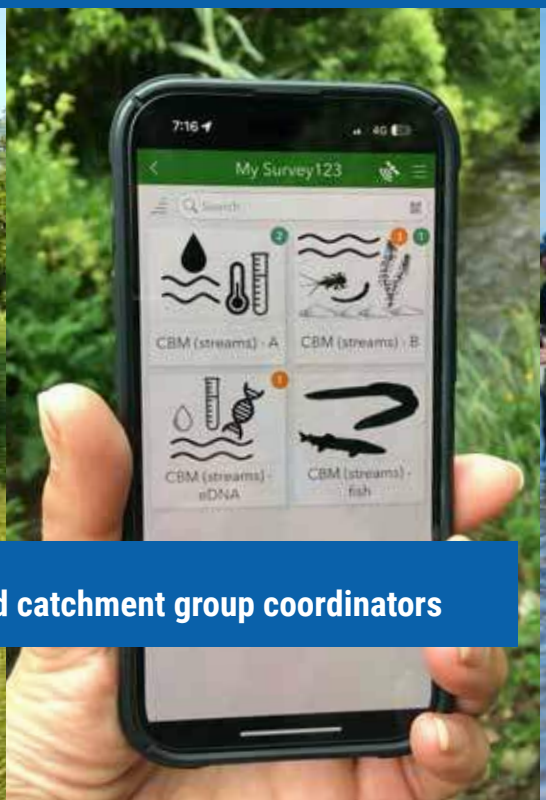
NIWA
Taihoro Nukurangi

MAKE YOUR STREAM MONITORING DATA COUNT!

A national quality assurance framework for community-based monitoring in Aotearoa New Zealand



Part 1: Guidance for community and catchment group coordinators

Prepared for Envirolink

Make your stream monitoring data count!

A national quality assurance framework for community-based monitoring in Aotearoa New Zealand

Part 1: Guidance for community and catchment group coordinators

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The national CBM quality assurance framework is supported by:

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Foreword

It has never been more critical to have communities and landowners engaged in monitoring our freshwater streams, rivers and lakes. Time and again, evaluations of our existing water quality monitoring data reveal a critical need for better coverage and more frequent data collection, if we are to understand how land and water use affects water quality. We need to really understand cause-and-effect relationships to improve the quality of water in those areas where it is currently poor and to maintain good quality in areas of low impact.

Community-based monitoring (CBM) can extend the coverage of data on our nation's waterways, as well as support water quality improvement in local rural and urban catchments. The professional monitoring programmes run by regional councils and research agencies can never capture data on individual catchments at the scale CBM can. However, professional water quality monitoring agencies and individuals can offer a wealth of advice to support community and catchment groups to collect good data: data that are relevant and collected in the same way as existing data, so that trends across time and space can be established. Consistency in methods and in the choice of components to measure, and the sound design of monitoring plans, are vital to ensure the data are valuable.

This guidance document and the overarching national quality assurance framework for CBM in Aotearoa New Zealand, are designed to provide all of the information that a community or catchment group needs to make sure their data will be of value to them, and to national efforts to improve water quality.

New Zealand's natural environments, in particular freshwater quality, continue to come under pressure from development and climate change. This has triggered a response from many community groups, creating a call to action. These groups are many and varied, including local iwi, catchment collectives, urban community initiatives, environmental groups, and industry representatives. All these groups have a common vision of ensuring good quality fresh water for future generations. Taking ownership infers a responsibility to the individual or group to take action to achieve this. The vision provides a pathway to targeted outcomes which are often informed by science-based measures, or indicators, of success. The national quality assurance framework for CBM includes many such indicators to choose from to help monitor progress.

A wealth of information is being collected by groups across the country. To give this information power we need consistency in data collection and to ensure the data are of known quality and fit for purpose. The national framework and electronic templates outlined in this guidance document address this, providing the potential to collate each individual's or group's data into a national story of returning our awa to good health.

This national framework will strengthen the credibility of CBM in New Zealand and recognises the significant time and efforts CBM groups are investing to improve the understanding and health of our waterways locally and nationally.

Dr Jenny Webster Brown
Director Our Land and Water National Science Challenge

Lloyd McCall
Pomahaka Catchment Group

What is community-based monitoring?

Community-based monitoring (CBM) is a form of citizen science where members of the public, as individuals or organised groups (e.g., catchment groups), collect scientific data, rather than 'professionals'. Alternative terms to CBM include 'volunteer monitoring', 'locally based monitoring' or 'participatory monitoring'. There are many types of CBM.

Acknowledgments

Many people and organisations from a variety of science, catchment management and environmental data backgrounds have contributed in some way to the development of this national guidance.

Our thanks must first go to the many community and catchment monitoring groups across Aotearoa New Zealand participating in freshwater monitoring and management. The extent of this grassroots activity is what led a group of regional council staff, initially championed by Sheryl Miller and Mark Heath at Greater Wellington Regional Council (GWRC), to identify a need to build on the existing resources available to support community-based monitoring (CBM) of fresh waters.

Amanda Valois (GWRC, formerly NIWA), Sandy Haidekker (Hawke's Bay Regional Council), Shirley Hayward (Environment Canterbury), Joanna Wilson (Nelson City Council), Ange Perks (Bay of Plenty Regional Council), Sam McLachlan (Environment Southland), Maddison Jones (Auckland Council), Kim Jones (Mountains to Sea Conservation Trust), Alice Bradley (Ministry for the Environment), Justin Kitto (DairyNZ) and Elaine Wright (Department of Conservation) formed the core of the working group established to support this project. Their input was instrumental for scoping and testing ideas during the development of the QA framework and guidance.

Within NIWA:

- Jane Robbins developed the ArcGIS Survey123 field form templates, building on initial groundwork by Daniel Morrish and advice from Tilman Steinmetz,
- Mike Bargh assisted with aspects of the Monitoring and Quality Plan template,
- Cathy Kilroy, Rob Davies-Colley, Fleur Matheson, Elizabeth Graham, Rebecca Stott, Andrew Harper, Evan Baddock and Jenni Gadd reviewed draft material for specific freshwater indicators, and Cathy also reviewed the first draft of this guidance,
- Fenella Falconer provided details of SHMAK test kits and resources,
- Stephen FitzHerbert, Erica Williams and Paula Blackett contributed insights on working with community and iwi groups, and
- Sally Shand, with support from the Mark Tucker, established the design layout of this guidance document.

Funding

Development of this guidance was funded by MBIE Envirolink Tool grant C01X2102. This grant was championed by GWRC on behalf of NZ regional and unitary councils' Surface Water Integrated Management Special Interest Group (SWIM SIG), with support from the Environmental Data SIG and Biodiversity Working Group.

