at paddock scale). This identifies the landscape susceptibility to contaminant loss and soil greenhouse gas (GHG) emissions.

Redox (reduction and oxidation) – an important environmental process that controls the mobility of phosphorus, the breakdown of nitrate (e.g. nitrogen through denitrification), and the production of GHG in soils, aquifers, and water. Redox conditions are referred to as Reducing or Oxic.

Oxic refers to soil, aquifer, or water that contains abundant oxygen. When oxygen is abundant, phosphorus is normally less mobile, it sticks to soils and aquifer materials. However, when oxygen is abundant there is little opportunity for nitrate to be removed (i.e., via denitrification). Oxic conditions in soil or aquifers also limit the production of GHG.

Reducing refers to soils, aquifers, or water that contain low concentrations of oxygen. When oxygen is low, phosphorus is more mobile; it does not stick as readily to soil or aquifer materials and can be leached. When oxygen is low there is a greater opportunity for nitrate to be removed (i.e., via denitrification). Reducing conditions in soil or aquifers favour the production of nitrous oxide and in some instances methane, both of which are GHG.

# Executive summary

**In response to the pressing need for sustainable land management practices in the Mataura Catchment, Land and Water Science Ltd (LWS) and Thriving Southland collaborated on the *Understanding your landscape's resilience: Beyond Regulation* project. This innovative initiative, made possible through funding from the Agmardt Food and Fibres Aotearoa New Zealand Challenge, was designed to identify targeted mitigations to reduce environmental impacts while aligning with farmers' goals and regulatory requirements.**

The project adopted a holistic approach, leveraging cutting-edge scientific landscape data and in-depth farm system analysis to develop effective mitigation pathways for soil, greenhouse gas and water quality outcomes. Utilising high-resolution physiographic mapping and comprehensive farm system assessments, the project provided valuable insights at both catchment and farm scales, empowering land users to meet their environmental responsibilities effectively.

LWS's development of the physiographic environments classification proved instrumental in understanding the variations in water quality influenced by diverse factors such as climate, topography, geology and soils. This sophisticated mapping facilitated the identification of contaminant susceptibility at individual property scales, enabling precise and targeted mitigation efforts.

Through the implementation of three carefully chosen case studies, representing dairy, sheep and beef, and arable farming systems, the project showcased the practical application of scientific insights at property scale. By strategically bundling low-cost farm system mitigations with landscape interventions, farmers were able to effectively reduce contaminants, emphasising the importance of integrating multiple strategies for optimal results.

## KEY LEARNINGS FROM CASE STUDIES:

» **Case study 1:** A dairy farm near Brydone, South of Gore, highlighted the importance of bundling low-cost farm system mitigations with landscape interventions to reduce contaminants effectively. While capital-intensive additions like loafing barns may not provide significant environmental mitigation, retiring sidling areas and reducing grazing intensity proved to be viable strategies.

» **Case study 2:** A sheep and cattle farm near Wendonside, north of Gore, emphasised the significance of aligning hydrology and landscape susceptibility insights to guide investments in minimising losses. By carefully considering farm system changes and costs, the farm identified opportunities for changes in farm systems, wetland installation, and forestry integration to mitigate water quality concerns.

» **Case Study 3:** An arable farm near Balfour in Northern Southland highlighted the importance of targeting nutrient applications and treating contaminants leaving the farm boundary to effectively reduce environmental impact. While upfront capital investment in wetland development was needed, the farm identified strategies such as reviewing crop rotations and nutrient targeting to mitigate nitrate accumulation in groundwater.

These case studies exemplify the practical application of scientific insights to develop bespoke mitigation solutions tailored to the unique characteristics of each farm, thereby fostering collaboration between farmers and catchment groups, and laying the groundwork for long-term environmental resilience.

A robust extension programme, including interactive field days, accessible digital resources, stakeholder meetings and targeted presentations, ensured the widespread dissemination of project findings to the broader community. Ongoing engagement with catchment groups and individual farmers remains a cornerstone of the project's strategy, facilitating the continuous exchange of insights and supporting the widespread adoption of sustainable practices.

The project outcomes have yielded invaluable insights into the environmental challenges and mitigation opportunities within the Mataura Catchment. Looking ahead, further collaboration and dissemination of findings will be paramount in driving positive change and enhancing the overall environmental health of the catchment.

Recommendations include addressing existing gaps in forestry integration, wetland implementation, lower intensity land use change, and policy support.

The project aims to expand its reach through comprehensive training programmes and the development of accessible resources, ensuring the widespread adoption of sustainable practices not only within the Mataura Catchment, but further afield.

# The project

## Many farmers are actively seeking opportunities to reduce their environmental impact to meet their own goals, as well as regulations, consumer and community expectations.

Land and Water Science Ltd (LWS), along with Thriving Southland, were successful in applying to the Agmardt Food and Fibres Aotearoa New Zealand Challenge to fund the *Understanding your landscape's resilience: Beyond Regulation* project.

This collaborative project, based in the Mataura Catchment, aims to leverage scientific landscape data and farm system analysis to identify targeted mitigations that can reduce environmental impacts.

Through the development of high-resolution physiographic mapping, combined with detailed farm system analysis, we can provide effective and cost-effective mitigation pathways for soil, greenhouse gas and water quality outcomes at both catchment and farm scale.

Implementing a high-resolution (information at a finer scale) approach to help land users meet their environmental responsibilities requires significant innovation, including bridging the divide between science outputs and practical guidance at property and paddock scale.

## Method

Landscape variability plays a significant role in governing the type and severity of water quality and soil GHG outcomes, even when land use is the same. This means that two identical farms side-by-side may have different water quality and soil GHG outcomes if the landscape settings beneath them differ.

Using a combination of airborne and ground-based radiometric survey data (gamma-ray spectroscopy), along with ground truthing as an important validation step, high resolution mapping was developed to reveal the landscape's relative susceptibility for soil GHG emissions and water quality contaminants across the Mataura Catchment. This mapping enables the identification of mitigation opportunities and supports the consideration of land use activities/farm systems.

Three case study farms were used to apply the science at property scale. This provided a way to demonstrate actions and mitigations that could be undertaken in different landscape settings on a dairy farm, sheep and beef farm and an arable farm.

A multi-disciplinary team[1] with expertise in landscape susceptibility mapping, water quality science and farm systems met with all case study farmers. Current options and technologies available were considered as mitigations. Options for reducing environmental impact were discussed and perspectives sought on practicality, cost, impact on the farm system, and likely environmental consequence of the mitigation.

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[1] Refer appendix 1 for list of team members for each case study.

Changes in environmental impact were estimated using OverseerFM modelling and riparian margin calculations, and compared to the 2020/21 season. The estimated changes in total greenhouse gas emissions (methane, nitrous oxide and carbon dioxide combined) are reported. In addition, the estimated changes in nitrous oxide emissions are identified to align with the specific opportunities identified in the landscape susceptibility mapping.

The high-level impact of farm system change on capital investment and farm working expenses was explored through partial budgeting. The cost of greenhouse gas emissions pricing has not been calculated; decisions are yet to be made by the Government on an agricultural emissions pricing scheme. All work throughout the project has been peer-reviewed.

Case studies have been presented to the individual farmers for discussion. The landscape content was combined, presented digitally and made available to Mataura Catchment farmers via a program that combines maps and geographic information into an interactive format (ArcGIS StoryMap).

## Learnings have been extended through:

- a field day
- resources and information on the Thriving Southland website:
  - case studies
  - video content on project concept and method
- video content for rural professionals
- two radio interviews on the Hokonui Radio farming show
- rural professional updates (as part of various regular contact meetings)
- stakeholder meetings (Environment Southland governance and management, Hokonui Rūnanga, Te Ao Mārama)
- conference presentations (Rural Women, NZARM).

Extension activities are ongoing. Now that the project is complete, the focus will shift to presenting findings at the forthcoming Thriving Southland Catchment Group Forum and to individual catchment groups as needed or requested.

# State of the Mataura Catchment

**The Mataura River catchment is located within the Southland and Gore districts of New Zealand. It extends from the lower reaches of Lake Wakatipu in the north, all the way down to the coast at Fortrose where the Mataura River discharges into the Toetoes Estuary. The catchment's total area is about 640,000 hectares (ha) and is the second largest developed river catchment in Southland. Approximately 540,000 ha (84% of the area) is developed, which represents the highest percentage of any catchment in the region.**

The Mataura River and Toetoes Estuary are an important source of mahinga kai, particularly kanakana, inanga and tuna. Land use and various industrial and municipal water discharges are key contributors to the degradation of water quality in the Mataura catchment. Currently the Toetoes Estuary is considered to be in poor condition.

Water quality in this catchment is showing stress in terms of faecal bacteria *E. coli* (surface water), nitrogen (surface and ground water), phosphorus (surface water), and the macroinvertebrate community index (MCI). However, there are distinct variations in the landscape settings throughout the catchment, which influence water quality.

## Surface water

There are 18 sites in the Mataura River catchment where water quality is measured, with the upper catchment exhibiting very good to good water quality, which deteriorates downstream as the cumulative effects of land use activities and various industrial and municipal discharges take effect. Overall, surface water quality in the Mataura Catchment is characterised by elevated nitrogen, phosphorus, sediment, *E. coli* and degraded macroinvertebrate community index (MCI). A recent report by Land Water People (LWP) estimated nutrient load reductions required to meet catchment objectives are 79% for total nitrogen and 58% for total phosphorus[2]. The Mataura Freshwater Management Unit exhibited the highest levels of suspended sediment, with 61% of sites in D band in 2019 and only 35% of sites meeting visual clarity objectives[3].

[2] Snelder, T. (2020). Assessment of Nutrient Load Reductions to Achieve Freshwater Objectives in the Rivers, Lakes and Estuaries of Southland Including Uncertainties: To inform the Southland Regional Forum process. Prepared for Environment Southland by Land and Water People.

[3] Norton, N., Wilson, K., Rodway, E., Hodson, R., Roberts, K. L., Ward, N., O'Connell-Milne, S., DeSilva, N., & Greer, M. (2019). Current environmental state and the "gap" to draft freshwater objectives for Southland. *Environment Southland Technical Report, 12.*

## Groundwater

The area surrounding the upper Mataura is characterised by distinct water quality challenges that relate to the highly variable landscape. The Edendale, Wendonside and Waimea areas have several small, but locally important, areas of elevated groundwater nitrate that exceed the World Health Organisation (WHO) drinking water standards (Rissmann, 2012; Environment Southland Data, 2023).

In the case of the Waimea, high concentrations of nitrate is discharged into the Waimea Stream (Rissmann and Pearson, 2018). Poorly-drained soils in low lying areas are prone to runoff, exporting contaminants via mole-pipe drainage. More broadly, the hill country surrounding the lowland plains is prone to runoff, leading to sediment, *E. coli* and particulate phosphorus loss. Localised water quality issues manifest as exceedances against regional and national freshwater guidelines.

Groundwater quality in the aquifers of the Lower Mataura include localised areas with elevated nitrate, phosphorus and microbial contamination. Generally, nitrate poses less risk across this zone due to mixed redox states, i.e., both oxic and reducing, in groundwater, reflecting reducing conditions in the soil zone and shallow depth of organic-rich lignite measured sediments. These conditions increase the potential for denitrification to naturally remove nitrate in shallow groundwater. However, reducing conditions also enhance phosphorus mobility, resulting in elevated phosphorus levels in areas with reducing conditions. In areas with oxic groundwater, nitrate concentrations are elevated, while phosphorus concentrations are low. Groundwater quality in this zone may also be compromised by naturally occurring elevated iron and manganese concentrations in reducing aquifers.

## Toetoes Estuary

Currently, the Toetoes Estuary, where the Mataura River discharges at Fortrose, is considered to be in poor condition. The estuary has areas that are currently assessed as D band (poor) for macroalgae, Gross Eutrophic Zone (GEZ), mud content and sediment oxygen levels. A recent NIWA report stated that most (~95%) of the nutrient load to the estuary comes from the Mataura River[4]. The nutrients from the Mataura River dominate the Mataura arm and lower estuary, but also supply approximately 38% of the total nitrogen (TN) and total phosphorus (TP) in the Titiroa arm of the estuary. Overall, a reduction in nutrient and sediment inputs is needed to improve the estuary classification above D band (poor). Additionally, a reduction in faecal bacteria is necessary to achieve at least C band (fair) or better at the estuary monitoring sites.

[4] Plew, D., Dudley, B., Shankar, U. (2020) Eutrophication susceptibility assessment of Toetoes (Fortrose) Estuary. NIWA Client Report, 2020070CH: 58.

# Environmental contaminants

## Greenhouse gases

Rising concentrations of greenhouse gases in the atmosphere increase the earth's temperature. Greenhouse gases consist of long-lived gases, such as carbon dioxide and nitrous oxide, as well as short-lived gases, like methane.

**The New Zealand Government has the following legislated emissions targets:**

- reduce methane ($CH_4$) emissions by 10% below 2017 levels by 2030, and by 24-47% by 2050
- reduce nitrous oxide (N2O) and carbon dioxide (CO2) to net zero by 2050.

Both methane and nitrous oxide are very potent greenhouse gases. Methane's warming potential is approximately 30 times more powerful than carbon dioxide. The predominant source of methane in New Zealand farming systems is from ruminant digestive systems.

Nitrous oxide's warming potential is approximately 300 times more powerful than carbon dioxide. Nitrous oxide forms in the soil through microbial processes, primarily nitrification and denitrification, influenced by factors such as soil temperature, nitrate concentrations and soil saturation levels. Lower volumes of nitrous oxide are generated under conditions of low soil temperatures, low nitrate concentrations and unsaturated topsoil, while higher volumes are produced under elevated soil temperatures, high nitrate concentrations and saturated topsoil.

