Ministry for the Environment
Manatū Mō Te Taiao

Ministry for Primary Industries
Manatū Ahu Matua

FRESHWATER MANAGEMENT GUIDANCE

# A Draft Guide to Monitoring

## Under the National Policy Statement for Freshwater Management 2014 (as amended 2017)

New Zealand Government

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# 1 Introduction

Under the National Policy Statement for Freshwater Management (Freshwater NPS), regional and unitary councils (councils) are required to establish in plans what values the community holds for freshwater, then maintain or improve water quality by setting freshwater objectives and limits to uphold those values.

To show whether their plans are effective, councils must develop a monitoring plan to guide how they will monitor progress towards, and achievement of, the values the community hold for freshwater and the freshwater objectives they have set.

This guide is aimed at council planners, resource managers, and scientists. It discusses the development of a monitoring plan and what it must include.

Monitoring plans are intended to be practical and affordable. The Freshwater NPS does not require councils to monitor every drop of fresh water; monitoring only needs to occur at sites that represent the freshwater management unit (FMU). When choosing how, when and where to monitor, councils should consider what information is currently collected/held (eg, as part of the state of the environment monitoring), and what (if any) additional information is required.

The guide is not intended to be a stand-alone document. It should be read in conjunction with the other guidance documents for the Freshwater NPS (see below) and the references provided within this document, particularly on matters such as trend analysis and representative site selection. There is a wealth of information already available on these topics which should be used.

For more information see Water quality monitoring – policy intent and guiding materials. For more information about freshwater management units see A guide to identifying freshwater management units.

This guide is being released as a draft. We welcome your feedback or suggestions on the content. If you would like to provide feedback, please email freshwater@mfe.govt.nz. A finalised guide will be published in March 2018.

# 2 The monitoring requirements

## 2.1 Monitoring for freshwater objectives and values

**Objective CB1**

To provide an approach to the monitoring of progress towards, and the achievement of, freshwater objectives, and the values identified under Policy CA2(b).

The objective states the purpose of **Part CB – monitoring plans** which is to monitor progress towards, and the achievement of, freshwater objectives and values. The policies which sit underneath the objective provide direction on how to achieve this objective.

### Establishing values and setting freshwater objectives

Policy CA2 of the Freshwater NPS sets out the process for establishing values for fresh water and setting freshwater objectives to ensure those values are maintained (or improved) over time. Councils will need to establish the values for a FMU through discussion with the community, including tangata whenua, for the compulsory national values in Appendix 1, and any other values the regional council identifies.

Councils must then set freshwater objectives for all of the attributes in Appendix 2 of the Freshwater NPS to uphold those values, and employ any other attributes that the regional council considers appropriate. Monitoring will therefore need to relate to all of the Appendix 2 attributes, as well as any other attributes a council identifies and sets objectives for. For more information about identifying attributes and setting freshwater objectives see A Guide to the NPS-FM, A draft guide to attributes in appendix 2, and Guidance on implementing the NPS-FM.

### Monitoring and reporting

Monitoring data will be essential for determining the current state of the FMU then setting freshwater objectives in relation to this (ie, does the community wish to maintain the current state or improve it). The current state will also provide a starting point from which to assess whether freshwater objectives are being achieved.

Councils are required to establish monitoring plans to detail how they will monitor progress towards, and achievement of, freshwater objectives and values. Monitoring plans are a mandatory requirement under the Freshwater NPS but they do not have to be developed in a specific way (for example using a Schedule 1 process) or be incorporated into the regional plan. The monitoring plan can be a living document, and can be thought of as a regional monitoring strategy.

Councils are also required to make monitoring information available to the public. This is aligned with the requirements in section 35 of the Resource Management Act 1991 which requires councils to report every 5 years on the state of the environment. Public reporting under the Freshwater NPS can be aligned with the RMA requirement.

# 3 Developing a monitoring plan

Councils should use their existing monitoring strategy/network as a starting point when developing a monitoring regime and plan under the Freshwater NPS. When preparing the monitoring plan, consider what should be included in the body of the plan, what could be in appendices, and what could be presented in tables, diagrams or maps.

## 3.1 What a monitoring plan must include

**Policy CB1**

By every regional council developing a monitoring plan that:

a) establishes methods for monitoring progress towards, and the achievement of, freshwater objectives established under Policies CA1-CA4;

aa) establishes methods for monitoring the extent to which the values identified under Policy CA2(b) are being provided for in a freshwater management unit. These methods must at least include:

i. surveillance monitoring of microbial health risks to people at primary contact sites in accordance with Appendix 5;

ii. the monitoring of macroinvertebrate communities;

iii. measures of the health of indigenous flora and fauna;

iv. information obtained under Policy CB1(a) and Policy CC1; and

v. Mātauranga Māori;

## 3.2 Methods for monitoring freshwater objectives – Policy CB1(a)

For information on monitoring the attributes in Appendix 2 of the Freshwater NPS, see *A Draft Guide to Attributes in Appendix 2 of the National Policy Statement for Freshwater Management 2014*. The guide explains the rationale for attributes, how they can be used to set freshwater objectives, and monitoring progress towards them. The information gained through monitoring whether freshwater objectives are being met will form one of the key indicators of whether the values are being upheld (as per policy CB1(aa) below).

The guide also discusses sampling considerations for each attribute, and relevant monitoring protocols. The appendix of this guide contains a reference list of guidance and guidelines for monitoring different attributes, which councils may find useful.

# 3.3 Methods for monitoring freshwater values – Policy CB1(aa)

The methods for monitoring whether the values a community holds for their fresh water are being upheld **must at least** include the matters listed in i-v of Policy CB1(aa). This is not an exclusive or exhaustive list. The policy does not require these methods to be employed at every representative monitoring site as this may not be possible. For example, there may be limited sites where monitoring native fish populations is appropriate, and macroinvertebrate monitoring is usually only practical in wadeable streams.

The intent is that within an FMU a range of monitoring approaches are used to indicate whether the values a community holds for the water body are being met.

## Surveillance monitoring of microbial health risks

Policy CB1(aa)(i) directs councils to undertake surveillance monitoring at primary contact sites (as identified in a regional plan) according to the matters set out in Appendix 5 of the Freshwater NPS. The purpose of monitoring microbial health risk weekly is so councils can evaluate the potential health risks in places people swim and inform people when it is not safe to swim.

