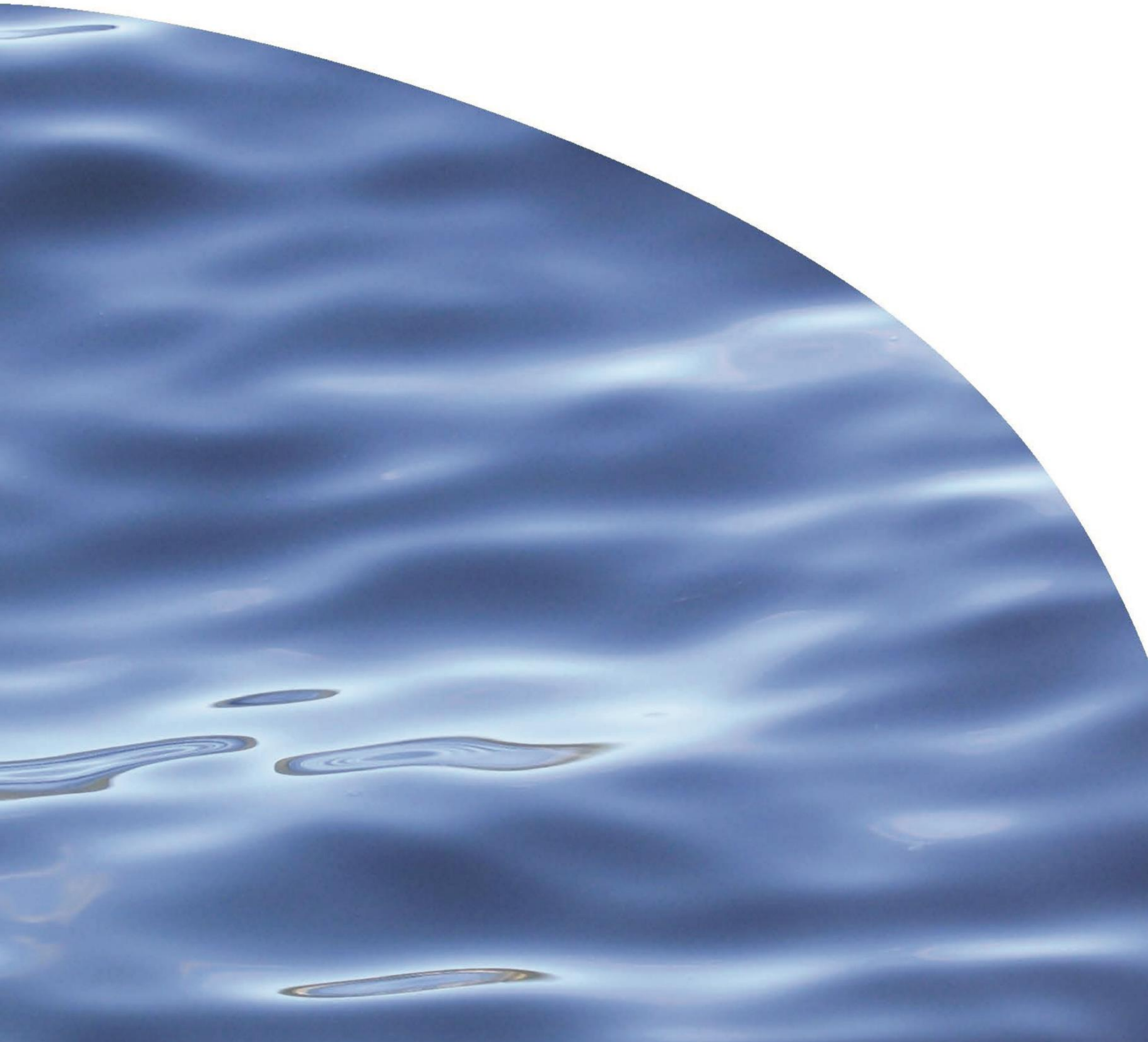
REPORT NO. 3681

A RIVER HEALTH MONITORING FRAMEWORK FOR SOUTHLAND CATCHMENT GROUPS



A RIVER HEALTH MONITORING FRAMEWORK FOR SOUTHLAND CATCHMENT GROUPS

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Prepared for Thriving Southland

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ISSUE DATE: 4 August 2021

RECOMMENDED CITATION: MacNeil C, Holmes R 2021. A river health monitoring framework for Southland catchment groups. Prepared for Thriving Southland. Cawthron Report No. 3681. 27 p. plus appendices.

EXECUTIVE SUMMARY

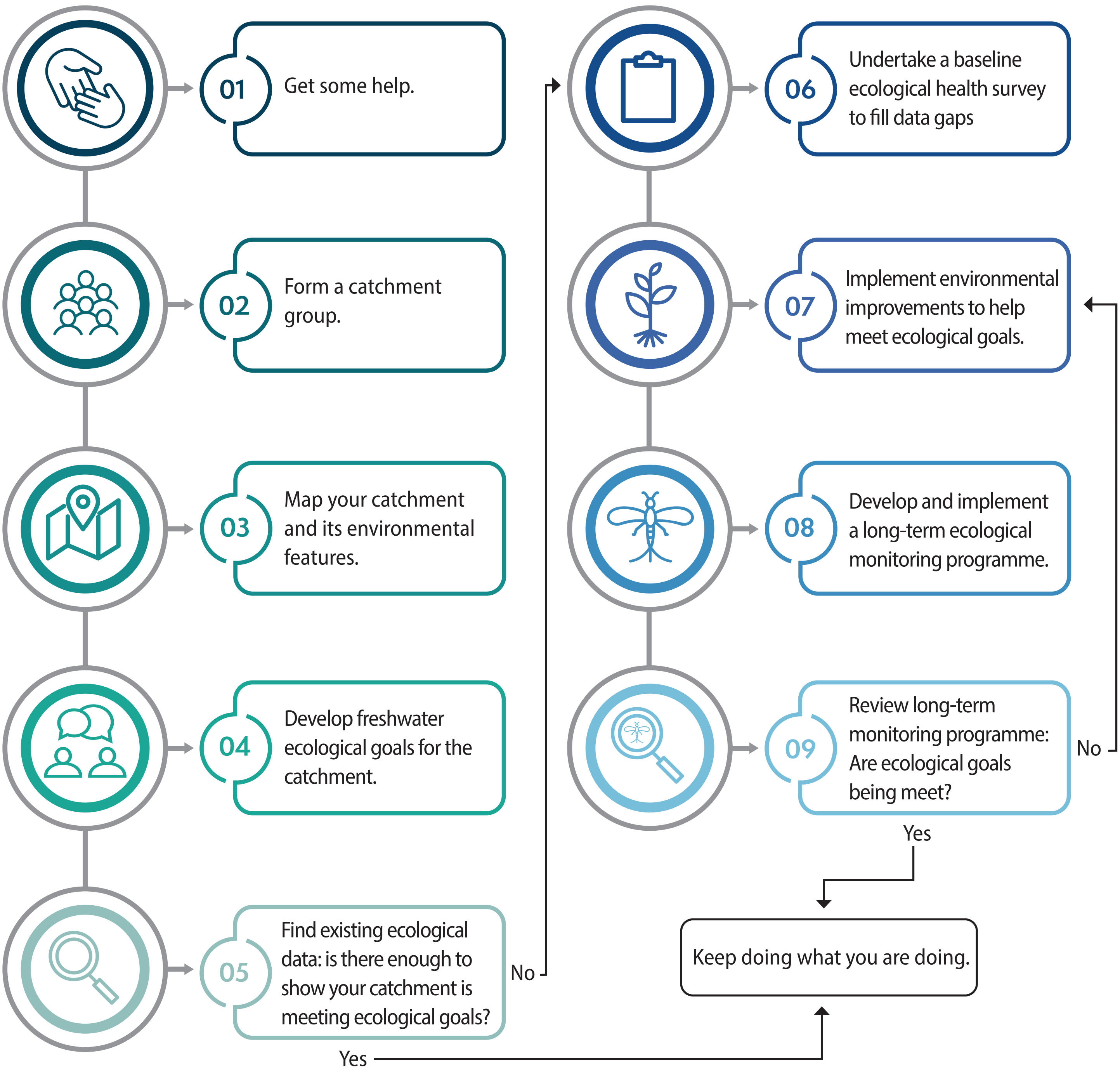
This report provides a toolkit for monitoring the impacts of farm environmental improvements on river health in Southland catchments. It is intended to enable catchment groups, with the help of rural professionals, to set up in their own freshwater monitoring programmes.

The report details the steps that will lead to a successful monitoring project by a catchment group. For annual river health monitoring sites, it is recommended that macroinvertebrates and river habitat are assessed as a bare minimum. In addition, *E.coli*, nitrate, phosphate and water clarity are four indicators that are really useful for monitoring water quality in farming catchments. These can be measured in any site and at weekly, monthly or yearly intervals, upstream and downstream of areas of land use change or environmental improvement.

On the following pages is a flowchart that shows the key steps in setting up a monitoring programme, followed by a checklist for the key steps which link to sections of the main report where further information can be found. Finally, a picture is shown of a potential long-term catchment monitoring design in a small to medium-sized river. This monitoring programme example takes into account catchment features such as locations of land use change, areas of environmental improvements, presence of tributaries and presence of existing Regional Council State of Environment monitoring sites. Positioning monitoring sites upstream and downstream of areas of land use change and areas of environmental improvement is a practical way to assess either of these on river health.

This document contains a more comprehensive and detailed river health monitoring programme for catchment groups, than that outlined in the shorter, complimentary report 'Getting Started : Ecosystem Health Monitoring for Catchment Groups' (link). It is designed for catchment groups who wish to expand their monitoring programme beyond the two parameters (river habitat assessment and macroinvertebrate community assessment) outlined in the short report.

Key steps for catchment group freshwater health monitoring



Checklist for catchment group freshwater health monitoring

01

Get some help.

Contact rural professionals who can help with access to funding and expertise (e.g. Thriving Southland, Beef+Lamb, DairyNZ, regional councils, Landcare Trust).

See Sections 3 & 7.

02

Form a catchment group.

With the help of rural professionals, get together with other farmers, Iwi and stakeholders in your catchment.

See Section 2.

03

Map your catchment and enviromental features.