We also gratefully acknowledge the following additional co-funding:

- NIWA's Environmental Information Centre (SSIF project EIEM2304) – for pilot investigations into electronic collection and transfer of third-party monitoring data,
- GWRC – for the development of a concept Survey123 water sampling field form template for Wairarapa catchment groups,
- Our Land and Water National Science Challenge – for an initial multi-organisational workshop on CBM data stewardship in NZ, review of the final draft guidance, and outreach support,
- Natural Biological Heritage National Science Challenge – for contributing to the initial scoping phase for developing the framework,
- Hill Labs – for water sample nutrient testing as part of a paired comparison of lab analysis with nutrient self-test kits,
- Ministry for the Environment – for supporting extension and outreach activities, including testing implementation of draft material via the Wai Connection programme.

Catchment coordinator attendees at the Mountains to Sea Conservation Trust's Wai Connection freshwater training wananga in Porirua, September 2023.

Outside of the working group and NIWA we gratefully acknowledge review contributions to the framework from Liz Gibson (Mountains to Sea Wellington), Shelley McMurtrie (EOS Ecology) and Nathan McKinley (EOS Ecology). Ideas, feedback or other support were also provided by Alastair Cole (MPI, formerly NZ Landcare Trust), Tania Bramley (NZ Landcare Trust), Sheryl Miller (Mountains to Sea Wellington), Ara Heron (Hill Labs), Jane Sherrard (Hill Labs), Susan Welsh (Wilderlab), Amy Gault (Wilderlab), Mike Ede (formerly Marlborough District Council), Bianca Lilley (Auckland Council), Hazel Meadows (Auckland Council), Helen Shaw (formerly Environment Canterbury), Jeff Cooke (Hawke's Bay Regional Council), Melt Velde (GWRC), Tash Styles (GWRC), Emma Chibnall (Marlborough District Council), Kevin Collins (Collins Consulting), Michele Lloyd (formerly of StatsNZ), Jenny Webster-Brown (Our Land and Water National Science Challenge) and Richard McDowell (Our Land and Water National Science Challenge).

Kati Doehring (Cawthron Institute) completed an independent review of the guidance and Annalise Chan completed the final stages of the design.

Feedback from various community groups and catchment coordinators helped us to develop and refine the draft monitoring plan and electronic survey form templates. Special thanks to Philippa Eberlein (Friends of the Maitai), Martin Evans (Friends of Awa Matakanakana) and the many catchment coordinators that attended the MTSCT's Wai Connection freshwater training wananga in September 2023. We also thank the National Advisory Group for Freshwater Citizen Science that provided a forum to discuss and promote the framework.

We are grateful for the contribution of images from many sources: NIWA, GWRC, Hill Labs, Wilderlab, EOS Ecology, Mountains to Sea Conservation Trust, Mountains to Sea Wellington, Friends of the Maitai, Allan Sheppard, Terry Parminter, Cawthron, and the U.S. Wildlife Service.

Finally we would like to acknowledge:

- the CBM quality assurance resources developed by the international community, in particular the US Environmental Protection Agency and WaterWatch Australia, and guidance and tools developed by citizen science researchers and practitioners involved in the Chesapeake Monitoring Cooperative – these resources provided inspiration and a starting point for developing a framework for NZ community-based stream monitoring
- the many members of the wider NZ freshwater science community across NIWA, the Cawthron Institute, universities and councils that have developed the various national freshwater monitoring guidance and standards on which this framework has drawn.

SECTION 1

Introduction

Rural and urban community-based monitoring (CBM) of fresh waters is growing in Aotearoa New Zealand (NZ).

This growth in monitoring has been boosted by concern for the health of our streams, rivers and lakes as well as a need for more data to support catchment-based freshwater management under the National Policy Statement for Freshwater Management. Recent advances in technology, including low-cost water quality sensors, environmental DNA (eDNA) and data collection tools, have also opened up exciting new opportunities for communities to monitor fresh waters.

This guidance document sets out a national quality assurance (QA) framework for community-based freshwater monitoring initiatives, with a focus on monitoring stream health. It has been prepared at the request of New Zealand's regional and unitary councils to support CBM groups to collect stream data that are of a known quality and fit for purpose. In many cases, this purpose aligns with informing one or more aspects of catchment-based freshwater management, such as characterising the existing condition of a stream, identifying contaminant 'hotspots', or tracking improvements in stream health following catchment or riparian restoration work.

National Policy Statement for Freshwater Management (NPS-FM)

The NPS-FM is a government policy under the Resource Management Act 1991. It directs how rivers and other freshwater bodies in NZ are to be managed by regional councils.

What is QA and why is it important?

Quality assurance in environmental monitoring is all about making sure that plans and procedures are in place to ensure that the data collected are accurate, reliable and fit for the intended purpose or end use. This is why QA is important in all environmental monitoring, whether it is carried out by specialists or by community groups.

Why does community-based monitoring need a national QA framework?

Stream monitoring data are being collected by many different catchment and community groups across NZ but the data are collected to different standards and stored in various formats and locations. Where CBM data are publicly available, the collection methods and standards are often unknown or not readily available with the data. This makes it difficult to consider using CBM data alongside the data collected by regional councils and other organisations with statutory responsibilities for environmental monitoring, management and reporting.

Over the last decade National Environmental Monitoring Standards (NEMS) have been developed to support these organisations in collecting data using consistent methods and to known quality standards. A similar national framework for CBM groups will help increase the visibility and application of CBM data in freshwater management.

The QA framework aims to provide CBM groups with confidence that the stream data they collect will:

- meet their needs
- be recognised by regional councils and other organisations as being credible and fit for purpose, and
- support potential re-use by third parties.

The framework focuses on monitoring of stream health and is built around 28 indicator variables (indicators). These indicators describe physical, chemical and microbiological water quality (e.g., visual clarity, nutrients), aquatic life (e.g., macroinvertebrates, fish), physical habitat (e.g., shade) and water quantity (e.g., velocity, rainfall). Some of these indicators are also relevant to monitoring of lakes and coastal waters.

All CBM data can be useful for one or more purposes provided that key information about monitoring site locations, data collection methods and quality checks are available with the data.

What does the framework provide?

The national CBM QA framework includes:

- A **Monitoring and Quality Plan** template to help establish a clear monitoring purpose, what will be monitored, and where, how and when the monitoring will be carried out.
- This **guidance document** outlining the framework and providing
  - information to support completion of a Monitoring & Quality Plan, and
  - for each monitoring indicator, the measurement methods and supporting observations and measurements, as well as training and quality checks.
- **Electronic field form templates** for use on your mobile phone, tablet or computer to support efficient, standardised capture of field measurements and observations, supported by built-in, automated quality checks and calculations.
- A **background document** (Milne et al. 2023) that sets out how the framework was developed and the selection of indicators and measurement methods.

Both this guidance document and the background document, together with information on the monitoring plan and field form templates can be accessed on-line at:
www.waiconnection.nz/pages/programme

What isn't included in the framework?

The national CBM QA framework does not provide for storage or exchange of CBM stream data. However, the framework's monitoring templates ensure that CBM data are collected and recorded consistently. This will help make it easier to share and re-use CBM data in the future.