## Nitrate

Nitrate is highly soluble and can easily move through the soil if not utilised by plants and microorganisms. It can then be transported to ground and surface waters, leading to potential human health and ecological issues. Nitrogen, an essential element for plant growth, is typically introduced to pastures through various means such as biological fixation in clovers, as fertiliser (in both synthetic and organic form), effluents or livestock urine. Factors such as slope and soil thickness play a crucial role in nitrate generation. Flatter lands with deeper soils tend to produce higher levels of nitrate, which may be lost below the root zone during periods of soil water drainage, often occurring in the cooler months of the year.

## Organic and ammoniacal nitrogen (TKN)

Total Kjeldahl Nitrogen (TKN) is a measure of organic and ammoniacal N. Organic nitrogen is mineralised to form ammoniacal N, which is then oxidised to nitrite and ultimately nitrate. The loss of excessive TKN from land is therefore an important factor controlling stream health. However, it is important to note that all natural systems contain TKN, with TKN loss occurring from natural state landscapes as well as farmed land. The main difference between natural state and any developed landscapes is the magnitude of losses. Commonly, TKN losses are elevated for soils that are poorly-drained or prone to saturation for extended periods of the year. Soils with elevated organic carbon contents, such as peat and podzols, are more likely to lose high concentrations of TKN than well-drained mineral soils.

Ammoniacal nitrogen ($NH_4$-N) is the form of nitrogen present as either ammonia ($NH_3$) or ammonium ($NH_4$). It can be toxic to aquatic life at high concentrations. There is often a high potential for ammoniacal nitrogen associated with "reducing" soils. This includes poorly-drained soils with higher organic matter content and poor aeration. Ammoniacal nitrogen is less mobile than nitrate and tends to bind to soil particles, particularly those with a high clay content. As a result, it can be more easily transported to waterways during runoff after rain.

## Particulate phosphorus

Phosphorus is a nutrient for plants and algae. High concentrations in waterways can cause weed growth and algae blooms. Sources of phosphorus include the weathering of rocks, soil erosion, and the application of phosphate fertilisers to pastures, as well as dung from livestock.

Particulate phosphorus (PP) refers to phosphorus that is associated with particles such as suspended sediments. Phosphorus binds to soil particles, so when soil is lost by runoff it takes the phosphorus with it.

Particulate phosphorus loss requires water to erode and carry sediment that is enriched in phosphorus to a waterway. The risk of runoff is elevated with increasing slope of land. Soils with elevated P-retention can sequester significant quantities of P from fertiliser or animal waste. Erosion of such soil can transport large amounts of P to waterways, contributing to eutrophication.

Imperfect to poorly-drained soils are more susceptible to particulate phosphorus (PP) loss through runoff or mole-pipe drainage. Conversely, well-drained soils have lower susceptibility to PP loss, although those with elevated Olsen P values may release higher concentrations of dissolved phosphorus into the soil solution. Managing Olsen P values for pasture production and economic returns within optimal ranges helps mitigate dissolved phosphorus leaching.

## Dissolved reactive phosphorus

Dissolved reactive phosphorus (DRP) refers to the soluble phosphorus compounds in water, and is the dissolved P fraction that is not attached to sediment. It is a nutrient for plants and algae, and high concentrations in waterways can cause weed growth and algae blooms.

## Sediment

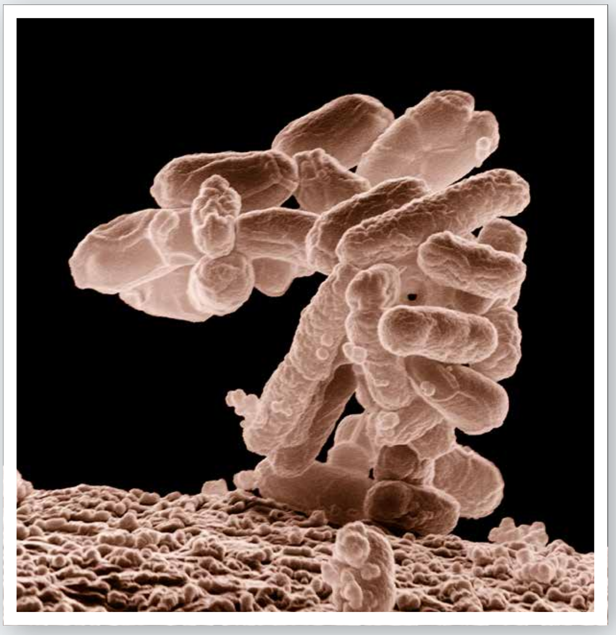
Sediment comprises loose sand, silt, clay and other organic particles suspended in waterways or settled on the bottom. It originates from soil erosion or the decomposition of biological material, and is transported by water, wind and ice to water bodies. While sediment is a natural component of waterways, its type and quantity are strongly influenced by the geology, topography and land use practices of the surrounding area.

Weaker or fine-textured rock types, such as mudstone, naturally contribute to higher sediment loads and more turbid water due to their increased erodibility. Land use practices can further elevate sediment levels, especially when they cause structural damage to soils or leave soil exposed. Sediment enriched with nutrients, common in agricultural areas, poses a greater risk to water quality than sediment from natural sources or areas with lower land use intensity.

Sediment includes organic matter, clay and silt. Sediment loss from the land occurs in a variety of ways. Mass wasting (the movement of soil and earth under gravity) generates slumps, slips and terraces ('sheep tracks') that increase the surface roughness of land. Water running across the rougher parts of the landscape smooth these areas off and carry sediment to waterways. The fine sediment content of soils, i.e. silt and clay, is also an important control over sediment generation and loss. Soils formed in mudstones, for example, tend to have a high clay content which is more easily lost to water, than soils formed in a coarse sandstone. Surface runoff across wet soils is one of the main mechanisms driving sediment loss.

## *E. coli*

Microbes are the hardest contaminants to model. They are dynamic and vary with sunshine intensity, temperature, soil pH, stream types (soft vs. hard-bottomed) and with land use activities (calving/lambing etc). As a general rule, *E. coli* loss from the land is correlated with runoff, mainly as overland flow. Water running across the land surface entrains animal waste. Bacteria and viruses are very sticky, adhering to soil particles and piggybacking their way to streams. Tile drainage can also export significant quantities of bacteria to streams. Any modification of the soil to speed up water drainage can increase the susceptibility of microbial export. However, overall, runoff is the main vehicle for bacterial transport.



For more information on environmental contaminants, see www.landscapedna.org/science/water-quality-contaminants/

# Land use

**The Mataura River catchment is approximately 540,000 hectares in size. Environment Southland's land use map was used to inform land use classes (Pearson and Couldery, 2016).**

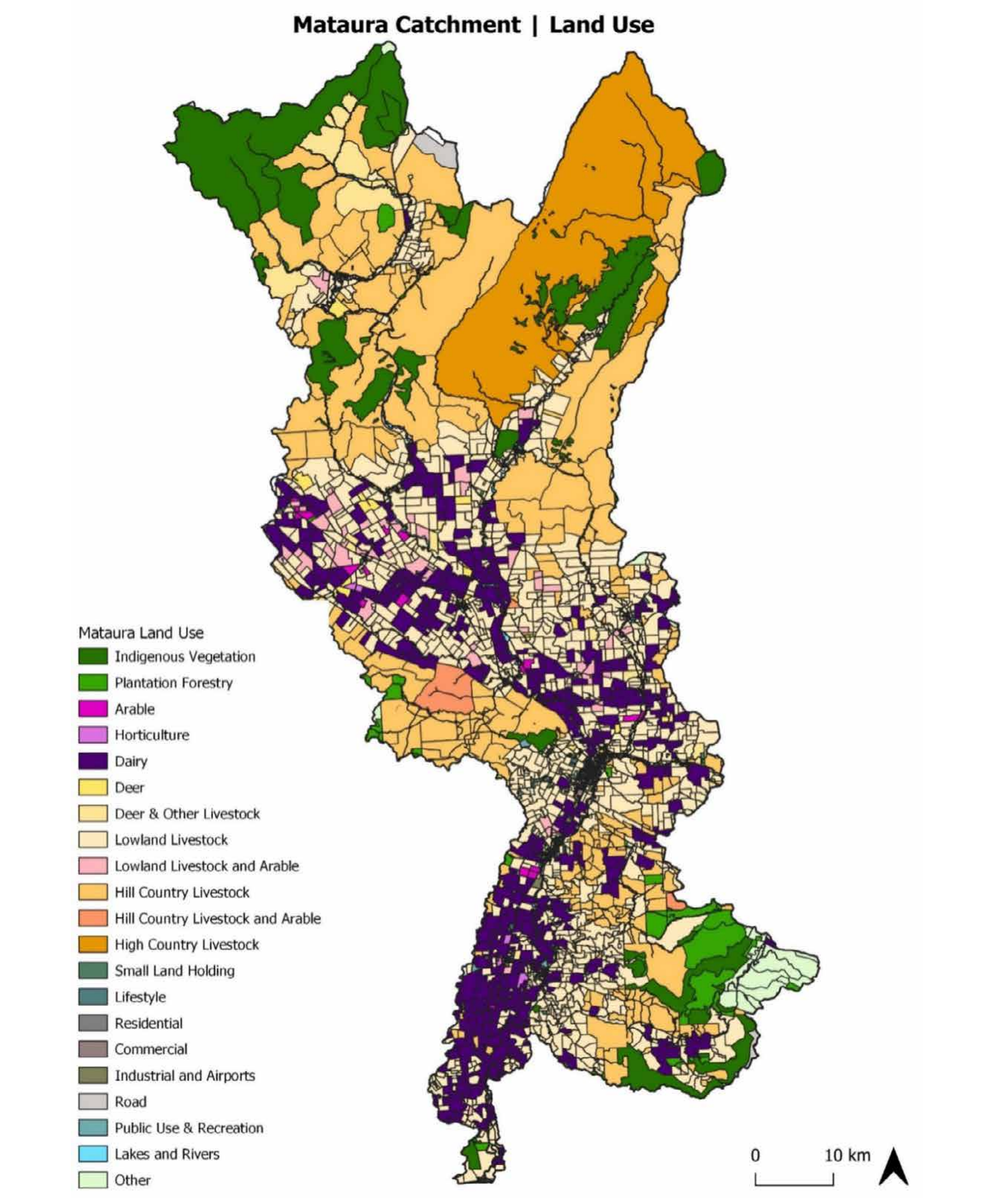



**Figure 1: Land use in the Mataura catchment.**

**Table 1: Land use summary in the Mataura catchment**

| Mataura Catchment Land Use | Area (Ha) | % of catchment |
|---|---|---|
| Indigenous Vegetation | 64,425 | 12.0 |
| Plantation Forestry | 10,811 | 2.0 |
| Deer | 2,430 | 0.5 |
| Deer & Other Livestock | 10,402 | 1.9 |
| Dairy | 65,173 | 12.1 |
| High Country Livestock | 60,189 | 11.2 |
| Hill Country Livestock | 148,550 | 27.6 |
| Hill Country Livestock & Arable | 3,964 | 0.7 |
| Lowland Livestock | 135,028 | 25.1 |
| Lowland Livestock & Arable | 8,679 | 1.6 |
| Arable | 1,801 | 0.3 |
| Horticulture | 487 | - |
| Small Land Holding | 1,321 | 0.2 |
| Lifestyle | 639 | - |
| Public Use & Recreation | 940 | 0.1 |
| Residential | 1,026 | 0.2 |
| Industrial & Airports | 392 | - |
| Commercial | 181 | - |
| Other | 9,648 | 1.8 |
| Lakes and Rivers | 3,734 | 0.7 |
| Roads | 7,278 | 1.4 |

# Landscape susceptibility

**Variability in climate, topography, geology and soils significantly influences the type of contaminant and severity of water quality outcomes, even when land use remains consistent (Rissmann et al. 2016; 2018, 2019, 2024). We refer to the variability in climate, topography, geology and soil as 'landscape factors'.**

They encompass the physical, chemical and biological (organic matter) components of the earth, which determine the susceptibility or 'risk' of the landscape to contaminant loss (see Figure 2). Landscape factors, especially soil texture and drainage, also play a significant role in governing soil greenhouse gas (GHG) production.

In geologically diverse landscapes like New Zealand, the type and severity of contaminant loss vary significantly. Even in relatively simple landscape settings, variations in these factors may account for the majority of spatial variation in water quality compared to land use alone.