List and map important catchment features such as: recreational sites (e.g. swimming and fishing spots), sites for environmental improvements, tributaries, changes in land use and areas of native bush.

See Summary Figure and Section 3.

04

Develop freshwater ecological goals.

Talk with landowners, Iwi and stakeholders to develop ecological goals for the catchment. These might include goals to meet environmental regulations or support cultural / ecological values in your catchment, like fisheries.

See Sections 3, 4 and 7.

05

Find existing ecological data.

Summarise existing ecological data to determine the current state of waterbody health and ecological knowledge in your catchment. Your regional council is the first place to look for existing data

See Sections 3 and 7.

06

Undertake a baseline ecological health survey.

After determining the types and locations of environmental data in your catchment (and where ecological data is lacking) develop a plan to collect data to fill those gaps. This will help your catchment group develop a baseline data set suitable for assessing environment change against. You will need support from rural professionals for this step.

See Sections 4, 5 and 6.

07

Implement environmental improvements to help meet ecological goals.

Develop and implement on-farm environmental improvements that will help meet environmental goals. These should be done as part of your Farm Environmental Plan process.

See Section 3.

08

Develop and implement a long-term ecological monitoring programme.

Design the ecological monitoring programme so it aligns with the environmental improvements and their locations in your catchment. Consider waterbody type, catchment features such as tributaries and available resources when designing a programme.

See Summary Figure, Sections 3, 4, 5 and 6.

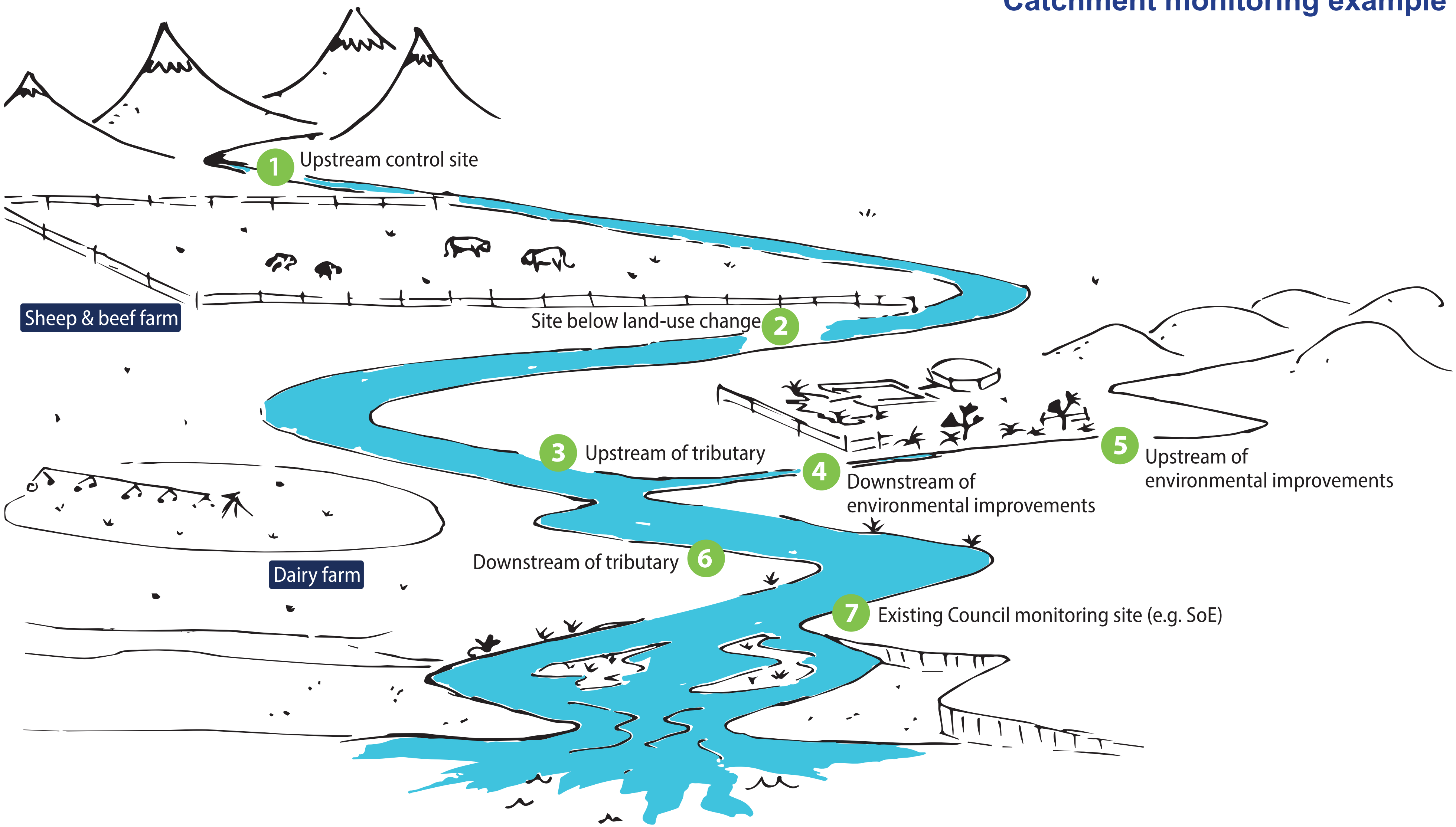
09

Review long-term monitoring programme.

Are you heading towards meeting your environmental goals? Is environmental progress happening at an acceptable rate? If not, review the scope and extent of your environmental improvements.

See Sections 5 and 6.

Catchment monitoring example



Summary Figure. An example of monitoring in a small to medium-sized catchment. Shown are seven different monitoring locations that serve various functions within a long-term catchment scale monitoring programme. They are case-specific. We suggest that, at a minimum, macroinvertebrates and habitat are assessed annually at monitoring sites. We also suggest *E. coli*, nitrates, phosphates and water clarity as a minimum collection of indicators used to monitor water quality in farming catchments.

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1. HOW TO USE THIS REPORT

This report presents a framework for catchment groups in Southland to set up a programme to monitor the impacts of land use change and improvements in land management practices on waterbodies. Nutrient enrichment in the form of excess phosphate and nitrate runoff, sedimentation of rivers from run-off and eroding riverbanks and *E. coli* inputs from livestock, are all acknowledged as core problems in Southland catchments. To see if land use changes / improvements in land management are changing river health, use the checklist in the executive summary and the relevant sections of the report to decide how and where to set up sites in a catchment, as well as what and how to monitor.

The report is divided into numbered sections:

Section 2: Starting up a catchment monitoring group – some ways to improve the chances of success.

Section 3: Finding out what is already going on in the catchment.

Section 4: Things to consider when setting up river sites and a monitoring programme.

Section 5: What river health indicators are and how to use them to detect and monitor changes due to land management practices.

Section 6: Potential pitfalls to be aware of when monitoring.

Section 7: Useful contacts and sources of information.

2. STARTING UP A CATCHMENT MONITORING GROUP – SOME WAYS TO IMPROVE THE CHANCES OF SUCCESS

‘Ten Principles’ of successful community projects have been described (Robinson et al. 2018) and these can be adapted to river health projects for Thriving Southland catchment management groups (Table 1). If these principles are broadly adhered to, the likelihood of success of any monitoring project will be improved.

Table 1. Ten principles for successful community projects as applied to Thriving Southland catchment management groups (adapted from Robinson et al. 2018).

1. **Farmers and other stakeholders are actively involved**, they may volunteer or be identified to act as contributors, collaborators, or as project leaders and have a ‘useful’ role in the project.
2. **Needs to be a ‘real science’ useful outcome** such as a realistic attempt to detect and monitor the impact of land-use changes and improvement measures on water quality and river health
3. **Projects should benefit both catchment groups and the greater public**, including goals such as contributing to evidence that can influence policy, linking catchment groups with each other and the wider community, encouraging learning opportunities and providing personal enjoyment.
4. **Members of the group are involved in all different stages of the scientific process or project**, such as deciding on sites, what indicators to use, gathering and analysing information and circulating results.
5. **There needs to be a mechanism to alert catchment groups and individuals within groups as to how their results are being used** and the practical outcomes from project results.
6. **Problems such as ‘operator error’ should be recognised and accounted for** at the sampling design stage, so farmer/public involvement is still encouraged while increasing value and reliability of the information collected.
7. **Sharing information and results (ongoing and final) should be encouraged** within and between catchment groups, during or after the project, unless there are security / privacy concerns.
8. **Catchment groups and their members should be suitably acknowledged** for their time and effort in project communications, result reporting and publications.
9. **A range of benefits and outcomes should be considered in assessment of any projects**. This could include scientific outputs, data quality, participant experience and knowledge sharing within and between catchment management groups, capacity building within the farming community, increased farmer dialogue on catchment issues and policy impact.
10. **Leaders of catchment groups need to take into account legal, health and safety and ethical issues**, such as data sharing agreements, member health and safety when sampling and level of consultation within and between group members.

3. FIND OUT WHAT IS ALREADY GOING ON IN THE CATCHMENT

This report describes how to set up a monitoring framework and the things to consider when choosing monitoring sites, how and when to monitor and what indicators to use. All of this is useful only if the catchment group fully understands what existing river monitoring is currently being done, including where and why, as well as what changes in land use or land management actions are being undertaken, including where and why.

The Southland region covers an area of 34,000 km^2 and is drained by four major river catchments, the Mataura, Aparima, Waiau, and Oreti. Combined, these catchments cover over half (54% or 18,305 km^2) of the region. The Land, Air, Water Aotearoa (LAWA) website has been set up to share environmental data and information on such catchments. According to LAWA, Environment Southland (ES) monitors 96 river and stream sites for 'river quality' and this includes water quality (including nutrients such as phosphates and nitrates and *E. coli* concentrations), ecology and suitability for swimming (https://www.lawa.org.nz/explore-data/southland-region/river-quality/).

Appendix 1 of this report provides, via step-by-step instructions and direct weblinks, an example of how to access *E. coli* monitoring data for a typical Southland monitored stream. We use the Cascade Stream at Pourakino Valley Road as an example.