The Freshwater NPS requires weekly surveillance monitoring at sites that are representative of the sites identified for primary contact, ie, not necessarily every site, and only during the time of year nominated by the councils (for example swimming spots during summer). And if:

- *E. coli* exceeds a threshold of 260 *E. coli* per 100ml, sampling must be increased to daily where practicable, and the sources of microbiological contamination should be investigated
- a single sample is greater than 540 *E. coli* per 100ml, the public must be notified that the site is unsuitable for recreation until further sampling shows a result of 540 *E. coli* per 100ml or less.

**This requirement is based on the alert and action modes for surveillance monitoring in the 2003 *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas* (the Guidelines). Changes to the Freshwater NPS are not intended to replace the Guidelines. Councils are encouraged to make use of the Guidelines when giving effect to the Freshwater NPS; they provide additional information on good practice when managing health risks at swimming sites (eg, sanitary surveys).**

Guidance on selecting monitoring sites for *E.coli* will also be addressed in the guidance on swimming due to be published in November 2017.

## Monitoring macroinvertebrate communities

Policy CB1 requires monitoring of macroinvertebrate communities. It is linked to Policy CB3 which specifically requires the use of the Macroinvertebrate Community Index (MCI). The intent of Policy CB1 however, is to signal that additional methods to MCI may also be used if it is considered appropriate (eg, QMCI or EPT).

Policy CB3 requires councils to utilise the MCI monitoring protocol but also directs what to include in the monitoring plan if an MCI score falls below 80 or there is a declining trend. This is that councils must investigate the cause, and take steps where possible, to halt the declining trend and improve on a score of below 80. A technical report from Environment Waikato[1] details the approach they have taken to monitoring the ecological conditions of wadeable streams and contains a good discussion on inferring ecological relevance of statistically significant changes.

Not that improvement on a score below 80 is not necessary if the cause of the decline is determined by the council investigation to be due to naturally occurring processes, pests or unwanted organisms (both defined in the Freshwater NPS) or due to the effects of infrastructure listed in Appendix 3 (note that this is currently empty).

As part of the obligation to use the MCI, the Cawthron User Guide for the Macroinvertebrate Community Index has been incorporated by reference into the NPS. See here for a copy: A User Guide for the Macroinvertebrate Community Index. The User Guide describes the merits of MCI and other biotic indices, contains a section on sampling site selection for a representative site (section 4), a discussion on how to interpret the MCI scores (section 3.4), and how to apply trend analysis to long-term MCI monitoring results (section 5).

The User Guide also contains a good discussion on the value of supplementing MCI with other complementary biological assessments to develop a fuller picture of ecological health and/or environmental change in a meaningful way (see also the next section).

## Measures of the health of indigenous flora and fauna communities

Objective A1 of the Freshwater NPS is to *safeguard the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems, of fresh water*. To help achieve this objective there is a compulsory value of 'Ecosystem health' which must be provided for through the setting of freshwater objectives and limits. The ecosystem health value descriptor states that '*in a healthy freshwater ecosystem ecological processes are maintained and there is a range and diversity of indigenous flora and fauna'.*

If the purpose of monitoring is to determine if a value is being provided for (as required by Policy CAB2(aa)) it will necessarily need to include the monitoring of the health of communities of flora and fauna. A diverse range of information is needed to determine if a community is 'healthy' and resilient, including diversity surveys, population density surveys, and habitat evaluations.

Multiple resources are available to help determine the appropriate monitoring focus and protocol. For example, see LakeSPI which uses submerged aquatic plants as an indicator of lake condition in New Zealand lakes at Lake monitoring in New Zealand and the index of biotic integrity (IBI) developed for freshwater fish in New Zealand streams[2]. See also the reference section at the end of this guide.

## Information obtained under Policy CC1 – Accounting

Part CC of the Freshwater NPS requires councils to operate freshwater quality and quantity accounting systems to collect information about contaminants being discharged into water bodies and water being taken from them.

[1] https://www.waikatoregion.govt.nz/assets/PageFiles/22680/TR201217.pdf.

[2] https://www.researchgate.net/publication/8199423_Application_of_the_Index_of_Biotic_Integrity_Methodology_to_New_Zealand_Freshwater_Fish_Communities.

This accounting information forms a key part of the data required for setting freshwater objectives, and then monitoring whether the freshwater objectives are being achieved. This information will contribute to the analysis of whether the compulsory values and any other national values are being upheld. A monitoring plan would ideally therefore include details of freshwater accounting systems. See A Guide to Freshwater Accounting for more information about freshwater accounting.

### Mātauranga Māori

Regional councils are required to monitor progress towards freshwater objectives and values in a way that is informed by Mātauranga Māori. Mātauranga Māori encompasses traditional knowledge, and the transfer of knowledge, about the nature of the world. As a method, Mātauranga Māori can articulate the state of our environment from a Māori perspective.

This new monitoring requirement will help councils get a fuller picture of fresh water in their rohe and will also help them understand how well they are providing for Te Mana o te Wai.

The requirements to consider and recognise Te Mana o te Wai places the health and well-being of water bodies at the forefront of community discussions, including when setting freshwater objectives. Because freshwater objectives will provide for the 'three healths' of Te Mana o te Wai (Te Hauora o te Tangata, Te Hauora o te Wai, and Te Hauora o te Taiao) councils will need Mātauranga Māori to understand their progress towards achieving those objectives.

The practice of Mātauranga Māori can be specific to each rohe and iwi or hapū and while some mana whenua groups may be happy to work with councils to draw on Mātauranga in monitoring, others may not. Therefore, in developing monitoring methods informed by Mātauranga Māori regional councils will need to work closely with their local iwi and hapū to develop a plan.

## 3.4 Standardisation of environmental monitoring methods

Regional councils are making a lot of progress in establishing consistent approaches to environmental monitoring and reporting. The Environmental Monitoring and Reporting (EMaR) and National Environmental Monitoring Standards (NEMS) projects are a large part of this.

EMaR develops and operates environmental data collection networks, and a widely accessible national reporting platform, called Land, Air Water Aotearoa (LAWA). Working groups are set up to develop environmental monitoring modules that are published on LAWA, and to improve national consistency in methods.