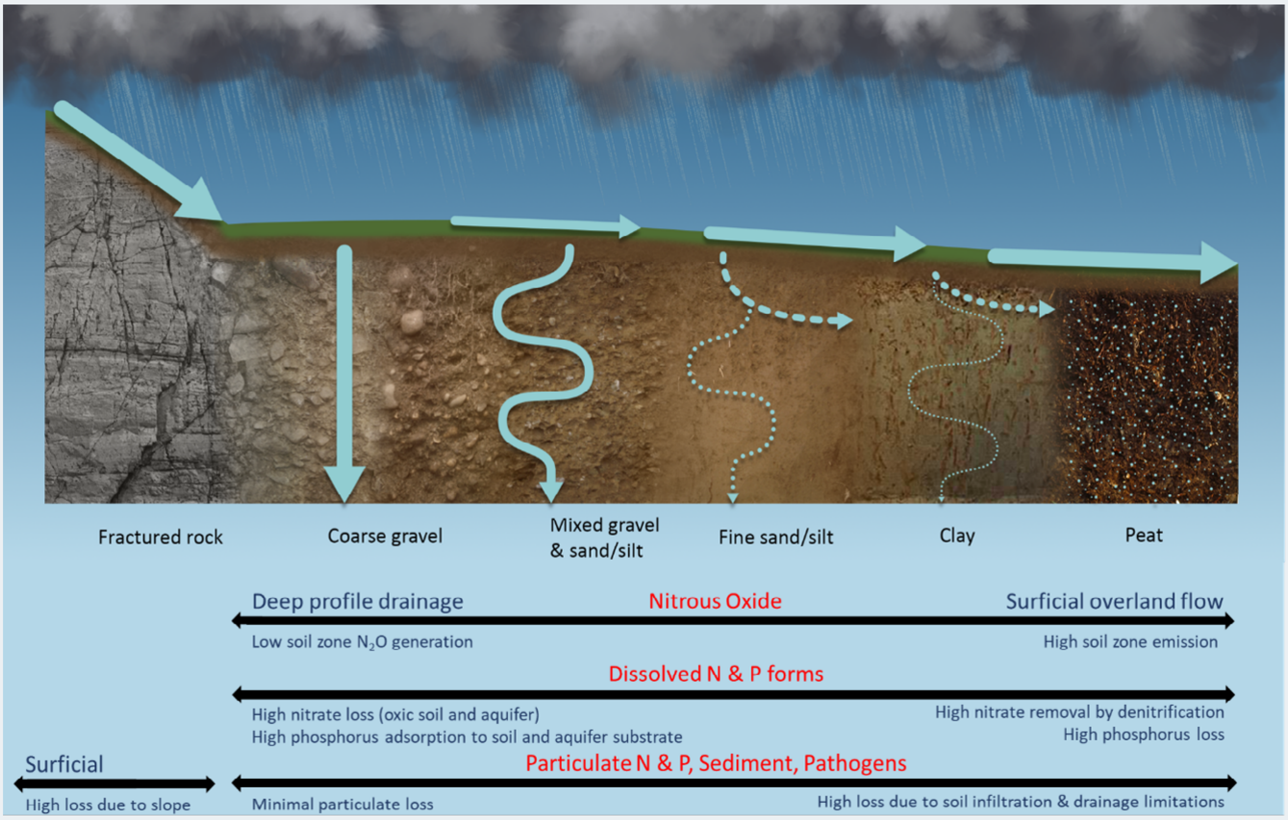



**Figure 2: Conceptual diagram of susceptibility for contaminant loss under various landscape properties. Susceptibility for contaminant loss is strongly controlled by the pathway water takes to leave the land and the chemical processes of reduction-oxidation.**

Land and Water Science (LWS) has generated a classification that maps the landscape factors which control variation in the type and severity of water quality issues (Rissmann et al., 2018, 2019, 2024). The classification, Physiographic Environments of New Zealand (www.LandscapeDNA.org), is designed to support land users in understanding how and why water quality variation occurs across the landscape. It also identifies the most important susceptibility on their property, thereby targeting actions specific to their location and the issues they face.

This mapping is undertaken by combining existing soil, geological, topography and climate data to get an integrated understanding of the landscape factors controlling variation in water quality. The map has a resolution of 1:50,000. At this scale, it is appropriate for providing small catchment scale context but is not at the resolution suitable for property or paddock scale decision-making.

The Mataura River catchment physiographic setting is provided in Figure 3 and Table 2. Alpine and Bedrock environments comprise 53% of the catchment, with the lowlands dominated by the reducing soil oxidising aquifer (18.2% of the catchment) and oxidising soil and aquifer environment (16.1% of the catchment). Bedrock environments, particularly weak bedrock, are highly susceptible to sediment loss. In the lowlands, in oxidising environments nitrate is the main contaminant of concern as a high volume of precipitation drains through the soil to the underlying aquifer. In reducing environments sediment, sediment-bound P, organic and ammoniacal nitrogen, and *E. coli* are most susceptible to loss as drainage moves more laterally or over the land.

The highest risk to water quality occurs during overland flow (runoff) events due to minimal interaction between contaminants and the landscape (assuming there is a contaminant source from land use). In intensively farmed environments, pulses of overland flow may contain the full range of contaminants, including sediments, organic matter, phosphorus, organic and ammoniacal nitrogen, and pathogens (*E. coli*). These contaminants may be discharged directly to stream. Once in stream or as deposited sediments, organic nitrogen, ammoniacal nitrogen, organic and inorganic phosphorus undergo transformation, potentially releasing nitrate and dissolved reactive forms of nitrogen into the overlying water column.

By comparison, water and contaminants that infiltrate a permeable soil and percolate below the root zone typically experience much higher rates of contaminant removal via filtration (including straining), absorption/adsorption and other processes, greatly reducing the total load of contaminants. Organic and ammoniacal forms of nitrogen that are retained by the soil during infiltration and percolation may be converted to nitrate, which can be lost by leaching. However, relative to overland flow, the amount or load of contaminants lost via leaching is small, or at least restricted to a single contaminant form i.e., nitrate. For these reasons, attenuating agricultural runoff is considered a high priority.

With regards to overland flow, the majority of contaminant losses from a property can occur over a small number of these events during the year. Artificial drainage is installed to minimise the occurrence of overland and lateral flow. Where soil drainage has been improved, the natural ability of the soil to filter and adsorb contaminants is increased but its ability to denitrify decreases.

All contaminants may be transported through the artificial drainage network but often in smaller quantities than would have been discharged by surface runoff. The ability to remove nitrate nitrogen naturally through denitrification is also reduced.

For specific details on each physiographic environment and its landscape susceptibility see www.landscapedna.org/science/physiographic-environments/

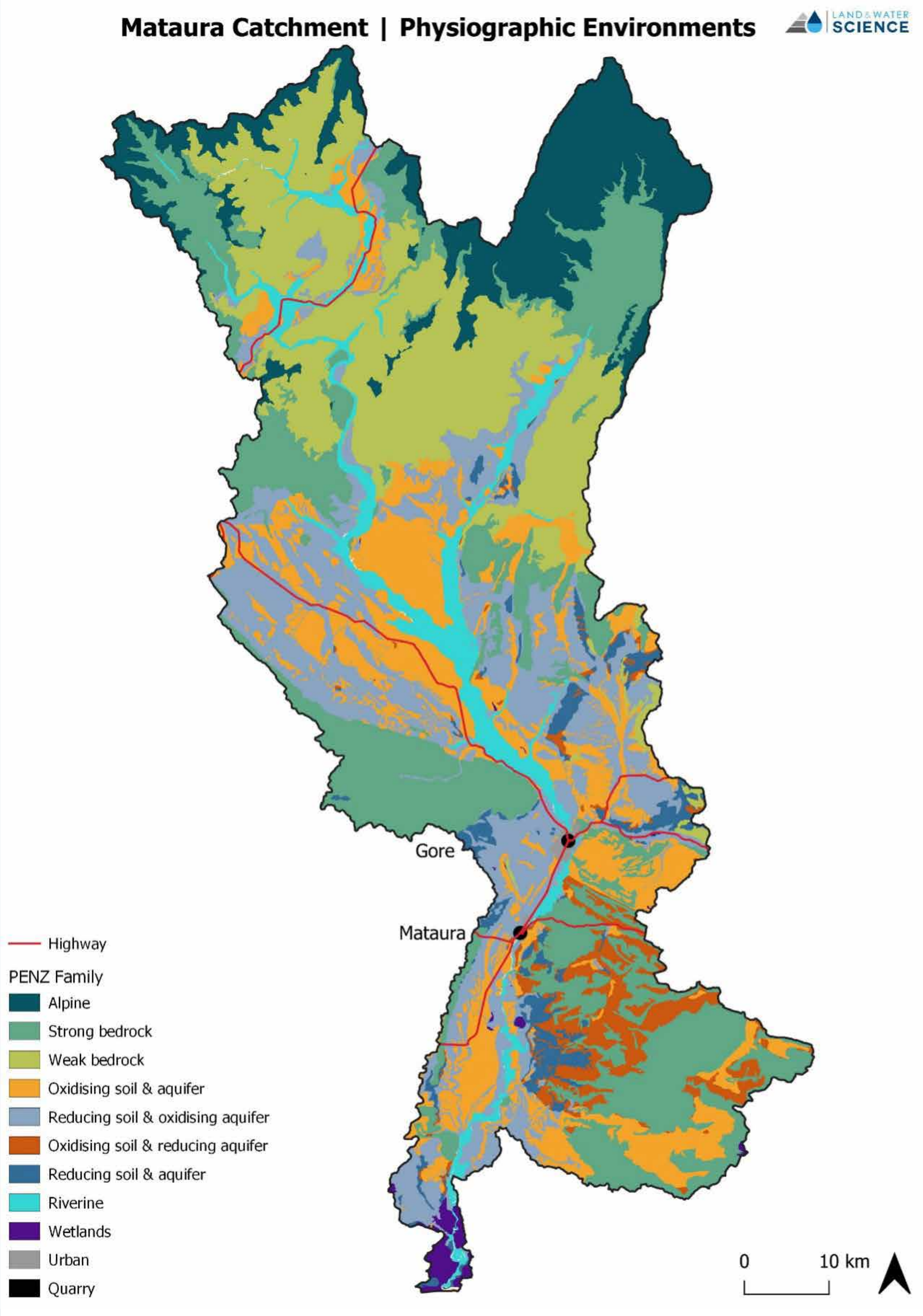



Figure 3: Physiographic Environments of the Mataura catchment.

**Table 2: Physiographic Environment summary for the Mataura Catchment**

| Physiographic Environment | Area (Ha) | % of catchment |
|---|---|---|
| Alpine | 57,564 | 10.7 |
| Bedrock (Strong) | 128,979 | 24.0 |
| Bedrock (Weak) | 100,855 | 18.7 |
| Oxidising soil & aquifer | 86,921 | 16.1 |
| Reducing soil oxidising aquifer | 97,784 | 18.2 |
| Oxidising soil reducing aquifer | 19,858 | 3.7 |
| Reducing soil & aquifer | 14,355 | 2.7 |
| Riverine | 27,661 | 5.1 |
| Wetlands | 3,306 | 0.6 |
| Urban | 1,200 | 0.2 |

## Susceptibility of case study farm

LWS has undertaken a new, high-resolution physiographic approach to mapping the inherent and varied susceptibility of the landscape to land use activities at individual property scales. The resolution of the mapping is 50x50m providing a much more detailed understanding of contaminant susceptibility than physiographic environments on their own. The maps have a sufficient resolution to display variations in susceptibility at the paddock scale.

The maps of landscape susceptibility highlight the various contaminants and their forms using a scale of 0-100 (0 being low and 100 being high susceptibility). The landscape's dominant influence on contaminant production and transport stresses the importance of considering these spatially-driven factors more attentively.

**For the susceptibility models presented below, it is important to emphasise the following:**

A. they are entirely independent of land use and only identify the natural susceptibility of the landscape to contaminant loss associated within soil, geology and topographic factors, like slope and elevation

B. they do not consider any existing environmental management practices or physical mitigations that are already in place, like sediment traps and wetlands

C. they do not represent actual contaminant losses or loads.

The susceptibility maps are coloured from red, reflecting elevated susceptibility to the contaminant or emission in question, to blue, reflecting low susceptibility.

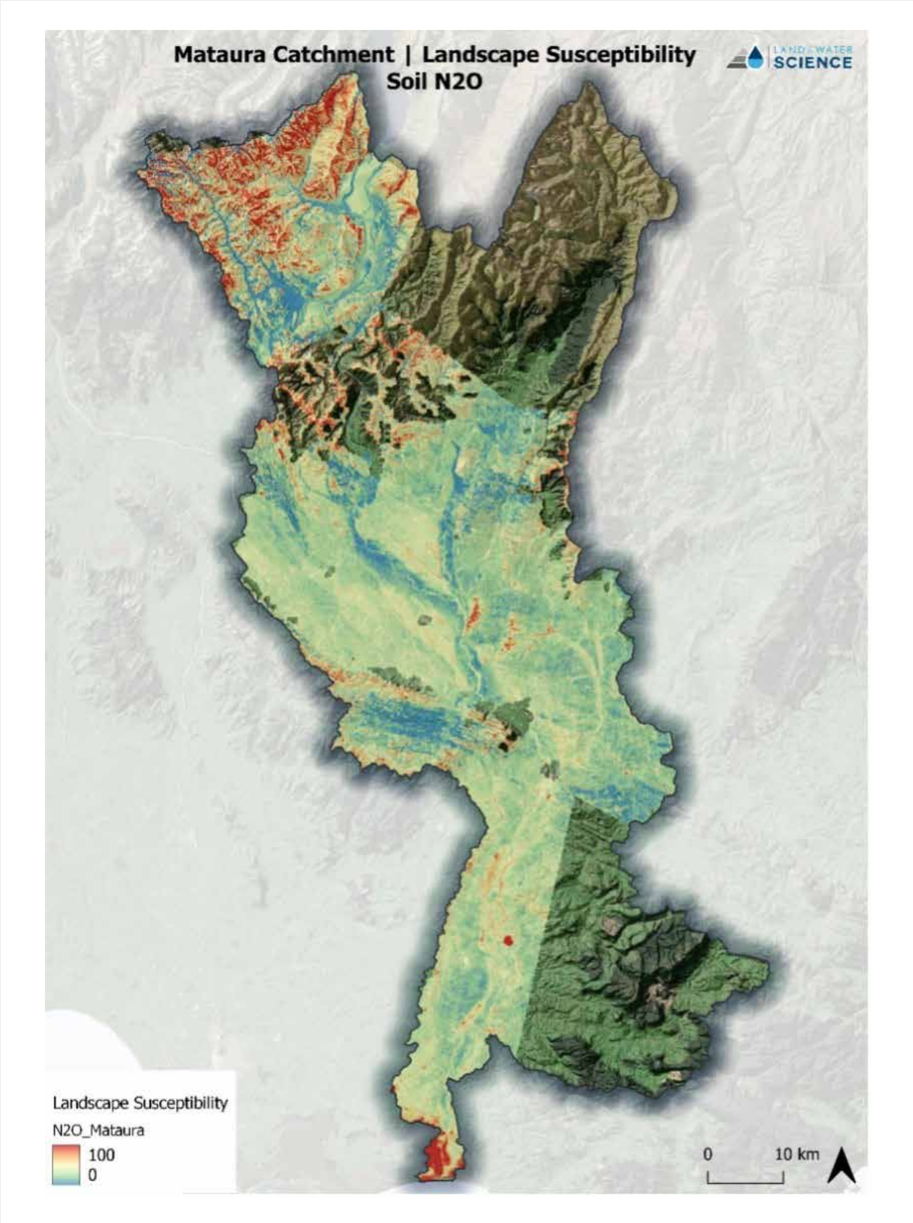



Figure 4: Landscape susceptibility to nitrous oxide.