Most ES sites are located in lowland catchments and hill country (see Environment Southland's website, www.es.govt.nz). Water quality (e.g. pH, temperature, nutrients and dissolved oxygen) is monitored monthly at a number of sites in over forty rivers. Ecological health is assessed by monitoring algae on the river-bed monthly and macroinvertebrates (aquatic insects, shrimps, worms and snails found on the stream-bed) are monitored annually. Environment Southland's own reports also provide a readily available record of the water quality monitoring datasets and specific issues (such as nutrient levels and faecal contamination) for the Southland region, with information ranging from the regional to sub-regional scale (see www.es.govt.nz). The Stats New Zealand website provides additional information on water quality and agricultural indicators for both New Zealand as a whole and Southland and so is another useful reference tool (https://www.stats.govt.nz/topics/fresh-water).

Environment Southland's State of the Environment (SOE) water quality monitoring programme is geared to providing an overview of the current state of river water quality in the region (www.es.govt.nz and https://www.stats.govt.nz/topics/fresh-water). It is not specifically set up to find out how land use changes in the catchment, land management improvements or river restoration projects are impacting on river water quality. Nevertheless, knowledge of the location of existing SOE sites and what they are monitoring is very useful. If used wisely, this information can be used to supplement and back up the design and results from a catchment group monitoring programme, to get more 'bang for your buck'. For instance, SOE site data within the same river could be used as a comparison to catchment group results. Alternatively, SOE sites could be included into the catchment group monitoring design itself, so that new monitoring sites do not duplicate SOE sites but can be located further upstream or downstream in the river. This could then increase the area of river being monitored to detect the impact of land use change, without wasted effort.

It is a priority to get information about on-farm actions and changing land use practices that are being implemented to improve river health. A crucial initial starting point is to identify and quantify on-farm actions, whether it be increasing fencing to keep stock away from a watercourse, or setting up treatment wetlands to improve sediment management. If there is a basic lack of information on what is being attempted to improve things, where it is occurring in the catchment, when it is occurring in the catchment and over what duration, it is very difficult to work out if these actions are making any difference to river health. Work is underway to help fill this information gap. A register of land management actions that can be linked to water quality outcomes is being set up. This will be a free online tool to record actions to improve water quality in farming catchments and will provide farmers with the information they need, in order to identify and invest in the most efficient management practices to improve water quality in their area (https://ourlandandwater.nz/incentives-for-change/national-register-of-actions/). Table 2 provides a summary of river health improvement aims and common farm management actions that could be undertaken to achieve them.

At the end of this report, we provide a list of useful contacts and sources of information. This is not meant to be exhaustive but a starting point for a catchment group to refer to.

Table 2. Land use–river health improvement aims and common farm management actions to achieve them (adapted from Doehring et al. 2020).

Improvement aims	Farm management action
Improving riparian zone for adjacent watercourses	Fencing, stock exclusion, vegetated buffer strips, riparian management plan, construction of artificial and natural seepage wetlands
Improving grazing and crop management practices to protect river health	Restricted grazing, off pasture animal confinement, change animal type, supplementary feeding with low-N feeds, minimum tillage of seed, cover crop after harvesting, stubble mulching, contour cultivation, grazing and crop management plan
Improving use of and diminishing run-off of nutrients and contaminants	Restricted grazing (of winter forage crops), off-pasture animal confinement, bridging stock stream access, sediment traps, change animal type, precision application of fertiliser, denitrification beds, supplementary feeding with low-N feeds, low water-soluble P fertiliser, nitrification inhibitors, nutrient and contaminant management plan
Improving soil conservation and erosion control	Sediment traps, restricted grazing (of winter forage crops), off pasture animal confinement, afforestation / windbreaks, bridging stock stream access, contour drains and contour cultivation, minimum tillage, silt fence / trap, stubble mulching, soil conservation plan, critical source run-off management plan
Improving water use	Precision irrigation, refurbishing and widening flood irrigation bays, water use management plans
Improving effluent management	Greater effluent pond storage, low-rate application to land, enhanced pond system, effluent management plan
Common to all farms	Farm Environment Plan (FEP), Good Management Practices (GMP), participation

4. THINGS TO CONSIDER WHEN SETTING UP A RIVER SITE MONITORING PROGRAMME

4.1. Some definitions to start with

This report uses the following terms to describe which things in the catchment are being monitored and what is being used to measure them.

River water quality refers to the physical and chemical characteristics of water. It can be affected by both point-source (from a pipe or drain) and diffuse (from general land run-off or seepage) pollution. It includes things such as dissolved oxygen, water clarity, nutrients like nitrate and phosphate and faecal microbial contaminants.

River health is a much broader concept than water quality, it includes water quality but also water quantity, the physical habitat of the river, the animals and plants in the river and the way they interact (ecological processes). In a healthy unpolluted river, the water quality, quantity, habitat and ecological processes (such as the decomposition of organic matter such as decaying leaves) are good enough to maintain animal and plant life similar to that found in river sites located in native bush or conservation areas, which are often situated at the top of a catchment.

Indicator refers to a measure of river health which is used to show how changes in land use or land / river management affect water quality, water quantity, physical habitat, aquatic life or ecological processes in the river.

4.2. Monitoring objectives – some basics to think about when first setting up a framework of monitoring sites

If possible, catchment group monitoring should complement and not duplicate council monitoring. Building on existing monitoring would be the simplest way to immediately expand the scope and effectiveness of catchment group monitoring. Water quality monitoring is typically carried out on a monthly or quarterly basis by regional councils. For instance, catchment groups could try to match this timing if they are able, as it will make their results more comparable and provide them with reference conditions for their own results. Any opportunities to restructure State of the Environment (SOE) monitoring networks by the regional council to take into account contributions by catchment monitoring groups should be explored. Many regional councils are currently reassessing their freshwater monitoring networks in response to recent freshwater policy updates (e.g. National Policy Statement for Freshwater Management).

Any monitoring or sampling framework must balance the catchment group's resources (time, effort and funding) with the reliability of the data collected using the chosen indicators. The timing and the spatial coverage of a monitoring project is critical. For example, an investigation of nutrient run-off from a farm may show a relationship between farming activity and river water quality in the summer but not in autumn or winter months (Johnson et al. 1997). It is always better to have a comprehensive record of reliable 'meaningful' data at a few sites rather than unreliable data from many sites. An option to increase the coverage of a catchment group's monitoring would be to monitor several sites, but on a rotating basis. This has the major drawback of lessening the ability to detect long-term trends in river health. This option is good for a broad-scale assessment of the state of a large section of a river or an area of a catchment, but less useful for tracking change in the short term (5–10 years).

Successful monitoring projects tend to have the following things in common:

- Clear aims and objectives, such as improvement in an identified stretch of river downstream of a farm or group of farms where land use change or pollution mitigation measures have taken place.
- Aims and objectives are SMART (specific, measurable, attainable, relevant, and time-bound).
- Aims and objectives can be realistically measured by the catchment group and / or scientists working with the group.

4.3. Types of monitoring site

4.3.1. Before-after-control-impact

Land use change, changing farm management practices and restoration / improvement projects often occur at a specific site or farm. A '**Before-After, Control-Impact**' or **BACI** design is an effective way to detect and monitor how land use changes at the site- or farm-scale lead to changes in river health. Following the BACI design, a downstream site subject to on-farm practices is assessed, relative to a control site upstream of the farm. This control site provides a reference 'baseline' to compare any changes in an impacted or restored site's river health. A BACI approach is particularly suited to assess actions to improve or stop point-source pollution, such as using sediment traps or by shifting the location of winter crop paddocks, with monitoring sites located upstream and downstream of the intervention.

While a BACI design is very useful, there are some issues for catchment groups to be aware of:

- Some farmers may have carried out changes to a greater or lesser degree and over different time frames, while other farmers may not have implemented any changes. Have existing land management actions been identified and have they been measured?

- BACI studies are most suited to small (low order) streams where there are fewer confounding issues and changes in river health have the potential to occur over relatively short time periods compared to larger streams. How big is the stream and how long before we expect to see change? (see Parkyn et al., 2010; Restoration Indicators Toolkit https://niwa.co.nz/sites/niwa.co.nz/files/import/attachments/Restoration-Indicators-4-WEB.pdf).
- Activities elsewhere in the catchment could influence BACI results, particularly in larger streams. Activities such as fertiliser application, irrigation or other catchment-scale pressures can be overlapping and spread throughout a catchment. This could mean that establishing true control-impact comparison sites may not be realistic. For example, pollution prevention measures set up at an individual farm scale may not improve river health (as detected by river health indicators), if other water quality issues exist in the same catchment at the same time, especially if they are upstream of that farm.
- Control (reference) sites can be hard to find, particularly in lowland streams. Ideal control (reference) sites would be in an undisturbed native bush area of the same river system. If these are difficult to find, a 'guiding image' could be used instead. The 'guiding image' is what a healthy stretch of the river might look like without pollution or water quality issues. Guiding images of healthy rivers and streams can be created from historical records for the river and / or by visiting undisturbed sites in other parts of the catchment or region.

4.3.2. Long-term trend monitoring

If the BACI approach is not realistic for the above reasons, an alternative is **long-term trend monitoring** to detect changes in river health indicators over time. This requires a lot of repeated monitoring over a set time frame to determine whether a change over time is statistically significant or not.

The three types of long-term sites are seasonal, annual and control / reference:

- Seasonal sites are used over weeks to months, for often, very frequent monitoring of specific issues, such as water quality samples downstream of an effluent discharge from a drain or pipe.
- Annual sites are sampled each year, and this may be relevant for indicators linked to aquatic life such as macroinvertebrates and aquatic plants (macrophytes). Comparing samples from the same season (i.e. summer) across years is a good way to track long-term changes in the river.
- As with BACI studies, long-term control sites are those located as close as possible to an impact location without being influenced by the impact itself, such as immediately upstream of a discharge pipe. Monitoring at these control sites not only provides a baseline to compare other sites with, but also provides information on long-term change in river health due to global factors such as climate change.

Clearly, different types of long-term monitoring sites provide different data to answer different questions. To look at changes in river health over different spatial and time scales, a monitoring framework would ideally include all three types of sites (seasonal, annual, and control or reference).

If long-term trend monitoring is used, monthly sampling of water quality parameters is recommended if resources allow, as this would capture the variability seen during different seasonal and flow conditions. After 5 years of monthly monitoring it should be possible to detect any significant trends in water quality.