The NEMS steering group has prepared a series of standards that prescribe technical standards, methods and other requirements associated with monitoring a number of environmental parameters. NEMS is also involved in quality coding, ie, selecting the right standard of data for the analysis you're doing. NEMS output has been focused mainly in the hydrological sphere but wider issues (eg, air quality) are being worked on. For more information about NEMS and the standards developed to date see Factsheet: (NEMS) National Environmental Monitoring Standards and the NEMS website.

## 3.5 Pragmatism and monitoring

There will be times when pragmatism will be appropriate when selecting monitoring methods. Adopting a pragmatic approach to monitoring could help councils be efficient with their resources and avoid unnecessary monitoring, for example, in situations where there is a high level of confidence that the fresh water is meeting a set objective. While some monitoring is still necessary to provide evidence to the community that the objective is being met, an extensive sampling regime may be of little additional benefit.

In cases where certain attributes are known to *not be a problem*, monitoring could be conducted less frequently, or through different methods. For example, where the amount of periphyton biomass is considered likely to meet freshwater objectives, monitoring could be carried out using quicker and less costly visual inspection methodologies. If the visual inspection indicates that a site is approaching the extent of periphyton abundance allowed under the set objective, the monitoring approach could be extended to include measurement of *chlorophyll a*. A similar approach may be suitable for the monitoring of cyanobacteria, with visual inspection used alongside measures of cell counts or bio-volume.

There may also be times when it is appropriate to use a proxy measure to support monitoring. For instance, in an FMU where the majority of the catchment is a low-impact land use such as national park/conservation estate, monitoring is likely to show that the quality of water is high. Changes to land use within such a catchment may result in changes to water quality. It could therefore be appropriate to monitor land-use change as a proxy measure to indicate when monitoring may need to be increased to detect any changes in water quality.

It may be possible to involve community members in monitoring. Using community volunteers may allow a council to monitor more sites. For some freshwater objectives it may also be more appropriate to have members of the community conducting monitoring, for example, for some cultural values (see, for example, the section on Mātauranga Māori).

Where pragmatic monitoring approaches are adopted, it is important to document the chosen approach in the monitoring plan, and the reasons why it was selected. The approach should also be reviewed regularly and adapted to ensure it remains appropriate over time.

# 4 Identifying representative sites

**Policy CB1**

By every regional council developing a monitoring plan that:

b) identifies a site or sites at which monitoring will be undertaken that are representative for each freshwater management unit

The chemical properties or ecological values of water vary, often over very short distances and it is not possible to monitor every drop of water in a region. For these reasons the Freshwater NPS requires monitoring to be undertaken at sites the council has identified as the points which represent the water environment for that FMU or part thereof ie, a representative site.

When selecting representative monitoring sites, a council should consider a range of factors including among other things, what freshwater objectives are set, ease of access, and budget. Once a site is selected this will be the point used to establish whether or not a freshwater objective is being met – regardless of whether the water environment varies upstream or downstream of this site.

Further considerations for site selection may include efficiency. It will be more efficient to monitor multiple objectives (attributes) at one site within an FMU. However, different monitoring sites may be required depending on FMU complexity, and multiple sites may be needed to assess some objectives. In practice this means that an FMU monitoring plan may contain a 'family' of sites. For example, attributes for biomonitoring can be more sensitive than water chemistry to local scale influences, so multiple sites may be required to be representative of the FMU.

Spatial representativeness is another important consideration. The location of sites should reflect the geophysical complexity of the landscape in the FMU. To gain scalable and representative data on trends in large FMUs, sites should be located to reflect the geophysical variability. Spatial representativeness requires:

(i) data from all waterbody/landscape classes

(ii) the number of sites in each physiographic class and the total area of land in that class to be proportional.

For example, land-use intensity, groundwater residence times, and soils may vary across an FMU – the location of monitoring sites should take these characteristics into account. Multiple sites across an FMU may be required to ensure representativeness.

The state of freshwater attributes varies at different sites in most water bodies, and between them, making selection of 'representative sites' for objectives a challenging task. To assist in selecting representative sites, two aspects must be explored:

- water body type and response
- types of sites.

# 4.1 Water body type and response

A range of factors affect fresh water. Physical, chemical and biological attributes measured in freshwater bodies are affected by many interacting factors and processes, which operate over different areas and time periods.

The sensitivity of waterbodies to attributes varies. For example, standing waters (eg, lakes and wetlands) are known to be relatively sensitive to contamination because they act as sinks for in-flowing water, storing any contaminants for long periods of time. They are likely to respond slowly to changing inputs. In contrast, flowing waters do not usually store contaminants and respond more rapidly to change. So, at any given point in a river, impacts on fresh water are the result of both local and distal influences.

# 4.2 Types of sites

For monitoring plans, three basic long-term site types may have a role:

- seasonal
- annual
- control/reference.

Each of these may be complemented with sites used for special investigations or rotating sites.

## Long-term sites

Long-term sites are those that are generally monitored at regular intervals (eg, monthly or quarterly) or continuously (eg, flow sites) over a decade. They account for lag times, year-to-year variability, and the need to reliably detect trends. Trend analysis can only be conducted reliably on data that are collected at the *same site* for the *same attributes* by the ***same protocols*** over a *suitably long period* of time (Davies-Colley et al, 2012).

Trend analysis will not be meaningful until sampling at a site has been maintained for years. Replacement of an existing site with a closely related site (such as one further downstream) might not preclude trend analysis, but a sufficient period of overlap between data records is required to ensure continuity.

This should not preclude introducing new monitoring sites to ensure representation is achieved. It simply means there will be a time lag before effective trend analysis can be achieved.

## Why not rotate long-term water quality sites?

Monitoring at a series of sites periodically according to a cycle (rotating sites) is an approach that has been used in New Zealand. Although this strategy increases spatial coverage, it reduces the ability to identify trends (inter-annual variability due to climate, gaps in data, and rapid changes in an attribute can confound analysis). The Office of the Auditor-General reviewed freshwater monitoring in four regions and found that in one region data was inadequate to describe trends because the council had used rotating sites (Office of the Auditor-General, 2011).

In the United States, the National Water Quality Assessment programme over the period 1992–2008 found that important trends, such as those for concentrations of many pesticides, occurred within a few years. It was found, however, that these trends were not adequately characterised using data derived from rotating sites (Rowe et al, 2013). For this reason, the United States Geological Survey has discontinued their policy of rotating sites.