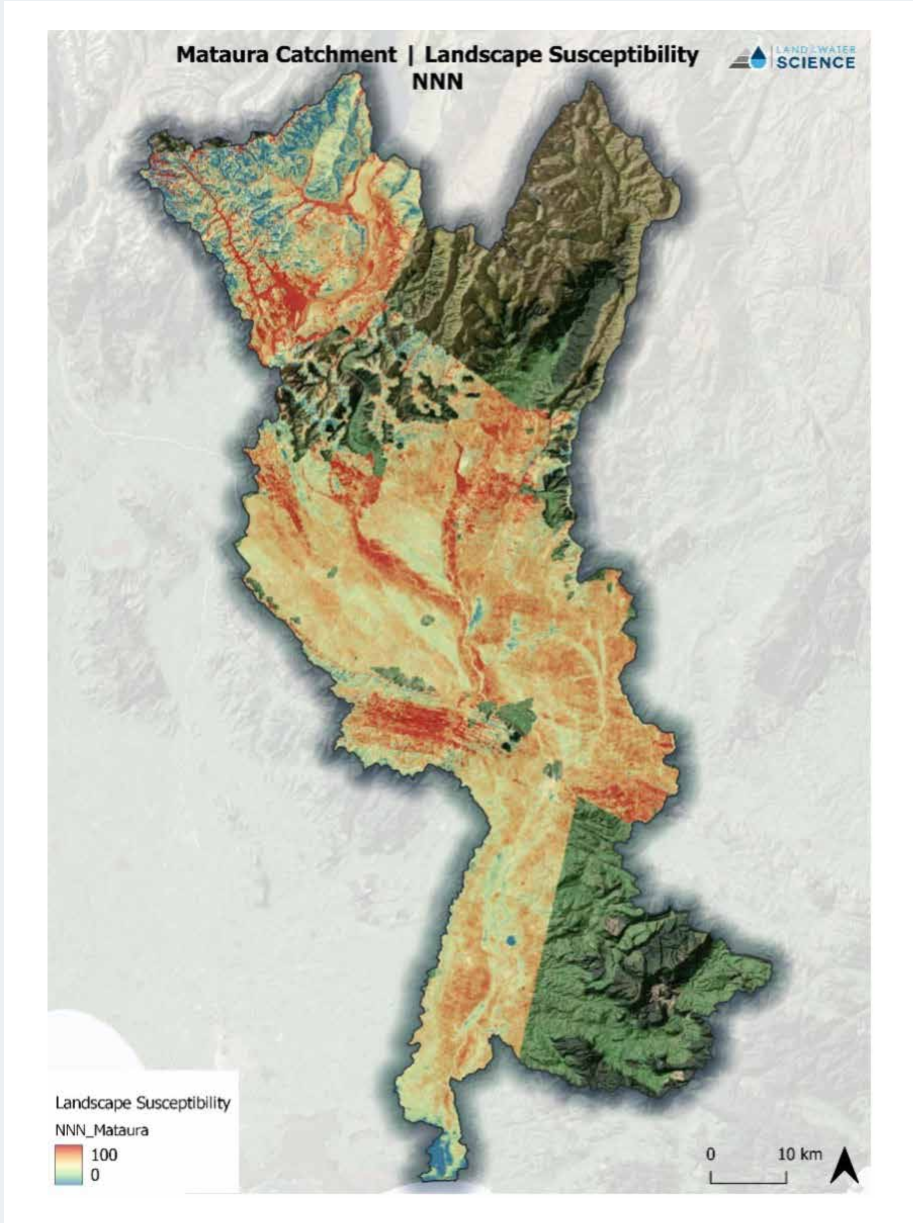



Figure 5: Landscape susceptibility to NNN (Nitrate- Nitrite-Nitrogen).

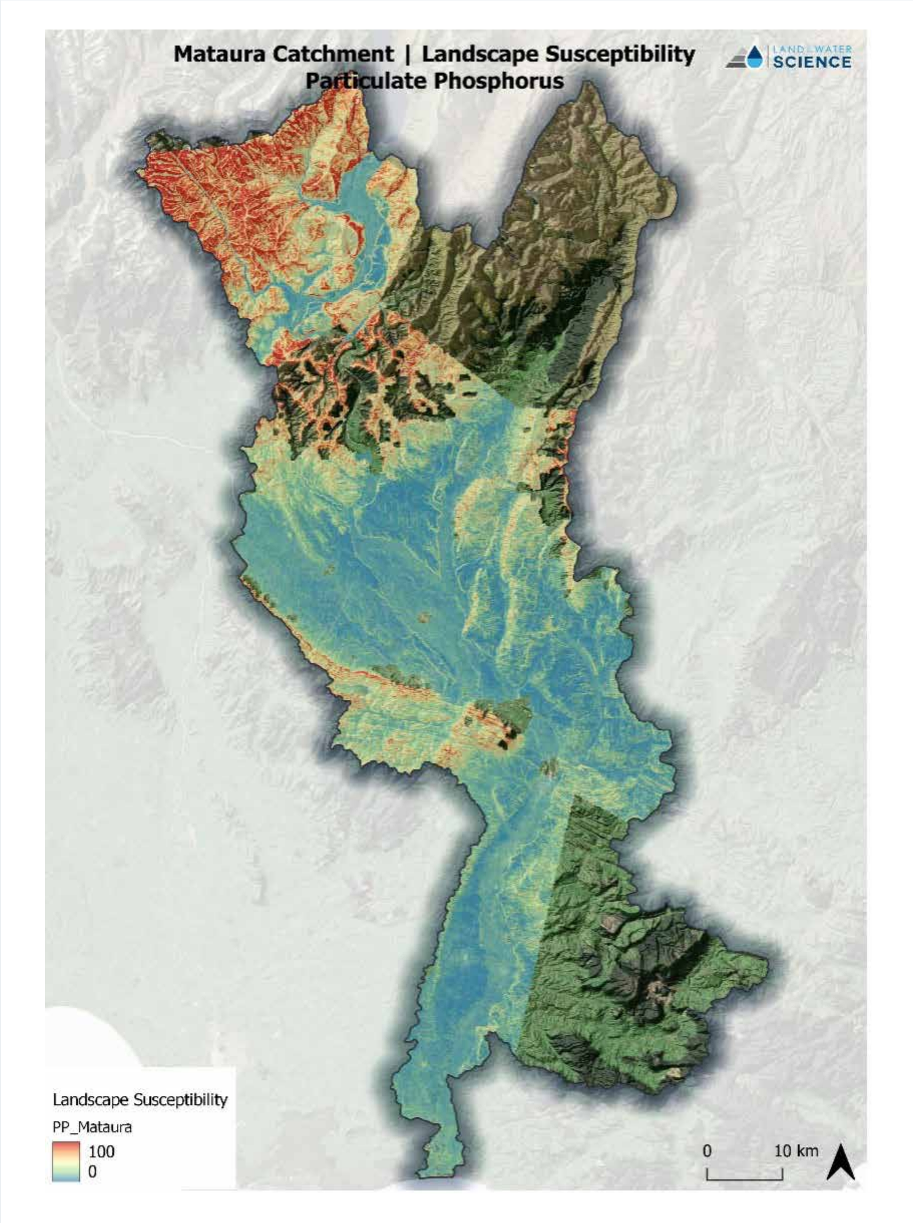



Figure 6: Landscape susceptibility to PP (particulate phosphorus).

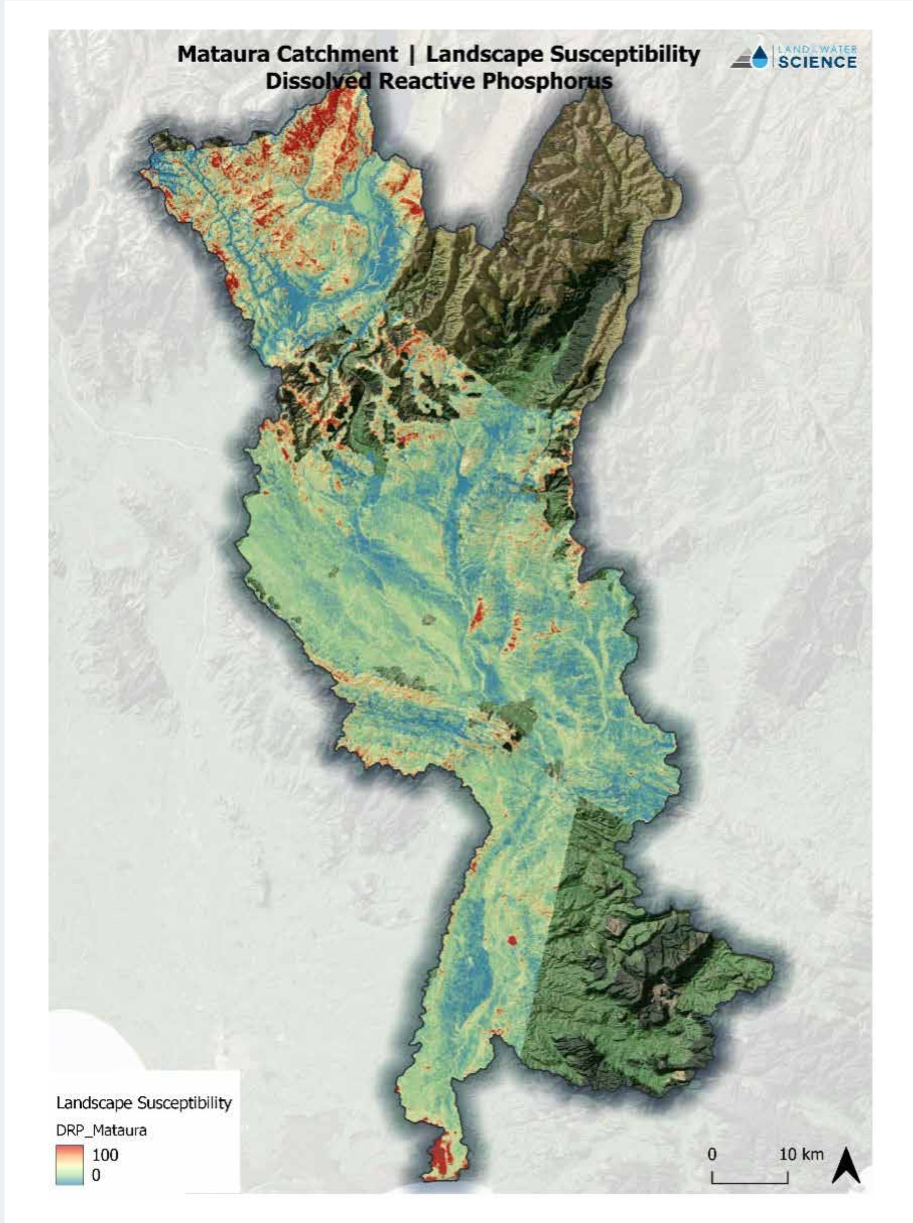



Figure 7: Landscape susceptibility to DRP (dissolved reactive phosphorus).