4.4. Choosing monitoring sites – first steps

It is worthwhile undertaking a pilot survey to identify suitable monitoring sites and as accurately as possible work out where changes in land use are taking place. Sites can be chosen based on local knowledge, any available records (on farm and stream location and water quality data) and practical concerns such as site accessibility and areas in the river that can be safely sampled without health and safety concerns. Maps and Google Earth are useful to determine where catchment features are that might influence water quality (for example large patches of remnant native bush or significant tributaries). Ideally, sites should be located to take into account catchment features, often being positioned above and below major features. For instance, if monitoring the impacts of land use change, choose sites upstream and downstream of the change and consider any tributaries downstream. While you may need more than one site in the main river downstream of the land use change to ascertain the length of main river affected, you should also sample downstream of any tributaries in the main river. When sampling these tributaries, sample upstream and downstream of where the tributary feeds into the main river as this will give an indication of the influence of the tributary on the river health of the main river stem.

Within the monitoring network, a simple top of the catchment site (i.e. with no land use impacts) and bottom of the catchment site would allow assessment of land use change effects at the catchment scale and allow comparison between catchments if this is needed. If different catchment groups choose to compare their results to one another and coordinate their monitoring programmes, then right at the start, there should be clear agreements on data collection (i.e. what is measured and when) data storage (i.e. how results are stored and who takes responsibility for this) and data validation (i.e. checking different groups are measuring things the same way) right at the start. This will increase the usefulness of data, the training opportunities and the interest for group members.

Practice runs of sampling by group members are recommended, as this will show the time and effort required and give a general idea of the overall monitoring framework that can be realistically attempted. For instance, as far as possible, all river sites should be monitored on the same day or week.

4.5. Include freshwater farm plans

Farmers are already using existing farm plans to manage environmental risks, including risks to river health. Eventually these will be replaced by Freshwater Farm Plans (FW-FP), which are part of the Essential Freshwater package introduced in 2020. This is an integrated planning approach that will collect all farm planning requirements into a single place (see https://www.mpi.govt.nz/agriculture/farm-management-the-environment-and-land-use/protecting-freshwater-health/towards-a-certified-freshwater-farm-plan-system/ for full details). Detailed knowledge and communication of proposed improvements in farm plans of catchment group members are an ideal starting point for groups to focus their efforts with a BACI and / or long-term monitoring approach to monitoring.

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5. WHAT RIVER HEALTH INDICATORS ARE AND HOW TO USE THEM

5.1. What are some of the things we need to measure?

One of the main pressures on river health in Southland (and New Zealand more widely), is intensive agriculture, with drainage networks discharging water with high nutrient (nitrates and phosphates) and suspended sediment loads to receiving streams. When stock have access to unfenced sections of rivers, they defecate in the water and their movement causes stream bank erosion. When it rains, bacteria such as *E.coli* (*Escherichia coli*—found in the guts of mammals and birds and in their faeces), are also carried as run-off into rivers and streams and groundwater, posing a health threat to river users. Overland flow and nutrient loss from stock wintering practices can be a major problem during wet months when soils are saturated and / or compacted. High nutrient levels may increase progressively down catchments, and this can be reflected in the types and cumulative numbers of animals and plants present in rivers / streams at various points in the catchment. On the other hand, many farmers are using practices such as fencing and planting to reverse stock damage, and the effects (recovery) of these efforts on water quality need to be measured too. Therefore, water quality and physical habitat features are key measures of river health in agricultural settings.

5.2. Indicators that are relevant to river health in farming catchments

The Ministry for the Environment (2009) identified several river health and water quality measurements deemed suitable for measuring the effects of farming land use practices on water quality. Table 3 includes these chemical, biological (animal, plant and bacteria) and physical measures, what they can show, and how they might respond to land use influences. Grouped together, the measurements in Table 3 will provide a starting point for detecting and monitoring river health changes due to agriculture land use changes.

Table 3. Chemical, biological (animal, plant, microbe) and physical measures that could be used to reflect or indicate on-farm issues that can have major impacts on river health (adapted from MfE 2009).

Chemical, biological and physical measures	What can they show or measure and possible impacts on river	Agriculture land use and practices
Nutrients - Nitrates and phosphates etc.	How intensively land is farmed, efficiency of fertiliser and effluent management, indicate level of nutrient enrichment in river, cause nuisance weed growth	Run-off of fertiliser into river via leaching and surface run-off. Effluent going into river via drains or directly from stock via unfenced sections of river
Ammonia	Toxic to stream life such as fish	Discharges of dairy effluent
Dissolved oxygen	Capacity of river to support life	Levels can decrease due to microbes breaking down organic waste and effluent in river
Periphyton and macrophytes (Algae 'slime layer' and aquatic plants)	Indicate extent of nuisance weed and algae growth. May result from nutrient enrichment, increased light and temperatures. Negative impact on swimming, fishing and appearance	Diffuse run-off and leaching of fertiliser / effluent, stock access to rivers, effluent discharging via drains, direct discharges, leaching, removal of bankside tree cover / vegetation decreasing shade
Bacteria (*Escherichia coli*)	Measure of faecal matter in river. Negative impact on swimming, fishing and stock drinking sources	Diffuse run-off of effluent, stock access to river, effluent discharging via drains, direct discharges
Macroinvertebrates (stream insects, worms, snails, shrimps)	Indicate general river health, can reflect both short and long-term conditions	Diffuse run-off of effluent, stock access to river, effluent discharging via drains, direct discharges, removal of bankside vegetation
Fish	Indicate general river health, can reflect both short and long-term conditions	Diffuse run-off of effluent, stock access to river, effluent discharging via drains, direct discharges, removal of bankside vegetation, fish passage barriers
Water temperature	Promote nuisance weed and algae growth. Stress sensitive aquatic life when it is too warm	Increased by bankside removal of trees / vegetation
Conductivity (related to concentrations in water)	Indicate different water source contributions and / or nutrient concentrations	Run-off of fertiliser / effluent; stock access to river
Physical stream habitat, suspended solids and water clarity	Condition of bankside vegetation, bank slope. Fine sediments from erosion and soil loss. Impact on habitat, recreation and appearance	Removal of bankside vegetation, erodible and unstable land, stock access to river, channelisation
Stream flow	Stream flow at the time of sampling should be measured to put other indicators in context, since they will vary with flow	Catchment and channel disturbance, water abstraction

5.3. How to decide what is good indicator

A good indicator needs to be:

- easy to measure
- measured in a way that is accurate
- measured in a way that is repeatable, whether by the same person or another
- sensitive to the changes we want to measure but also be robust to natural variability in the river (i.e. things like water temperature in a river will change a lot during the day)
- inexpensive
- provide easily understood information.

The measurements outlined in Table 3 were not specifically designed for catchment groups. However, the National Institute of Water and Atmospheric Research (NIWA) in partnership with the Federated Farmers of New Zealand has developed a Stream Health Monitoring and Assessment Kit (SHMAK) for citizen scientists (https://niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit, see Table 4). This provides a range of practical indicators and methods that catchment groups can use easily to assess the state of rivers and streams. It allows river health to be tracked over time, so using the indicators in the Kit can show if things are getting worse, improving, or staying the same. The Kit also provides useful advice on designing a monitoring programme, choosing indicators, explaining what each indicator measures, explains how to measure each indicator in a scientifically robust way and how to interpret and understand the data obtained.

We strongly recommend that a selection of the SHMAK indicators described (Table 4) form the backbone of a catchment group river health monitoring programme. Some SHMAK indicators measure mainly one thing such as temperature or water clarity (how clear or discoloured the water column is) but some are ‘integrated’ indicators. This means they can give a very useful overall assessment of river health, as the indicators themselves, such as the bottom-dwelling (benthic) macroinvertebrate community, or algae ‘slime layer’ (called periphyton) community can reflect (or integrate) a range of different water quality pressures within the river reach and even the catchment as a whole.

Table 4. Summary of SHMAK indicators, practical measurement methods and examples of what it can indicate to catchment groups relevant to agricultural land management practices (see https://niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit for details of indicators and methods).

SHMAK Indicator	SHMAK measurement method	Examples of what can it tell catchment groups
Visual clarity	Clarity tube or black disc	Livestock grazing increasing fine sediment inputs
Water temperature	Thermometer	Removing shade trees from riparian areas
Conductivity	Conductivity meter	Salt content, relative input of groundwater, supports information from other indicators
Nitrate	Colorimetric methods, visually assessed by colour comparator	High nitrate levels can result from fertiliser run-off and livestock excretion and high levels risk nuisance 'weed' (periphyton and macrophytes) growths
Phosphate	Colorimetric methods, Hanna® Instruments' 'phosphate checker' device	Level of fertiliser run-off and soil erosion
E.coli bacteria	Select *E. coli* count plate on colour-specific growth media	Inputs of faecal contamination from cattle and human sewage
Periphyton	Two visual methods – the stone method and the viewer method	Levels of nutrient enrichment
Macrophytes	Macrophyte water surface cover index and macrophyte 'clogginess' index	Levels of nutrient enrichment
Benthic macroinvertebrates	SHMAK index, levels 1-3 collection methods using sieve or kick-net	Overall indicator of habitat and water quality conditions, especially organic water quality
Fish	Spotlighting	Range of fish, presence or absence, can reflect habitat and water quality factors
Current velocity	Timed floating object (e.g. orange)	Speed of water flow
Streamflow	Combine measures of current velocity and cross-sectional area of stream as measured by water depths at 5-10 equally spaced point across channel	Key measure of 'state of flow', puts water quality measurements into context as many indicators change with streamflow
Stream habitat	SHMAK visual assessment of eight different aspects of stream bed, banks and riparian zone.	Indicate what human activities may have degraded stream habitat (e.g. river-bank erosion and increased sedimentation)
Streambed composition	SHMAK level 2 - Wolman walk, streambed particles picked up, measured, different size classes counted	Can indicate what sort of fauna would be expected if water quality and flow are sufficient, a covering of sediment could indicate soil erosion
Rubbish	Visual estimate of different rubbish types and scale system SHMAK level 1	Littering or dumping.

5.4. Choosing a set of indicators – what to consider

Available expertise and resources will determine what selection or subset of indicators are used. If resources are insufficient to do all or most of Table 4, we would recommend prioritising the following as indicators of river health in agricultural catchments:

1. physical stream habitat assessment
2. stream water *E.coli* concentration
3. stream water nitrate concentration
4. stream water phosphate concentration
5. stream water clarity
6. SHMAK or MCI macroinvertebrate index.