It is better to have a complete record of reliable data at a few sites, than many data of questionable value from many sampling sites (World Meteorological Organization, 2013). The accepted advice is to sample any long-term water quality sites monthly (Davies-Colley et al, 2012), rather than attempt to cover more sites by rotating sites. Modelling, underpinned by data derived from special investigations (as required), is an option for extending the spatial coverage of sites.

Rotation of sites is useful for providing supporting data, where trends are not needed (Davies-Colley et al, 2012).

## Seasonal sites

Seasonal sites provide data from very specific, short-term (and sometimes high-frequency or continuous) monitoring. Examples include measurement of dissolved oxygen (DO) concentrations in receiving waters downstream of point source discharges, or water temperature in critical reaches. Thermal stress and oxygen stress are typically only issues during summer low-flow periods, so continuous temperature and DO monitoring would normally be done only over summer. These sites would typically operate during the period November to April each year.

Some councils may also use seasonal sites for health and safety reasons, for example, high country lakes may only be monitored in summer because of the danger of sampling in other seasons. Where this is the case, councils will need to consider that bias when analysing those data.

## Annual sites

Annual sites are those that need only be visited annually or once every few years. This is relevant for biotic attributes such as plant communities in lakes (LakeSPI) because biotic indicators generally integrate over time scales of months or longer.

## Control/reference sites

Control sites assist inference, linking an impact or treatment to an environmental change. They are locations chosen to be as similar as possible to the impact location, except for the presence of the impact process. Unlike laboratory situations, the aim is not to produce constant conditions by tightly regulating environmental variables, but to create a sampling scheme where observed differences can be attributed to the impact process in question, and not to other processes. A common example is BACI (Before-After, Control-Impact) designs (Downes et al, 2002).

Reference condition sites are a type of control site, but are located in areas that are representative of minimally disturbed physical, chemical and biological conditions. Establishment and operation of reference sites provides a baseline for comparing to sites in FMUs where human activity or freshwater management is occurring. These sites will:

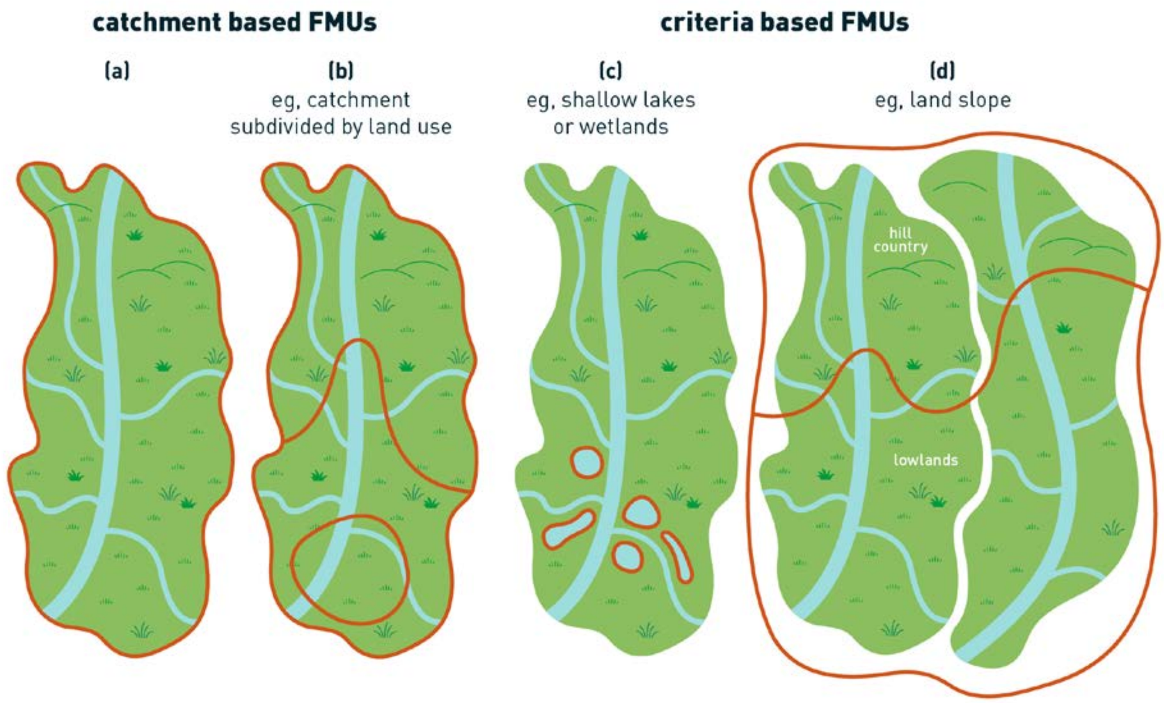
- provide information to assess the relative contribution of global drivers (eg, climate fluctuations) to the attribute state
- provide background concentrations and reference biological conditions against which degradation of waters may be measured
- anchor water quality modelling.

## 4.3 How can FMU definition influence site selection?

The Freshwater NPS requires regional councils to divide their regions into FMUs. Councils will use a variety of approaches to define their FMUs because of variation in physical geography, water quality, community values, and other factors. The River Environment Classification (REC)[3] and Freshwater Ecosystems of New Zealand (FENZ) database may also be of use. Some councils have based FMUs on traditional surface water catchment boundaries, while others have grouped multiple water bodies with similar characteristics (see figure 1 below). For more information about identifying FMUs, see *A guide to identifying freshwater management units*.

**Figure 1 Some approaches to FMU definition**

(a) surface water catchment, (b) surface water catchment divided into multiple FMUs, (c) nested FMU of shallow lakes or wetlands within another FMU, and (d) cross-catchment FMUs (eg, hill country and lowlands)




Some FMUs will have obvious monitoring plans. For example, those defined by surface water catchments may have existing sites with long-term records for a range of attributes that represent the freshwater objectives for the FMU (figure 2a).

[3] https://www.niwa.co.nz/freshwater-and-estuaries/management-tools/river-environment-classification-0.

## 4.4 Identifying representative sites – case studies

**Case study 4.4a Hakataremea River catchment monitoring sites**

The FMU defined by the Hakataremea River catchment has a long-term monthly water quality site (NRWQN site), continuous river-flow monitoring, and a contact recreation monitoring site at the bottom of the catchment.