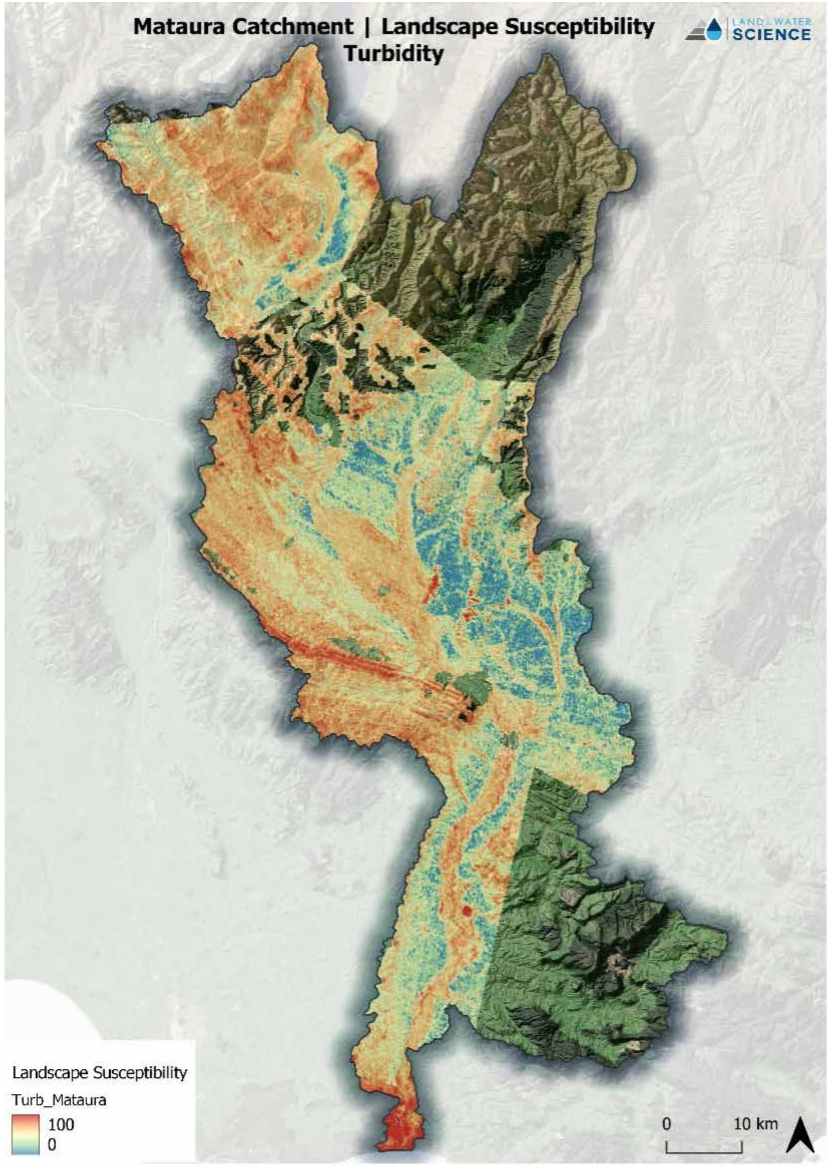



Figure 8: Landscape susceptibility to sediment as indicated by turbidity.

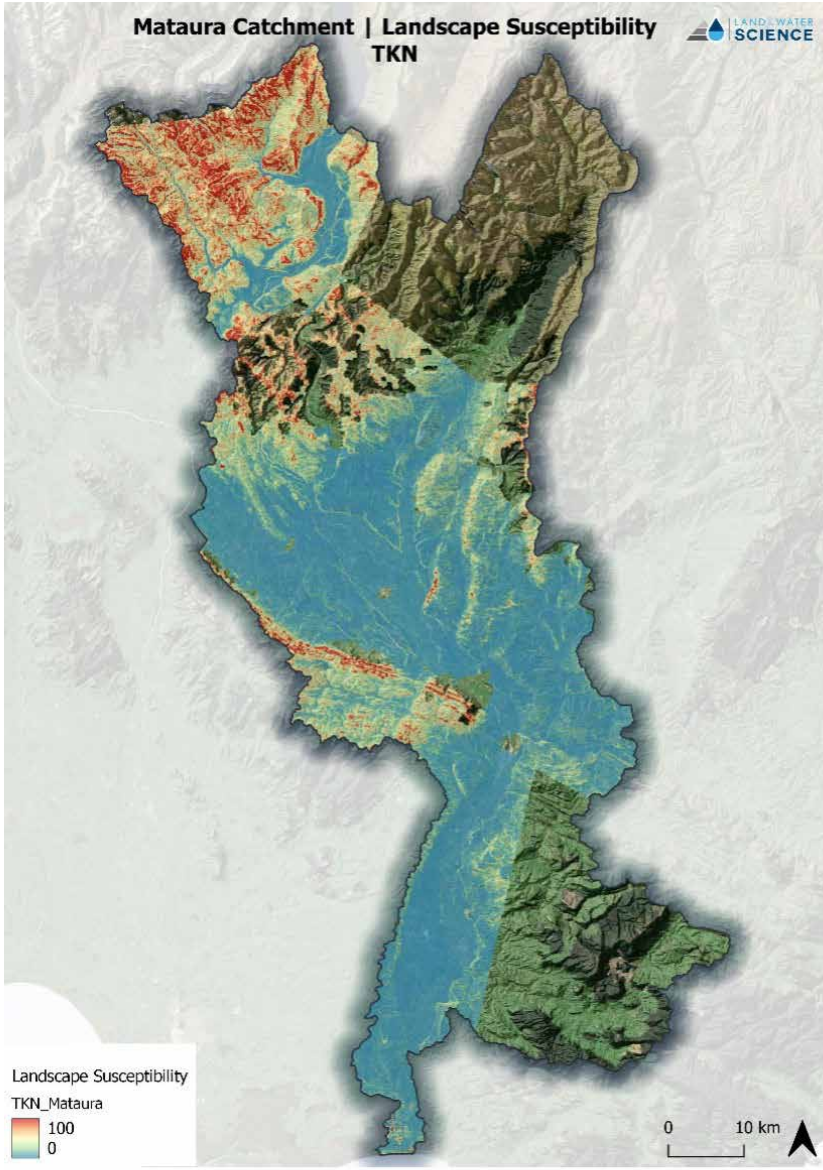



Figure 9: Landscape susceptibility to organic and ammoniacal nitrogen.

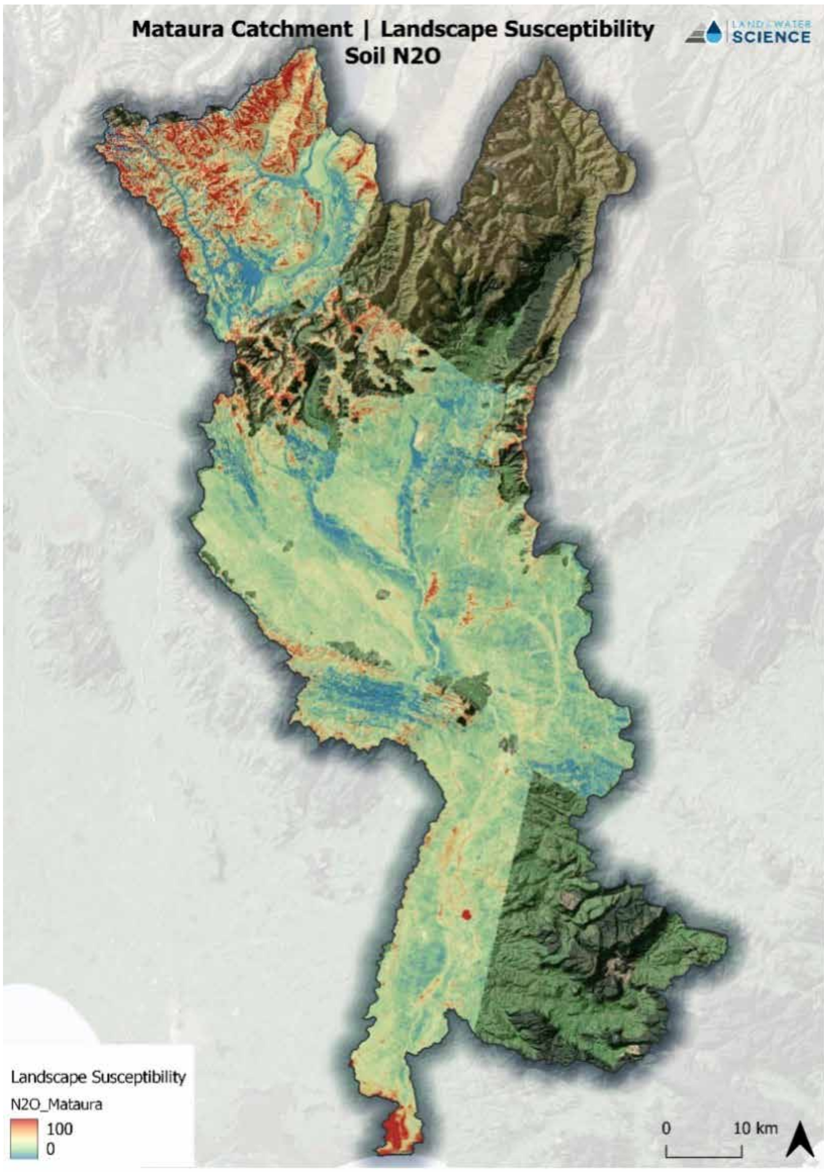
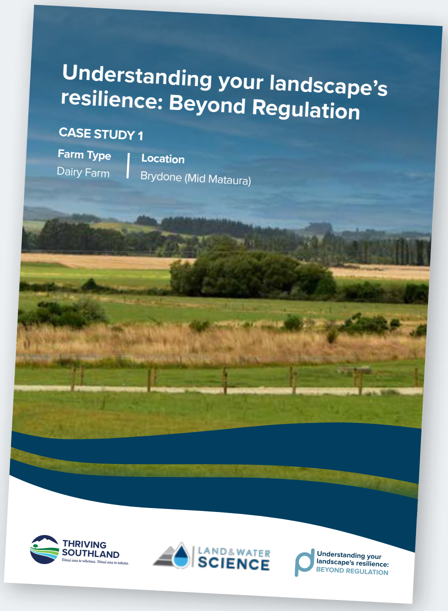



**Figure 10: Landscape susceptibility to *E. coli* (Escherichia coli) contaminants. Microbial contaminants are disease-causing organisms. *E. coli* (Escherichia coli) is just one type of bacteria commonly found in the gut of warm-blooded animals and people.**

# Case study 1




## The farm

This case study was conducted on a 172ha dairy farm owned and operated by a farming family located near Brydone, south of Gore.

**Their goals include:**

- operating a robust long-term business covering all aspects: people, environmental sustainability, animal welfare and financial stability
- paying off debt
- prioritising time with their young family
- future-proofing their wintering system.

The farm consists of two flat to undulating terraces (< four degrees slope), connected by a prominent terrace (steep sidling). Seeps and springs occur along the terrace base, with a drainage channel running along the bottom, intercepting and conveying nitrate-rich groundwater to the local stream network and, ultimately, to the Mataura River. Adjacent to the top terrace is a drainage channel connecting to Ota Creek. The majority of soils on the property are well-drained, with a smaller area of poorly-drained soils, mainly located on the lower terrace.

Situated at an elevation of 64 to 42 meters above sea level, the farm experiences a mean annual rainfall of 1,100mm and an annual temperature of 10.1°C.

Operating as a milking platform, the farm peaks at 500 cows, with the majority of cows wintered off-site and all replacements grazed elsewhere. The farm consistently exceeds the district average for both pasture and milk solid production.

## The catchment

The farm is located in the mid Mataura catchment. The upper terrace falls within the Edendale Groundwater Management Zone (GMZ), while the lower terrace falls within the Lower Mataura Groundwater Management Zone (GMZ). Many parts of the Edendale GMZ show very high nitrate concentrations, commonly above the World Health Organisation (WHO) nitrate in drinking water standard of 11.3 mg/L NO3-N. Where groundwater bores intersect the unconfined gravel aquifer of the Edendale GWMZ, nitrate concentrations range between 4.5 to 16.8 mg/L NO3-N, with median and 95th percentile values of 7.2 and 14.6 mg/L NO3-N, respectively (n = 41 bores; Environment Southland Data, 2018 – 2022).

## Landscape susceptibility

The case study farm predominantly lies within the oxidising soil and oxidising aquifer environment. Deep drainage to the underlying aquifer serves as the dominant hydrological pathway, with some lateral flow. The oxidising environment has a high capacity to filter and adsorb contaminants and resist erosion (minimal sediment, particulate P and microbial losses) but a limited capacity to remove leached nitrate once it has escaped the root zone. Consequently, leached nitrate can accumulate in the aquifer over time, increasing its concentration in groundwater and the contribution of these nitrate-rich groundwaters to surface waters' baseflow.

Minor areas of the reducing soil oxidising aquifer environment are present on the farm. This environment is typically found in lowland areas with finely textured silt or clay-rich, imperfect to poorly-drained soils and oxygen-rich underlying aquifers. These soils exhibit diagnostic grey colours and distinctive rust-coloured spots. The landscape's ability to filter and adsorb particulate contaminants largely depends on water infiltration into the soil.

The natural drainage of these soils has typically been altered by artificial drainage to lower the water table and improve soil drainage, thereby reducing the occurrence of overland flow, the modification allows more particulate contaminants to be filtered by the soil and minimises runoff. However, it creates a pathway for water to transport dissolved (and some particulate) contaminants. These areas are also likely to experience elevated soil nitrous oxide loss.

## Environmental mitigation opportunities

Discussions with the farmer about landscape susceptibility risk and farm systems analysis identified opportunities to build a resilient farm system and reduce environmental impact.

**Mitigation opportunities identified include:**

1. retiring the sidling area from grazing and establishing wetlands to capture and treat water emerging from springs on the top terrace
2. targeting critical source areas on the north-western boundary adjacent to the Ota Creek drain
3. reducing grazing intensity on the bottom terrace
4. implementing a farm systems bundle of low-cost mitigations to reduce contaminant loadings:
    - changing all in-shed feeding to lower crude protein feed, like barley grain
    - reducing Olsen P from 40 to 35 and applying fertiliser at maintenance levels
    - applying whey at maintenance levels for P
    - using phosphate fertiliser in the form of low solubility formulations
    - applying nitrogen as SustaiN instead of urea
    - reducing synthetic nitrogen (from 176 to 130kg N/ha) on the effluent area to partially account for nitrogen applied in effluent
    - adjusting synthetic nitrogen application when whey is applied, to account for nitrogen in whey.
5. incorporating 20% plantain into the pasture sward
6. implementing a loafing barn for the winter (525 cows)
7. implementing a loafing barn for the winter (525 cows), with effluent and solids exported
8. constructing a freestall barn for extended lactation and winter.