These six indicators would provide:

- both short- and long-term indicators of river health and habitat conditions (macroinvertebrates)
- an indication of nutrient enrichment and run-off issues (nitrates and phosphates)
- an indication of potential human health issues (*E. coli*)
- a rapid appraisal of conditions (habitat assessment and clarity).

5.4.1. Physical stream habitat assessment

As detailed in Table 4, a SHMAK visual habitat assessment is available (method described in https://niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit). However, we would recommend replacing or supplementing the SHMAK habitat assessment by the more recently developed Rapid Habitat Assessment (RHA; Clapcott 2015). The RHA is also used in State of Environment (SOE) monitoring by local councils and so it would be useful for catchment groups to use the same method for comparative purposes. Easy to follow instruction courses are available online to support citizen science use (Appendix 2; https://www.facebook.com/NZLAWA/videos/introduction-to-the-rapid-habitat-assessment-rha/625144961670052/).

There are also various, more intensive quantitative and semi-quantitative protocols for stream habitat assessment. The choice of protocol may be adjusted to fit the level of expertise and resources available. The following link provides a more intensive habitat assessment that might be suitable if you are planning to substantially change the stream channel (https://www.envirolink.govt.nz/assets/Envirolink/Stream20Habitat20Assessment20Protocols.pdf).

5.4.2. *E. coli*

The *E.coli* count plate method detailed in SHMAK could be replaced by the arguably more user-friendly and quicker on-site quantitative *E. coli* water quality test kit. These have recently become available (e.g. the Aquagenx® Compartment Bag Test (CBT) Water Quality Test Kit; see https://www.youtube.com/watch?v=jyafqpmx82s for easy to follow instructions; Figure 1).

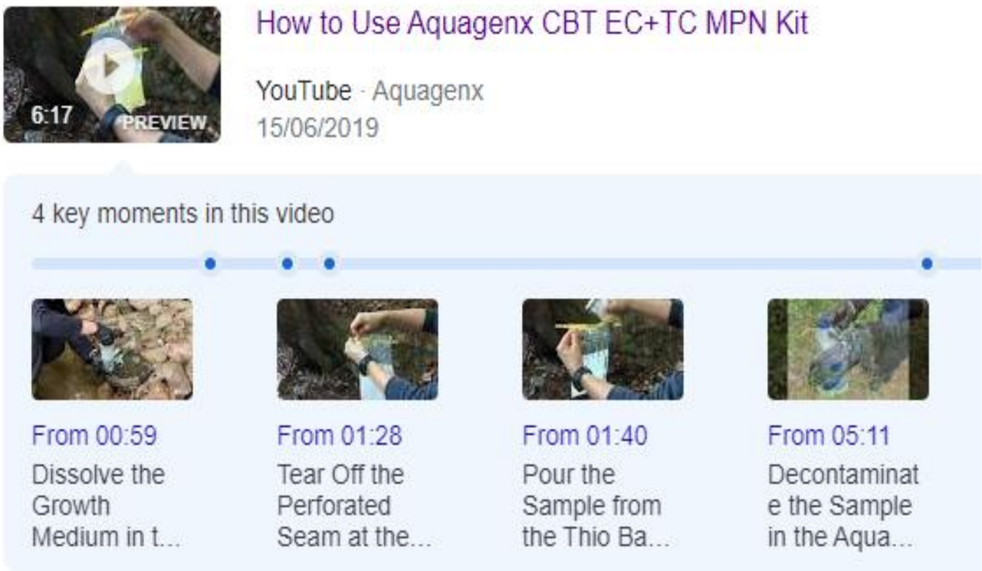

Figure 1. Aquagenx field *E. coli* sampling kit instruction video link and key stages in using the kit highlighted.

5.4.3. Nitrate and phosphate

The SHMAK nitrate and phosphate methods, while appropriate to a citizen science approach, may not have the necessary reliability and accuracy for the precision demanded by baseline standards of the National Policy Statement for Freshwater Management 2020. They may be most useful for initial assessment of general levels of these nutrients in various sites and identifying if there is a problem. Then it might be appropriate to send water samples from 'problem' sites to an accredited laboratory for professional chemical analysis. In terms of phosphates, it is recommended that soluble reactive phosphorus is what is requested for analysis by a laboratory, as this is the most useful indicator as regards water quality issues.

5.4.4. Clarity

Visual clarity can be measured using a SHMAK clarity tube (https://niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit). This is a 1-metre-long, 50-mm-diameter clear acrylic tube. The tube has a black target attached to a magnetic slider which is moved through the tube away from the eye, until it is not seen anymore. The clearer the water, the further away the black target can be seen. Clarity or its related indicator, turbidity, can be measured over a time period, instead of a one-off reading. A short NIWA training video is available on how to use the clarity tube (https://niwa.co.nz/videos/shmak-water-quality-%E2%80%93-visual-clarity). For clear water rivers (clarity greater than 1 m), the clarity tube is unable to provide particularly useful information. In those cases, water clarity can be measured using a black disc and underwater viewer (Water clarity — Science Learning Hub) to determine how far the black disc can be seen underwater.

5.4.5. Multi-probe loggers

If funds are available, multi-probe monitoring loggers are available for purchase or lease from several New Zealand suppliers and could be deployed at selected sites in the catchment to supplement data collected by catchment group field sampling. Continuous monitoring of variables such as dissolved oxygen, temperature, flow and turbidity (which is related to clarity) are very useful if resources allow, because they can show daily changes in water quality that are often missed by one-off water samples. Such probes could be deployed at those sites perceived to be at most risk of pollution and / or moved throughout the catchment periodically to expand coverage. Getting an accurate picture of variables that vary greatly over the course of a day is important. For instance, daily dissolved oxygen fluctuation can help determine if there is enough oxygen to support a variety of stream life. For example, trout are highly sensitive to dissolved oxygen fluctuation, which can be caused by excessive amounts of aquatic weed and algae. Oxygen levels can get very low at night when aquatic plants respire, so it is useful to know these levels, which would be missed by daytime sampling.

5.5. Macroinvertebrate Community Index

This is a very good, cost-effective integrated indicator. Macroinvertebrates are creatures without backbones that are visible to the naked eye. They are relatively sedentary, tending to remain in the same reach / site while living underwater and are long-lived (often surviving for a year or more). The presence or absence and changing numbers of different macroinvertebrate species reflects changes in their environment such as increased or decreased pollution levels, habitat disturbance, floods and droughts. Sampling macroinvertebrates is cost-effective when compared with collecting data on fish.

Sampling macroinvertebrates usually involves using a net (either a pole-mounted ‘kicknet’ or a frame-mounted ‘Surber sampler’—see Figure 2). This is placed downstream of a patch of stream. The streambed patch is then disturbed (with a foot, or a hand in the case of the Surber sampler) and the macroinvertebrates are captured as they drift into the net with the river current. Once collected, the macroinvertebrates are transferred into plastic pottles and preserved with alcohol (usually 70% ethanol or methylated spirits). The sample can be processed in the laboratory in various ways to indicate the ecological health of a river.

Although there is a SHMAK 'health' index for macroinvertebrates collected by citizen science groups (methods fully described at https://niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit), the Macroinvertebrate Community Index (MCI) score (Stark et al. 2001) is the most commonly used indicator of river health. For example, all regional councils use this index to report river health at freshwater SOE sites.

Figure 2. A macroinvertebrate sample being taken using a Surber (box) sampler. Note the use of scrubbing brush to dislodge animals from stone surfaces.

The MCI score is generated by the presence or absence of different macro-invertebrate species. The basic principle is that different macroinvertebrates (for example mayflies, snails and worms) respond differently to the effects of pollution. Some macroinvertebrates can tolerate moderate to high levels of pollution (for example increases in sediment or nutrient levels), while other animals disappear from river communities as pollution levels increase (Figures 3 and 4).

To calculate the MCI, each macroinvertebrate species is identified under a microscope and given a score related to their pollution tolerance (ranging from

1 – taxa very tolerant to pollution, such as worms, to 10 – taxa very sensitive to pollution, such as some mayflies). Individual species scores are combined using a simple spreadsheet-based calculation. MCI scores can range between 0 and 200 but it is rare to find MCI values greater than 150 (indicating pristine condition) or less than 50 (indicating severely degraded or polluted habitat). Tolerance values for the species found at a site are combined, which gives the overall MCI: excellent (> 119); good (100–119); fair (80–99) and poor (< 80). A higher MCI generally indicates better river health, but it should be noted that on its own, the MCI does not fully account for natural variation in river types. Even under natural conditions, some rivers will never achieve an excellent quality rating, and this can be due to factors such as type of riverbed substrate or climate.

There are other ways to interpret macroinvertebrate community data, such as the Quantitative MCI (QMCI). This is a variation of the MCI which weights the overall index value according to the most abundant species present. Table 5 shows some 'water quality classes' to help interpret MCI and QMCI score ranges.

Table 5. Water quality classes and descriptions for interpreting Macroinvertebrate Community Index (MCI) and Quantitative MCI (QMCI) scores (adapted from Stark & Maxted 2007a, 2007b).

Water quality class	Description	MCI	QMCI
Excellent	Clean	> 120	> 6.0
Good	Possible mild pollution	100–120	5–6
Fair	Probable mild pollution	80–100	4–5
Poor	Probable severe pollution	< 80	< 4

The following weblink presents a user guide for calculating the MCI and QMCI: https://environment.govt.nz/publications/a-user-guide-for-the-macroinvertebrate-community-index/part-2-guidelines-for-using-the-mci-qmci-and-sqmci/

A catchment group needs to decide whether to use the SHMAK kit-based macroinvertebrate protocol or the MCI protocol, which is best processed by expert taxonomists. Pursuing the SHMAK method requires a degree of group training in macroinvertebrate identification and has the benefit of catchment group members gaining a better understanding of how macroinvertebrates are used as ecological health indicators. It is also cheaper. The advantage of collecting samples for professional processing is that it will requires less effort by a community group and will be directly comparable to samples collected by regional councils, other government bodies and research institutes within the same catchment. This will enable better comparison with existing data within a catchment, regionally or nationally.