Upstream there are three long-term quarterly water quality monitoring sites (including flow estimates derived from flow recorders or staff gauges), and one stream health site. Two of the quarterly water quality sites became monthly sites in 2013. A number of quarterly sites (with almost a decade of records) were closed in 2013 after a monitoring plan review, to have monthly monitoring across the network (ie, to get better temporal frequency, some spatial intensity had to be sacrificed) (Kelly et al, 2014).

This catchment has a good history of monitoring and a range of sites with long-term records. This provides a good starting point for identifying representative sites and for developing the monitoring plan.

In other circumstances, however, a single site with a long-term record may be unable to provide information for a significant proportion of the FMU. For example, the long-term site may be on one branch of a major river, or may be upstream of a significant area of the catchment (figure 2b).

**Case study 4.4b Hurunui catchment monitoring sites**

The Hurunui catchment has five long-term monthly water quality sites (including NRWQN sites at Mandamus and at SH1), one long-term quarterly site, and a new monthly site. The most downstream site (SH1) is 16 kilometres upstream of the catchment outlet (Kelly et al, 2014), and so a substantial area of the catchment is not monitored at present. In this case, a special investigation might be needed to establish a relationship between the catchment outlet and the monthly site. After a few years of data collection, a decision could be made whether to retain the site as a long-term monthly site, or to close the site.

New sites have been proposed for special investigations to help in limit setting. These include investigations in the Waitohi catchment looking at groundwater quantity, and where flows are going to and coming from in the lower reaches. There is also a Hurunui-Waiau zone-wide groundwater quality sampling programme designed to help understand the current groundwater quality.

**Case study 4.4c Representative sites for shallow lakes in the Hawke's Bay**

Monitoring shallow lakes is challenging because regime shifts between macrophyte-dominated clear water states and de-vegetated, turbid states can occur rapidly, triggered by storms, inflows of dirty water, nutrient enrichment, and invasive pests – especially fish (Schallenberg and Sorrell, 2009). For example, the 1968 Wahine storm caused a collapse of the macrophytes and triggered a regime shift in Te Waihora (Hughes et al, 1974).

There are four sizable shallow lakes in the Hawke's Bay region – Hatuma, Poukawa, Rūnanga and Oingo. All are located on private land not regularly accessed by the public. Lake Poukawa, south-west of Hastings, is very shallow (< 1 metre), culturally significant to iwi, and has been declared a non-commercial fishery. The lake area varies with fluctuating water levels; the main inflows are drains and the controlled lake outflow enters Poukawa Stream. Lake Hatuma, near Waipukurau, has a large wetland that provides valuable wildlife habitat. Lake Rūnanga (0.9 metre deep) and Lake Oingo are north-west of Hastings, and are eutrophic. Lake Oingo has maximum depth of 1.2 metres, and extensive wetlands. Until recently the lake was dominated by the invasive weed Hornwort (Ceratophyllum demersum). During the summer of 2014/15, however, the hornwort did not recover from its winter dieback and the lake has since been experiencing cyanobacterial blooms.

Monitoring of Lakes Rūnanga and Oingo started recently, and one year of monthly data exists. Currently the council proposes to monitor these lakes monthly for one year every five years. Oingo and Rūnanga have long residence times (712 days and 1926 days, respectively) as a result of low water inputs from their catchments, making them sensitive to nutrient inputs. Algal blooms have occurred previously, and reoccurrence continues to be a risk. Monitoring of the significant wetlands that fringe the margins of all these lakes has to date been qualitative (photo points) (Lamason, 2006). Limited data are available for Lake Hatuma and Lake Poukawa.

Several options exist for identifying representative sites – these depend on freshwater objectives and FMU definition. For purely illustrative purposes, we identify three hypothetical options (figures 2a-c). In all three options, at least one monthly monitoring site is required in each FMU, although the council could choose to have more than one site.

**Figure 2(a) Establishing potential monitoring sites for shallow lakes with the same objectives within a single FMU**

If all four lakes were part of one criteria-based FMU (shallow lakes), then at least one monthly water quality monitoring site would be required. Given that data for Oingo and Rūnanga have already been collected for one year, one of these lakes is the logical choice for establishing a monthly site where several attributes are monitored. Annual monitoring (Lake SPI) would be undertaken on the remaining lakes.

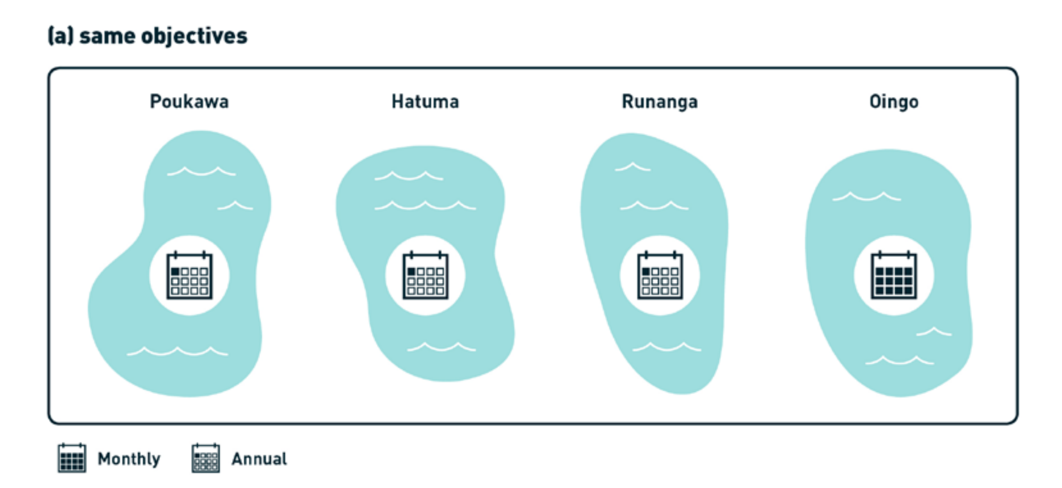



**Figure 2(b) Establishing potential monitoring sites for shallow lakes with different objectives – two FMUs**

Were the objectives for Lakes Oingo and Runanga to differ from those for Lakes Hatuma and Poukawa, then two FMU units could be established (eg, $FMU_{closed}$ and $FMU_{flushed}$), and a monthly monitoring site might be required for both FMUs (ie, an additional monthly site would be required.