While the framework helps CBM groups and third-party users of the collected data to identify the quality of each measurement or data point, it does not provide guidance on how to interpret the data (e.g., in terms of stream health).

Who should use the framework?

This guidance document has been prepared for CBM coordinators and others in organisations that support CBM groups.

While any CBM group will benefit from following the framework, it is mainly intended to assist those groups involved with:

- repeated data collection over time, as opposed to one-off data collection, and
- collection of data that are suitable for informing potential use or re-use by third parties (e.g., for catchment, regional or national freshwater reporting).

What is in this document?

Section 2	provides an **overview of the QA framework** and how to use it. It includes an illustration of how and where QA fits in the monitoring process and outlines how the framework was developed.
Section 3	outlines the **core components of a monitoring plan**, starting with the purpose (the WHY) for monitoring, along with QA considerations. Together these are combined into a Monitoring and Quality Plan that underpins fit for purpose community-based monitoring. The core components of the plan are outlined and will help your CBM group to complete the separate electronic Monitoring and Quality Plan.
Section 4	overviews each of the **stream health indicators**, grouped by indicator type (water quality, aquatic life, physical habitat and water quantity), including the measurement methods and equipment, what types of monitoring purpose each method is best suited to, and an indication of the time, cost and effort involved. Together with Section 3, the details in this section will help your CBM group to complete the WHAT and HOW components of your Monitoring and Quality Plan.
Section 5	sets out the **training and quality checks** required for each of the indicator measurements and includes useful resources as well as tips for getting the best possible data from your chosen method. Together with Section 3, this section will help your CBM group to complete the training and quality checks component of your Monitoring and Quality Plan.
Section 6	presents an overview of the **ArcGIS Survey123 electronic field forms** developed for recording observations and measurements of the different stream health indicators. This section also illustrates how to download and use the forms, and outlines some of the built-in quality checks.
Section 7	provides links to the various **guidelines and training resources** referenced in Sections 4 and 5 as well as other useful resources.

How to use this document

We recommend familiarising yourself with the framework in Section 2 before moving on to Section 3 and preparing a Monitoring and Quality Plan. Once you have a clear idea of your main reasons for monitoring, you will be able to dip in and out of the relevant parts of Section 4 and Section 5 to fully complete your Monitoring and Quality Plan. Section 6 will be useful when you're ready to hit the ground to start monitoring and have identified an organisation to host the electronic field forms.

What if my group is already monitoring?

Your group can use this document to review whether your existing monitoring is fit for purpose or needs revising. Prepare a Monitoring and Quality Plan if you don't have one, or check and update the existing plan using the guidance in this document.

Terms and symbols

A glossary is provided at the back of this document setting out definitions for various terms used in the text. The following symbols and coloured information boxes are used throughout this document.

Useful explanation

Key point to note

Further reading or resources

Links to other resources

Throughout this document we identify a wide range of relevant guidelines, videos and other on-line resources relevant to stream health monitoring. Because on-line links to these resources will change over time as the resources or websites are revised, most of the links are presented only once in Section 7.

Look out for the term 'specialist'

One term used regularly in this guidance is specialist. By this we mean a suitably qualified or experienced expert in the subject or topic matter of interest.

Stream health spans many areas of science, monitoring and catchment management (e.g., ecology, water quality, hydrology, land use, equipment selection and maintenance, data management) so advice from more than one type of specialist may be required.

SECTION 2

Overview: What's in the national QA framework and how to use it

The national CBM QA framework is all about making your data count! Good documentation of monitoring procedures and associated QA requirements is particularly important for CBM groups because concerns about the quality of CBM data are often cited as a reason why scientists and decision makers will not use the data.

In this section we introduce the common components of QA in environmental monitoring and describe those components that are included in the national CBM QA framework. We also outline how the framework was developed and should be used. More details are provided in the companion background report (Milne et. al 2023).

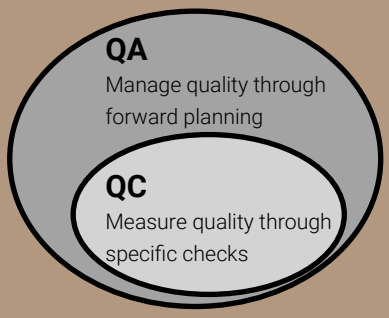
QA in environmental monitoring

Quality assurance, or QA for short, is essentially the planning and procedures put in place *before* monitoring starts to manage quality throughout all stages of the monitoring process. So as well as a monitoring plan, there needs to be a QA plan so that this monitoring is carried out in a way that will ensure the data collected are accurate, reliable and fit for the intended purpose.

Important components of QA include training, standard operating procedures (SOPs, which set out step-by-step instructions for carrying out the monitoring or data collection), and quality control (QC) measures that can confirm if the data collected are fit-for-purpose (Figure 2-1). These components are typically customised and documented separately for each individual monitoring programme based on the programme's purpose, scope and available resources.

The most critical part of ensuring credible data is preparing a monitoring plan that establishes a clear reason(s) for monitoring. In this national CBM QA framework, we combine the monitoring plan and QA plan into one so that quality is always front of mind when developing, carrying out or revising your stream monitoring activities.

Quality Assurance (QA) ≠ Quality Control (QC)



QA and QC are not the same but they are closely linked in quality management.

Despite their names:

- QA does not assure quality, rather it creates and ensures processes to manage quality. It is established to ensure monitoring activities can be implemented in a way that prevents issues arising with poor quality.
- QC does not control quality, rather it measures quality. QC activities monitor and verify that the quality standards defined in the QA process are met.

QA and QC activities are essential to producing data of known quality.

- QA example: A procedure outlining how to calibrate a pH sensor, including the standards it must meet (e.g., pH 7.0 ± 0.2).
- QC example: Checking the pH sensor before taking a measurement to ensure it is operating to the required standard (if not, the sensor is calibrated).

Accuracy, precision, bias, representativeness and resolution are some of the fundamental concepts in understanding and assessing data quality. These terms are outlined in the *Assessing data quality* box on page 29.