The estimated impact of these mitigation opportunities for individual contaminants and farm systems, as well as the financial impact, is summarised in Table 3.

Two scenarios were modelled, based on farmer goals (see Tables 4 and 5):

1. without significant capital investment: implementing a bundle of landscape and low-cost farm system mitigations
2. with significant capital investment: installing a loafing barn in addition to the bundle of landscape and low-cost farm system mitigations.

## Mitigation options

Mitigating through landscape features and minor farm systems changes provided a reduction in contaminant losses. With the addition of a loafing barn for winter there was an increase in most contaminants. The key driver was the increase in stock numbers on the farm over the winter, as animals previously grazed off-farm were now assumed to be in the barn. Bringing the cows home to the barn for winter also increased the amount of imported supplement required, with the result being that managing the increase in nutrients would be key to this system.

Table 3: Mitigation options

| Option | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/financial impact |
|---|---|---|---|---|---|---|---|
| 1 | Retire the sidling area from grazing and establish wetlands to capture and treat water emerging from springs from the top terrace. | – | – | 8% decrease | – | 4% decrease | Cost of installing wetlands will require site specific assessment. Rough estimate of $20,000. |
| 2 | Target critical source area on north-western boundary adjacent to the Ota Creek drain. | – | – | 5% decrease | – | 2% decrease | Cost of loss of productive land – buffer zone (0.5 ha). Cost of $3,600/annum. |
| 3 | Reduce grazing intensity on bottom terrace. | – | – | – | – | 2% | Small area of the farm, significant farm system impact to minimal reduction in contaminants. |
| 4 | Farm systems bundle of low-cost mitigations to reduce contaminant loadings.<br>» Changing all in-shed feeding to lower crude protein feed (e.g. barley grain).<br>» Reducing Olsen P to 35 and fertiliser applied at maintenance:<br>  » whey applied at maintenance for P<br>  » phosphate fertiliser in the form of a low solubility phosphate fertiliser<br>» Applying nitrogen as SustaiN instead of urea.<br>» Reduce synthetic nitrogen (to 130kg N/ha) on the effluent area to partially take account of nitrogen applied in effluent.<br>» When whey is applied, reduce synthetic nitrogen to take account of N in whey. | 3% decrease | 5% decrease | 5% decrease | 7% decrease | 7% decrease | Minimal farm system impact, cost of $6,420 per annum. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | 20% plantain in pasture sward. | <1% decrease | 4% decrease | 6% decrease | <1% decrease | – | Undersowing one-third of the farm each year $8,750/year. |
| 6 | Decrease stock numbers (by 7%). | 2% decrease | 5% decrease | 8% decrease | 6% decrease | 1% decrease | Decrease in profitability of $92,600/yr. Increased skill in managing pasture quality at a lower stocking rate. Maintaining current high level of per cow production would be challenging. |
| 7A | Loafing barn for the winter (525 cows). | 9% increase | 5% increase | 2% decrease | 10% increase | – | Decrease in profitability of $79,560/yr. May need more plant and machinery, effluent storage. Control over wintering. Managing nutrients key. |
| 7B | Loafing barn for the winter (525 cows), effluent and solids exported. | 8% increase | 4% increase | 4% decrease | 5% increase | – | Decrease in profitability of $79,560/yr, plus cost of moving effluent and solids (dependent on distance exported to). May need more plant and machinery, effluent storage. Control over wintering. Managing nutrients by exporting effluent and solids. |
| 8 | Freestall barn for extended lactation and winter. | 16% increase | 3% increase | – | 10% increase | – | Overall, a reduction in profitability of $99,683 per annum. May need more plant and machinery, effluent storage. Control over wintering. Managing nutrients key. |

## Scenario aligned to farmers' goals (without significant capital investment)

To achieve their goals, the farmers aimed to assess how aligning landscape features with their farm system could reduce environmental impact without requiring significant capital investment.

A scenario was developed to mitigate environmental impact by combining various strategies, and the resulting changes in both environmental and financial aspects were estimated. These estimates were then compared to the year-end 2021 nutrient budget. Environmental impact changes were assessed using OverseerFM, while financial impacts were evaluated through partial budgeting.

**Table 4: Combined mitigations without significant capital investment**

| Scenario | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/ financial impact |
|---|---|---|---|---|---|---|---|
| A | Mitigations combined:<br>» retire sidling to capture water emerging in springs to treat water flowing from the top terrace<br>» target critical source area on north-western boundary adjacent to Ota Drain<br>» farm systems bundle of low-cost mitigations to reduce contaminant loadings<br>» 20% plantain in pasture sward. | 4% decrease | 9% decrease | 31% decrease | 8% decrease | 13% decrease | Minimal farm systems impact, cost of $18,770 per annum, plus rough estimate of $20,000 for wetland. |

## Scenario aligned to farmers' goals (with significant capital investment)

The farmers also sought to assess the implications of future-proofing their wintering system, aligning it with a recently leased adjoining support block. To evaluate the potential environmental and financial impacts of this initiative, a scenario involving significant capital investment was developed. This scenario bundled together various mitigation options aimed at reducing environmental impact. Changes in both environmental and financial aspects were estimated and compared to the year-end 2021 nutrient budget. Environmental impact assessments were conducted using OverseerFM, while financial impacts were evaluated through partial budgeting.

**Table 5: Combined mitigations requiring significant capital investment**

| Scenario | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/ financial impact |
|---|---|---|---|---|---|---|---|
| B | Mitigations combined:<br>» install loafing barn for wintering 400 cows<br>» export effluent and manure from loafing barn to lease block<br>» retire sidling to capture water emerging in springs to treat water flowing from the top terrace<br>» target critical source area on north-western boundary adjacent to Ota Drain<br>» farm systems bundle of low-cost mitigations to reduce contaminant loadings<br>» 20% plantain in pasture sward. | 5% decrease | 2% decrease | 31% decrease | <1% increase | 8% decrease | Cost of $69,841 per annum, plus rough estimate of $20,000 for wetland. |

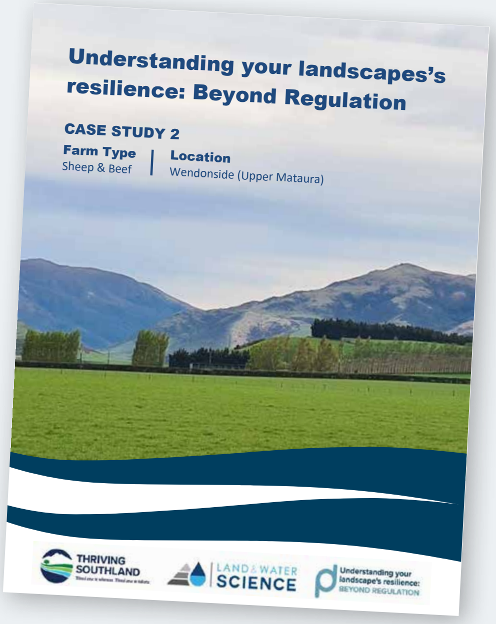
In scenario B, stock numbers on-farm increased in winter, as animals previously grazed off-farm were housed in the barn. Exporting effluent and manure from the loafing barn to the adjacent support block is key, targeting areas where supplements have been harvested to replace nutrients.

## KEY LEARNINGS

1. The main landscape susceptibility issue on the property is nitrate-nitrite-nitrogen (NNN) leaching associated with moderately to well-drained loess soils. These soils overlie a strongly oxidising aquifer that is susceptible to NNN accumulation. Soil nitrous oxide, PP and *E. coli* susceptibility are of lesser concern, mainly associated with poorly-drained Jacobstown soils and the southeastern corner of the property.
2. Using landscape susceptibility and understanding hydrological pathways identified a good opportunity to treat water coming from the top terrace. The presence of springs and seeps along the terrace's edge, extending for 45km, presents a feasible mitigation approach to reduce contaminant loss from the Edendale Terrace, offering substantial potential across the catchment.
3. Rather than focusing on a single large mitigation, bundling a series of low-cost farm system mitigations had minimal impact on the farm system/profitability.
4. Combining landscape mitigations with low-cost farm system measures resulted in meaningful reductions in contaminants. The case study farmers found these solutions achievable in terms of farm system fit, investment and annual cost.
5. The addition of a loafing barn for wintering cows, currently grazed off-farm, aligns with the farmers' goals for wintering control but does not provide environmental mitigation and entails significant capital investment.

"WE HAVE LOOKED AT OUR FARMS AND THOUGHT THERE IS NOTHING AVAILABLE FOR US TO MAKE A DIFFERENCE. LOOKING AT LANDSCAPE OPENS UP NEW AREAS WE CAN LOOK AT. THIS IS THE WAY FORWARD!"

# Case study 2




## The farm

This case study was conducted on a 733ha sheep and cattle farm owned and operated by a multi-generational farming family near Wendonside, north of Gore. The next generation currently leases the property, with plans to transition to farm ownership in the future.

**The farmers' goals are to:**

- set up succession planning within the business going forward
- improve animal performance to increase returns.

In the short to medium term, their priority is to generate cash surpluses to secure the business for themselves and the next generation.

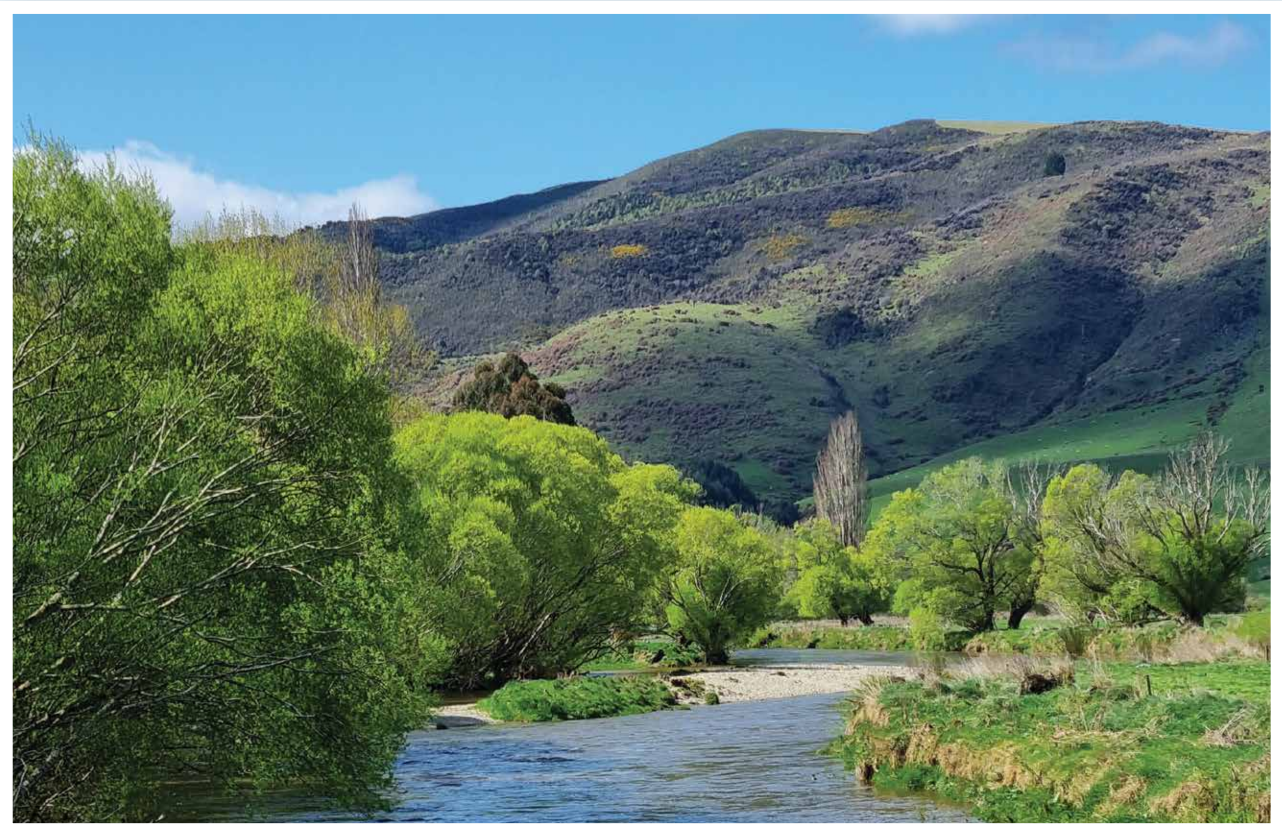
The farm ranges in contour from flat to steep faces and gullies. The Garvie Burn Stream runs along the western boundary, while several small spring-fed streams lead into the Rob Roy Creek, which flows along the northern and eastern boundaries. There is a range of soils on the property, with Crookston (moderately well-drained), Claremont (poorly-drained) and Fairlight (moderately well-drained) being the predominant types.

Situated at an elevation of 200 to 600 meters above sea level, the farm experiences a mean annual rainfall ranging from 910 to 1020mm and an annual temperature between 9.1-10.1°C.

The farm operates as a sheep and beef farm. In total there are 7659 revised stock units (RSU), with beef accounting for 21% (1597 RSU) and sheep comprising 79% (6062 RSU). The average stocking rate per hectare is 10.5 RSU / hectare.

## The catchment

The farm is located within the Wendonside catchment, which is a sub-catchment of the larger Mataura River catchment. In the Wendonside and Waimea areas, there are several small yet significant areas where groundwater nitrate levels exceed the WHO drinking water standards. The hill country surrounding the lowland plains is prone to runoff and associated sediment, *E. coli* and particulate phosphorus loss. These localised water quality concerns often result in exceedances of regional and national guidelines for freshwater standards.