Stonefly (two tails)

Mayfly (three tails)

Sandfly

Chironomid (midge - bloodworm)

Figure 3. Common river invertebrates. These are juvenile (larval) forms of adult flies. Stoneflies and mayflies can indicate good water quality, blackflies moderate water quality and chironomids poor water quality. (Photographs courtesy of Peter Hamill).

Cased caddisfly

Caseless caddisfly

Snail (Hydrobiidae)

Worm (Oligochaete)

Figure 4. More common river invertebrates. The top two pictures are caddisflies and these are juvenile (larval) forms of adult flies. The cased caddis constructs a home out of fine pieces of sand, gravel or vegetation, while the caseless caddis is free living. The bottom two pictures are of a common freshwater snail and a worm. Caddisflies can indicate moderate to good water quality; snails have wide tolerances of water quality and worms can indicate poor water quality. (Photographs courtesy of Peter Hamill).

6. POTENTIAL PITFALLS TO BE AWARE OF WHEN MONITORING

6.1. The importance of scale in time and space

River health indicators need to track any environmental responses in the river to changes in land use practices at the right scale. Within any monitoring framework, the spatial or 'landscape' scale of sample collection must also match the scale at which the river health indicator operates. In short, indicators work at different geographic and time scales. For example, macroinvertebrate communities respond mainly to changes in physical habitat at the reach or site scale rather than to the average physical habitat at the catchment scale. Macroinvertebrates can also respond rapidly to short-term high flow events.

Results obtained from catchment group monitoring sites must also allow for the location of the site in the catchment, whether it is in headwaters, middle reaches or lowland receiving waters. This is because many of the factors used to assess river health are themselves greatly influenced by where in a catchment the measurements are taken, regardless of levels of pollution (Table 6). The natural changes in river velocity, dissolved oxygen, temperature and other parameters, which occur from the top of the catchment to the bottom need to be allowed for when working out what a site's monitoring results are showing.

Different indicators also need to be measured at different time scales to be useful. For example, fish usually breed annually and therefore their sampling frequency should be annual. In contrast, dissolved oxygen concentrations can vary greatly over a daily cycle, so ideally oxygen levels in a stream would be sampled using loggers that measure oxygen continuously (e.g. every 15 minutes over 24 hour cycles). For instance, oxygen levels may be at the lowest just before dawn, because of plant / weed respiration during the hours of darkness. Because variables such as dissolved oxygen can vary greatly over the course of the day, if continuous data-loggers are not available, sampling should ideally be carried out at approximately the same time of day each time, for comparative purposes. If resources allow, continuous monitoring in the form of automatic data-loggers of variables such as dissolved oxygen, temperature, flow and turbidity are a way to account for daily variation in some water quality indicators. Loggers could be deployed for a single day, several days in a row, a week at a time, or continuously, depending on the purpose of the monitoring.

Table 6. Typical changes in river quality from top to bottom of an agricultural catchment (adapted from Stream Sense Manual, Waikato Regional Council (www.waikatoregion.gov.nz)).

Parameter	**Change from top to bottom of catchment**	**Underlying reason**
River / stream velocity	Gets slower	Gradient decreases, upland to lowland
Streambed substrate	Substrate gets smaller, from boulder to gravel	Gradient decreases, upland to lowland
Streambed flow types	Riffle areas of streambed decrease, pooled areas increase	Gradient decreases and slows river flow
Dissolved oxygen	Decreases	Gradient decrease, river slows, aeration decreases
Temperature	Increases	Less trees and shading and decreasing altitude
Turbidity – water clarity	Increases	Increasing erosion and runoff of sediment
Nutrient enrichment	Increases	Increasing inputs of nitrates and phosphates from agriculture
E. coli levels	Increases	Increasing inputs from animals and people
Biological Oxygen Demand (BOD)	Increases	Increasing amount of organic and waste matter
Macroinvertebrate community	Water quality sensitive species decrease, tolerant species increase	Habitat, oxygen and pollution inputs change

6.2. Recognising time lags

The likely time lag between land use change and any measurable effect on river health is important to consider. Improvements on land will rarely lead to an ‘instant fix’ of improved water quality and river health downstream. In general, it can take many months or years for ecological improvements to occur to the point where they are measurable using indicators in a mid-sized river (i.e. river that is just wadeable). Ecosystem health improvements in smaller tributaries can be expected to occur more rapidly, so it is a good idea to have some monitoring sites in smaller tributaries to get faster feedback on any farm’s environmental improvements.

The length of this time lag will vary depending on the size of catchment, geology, groundwater links, river flow conditions, rainfall and climate, location of land use change and the change or improvement in land use itself. For instance, the response to applying nitrate and phosphate-rich fertiliser to land may take many months before there is a measurable change in health indicators of adjacent rivers. Changes to land use practice can sometimes take years to be evident. Different indicators have different 'recovery trajectories', which means some things will recover faster than others once improvements are in place. For instance, the macroinvertebrate community usually recovers faster than the fish community. Parkyn et al. (2010) provides a useful river restoration toolkit, which gives a great deal of detail on how long it can be expected to take for individual indicators to show signs of recovery, that will be clear to community river restoration groups (available at https://niwa.co.nz/sites/niwa.co.nz/files/import/attachments/Restoration-Indicators-4-WEB.pdf).

How this lag may make itself known in a catchment group's monitoring results will be related to how the monitoring framework is designed, especially frequency of sampling. Lags can be a challenge for keeping group members engaged but using multiple indicators, both short and long term, increases the likelihood of detecting changes in river health. It is useful to consider how a range of indicators are likely to respond over time (i.e. some respond more rapidly to different actions than others) to manage expectations.

6.3. Further considerations

To compare results from selected rivers in catchments it might be practical to present results calculated for the whole period of monitoring by 'averaging out' results. Although this is useful for presenting data, it may also hide seasonal changes, that could be vital for assessing the impact of specific land use activities. For instance, *E. coli* levels in streams may be lower during summer than winter months, despite increased run-off in winter months, simply because of much greater amounts of *E. coli* washed in during winter months when river flows are at their peak (MfE 2009). Therefore, when reporting results, make sure the data selected are appropriate to the question being asked. For instance, in respect of the above example, data collected throughout the year may need to be shown for each season, to identify exactly what is going on.

7. USEFUL CONTACTS AND SOURCES OF INFORMATION

This document is complimentary to the much shorter, introductory report to river health monitoring 'Getting Started : Ecosystem Health Monitoring for Catchment Groups' MacNeil C, Holmes R. 2021 (Cawthron Report 3704, 17p. plus appendices). The shorter report can be used as an immediate 'hands-on' introduction to river health monitoring using two criteria, one based on river habitat assessment and one based on macroinvertebrate community assessment.

Listed below are other useful sources of information:

Beef + Lamb. Introduction to freshwater quality. (An industry toolkit to understand and monitor water quality).
https://beeflambnz.com/knowledge-hub/module/introduction-freshwater-quality

The Cawthron Institute. The MCI (Macroinvertebrate Community Index) explained by Cawthron Institute. https://www.facebook.com/NZLAWA/videos/the-mci-macroinvertebrate-community-index-explained-by-cawthron-institute/1848526138517611/

The Cawthron Institute. What is a healthy river ? https://vimeo.com/292855565

The Community/Land Manager Waterwatch Guide. Department of Environment Climate Change and Water New South Wales.131pp.
https://www.nswwaterwatch.org.au/files/21/Community-Groups/4/Community-Land_Manager_Waterwatch_Guide.pdf

Dairy NZ Water quality. (An industry toolkit to understand and monitor water quality).
https://www.dairynz.co.nz/environment/review-and-plan/water-quality/

Environment Southland. www.es.govt.nz

LAWA 2020 https://www.lawa.org.nz/explore-data/southland-region/ (river monitoring southland region) and https://ourlandandwater.nz/incentives-for-change/national-register-of-actions/(register of land-use actions in agricultural catchment)

NIWA SHMAK river monitoring online toolkit
https://niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit

River Habitat Assessment online instruction course (less than 10 minutes)
https://www.facebook.com/NZLAWA/videos/introduction-to-the-rapid-habitat-assessment-rha/625144961670052/

River Habitat Assessment – written instructions for quantitative and semi-quantitative methods for stream habitat assessment https://envirolink.govt.nz/assets/Envirolink/1519-NLRC174-National-Rapid-Habitat-Assessment-Protocol-for-Streams-and-Rivers.pdf

Stream Sense Manual, Waikato Regional Council (www.waikatoregion.gov.nz)

Stats New Zealand (freshwater) https://www.stats.govt.nz/topics/fresh-water

8. ACKNOWLEDGEMENTS

Thanks to McKayla Holloway for providing graphics and Peter Hamill for invertebrate photographs.

9. REFERENCES

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Parkyn S, Collier K, Clapcott J, David J, David B. Davies-Colley R, Matheon F, Quinn J, Shaw W, Storey R 2010. The restoration indicator toolkit: indicators for monitoring the ecological success of stream restoration. National Institute of Water and Atmospheric Research Ltd, Hamilton. 134 p.

Robinson LD, Cawthray JL, West SE, Bonn A, Ansine J 2018. Ten principles of citizen science. In: Hecker S, Haklay M, Bowser A, Makuch Z, Vogel J, Bonn A (eds.) Citizen science: innovation in open science, society and policy. London, UCL Press. pp 1-23.

Stark JD 1985. A macroinvertebrate community index of water quality for stony streams. Water & Soil Miscellaneous Publication 87: 53 p. National Water and Soil Conservation Authority, Wellington, New Zealand.