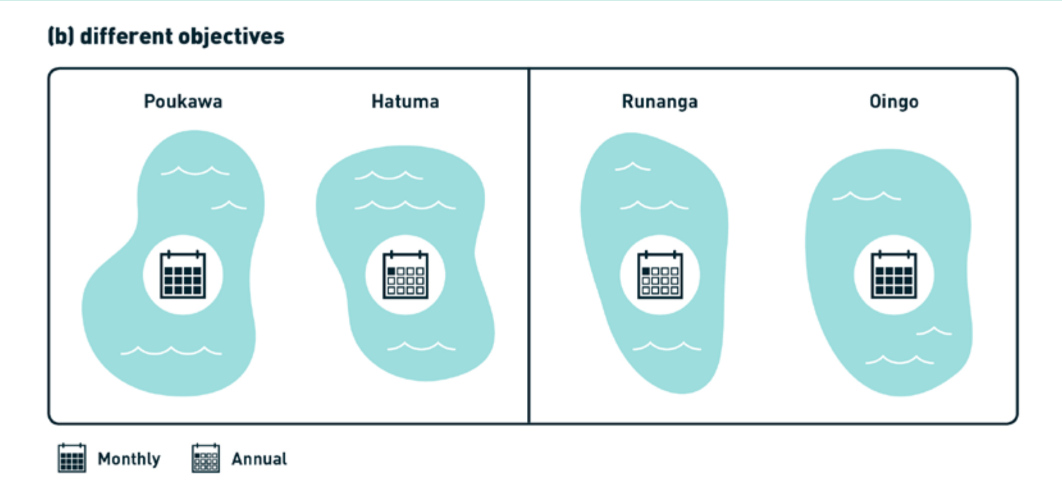
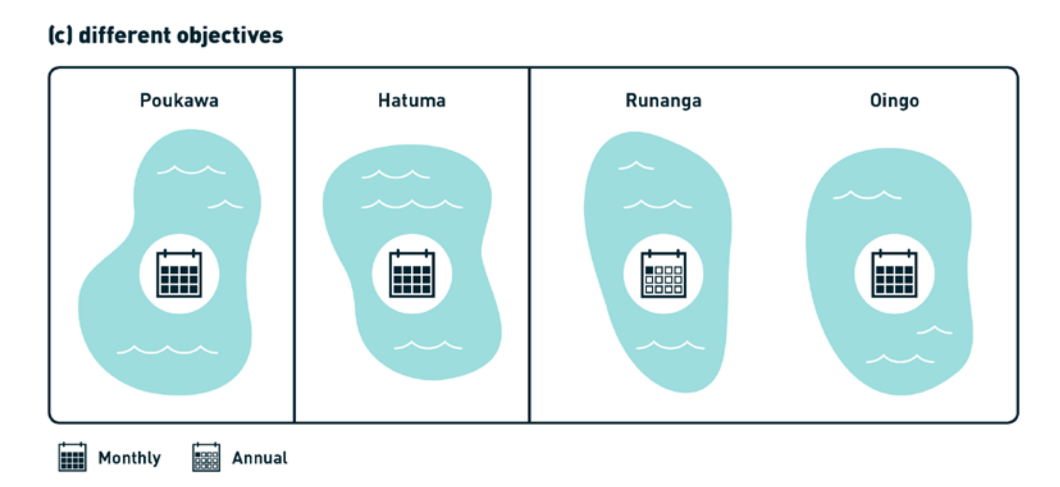


**Figure 2(c) Establishing potential monitoring sites for shallow lakes with different objectives – multiple FMUs**

If three or four FMUs were required due to differing objectives for the lakes, then three or four monthly sites would be required to monitor and report progress toward FMU objectives.




It is worth noting that annual lake condition surveys (eg, LakeSPI, which uses submerged aquatic plants as an indicator of lake condition) can be used to document a regime shift – but only after the event. However, annual monitoring may be insufficiently sensitive to predict change. Infrequent monitoring of lakes is inadequate to reliably detect short-term transient events, should detection and quantification of these be required to meet management objectives. Special investigations may be more valuable than annual monitoring to explore stressors and risks – these might include remote sensing of lake macrophyte beds and related water quality. Remote sensing provides maps of lake condition and can detect macrophyte beds in both clear and turbid water states or algal blooms in turbid water.

**Case study 4.4d Representative sites in the Upper Waitaki**

This case study is an example of how data and information may be used from existing sites.

The Upper Waitaki landscape varies from undeveloped hill country and alpine environments to intensive land use. Waterways include numerous lakes, streams, rivers and aquifers. The Upper Waitaki has a Water Management Zone Committee (WMZC) who have agreed to manage the Upper Waitaki freshwater resource as a single FMU. They have also decided that all of the national values, not just the two compulsory values (ecosystem health and human health for recreation), are appropriate for the FMU.

The Upper Waitaki WMZC is currently scoping how an integrated water monitoring framework might incorporate Environment Canterbury (ECan), consent holder, and voluntary monitoring data. A stocktake of active monitoring sites is under way, and the WMZC has started looking for ways to share data. "The purpose would be to share all the water monitoring data in a central place, so everyone can see how effective our collective work is" (Shepherd, 2015).

The large Upper Waitaki FMU contains many monitoring sites with varying record lengths, sampling designs and operating histories. Water quality monitoring by ECan in the Upper Waitaki was started in the early 2000s; relatively recently compared to the remainder of the ECan water quality network. ECan has been working to rectify the lack of data since 2002, with summer water quality surveys in 2003 and 2004 at recreational bathing sites. By 2005, 11 sites were monitored quarterly, but there was bias in the site selection towards accessible sites. In 2010, some of these sites were closed and additional sites were established in an effort to include bottom-of-catchment sites and to provide a longitudinal series of sites along some rivers.

In addition to the surface water quality sites, there are seven surface water quantity sites (recorders), plus a number of regularly gauged locations, recreational bathing sites (lake edge and rivers), aquatic ecosystem health sites, annual summer lake water quality surveys done by helicopter, and annual summer groundwater quality surveys (22 wells, with monitoring beginning mostly after 2012). Downstream of the FMU there is also a long-term monthly (NRWQN) water quality site operated by NIWA (Waitaki at Kurow), which has operated since 1989.

There are a number of consents with conditions requiring monitoring of water quality and quantity monitoring and reporting of results to ECan. Thirty-one properties in the Upper Waitaki have consent monitoring conditions relating to rivers, and 16 of these are active. Water quality data from consents are often collected seasonally, for example, during the irrigation season. Currently data from these consents are submitted in different formats and reviewed by ECan's compliance team. Most of these data have not been transferred to ECan's water quality database, but initiatives are under way to automate this.