## Landscape susceptibility

Variability in climate, topography, geology and soils significantly influences the type of contaminant and severity of water quality outcomes, even when land use remains the same.

The susceptibility models for the case study 2 property show a predictable pattern that is consistent with topographic controls. Topography governs aspect, slope and soil depth. These landscape factors interact to determine the land's susceptibility to saturation and erosion. Soil saturation and water runoff are key factors influencing susceptibility.

Where the land is flat, susceptibility is lower overall, whereas the steeper parts of the property, especially the western and to a lesser degree the north facing slopes, are most prone to contaminant loss. This pattern of differential susceptibility is typical of hill country settings, where topography and aspect interact to determine contaminant susceptibility profiles.

## Environmental mitigation opportunities

Discussions with the farmers about landscape susceptibility risk, hydrological pathways and farm systems analysis identified opportunities to build a resilient farm system and mitigate environmental impact.

**Opportunities identified within the current farm system include (see Table 6):**

1. using plantain in pasture
2. replacing 11.1ha of kale with 5.8ha of fodder beet for beef animals
3. replacing swedes with grass wintering (for sheep)
4. installing a standoff pad for R1 and R2 beef animals
5. installing a covered barn for R1 and R2 beef animals
6. removing 11.1ha kale crop.

**Opportunities identified through landscape intervention or land use change include (see Table 7):**

7. installing 23.35ha of wetlands with associated check dams
8. planting 36.9ha of plantation forestry and slightly reducing sheep numbers
9. planting 134ha of plantation forestry and discontinuing the beef breeding cow operation.

Additionally, a farm system optimisation scenario was modelled using Farmax (see Table 8).

## Mitigation options

During the site visit, opportunities to mitigate environmental impact were identified through landscape susceptibility analysis, farm systems analysis, and exploration of forestry opportunities. The property, categorised as an extensive sheep and beef farm, is relatively low intensity compared to other land uses in the catchment. While some reductions can be achieved through mitigation of the current low intensity farm system, reductions of a larger scale will be achieved through landscape intervention and land use change.

Table 6: Mitigation options within the current farm system

| Option | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/financial impact |
|---|---|---|---|---|---|---|---|
| 1 | Use of 5% plantain in 315ha of pastures. | No change | 1% decrease | 1% decrease | No change | No change | Include 1kg plantain seed in regrassing mix. Approximate cost $400 per year. |
| 2 | Replace 11.1ha of kale with 5.8ha fodder beet (for beef animals). | 1% decrease | 3% decrease | 2% decrease | 4% decrease | No change | Need 25T DM fodder beet crop to be a similar cost to kale based on a cents per kg of dry matter (DM) basis.<br>Management of heavy crops during wet weather can be challenging. |
| 3 | Replace swedes with grass wintering (for sheep). | 7% increase | 10% increase | 4% decrease | 23% decrease | No change | Need to build more feed up in autumn. Assumed increased nitrogen use by 33kg N/ha and no sale of supplement.<br>No significant difference financially.<br>Certainty of winter feed supply may be riskier if it's a dry summer/autumn. May need to consider some grass-to-grass regrassing. |
| 4a | Install a standoff pad for R1 and R2 beef animals. | No change | No change | 1% increase | No change | No change | To use overnight for 30 days in winter.<br>Difficult to model mitigation during adverse weather events.<br>Site preparation and fencing not costed (site specific). May require a consent (not costed).<br>Annual cost of $9,400 in wood chip. |
| 4b | Install a covered barn for R1 and R2 beef animals.<br>Remove 11.1ha kale crop. | 1% increase | 2% decrease | 9% decrease | 2% decrease | 1% increase | To use 24 hours per day for 92 days in winter.<br>Annual cost of $49,320 (no crop, debt serving, depreciation, running, R&M, supplement making, purchasing woodchip). |

## Mitigation options with landscape intervention/land use change

The wetlands are strategically located at discharge and junction nodes to mitigate environmental contaminants by targeting transport pathways. Check dams have been integrated into areas with rolling to steep contours to regulate water flow into the wetlands, enhancing their performance during high waterflow events.

There is an opportunity to integrate forestry into the landscape, especially those areas that are less productive and have a higher landscape susceptibility risk (in particular for phosphorus, sediment and DRP loss). Forestry can generate additional revenue through carbon credits instead of offsetting greenhouse gas emissions.

**Table 7: Mitigation options with landscape intervention/land use change**

| Option | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/financial impact |
|---|---|---|---|---|---|---|---|
| 5 | Install 23.35ha of wetlands (with associated check dams). | – | – | 20% decrease | – | 16% decrease | The areas that are repurposed into wetlands are of very low pasture productivity and will require no farm systems change.<br>Significant cost of wetland fencing and check dams $174,454. This scenario assumes that rock is available on farm, and wetland plants will regenerate.<br>Prioritising wetlands where the existing reticulated stock water system is available and where the wetland is calculated to provide the most mitigation for cost. |
| 6 | Plant 36.9ha of plantation forestry and slightly reduce sheep numbers. | <1% decrease | No change | 1% decrease | 2% decrease | 3% decrease | Small reduction in sheep numbers. Reduction in annual profit from the farm system of $11,160.<br>36.9ha forestry:<br>Internal rate of return (IRR) first rotation 9.5% (carbon at $60).<br>Peak cash deficit of ($173,048).<br>IRR second rotation 5%. |
| 7 | Plant 134ha of plantation forestry and remove beef breeding operation. | 12% decrease | 10% decrease | 10% decrease | 14% decrease | 15% decrease | Significant farm system change. Reduction in annual profit from the farm system of $24,222.<br>134ha of forestry:<br>IRR first rotation 7.2% (carbon at $60).<br>Peak cash deficit of ($183,760).<br>IRR second rotation 5.2%. |

## Farm system optimisation

Farm system optimisation through Farmax showed an opportunity to enhance the sheep enterprise performance and significantly increase profitability, whilst reducing environmental effects. There are options for pathways to improve sheep performance such as utilising the beef breeding herd across the entire property for pasture quality control, investigating different lamb breeds or investigating a reticulated water system.

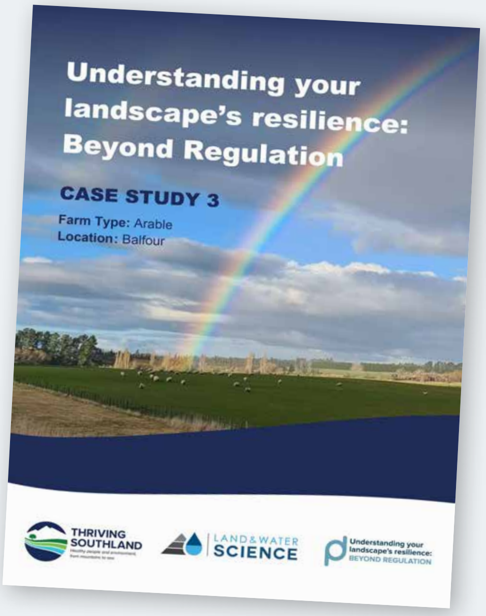
**Table 8: Farm system optimisation**

| Option | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/financial impact |
|---|---|---|---|---|---|---|---|
| 8 | System optimisation. | 1% decrease | 1% decrease | 1% decrease | 2% decrease | No change | Increased lambing, lambs finished earlier and heavier. Annual increase in profit of $33,724. |

## KEY LEARNINGS

1. The main landscape susceptibility issues across the case study property align with topographic controls, where topography influences aspect, slope and soil depth. These landscape factors interact to determine the susceptibility of the land to saturation and erosion.
2. Farm systems evolve over time to match land and stock class with variability in weather and product prices. Changes to the farm system and capital investment need to be carefully considered due to the interlinked nature of the farm system and the low returns that sheep and beef farmers operate with.
3. In a farm system of low intensity, limited opportunities are available to reduce contaminant loss without significant changes to the farm system change or incurring substantial costs.
4. Combining hydrology and landscape susceptibility insights enables us to identify where investments need to be made to minimise losses from the property.
5. Installation of wetlands within the landscape incurs costs and should be prioritised and targeted to areas with the most mitigation potential. Realistic installation may take time due to financial and time constraints.
6. Land use change to forestry can yield positive returns, but the key determinant is the opportunity cost of how the land is currently utilised. A long-term view needs to be considered in planning to account for no carbon revenue after the first rotation.
7. Forestry is a long-term investment that is more applicable to the landowner than the lessee.
8. Farm system optimisation through Farmax showed an opportunity to significantly improve profitability through enhanced lambing rates and faster growth rates, while also reducing environmental impacts. Further investigation is needed to explore options, including utilising beef cows across the whole farm, changing ram breeds and installing reticulated water systems.

# Case study 3




## The farm

The case study was conducted on a 321ha predominantly arable farm, with some areas dedicated to dairy grazing and sheep farming (owned and grazed). Additionally, 21.7ha of the farm is leased out for tulip production. Operated as a family-owned business, the farm is situated close to Balfour in Northern Southland, north of Gore.

**The farmers' goals are to:**

- focus on delivering cash surpluses during the current market volatility, to ensure survival
- consolidate their financial position, by building a robust business model that reduces reliance on commodities where possible
- establish a succession plan within the family, should any of the children express interest in both farming and value-add opportunities.

## The catchment

The property is situated within the Mataura Catchment and resides within an alluvial terrace between the Waimea Stream and the Longridge Stream (which flows along the eastern boundary).

It lies within the Balfour fan area, known as a 'nitrate hotspot'[1], with some of its groundwater zones exceeding New Zealand and World Health Organisation levels for safe nitrate concentration in drinking water. Due to the nature of the aquifer not being flushed by alpine or hill country water, the concentration of nitrate in some areas continues to build.

## Landscape susceptibility

The case study farm primarily falls within the oxidising soil and aquifer environment. Deep drainage to the underlying aquifer serves as the dominant hydrological pathway, with some lateral flow evident. This environment exhibits a high capacity to filter and adsorb contaminants, resulting in minimal sediment, particulate P and microbial losses.

As the landscape has limited ability to remove nitrogen once it has been lost from the root zone, there is a high risk of nitrate-nitrogen leaching into the shallow aquifer. Over time, nitrate can build up in the aquifer, increasing the concentration in groundwater and in-stream.

The balance of the property is located within the environment of a reducing soil oxidising aquifer. This environment occurs in lowland areas with finely textured silt or clay-rich, imperfect to poorly-drained soils and oxygen-rich underlying aquifers. The ability of the landscape to filter and adsorb particulate contaminants is largely dependent on how much water can infiltrate the soil.

The natural drainage of these soils has typically been modified by artificial drainage to lower the water table and improve soil drainage, reducing the occurrence of overland flow. This allows more particulate contaminants to be filtered by the soil and minimises the occurrence of runoff, but creates a pathway for water to transport dissolved contaminants. These areas are also likely to have elevated soil nitrous oxide loss.

## Environmental mitigation opportunities

Discussions with the farmers about landscape susceptibility risk and farm systems analysis identified opportunities to build a resilient farm system and reduce environmental impact.

**Mitigation opportunities identified include (see Table 9):**

1. targeting nutrients applied to meet plant requirements and uptake
2. reviewing crop rotations to reduce contaminant loadings, such as removing fallow periods, winter fodder crops, and adding grass baleage
3. removing or selling crop residues (rather than retaining) on 41.6ha of winter wheat
4. using low solubility phosphate fertilisers
5. sector 2 – preventing runoff and targeting tile drain outlets to intercept runoff
6. sector 3 – developing 3.3ha of wetlands and sediment traps to treat nitrates and dissolved reactive phosphorus
7. sector 4 – developing 7.3ha of wetland on the lowest point of the property, to capture subsurface drains from a significant portion of the property
8. Exploring alternative land use options, such as establishing 2ha of chestnuts, to reduce contaminant loadings.

**Selected mitigations combined include (see Table 10):**

1. targeting nutrients applied to meet plant requirements and uptake
2. reviewing crop rotations to reduce contaminant loadings, such as removing fallow periods, winter fodder crops, and adding grass baleage
3. sector 2 – preventing runoff and targeting tile drain outlets to intercept runoff
4. sector 3 – developing 3.3ha of wetlands and sediment traps to treat nitrates and dissolved reactive phosphorus
5. sector 4 – developing 7.3ha wetland on the lowest point of the property to capture subsurface drains from a significant portion of the property.