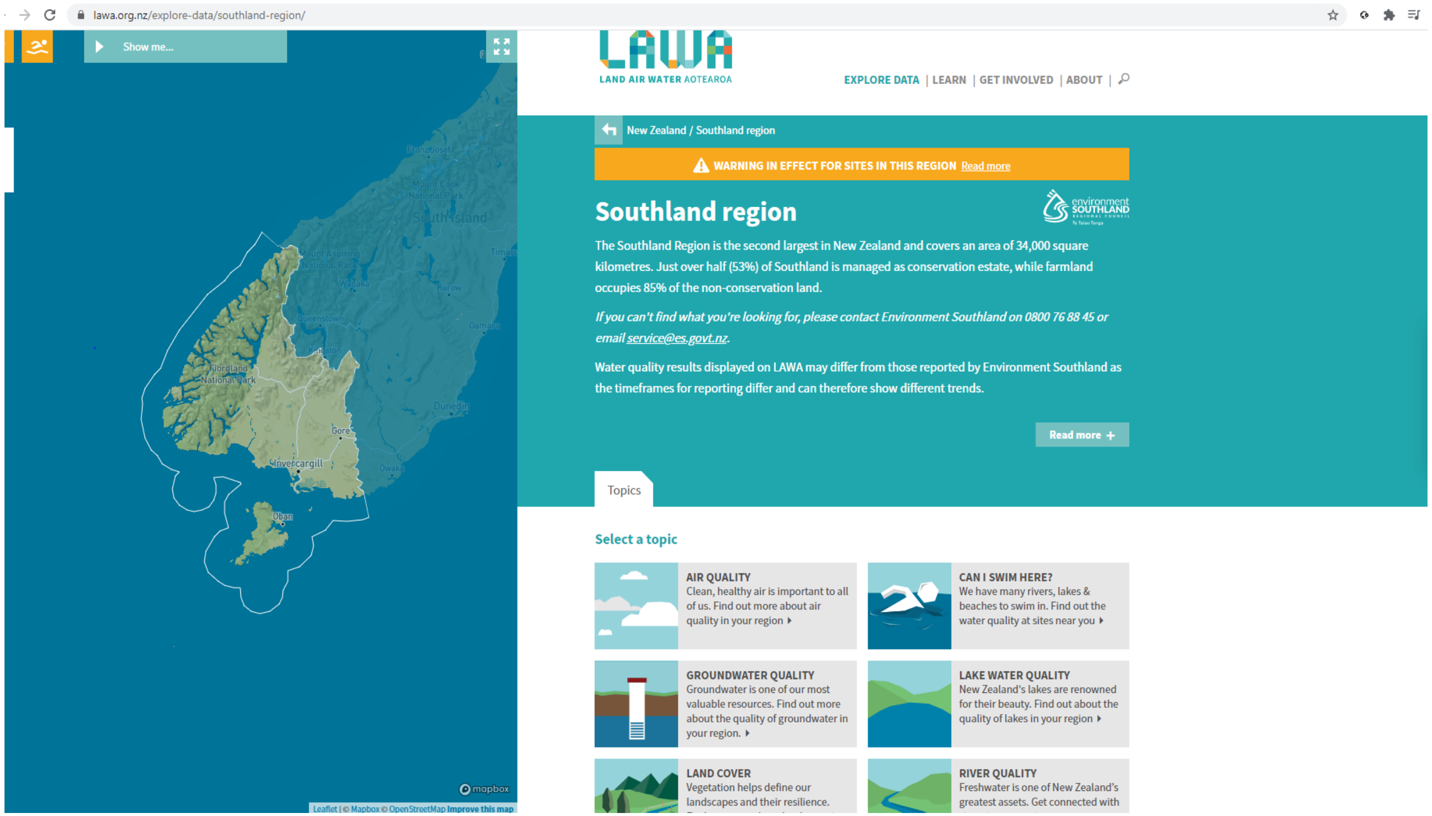
Stark JD, Maxted JR 2007b. A user guide for the Macroinvertebrate Community Index. Prepared for the Ministry for the Environment. Cawthron Report 1166. 58 p.

10. APPENDICES

Appendix 1. Example of accessing Land Air Water Aotearoa (LAWA) for *E.coli* monitoring results in a typical Southland stream.

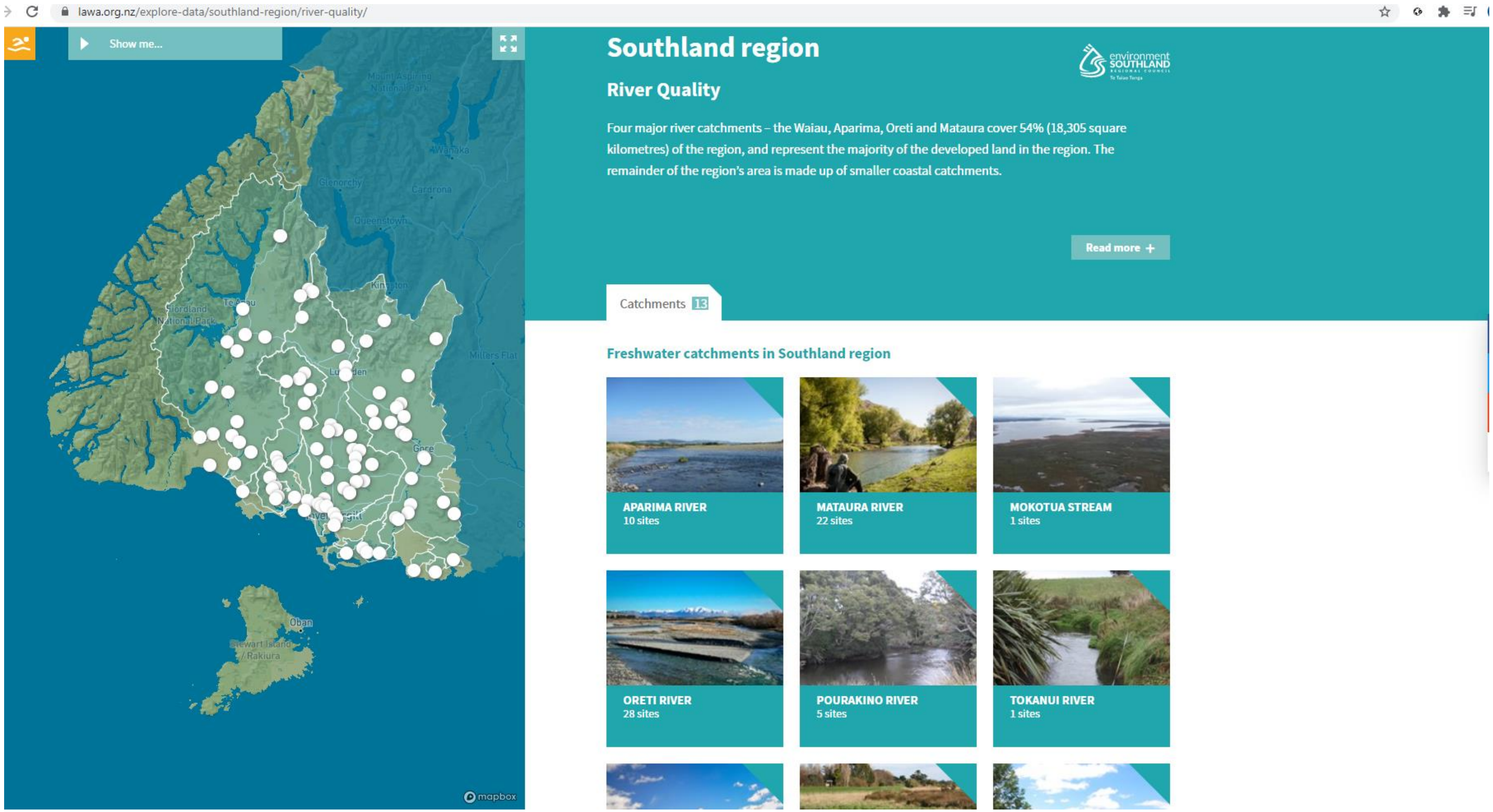
To access the Southland region in LAWA, type ‘LAWA’ in the search engine and then type in ‘Southland’ or click on Southland part of map, clicking on the below link takes you directly to the page.

https://www.lawa.org.nz/explore-data/southland-region/



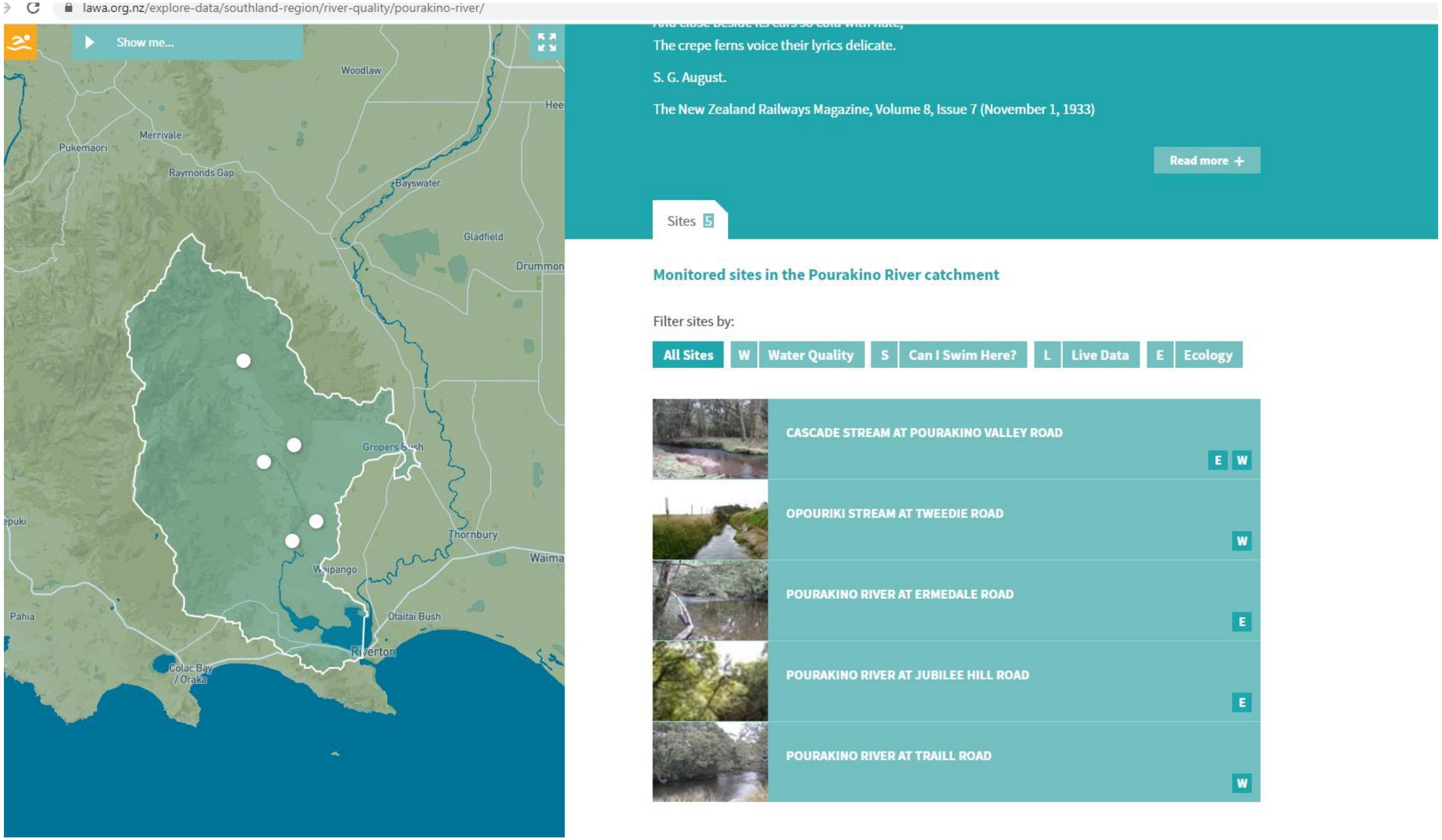
To access river quality in Southland region, click on the river water quality box on the page, or click on the link below.