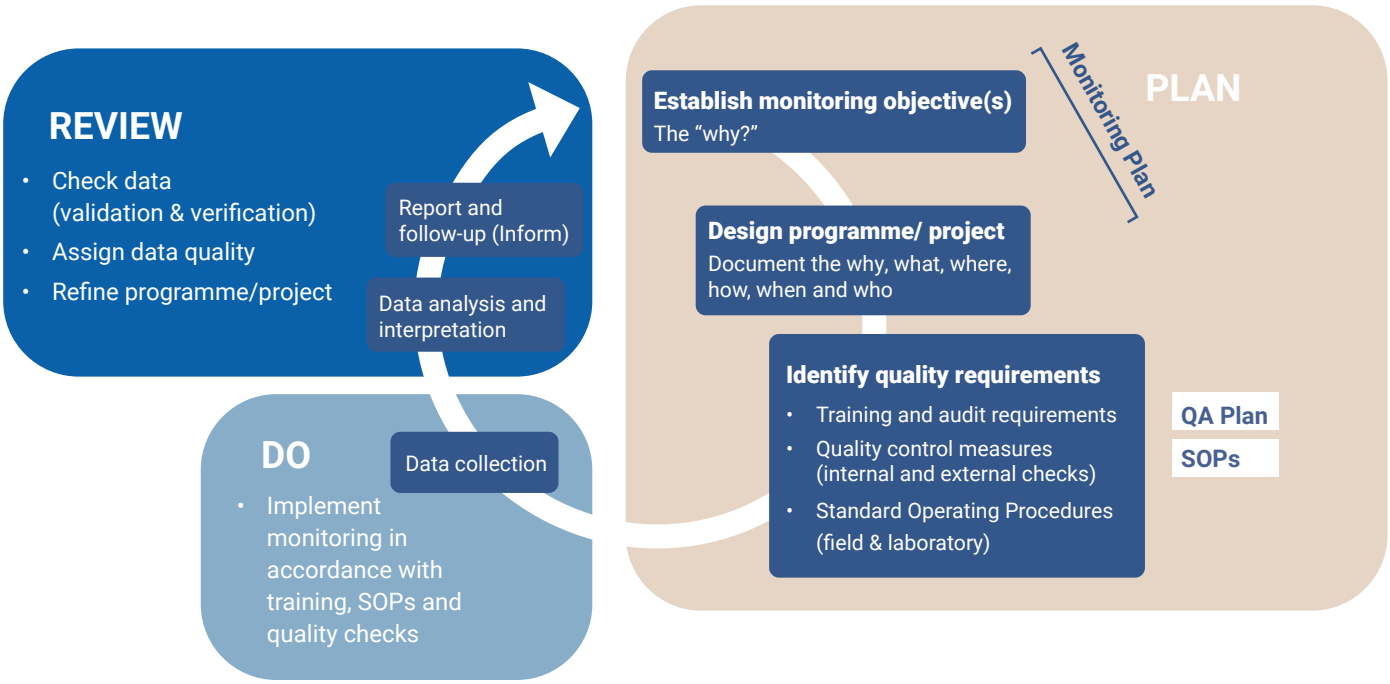


Figure 2-1: How QA fits within the general monitoring process. Monitoring can be thought of as a continuous loop of plan, do (implement) and review. Adapted from Valois and Milne (2021).

We do not include SOPs in the national CBM QA framework because the measurement methods for the stream health indicators included in the framework are already well established and readily available. Instead, we provide links to these methods and focus on setting out the quality checks required to ensure the methods are correctly followed and the results are robust.

How was the framework developed?

This framework was developed by building on a range of existing national monitoring and CBM guidance as well as a review of overseas approaches to CBM QA. The scope of the QA framework, including the selection of stream health indicators, measurement methods and core field form template components, were established with the help of a multi-organisational working group. This group included regional and unitary council staff spanning science, monitoring and community engagement, as well as representatives from central government, industry and not-for-profit organisations. The National Advisory Group for Freshwater Citizen Science[1] provided an additional informal forum to discuss ideas as well as identify opportunities to connect with community groups to trial the draft templates.

Health and safety

Working in and alongside streams involves risks that need to be assessed when selecting monitoring sites and managed throughout the life of a monitoring programme or project. Prepare a health and safety plan before monitoring starts and review it regularly. Things to consider include driving and parking, site access, weather, nuisance insects/plants (e.g., sandflies/wasps, nettle), if stock or other animals will be around, bank stability, and stream conditions that may affect sampling such as the current, poor water clarity and slippery rocks or deep mud. See the NIWA SHMAK field manual for tips on staying safe in the field. The NEMS *Safe Acquisition of Field Data in and Around Fresh Water* also provides some procedures for keeping safe while monitoring. A good general rule for working in streams is, **if in doubt, keep out.**

[1] The NAG-FCS is an informal advisory group that was originally established by NIWA in 2017 to support a revision of the Stream Health Monitoring and Assessment Kit (SHMAK). Today the group operates with a much broader purpose, bringing together people and organisations interested in supporting and advancing freshwater citizen science in NZ. The current advisory group membership includes representatives from central government, local government, research organisations, monitoring NGOs, industry and private consultancies. See: https://www.nzwatercitizens.co.nz/about/national-advisory-group.

Monitoring purpose

The framework has been designed to recognise that monitoring purpose and data use often differ across CBM groups. This is captured in three broad categories of data use: engagement and education, investigations and surveillance, and informing regulatory processes (Figure 2-2). In reality, the data use categories span a continuum, where planning, time, cost and QA requirements increase as a group moves from education and engagement activities on the left to informing regulatory processes on the right. Your group's monitoring questions and intended data use applications will therefore guide the investment level required.