## Mitigation options

**Table 9: Mitigation options – farm system, landscape and land use**

| Option | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/financial impact |
|---|---|---|---|---|---|---|---|
| 1 | Targeting nutrients applied to meet plant requirements and uptake (excluding land leased to tulips). | 8% decrease | 11% decrease | 20% decrease | 69% decrease | No change | Increase in soil testing costs. Decrease in fertiliser cost. Overall saving of $24,876. |
| 2 | Review crop rotations to reduce contaminant loadings (remove fallow period, remove winter fodder crop, add grass baleage). | 3% increase | 2% decrease | 6% decrease | 29% decrease | 3% decrease | Increase of $2000 in annual cost. |
| 3 | Remove/sell crop residues (rather than retaining) on 41.6ha of winter wheat. | 1.4% increase | 2% decrease | 1% increase | 5% increase | No change | Need to replace nutrients removed in the sale of straw. Need pasture in rotation to maintain soil organic matter/ structure. A total revenue increase of $17,348. Highly dependent on markets/ demand. |
| 4 | Use of low solubility phosphate fertilisers. | No change | No change | No change | No change | 6% decrease | Increase in fertiliser cost by $7,840. More product to handle. |

Table 9: Mitigation options – farm system, landscape and land use *continued*

| Option | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/financial impact |
|---|---|---|---|---|---|---|---|
| 5 | Sector 2 – prevent runoff and target tile drain outlets to intercept runoff. | No change | No change | 5% decrease | No change | 6% decrease | Fencing cost $3,300.<br>Capital cost of wetland establishment estimated at $6,700. |
| 6 | Sector 3 – develop 3.3ha of wetlands and sediment traps to treat nitrates and dissolved reactive phosphorus. | No change | No change | 9% decrease | No change | 9% decrease | Fencing cost: $6,100.<br>Capital cost of wetland establishment estimated at $10,000. |
| 7 | Sector 4 – develop 7.3ha wetland on lowest point of property to capture subsurface drains from a significant portion of the property. | 3% decrease | 2% decrease | 21% decrease | 2% decrease | 30% decrease | Retire 7.3ha of land currently used for grazing. Annual loss of income is $13,140.<br>Estimated capital cost of wetland establishment is $40,000. |
| 8 | Alternative land use option to reduce contaminant loadings (establish 2ha of chestnuts). | <1% decrease | 1% decrease | 1% decrease | 2% decrease | No change | Capital investment of $20,000<br>IRR of 18% (compared with winter wheat at 13%). |

## Scenario of bundled mitigation options

Table 10: Combined farm system, landscape and land use options

| Scenario | Brief description | Total GHG change | Nitrous oxide change | N loss change | N surplus change | P loss change | Farm system/ financial impact |
|---|---|---|---|---|---|---|---|
| A | Mitigations combined:<br>option 1 – targeting nutrients applied to meet plant requirements and uptake (excluding land leased to tulips)<br>option 2 – reviewing crop rotations to reduce contaminant loadings (remove fallow period, remove winter fodder crop, add grass baleage)<br>option 5, sector 2 – preventing runoff and targeting tile drain outlets to intercept runoff<br>option 6, sector 3 – develop 3.3ha of wetlands and sediment traps to treat nitrates and dissolved reactive phosphorus<br>option 7, sector 4 – develop 7.3ha wetland on the lowest point of the property, to capture subsurface drains from a significant portion of the property. | 12% decrease | 15% decrease | 54% decrease | 94% decrease | 47% decrease | Annual overall cost savings of $4,438.<br>Estimated $66,100 capital investment into wetlands and fencing.<br>Removing winter cropping increases winter feed supply risk, following a dry summer.<br>Retired 7.3ha from pasture grazing. |

## KEY LEARNINGS

1. The main landscape susceptibility issue on the property is nitrate-nitrite-nitrogen (NNN) leaching, primarily associated with moderately well-drained shallow soils with gravelly subsoils. These soil characteristics contribute to severe susceptibility to nitrate leaching. Additionally, these soils overlie an oxidising aquifer that is susceptible to NNN accumulation.
2. Targeting nutrients to match plant requirements and uptake resulted in a significant reduction in contaminants and achieved annual cost savings.
3. Capturing water from subsurface drainage and treating in wetland systems presents an opportunity to significantly reduce contaminants. Key to the implementation of this mitigation is the practicality of the proposed wetland site and the installation cost of the wetland.
4. Combining strategies to reduce contaminant loadings, such as targeting nutrient applications and adjusting crop rotations, along with treating contaminants as they leave the farm boundary, creates significant potential to mitigate contaminant loss from the case study farm. While it is estimated that there would be an overall cost saving, an upfront capital investment in wetland development would be required.
5. Land use change to new crops would need to occur at a large scale to have a significant impact on contaminants.

# Catchment mitigations

**Looking across the whole catchment or sub-catchment at all the landscape susceptibility layers, each area's key susceptibilities are highlighted. When linked with relevant water quality and hydrology results, this can highlight the focus areas for mitigations. This focus on the right areas and main risks allows for targeted mitigations.**

It also highlights areas when a sub-catchment, rather than individual farm, approach to mitigation is required to achieve the best outcome.

During the project we have observed that the landscape susceptibility mapping creates conversation within catchment groups. These conversations focus on the opportunity to target actions in the right place within the catchment for the most cost-effective mitigation. It also opens up the conversations around individual farmers coming together to look at mitigations with a more collaborative cross-farm boundary approach.

The power of landscape susceptibility mapping lies in its ability to serve as a conversation starter. This allows catchment groups to develop a pathway forward and take control in developing meaningful long-term options. In many ways, it shifts the conversation beyond regulation towards building long-term resilience within the catchment.

# Behaviour change

## Landscape understanding: impact on mitigation and farm operations

How has landscape understanding helped inform mitigation actions and day-to-day farm operations? The Understanding your landscape's resilience: Beyond Regulation project followed the KASA model of extension knowledge, attitude, skills and aspirations.

## Knowledge

Engaging farmers effectively involves providing information tailored to their specific farm landscapes, including paddock-level susceptibility and targeted mitigation strategies for maximum environmental benefit.

Ground truthing the landscape information by digging soil pits led to building confidence in the science. As the work is rolled out wider this may no longer be necessary as overall farmer confidence grows in the new information being delivered.

## Attitude

After witnessing the effectiveness of landscape mitigation measures, it becomes evident that aligning farm systems and soil management with individual landscape characteristics is essential. Considerable gains can be made by adding together the farm system opportunities and good management practices that align with the landscape susceptibility mitigations. This has been a takeaway from farmers both engaged in the case study, as well as at the field day.

## Skills

Farmers played an integral role in the discussions surrounding landscape and farm system mitigations. Their deep knowledge of the property and farm operations ensured mitigations were fit-for-purpose. The Beyond Regulation team valued this input when developing the primary mitigation outcomes. By incorporating financial considerations into the discussions, the team ensured that the proposed mitigations were both financially viable and well-grounded, instilling confidence in farmers to initiate changes.

The diverse expertise brought by the team members enhanced the skillset of all involved. Through a multi-disciplinary approach, the collaboration between farmers and rural professionals resulted in a well-balanced and achievable outcome that aligned with farmer aspirations.

## Aspirations (last in KASA but the most important part of the process)

As a project team, the first piece of work was to sit down with the farmers to understand their business, including the opportunities and challenges. Equally important was gaining insight into their goals and aspirations from a family perspective, with a particular focus on succession planning. While this foundational work was instrumental in guiding the case studies, it was not fully disclosed in the published documents. Nonetheless, it played a pivotal role in ensuring that the project outcomes were aligned with the farmers' goals, where possible.

## Change outcomes

Farmers have already started using the science and information provided through the process to begin reducing their environmental footprint.

**The farming family from case study one has within six months initiated a number of steps:**

- » fenced the terrace seeps
- » reviewed fertiliser recommendations against the soil type susceptibility and soil tests to improve efficiency
- » reduced their bought-in feed
- » reduced stocking rate.

They have reported that production is slightly behind, but profitability is tracking ahead.

The results from this case study prompted another farmer in the catchment group to invest in the process of undertaking radiometric testing on his own farm. He obtained a map of susceptibility areas and aligned soil tests to improve efficiency and profitability.

From the findings of the radiometric data, the farmer saw the opportunity to link the understanding from the case study project work with technology he already had on-farm, with his variable-rate fertiliser spreader. By using the science of the landscape and the farm system, he halved the amount of fertiliser used. A field day was also held to go through the process with rural professionals and farmers, highlighting the ability to create an efficient fertiliser programme.

Other farmers are also starting to use this information. One farmer reported that his overall fertiliser requirement had gone up to the agronomic optimum, as certain areas were in deficit.

The local catchment group is exploring larger scale mitigations that would be achieved by developing a drain fed by aquafer seeps into a wetland. This initiative has garnered support from the local dairy processor to help develop the work.

Other actions include engaging consultants to analyse their farms for potential plantings and investigating the formation of wetlands.

> "I USED TO LOOK AT ALL THE LITTLE THINGS YOU COULD DO AND DISCOUNT THEM, AS THEY WOULDN'T MAKE MUCH OF A DIFFERENCE. NOW I CAN SEE WHAT A BIG DIFFERENCE YOU CAN ACTUALLY MAKE WHEN YOU ADD THEM ALTOGETHER!"

## Farmer and rural professional feedback

At the field day, a survey found that 92% of farmers expressed they were highly likely, quite likely, or slightly likely to implement changes or take action on their farms.

Out of the farmers and rural professionals surveyed, 90% said they were excited or hopeful about the opportunities presented at the event.

# Future work recommendations

**During the project it became evident there were some gaps or barriers preventing farmers from implementing environmental mitigations on their farms.**

- **Integration of forestry:** there's a significant opportunity for integrating forestry, both exotic and indigenous, into farm landscapes, especially on larger properties. While expertise is available for plantation forestry, it's more difficult to access advice for small-scale forestry, which is often dispersed across the landscape.
- **Wetland implementation:** wetlands offer opportunities for on-farm water treatment and catchment-scale mitigation. Practical, cost-effective advice on wetland development is essential. Leveraging learnings from large-scale wetland projects currently occurring throughout New Zealand can facilitate more affordable implementation on a wider scale.
- **Lower intensity land use change:** lower intensity land use change offers environmental mitigation, particularly when implemented at scale. However, confidence throughout the value chain, including markets for the products, is crucial for individual farmers to adopt such changes. Providing 'end-to-end' information to farmers is essential.
- **Policy and regulatory support:** farmers need support from appropriate policy settings and regulators to implement environmental mitigations effectively. Further work is required on how linkages between farmers, policy makers and regulators can be strengthened to ensure change is enabled.

There have been many insights gained by the team during this project, as integrating landscape and farm systems to target mitigations has presented its challenges.

It would be beneficial to share these skills and processes with others, including farmers, rural professionals and scientists, through training and accessible resources. This would facilitate implementation on farms and link into future farm planning efforts.

There is an opportunity to expand this work more broadly, extending to other farms within the catchment and beyond, as it becomes increasingly practical for farmers. Developing a comprehensive communications plan to make this work more widely available would enable others to adopt these practices and potentially enhance them with new insights.

# Conclusion

**This project leveraged scientific landscape data and farm system analysis to identify targeted mitigations that can reduce environmental impacts. The landscape variability plays a significant role in governing the type and severity of water quality and soil greenhouse gas (GHG) outcomes, even when land use is the same.**

The project found there are good opportunities to reduce nitrogen and phosphorus loss without major impacts on profitability. However, reducing greenhouse gases proved more challenging, with significant impacts on the farm system and profitability.

The best results for reductions in contaminant loss came from bundling (or stacking) mitigations, showing the value of using multiple mitigations rather than relying heavily on a singular one. This multiple mitigation approach also supports implementation on-farm in a practical setting, allowing mitigations to be staggered progressively to reduce risk and cost.

Lower intensity farm systems are typically situated in more extensive landscapes, where the opportunity for mitigations is more heavily weighted towards the landscape than the farm system. Conversely, with more high-intensity farm systems, it is more likely to be the opposite, with more mitigation opportunities in the farm system than the landscape. The combination of landscape and farm systems is tailored to each farm, with targeted mitigations in the right place for each property.

Combining landscape and farm systems was observed as an effective way to engage with farmers. Using maps to complement their on-farm observations instilled confidence in farmers, as they understood the rationale behind mitigation efforts. In some cases, less productive areas of the farm were seen as valuable opportunities to repurpose or revert to their predevelopment state as a mitigation tool.

We will leave the last word to a case study farmer…

> "I THOUGHT YOU WERE GOING TO TELL ME TO PLANT SUN FLOWERS, THIS IS REALLY PRACTICAL – I CAN DO THIS."

# References


1. Refer appendix 1 for list of team members for each case study.
2. Snelder, T. (2020). Assessment of Nutrient Load Reductions to Achieve Freshwater Objectives in the Rivers, Lakes and Estuaries of Southland Including Uncertainties: To inform the Southland Regional Forum process. Prepared for Environment Southland by Land and Water People.
3. Norton, N., Wilson, K., Rodway, E., Hodson, R., Roberts, K. L., Ward, N., O'Connell-Milne, S., DeSilva, N., & Greer, M. (2019). Current environmental state and the "gap" to draft freshwater objectives for Southland. Environment Southland Technical Report, 12.
4. Plew, D., Dudley, B., Shankar, U. (2020) Eutrophication susceptibility assessment of Toetoes (Fortrose) Estuary. NIWA Client Report, 2020070CH: 58.


# Appendix 1

## Case study 1: Dairy Farm – Brydone

**Project team members:**

Richard Kyte – Thriving Southland

Clint Rissman, Andrew Boyce, Lisa Pearson – Land and Water Science Ltd

Miranda Hunter – Roslin Consultancy Ltd

Lynden Prebble – farm consultant

## Case study 2: Sheep and Beef Farm – Wendonside

**Project team members:**

Richard Kyte – Thriving Southland

Clint Rissman, Andrew Boyce, Lisa Pearson – Land and Water Science Ltd

Chris Beatson – Agrimagic Ltd

Miranda Hunter – Roslin Consultancy Ltd

Lynden Prebble – farm consultant

Don Frengley – forestry consultant

## Case study 3: Arable Farm – Balfour

**Project team members:**

Richard Kyte – Thriving Southland

Clint Rissman, Poppy Hardie – Land and Water Science Ltd

Emmanuel Chakiwizira – Foundation for Arable Research

Miranda Hunter – Roslin Consultancy Ltd

Dave Stevenson – Fairfield Farm Consultancy Ltd

All three case studies available to download at
www.thrivingsouthland.co.nz/beyond-regulation-mataura-catchment-project

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