https://www.lawa.org.nz/explore-data/southland-region/river-quality/



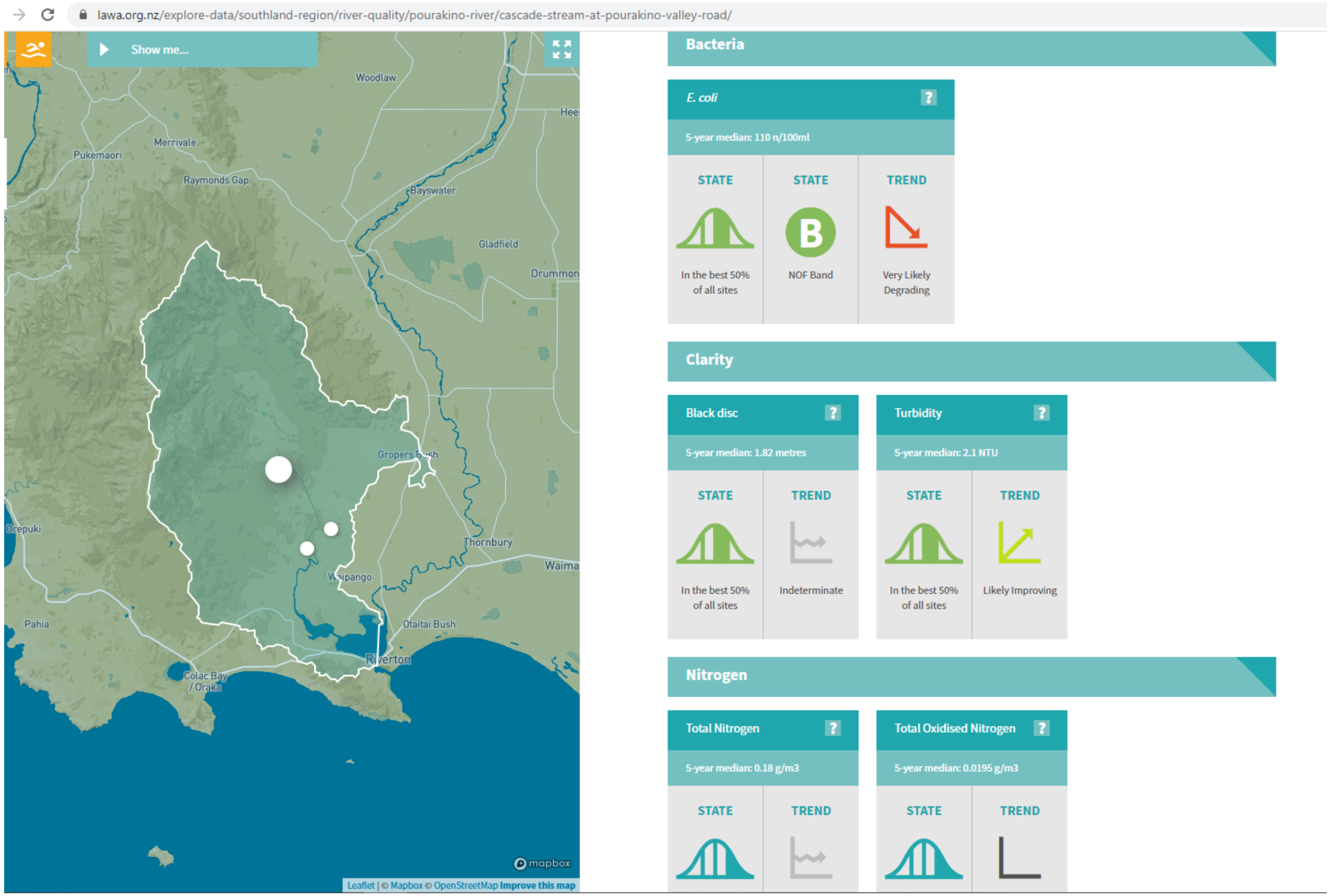
To access river quality in a specific river catchment – see this example of the Pourakino River catchment, click on the Pourakino catchment box or click on the weblink below.

https://www.lawa.org.nz/explore-data/southland-region/river-quality/pourakino-river/

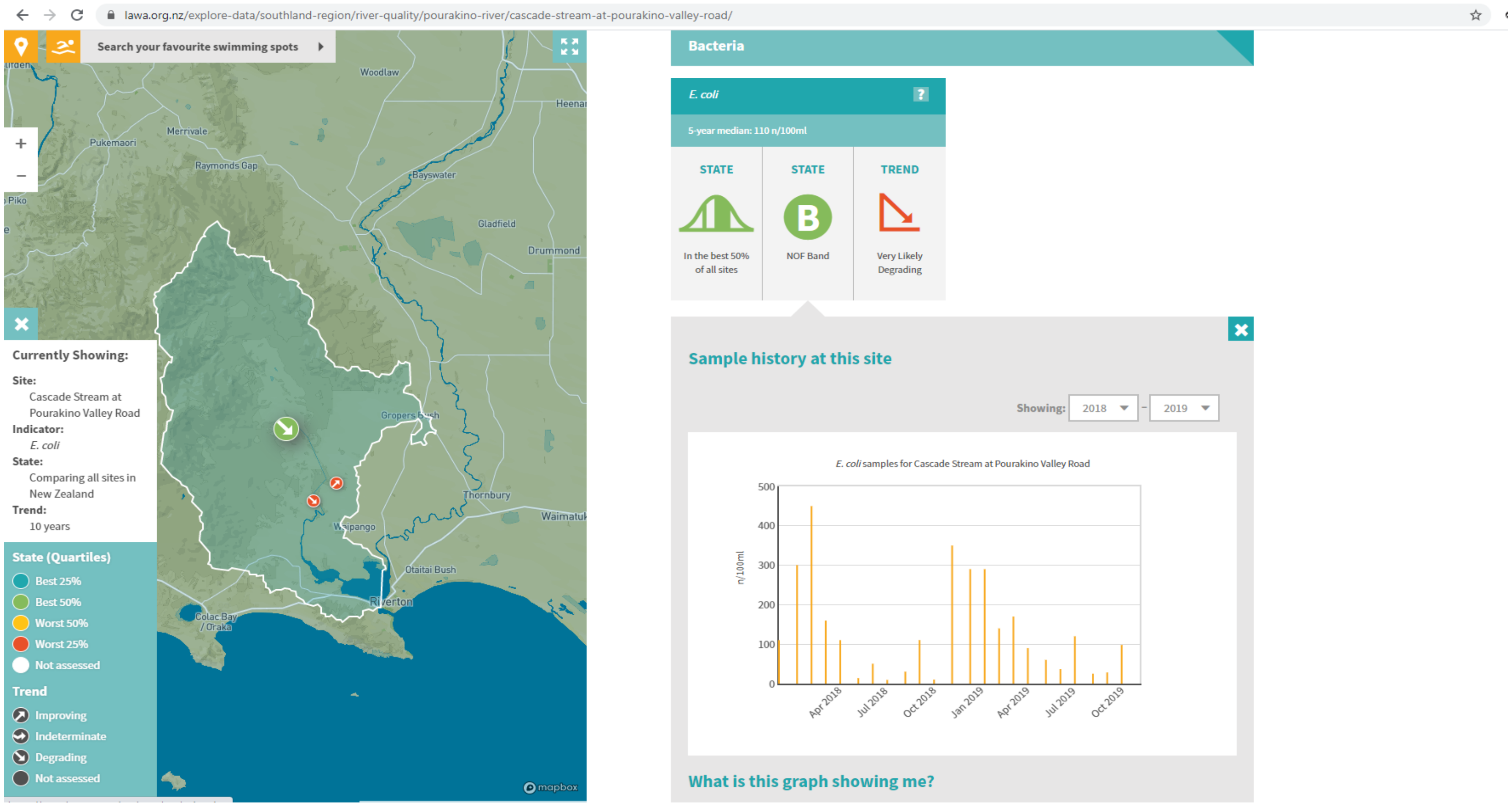


To access river quality in a specific river site in the Pourakino catchment – example of the Cascade Stream at Pourakino Valley Road, click on the Cascade stream at Pourakino Valley Road box or click on the weblink below.

https://www.lawa.org.nz/explore-data/southland-region/river-quality/pourakino-river/cascade-stream-at-pourakino-valley-road/



To access details of *E. coli* levels in Cascade stream at Pourakino Valley Road monitoring site, click on the *E.coli* 'box' or click directly on the weblink below.
https://www.lawa.org.nz/explore-data/southland-region/river-quality/pourakino-river/cascade-stream-at-pourakino-valley-road/ See *E. coli* results below.



Appendix 2. River habitat survey training film.

https://www.facebook.com/NZLAWA/videos/introduction-to-the-rapid-habitat-assessment-rha/625144961670052/

Introduction to the Rapid Habitat Assessment (RHA)

LAWA
17 March 2020 ·

With the Rapid Habitat Assessment (RHA) protocol, twenty minutes is all you need to find out the 'habitat quality score' for a river reach of your choice.

Developed by Cawthron Institute in partnership with regional councils, the RHA protocol doesn't require specialist gear. Learn how to do it here: cawthron.org.nz/.../servic.../rapid-habitat-assessment-protocol/