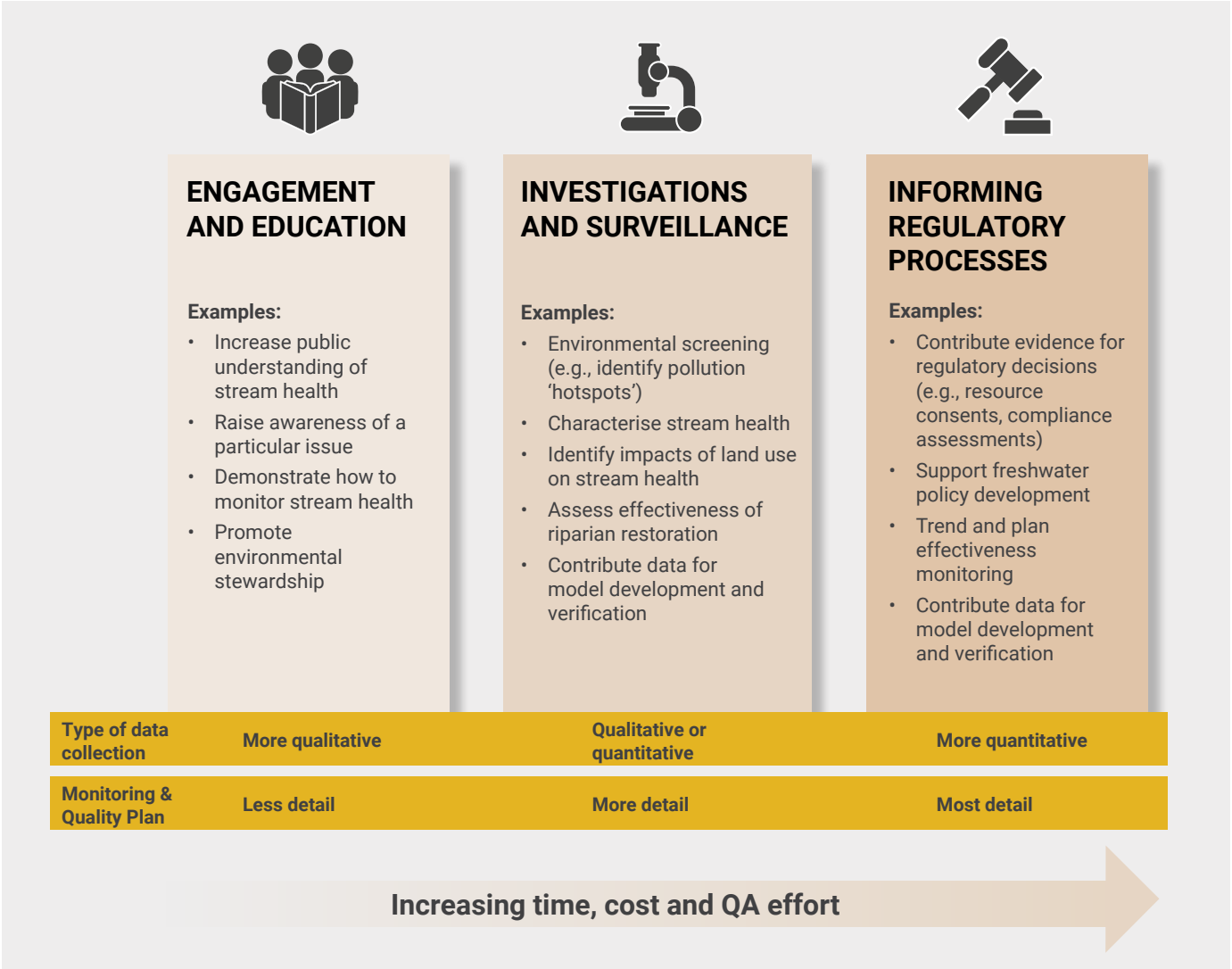


Figure 2-2: Data use categories in the national CBM QA framework with examples of possible data collection purposes that sit in each. Because the potential re-use of a CBM group's data by others (e.g., for catchment, regional or national modelling) may not be known, it is important that data collection methods and QA measures are documented and made available with the monitoring data.

Monitoring indicators

The framework is based around 28 commonly measured indicators of stream health (Figure 2-3). These indicators are relevant to 'ecosystem health' and 'human contact', two of four values that streams (and other fresh waters) must be managed for under the NPS-FM 2020.

Some indicators are also relevant to the other two mandatory freshwater values of the NPS-FM: 'threatened species' (e.g., dissolved oxygen, physical habitat quality) and 'mahinga kai' (e.g., visual water clarity, *E. coli*). However:

- the most appropriate indicators to monitor (and methods to use) for a threatened species will likely be species and potentially geographically specific, and will need identifying with the input of a specialist, and
- mahinga kai practices are area or rohe-specific, reflecting different traditions and practices, and should be developed and monitored by local Māori (i.e., tangata whenua).

What is stream health?

Stream health can mean different things to different people and is often closely aligned with their values. In this framework, stream health is a broad term that refers to both the stream ecosystem and the stream's ability to support human values and uses such as recreation and food gathering. The NPS-FM (see page 1) recognises five components of stream health: aquatic life, water quality, ecosystem processes, physical stream habitat and water quantity (Figure 2-3). Good ecological or ecosystem health underpins all other values and uses of water.

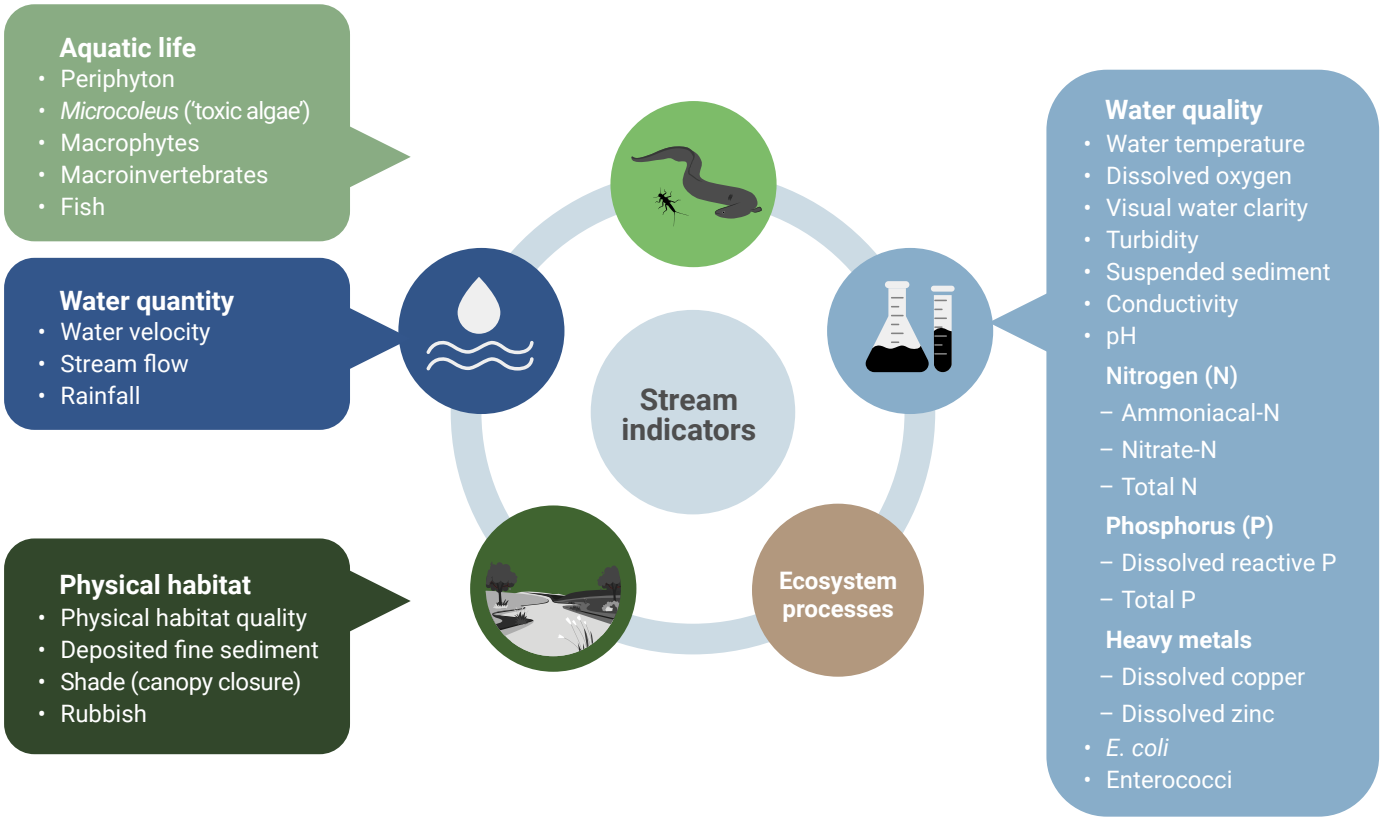


Figure 2-3: Indicators of stream health included in the national CBM QA framework. These indicators are grouped according to the five components of ecosystem health in the NPS-FM. Although *E. coli* and enterococci are living bacteria, they are listed under water quality in the framework where water quality includes physical, chemical and microbiological indicators. Ecosystem processes describe ecological processes such as the natural cycling of nutrients but no indicators are included in the framework at this stage as suitable CBM methods are still to be developed.