A number of irrigation collectives, catchment groups and individuals undertake monitoring for their own purposes. An example of this is the Benmore Irrigation Company, who undertake monthly water quality monitoring at a number of sites. Reference sites were identified from the existing state of environment surface water quality sites in a recent study (Gray, 2014). These include two small spring-fed streams and two alpine upland stream sites.

# 5 Recognising the importance of long-term trends

**Policy CB1**

By every regional council developing a monitoring plan that:

c) recognises the importance of long-term trends in monitoring results and the relationship between results and the overall state of freshwater in the freshwater management unit.

## 5.1 Long-term trends are important for assessing progress

Temporal trends are any non-zero slope between the start and end of a trend assessment period. Trends therefore always exist, even if very small.

Statistical trend assessment should be used to evaluate and demonstrate progress towards or away from freshwater objectives and values. Progress must be evaluated using statistical tests, rather than simply comparing whether individual samples are higher or lower than the next, because variation arising from isolated events can lead to incorrect or misleading conclusions.

Two commonly used procedures are the 'Two One-Sided Test' (TOST) detailed in Appendix A of Larned et al (2015), and the Seasonal Mann-Kendall test, which identifies the strength of evidence for a monotonic trend over time.

There are various other approaches that could be applied to water quality time series data, and new methods in software packages make it much easier to account for the often non-normal distributions that water quality data usually follow.

There are multiple resources available for undertaking trend analysis (see the references chapter for a selection). However, if unsure, it is recommended council staff seek appropriate statistical advice in designing their monitoring programmes and in evaluating their data.

## 5.2 Over what period should trend assessments be made?

There is no one-size-fits-all for this question. The best course of action would seem to be to sample monthly and to schedule trend assessments after 5, 10, and 25 years. Experience shows that after five years of monthly sampling, environmentally important trends of key water quality attributes (eg, total nitrogen and visual clarity) can start to become apparent. Assessments at 10-year intervals may align with the review period for the regional plan. Note that over a sufficiently long record (ie, 25 years), trends may be humped. For example, upward for the first five years followed by downward for the next five years. In such cases, performing only a 10-year assessment would likely miss the humped pattern. For this reason, adopting multiple trend assessment periods (eg, the suggested 5, 10 and 25 years) is a safeguard against reaching misleading conclusions.

It is helpful in practice to split trend assessment into two parts, as in section 5.3 which discusses how to infer the trend direction with good confidence, and then section 5.4 where the environmental importance of the trend is discussed.

## 5.3 Sampling frequency is important

It is important to consider the sampling frequency for monitoring sites. Trend tests for data sampled bi-monthly or quarterly fail to detect a trend that a monthly sampling regime could detect. On the other hand, sampling intervals greater than monthly will often compromise trend assessments. When examining sampling frequency sufficiency, it is possible to use a form of statistical power analysis[4] to examine the likelihood of obtaining confident results. Serial correlation testing (also called autocorrelation) is a statistical tool that can be used to determine the appropriate sampling frequency for a water quality variable.

These tools are useful because there could be instances when it would be inefficient to (for example) increase sampling frequency when there is little to detect and those resources could be better used elsewhere.

## 5.4 Are the trends environmentally important?

When developing their approach to trend assessment, councils could consider the following:

- Aim for a consensus on what rate of change would be considered environmentally important. For example, describe a meaningful rate as at least 1 per cent of the trend assessment median value per annum. There is no scientific consensus on what such as percentage should be.
- Define thresholds as targets towards freshwater objectives, so the trends show whether the objective is likely to be achieved in the timeframe accepted by the community. However, statistical sampling error can easily compromise this approach. That is, successive assessments of water quality states can change (eg, from B to C) even when the underlying populations have not changed. Water quality modelling may help determine whether the targets will be met within the time frames requested by the local community
- It is important to be aware of the limitations of the trend forecasting methods used (ie utilising differing statistical tools depending on whether changes in the catchment are anticipated or not. Water Quality modelling will be appropriate if changes are expected to occur in the catchment from further intensification or as a result of mitigations undertaken. Time series forecasting methods are also available but they are appropriate where change is not expected in the catchment.

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[4] Appendix A (Sample Size Calculation Formulae) (part A.2.2) (Ward et al, 1990).

- Define a critical time period for threshold crossing. Community buy-in to critical times for various water quality attributes is needed, and this may take some work. Critical times might differ between attributes (eg, DRP versus *E. coli*). Again, statistical sampling error may confound this approach.
- In streams and rivers, many water quality attributes are to some degree dependent on river flow. Flow at the time of sampling is needed to properly analyse and interpret water quality and biological monitoring data, but a continuous record of flow is important for load estimation and data interpretation, including calculation of flow indices.

## 5.5 Considerations when modifying a monitoring network

Modifications to a monitoring network or programme need to be considered with care. This includes changing a laboratory method or switching laboratories. This can induce a step change in reported results if the new laboratory method is biased relative to the old. If a change must occur, ideally there should be a period in which samples from a site are split and submitted to both laboratory procedures, as has been done for the Wellington region (Davies-Colley, 2015). This enables the concordance between the two methods to be characterised and accounted for during trend assessment calculations.

Consolidation of a network (ie, reduction in numbers of monitoring sites) will result in orphaned data, so the rationale for closing sites, and the loss of future information from that site (and other sites), needs careful consideration. For data to be useful for identifying long-term trends, they should come from a stable monitoring network. If sites are not consistently monitored over a long enough time period, it will not be possible to collect sufficient data to detect trends to adequately evaluate progress against freshwater objectives.

# 6 Responding to a declining trend

**Policy CB2**

By every regional council establishing methods, for example, action plans, for responding to monitoring that indicates freshwater objectives will not be met and/or values will not be provided for in a freshwater management unit and the achievement of, freshwater objectives established under Policies CA1–CA4.

This policy signals that if monitoring shows freshwater values or objectives are not being met (assessed using long-term trends as required by Policy CB1(c)) a response from the council is required. The response may range from, increasing the monitoring frequency and intensity, specific investigations or instigating catchment mitigations. Undertaking water quality modelling would help strengthen the case that an improvement from interventions will result. Modelling can also illustrate the rate of change expected. Whether or not this is met will determine what the next steps will be.