Measurement methods

The measurement methods included in the framework have been selected or adapted from existing nationally recognised standards and guidance. These methods are outlined in the companion background report and include a mix of methods used by regional councils (e.g., National Environmental Monitoring Standards, NEMS) and those designed for use by CBM groups (e.g., in NIWA's Stream Health Monitoring and Assessment Kit (SHMAK) and Auckland Council's Wai Care programme). In most cases, this means that more than one method is available to monitor a specific indicator. This is appropriate because monitoring purposes often differ across CBM groups and different monitoring purposes call for different methods and quality standards. Additionally, not all CBM groups may have the same amount of time or resources to spend on their monitoring.

The framework therefore strikes a balance between consistency and flexibility in measurement methods. Rather than dictate a single method, the framework generally provides several standard method options. Each method option includes relevant additional information (metadata) needed to support interpretation of your indicator measurement data or allow the quality of each measurement to be assessed.

Electronic templates

Both the Monitoring and Quality Plan and the electronic field form templates have been created using Esri's ArcGIS Survey123 software. Survey123 works on smart phones and other portable devices, as well as laptops and desktop computers.

ArcGIS software is well established worldwide and a growing number of NZ organisations, including many regional councils, are now routinely collecting freshwater and other environmental data using Survey123 smart forms. This means that the software is expected to be well supported into the future and there are many organisations with licences that can host and provide free access to the CBM survey forms. Additionally, Survey123 can be connected to other related GIS products so that CBM data can be communicated visually (e.g., in the form of graphs, maps and dashboards) and shared (Figure 2-4). ArcGIS Survey123 is already being used successfully in CBM initiatives nationally and internationally, and Esri offers software licences at a reduced price for not-for-profit CBM groups who may not need to work with a host organisation.

National Environmental Monitoring Standards (NEMS)

The NEMS are a series of technical standards and other documents that promote consistency in the collection of environmental monitoring data across NZ. As well as promoting best practice in data collection and processing, the standards include a quality coding framework for data so that the quality of data can be identified. For more information on NEMS, including a list of currently available freshwater monitoring standards, go to http://www.nems.org.nz/

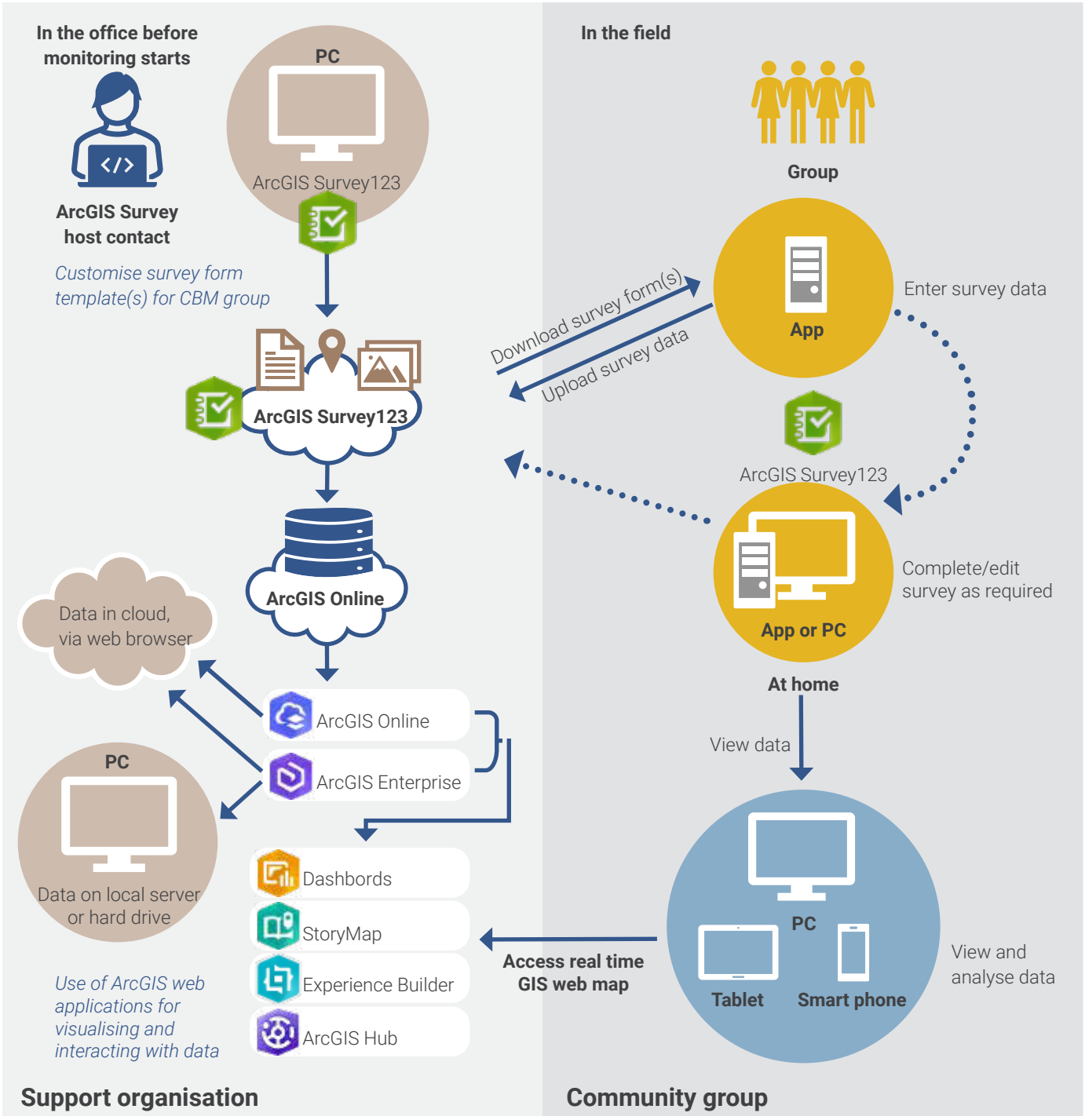


Figure 2-4: An overview of data collection under the national CBM QA framework and how the data could be accessed and shared. A support organisation (left) will create and host the electronic survey forms for a CBM group (right) to use through ArcGIS Survey123. Data access, storage and sharing should be agreed between the CBM group and host organisation before monitoring starts and will depend on the host organisation's ArcGIS licence, internal IT systems and resources.

How does my CBM group get started under the framework?

The first step in the framework is developing a Monitoring and Quality Plan (Figure 2-5). As well as the reason for monitoring and identifying your monitoring sites and indicators, this is where your CBM group will document its choice of measurement methods. The Monitoring and Quality Plan is covered in detail in Section 3. An electronic template and example of a completed plan are available here: www.waiconnection.nz/pages/programme

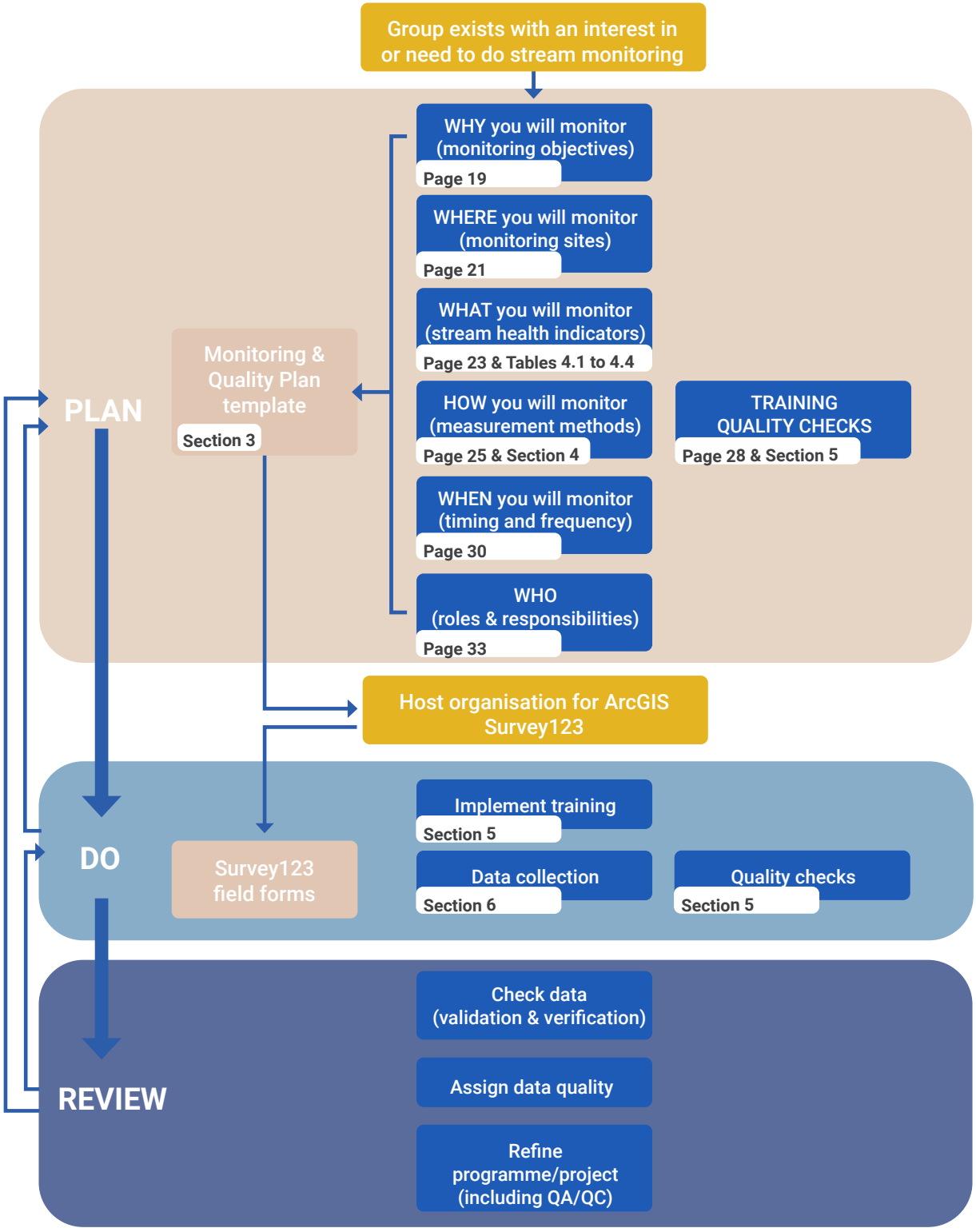


Figure 2-5: How to use the CBM framework with the various sections of this document that provide guidance.

The Monitoring and Quality Plan will also identify the host organisation that is providing your group with on-line access to your electronic field forms and any arrangements relating to data access, security, etc.

Some help from a specialist will likely be needed to develop or check your Monitoring and Quality Plan, receive training in monitoring methods, and provide external checks and support to ensure your group's monitoring remains on track. Access to the electronic field forms will also require an organisation with an ArcGIS Survey123 licence to 'host' your group's survey forms.

Once the Monitoring and Quality Plan has been prepared, attention can shift to gathering the necessary monitoring equipment and other resources and ensuring group members are trained to carry out the monitoring. During this period the organisation providing access to the electronic field forms may offer to pre-load your group's name and monitoring site details to customise the forms for use. This will save your group time by not having to re-enter the same details on every monitoring site visit. Internet access is required to download the Survey123 app and the field forms provided by your host organisation onto your mobile phone, tablet or computer.

Monitoring then commences in line with your group's Monitoring and Quality Plan. On each monitoring occasion (i.e., sampling visit), data are entered into the relevant electronic field form provided by the host organisation. Survey123 forms allow you to enter and upload the data on-line while in the field. Alternatively, the data can be entered into the Survey123 app offline for upload later. To assist groups that may wish to record details on a hard copy form in the field, printable templates are also available. These templates only capture essential field-based data. The data will then need to be manually entered into the electronic form on the Survey123 app for the automated calculations and quality checks to run.

For a few indicators, such as rubbish and rainfall, there are already freely available apps community-based monitoring groups can use to capture their measurement data. Rather than duplicate data entry through the CBM framework's Survey 123 field forms, we encourage community groups monitoring these indicators to capture their data using these existing apps (see Section 6).

What happens to the submitted data?

Data submitted via the Survey123 app are sent to the organisation hosting the survey. Depending on the host organisation's licence, the data may be stored in the cloud or, more likely where a council is the host organisation, downloaded onto a secure data server (see Figure 2-4). A range of options are available to ensure your group's data are accessible and secure. These options, including whether or not your group wish to share the data, should be explored with a host organisation(s) prior to commencing monitoring. The agreed position on data sharing should be documented in the Monitoring and Quality Plan.

Data access, privacy and sovereignty

Data sovereignty is about protecting the original owners of data and the privacy of the people that data may be about. It is closely linked with data security and ensuring that data collected or created in one country remain subject to that country's laws, regardless of where the data may be stored. In NZ, data sovereignty also seeks to protect knowledge and information from uniquely Māori sources. This aspect of data sovereignty recognises Māori as the indigenous people of NZ and relates to the rights and interests that Māori have to their digital information and its ethical distribution.

The national CBM QA framework is intended to promote sharing and re-use of monitoring data on stream health but only with the prior permission of the monitoring group and an understanding that personal details of monitoring group members will remain private and confidential. This is consistent with the NZ Privacy Act. Where iwi or hapū-based groups use some indicators and methods in the framework alongside mātauranga-based indicators of stream health, the host organisation will need to establish with the group how it will ensure protection of its mātauranga. Guidance is available in Te Kāhui Raraunga – Māori Data Governance Model (Kukutai et al. 2023).