The actions that will be taken should be detailed in the monitoring plan so the plan becomes a strategic tool which outlines what will occur given differing outcomes.

If a declining trend continues it will require a review of the effectiveness of the limits which have been set to achieve the values and freshwater objectives followed by a possible plan change (see section 5 on long-term trends).

# Appendix: Reference list of monitoring guidelines

**Existing guidance/guidelines applicable to National Policy Statement on Freshwater Management**

| Document | Link |
|---|---|
| Freshwater Monitoring Protocols and Quality Assurance NEMAR Variables Step 2 | www.mfe.govt.nz/sites/default/files/media/Fresh%20water/freshwater-monitoring-protocols-qa-nemar-variables-step-two_0.pdf |
| Stream Health Monitoring and Assessment Kit | www.niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit |
| Protocol for Monitoring Trophic Levels of New Zealand Lakes and Reservoirs | www.mfe.govt.nz/publications/fresh-water-environmental-reporting/protocol-monitoring-trophic-levels-new-zealand |
| Stream Periphyton Monitoring Manual | www.niwa.co.nz/freshwater/management-tools/ecological-monitoring/stream-periphyton-monitoring-manual |
| New Zealand Periphyton Guidelines: Detecting, Monitoring and Managing Enrichment of Streams | www.mfe.govt.nz/publications/freshwater-publications/new-zealand-periphyton-guideline-detecting-monitoring-and |
| Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas | www.mfe.govt.nz/publications/fresh-water/microbiological-water-quality-guidelines-marine-and-freshwater-recreation-7 |
| A National Protocol for State of the Environment Groundwater Sampling in New Zealand | www.mfe.govt.nz/publications/freshwater-publications/national-protocol-state-environment-groundwater-sampling-new |
| New Zealand Municipal Wastewater Monitoring Guidelines | www.waternz.org.nz/Folder?Action=View%20File&Folder_id=101&File=wastewater_monitoring_guidelines.pdf |
| Monitoring Species and Habitats in Terrestrial, Freshwater and Marine Environments | www.doc.govt.nz/getting-involved/run-a-project/our-procedures-and-sops/biodiversity-inventory-and-monitoring/freshwater-ecology/ |
| New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters: Interim guidelines | www.mfe.govt.nz/publications/fresh-water-environmental-reporting/guidelines-cyanobacteria |
| National Objectives Framework for Freshwater: An assessment of banding statistics for planktonic cyanobacteria | www.mfe.govt.nz/publications/fresh-water/national-objectives-framework-freshwater-assessment-banding-statistics |
| National Environmental Monitoring Standard – Dissolved Oxygen Recording | www.lawa.org.nz/media/16576/nems-dissolved-oxygen-recording-2013-06-1-.pdf |
| ANZECC 2000 Guidelines (Australian and New Zealand Guidelines for Fresh and Marine Water Quality) | www.mfe.govt.nz/fresh-water/tools-and-guidelines/anzecc-2000-guidelines |
| National Objectives Framework – Comments on the Need for Inclusion of Nutrient Levels for Lakes | www.mfe.govt.nz/publications/fresh-water/national-objectives-framework-comments-need-inclusion-nutrient-levels-lakes |

| Document | Link |
|---|---|
| Derivation of Indicative Ammoniacal Nitrogen Guidelines for the National Objectives Framework | www.mfe.govt.nz/publications/fresh-water/derivation-indicative-ammoniacal-nitrogen-guidelines-national-objectives |
| National Objectives Framework for Freshwater: Statistical considerations for Assessing Progress Towards Objectives with Emphasis on Secondary Contact Recreation Values | www.mfe.govt.nz/publications/fresh-water/national-objectives-framework-freshwater-statistical-considerations |
| National Objectives Framework: Statistical considerations for design and assessment | www.mfe.govt.nz/publications/fresh-water/national-objectives-framework-statistical-considerations-design-and |
| National Objectives Framework – Temperature, Dissolved Oxygen and pH | www.mfe.govt.nz/publications/fresh-water/national-objectives-framework-temperature-dissolved-oxygen-ph |
| Using Regional Council Periphyton Data (Chlorophyll a) to Predict Compliance with the NOF Bottom Lines | www.mfe.govt.nz/publications/fresh-water/using-regional-council-periphyton-data-chlorophyll-predict-compliance-nof |
| *AS/NZS 5667: Water quality – Sampling series* | www.standards.govt.nz |

## Other guidelines

| Document | Link |
|---|---|
| Cultural Health Index – Using the Cultural Health Index: How to Assess the Health of Streams and Waterways | http://www.mfe.govt.nz/publications/cultural-health-index-streams-and-waterways-feb06 |
| Cultural Health Index – A Cultural Health Index for Streams and Waterways: A Tool for Nationwide Use | http://www.mfe.govt.nz/publications/cultural-health-index-streams-and-waterways-tech-report-apr06 |
| Macroinvertebrate Community Index – A User Guide for the Macroinvertebrate Community Index | www.mfe.govt.nz/publications/freshwater-publications/user-guide-macroinvertebrate-community-index |
| Macroinvertebrate Community Index – Protocols for Sampling Macroinvertebrates in Wadeable Streams | www.mfe.govt.nz/publications/fresh-water-environmental-reporting/protocols-sampling-macroinvertebrates-wadeable |
| Draft guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels | www.mfe.govt.nz/publications/fresh-water/draft-guidelines-selection-methods-determine-ecological-flows-and-water-24 |
| Guidelines for the Measurement and Reporting of Water Takes | http://irrigationaccreditation.co.nz/watermeasurement/wp-content/uploads/2014/09/Guidelines-for-the-Measurement-and-Reporting-of-Water-Takes-2014.pdf |
| New Zealand Freshwater Fish Sampling Protocols | https://www.niwa.co.nz/static/web/New_Zealand_Freshwater_Fish_Sampling_Protocols.pdf |
| Kaimoana Survey Guidelines for Hapū and Iwi | www.mfe.govt.nz/publications/environmental-reporting/kaimoana-survey-guidelines-hapu-and-iwi |
| Recommendations for New Sites to Improve Representativeness in the New Zealand River Environmental Monitoring Network | www.mfe.govt.nz/publications/fresh-water-environmental-reporting/recommendations-new-sites-improve |

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