Capturing monitoring data electronically under the national CBM QA framework requires use of the ArcGIS Survey123 app. To make the app free for use by community groups, a person or an organisation with a valid ArcGIS licence must 'host' the field forms. All data submitted via the app will, at least initially, be stored in the host organisation's internet cloud service provider.

Regional councils and other organisations manage their data differently, so discuss this with the host organisation to ensure your group is comfortable with the data sovereignty and data protection agreements in place. Currently, cloud server capacity in NZ is limited and the cloud server will likely be in Australia in most instances. However, if the host organisation is a council or other government organisation, data storage in the cloud will likely be short-lived with frequent downloads of the data onto a secure local data server or other platform.

Many regional councils and other organisations are combining ArcGIS Survey123 data downloads with other compatible software in the ArcGIS suite to create data portals and hubs to allow community and catchment groups to freely view and share monitoring data (see Figure 2-4, page 12). Depending on the arrangements your group enters into, you may have the ability to keep some or all monitoring data private.

What if my group wants to use an indicator or measurement method that isn't in the framework?

The Monitoring and Quality Plan template has a space to capture any additional stream health indicators your group may be monitoring, as well as the measurement methods for these indicators. So don't let this stop you from using the framework tools.

Wherever possible, if you have selected an indicator that is in the framework, then also select one of the measurement methods included in the framework for this indicator. This increases consistency in data collection and therefore the ability to compare and combine your data with data from other groups and organisations.

How is the framework managed and kept up to date?

The regional councils of NZ collectively own this national framework and are responsible for future updates. This is likely to involve a multi-organisational effort, such as through the National Advisory Group for Freshwater Citizen Science. Check with your regional council as a starting point.

It is expected that additional indicators and/or measurement methods may be added to this framework in future if, and when, resources allow. The companion background report (Milne et al. 2023) outlines the key criteria for selecting indicators and methods. These relate to the indicator's relevance to stream health, community interest in the indicator, and the availability of a recognised, practical and affordable CBM method to measure it.

SECTION 3

Monitoring and Quality Plan

Preparing a plan is the most important step in organising your stream monitoring efforts. It establishes the reason or purpose for monitoring, the stream health indicators your group will monitor, and where, how and when the monitoring will be done.

In the national CBM QA framework, the monitoring plan also incorporates the measures your group will put in place to assess and manage data quality. The monitoring plan is therefore called a Monitoring and Quality Plan and serves as a one-stop plan to capture all of the essential elements of your stream monitoring.

In this section we take you through the different components of the electronic Monitoring and Quality Plan template that forms part of the national CBM QA framework. The information provided is intended to help your group complete the template rather than design your programme for you.

The template contains seven forms (A to G) to complete, each dealing with a different component of the plan (Figure 3-1). Always start with Form A, your monitoring purpose, because this establishes the foundation of the plan and determines what you monitor, where, how and when. It also determines the amount of QA effort your group will need to invest.

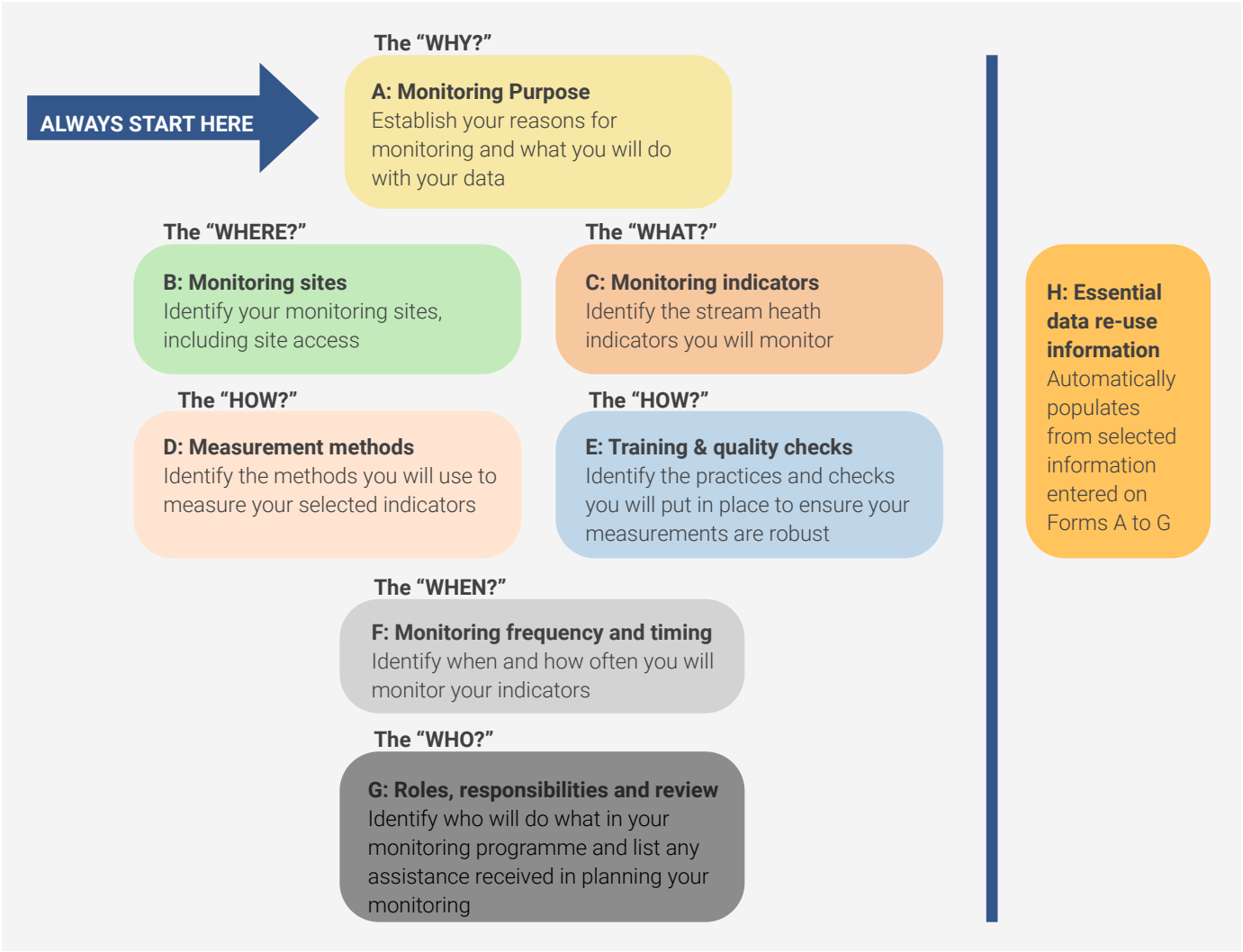


Figure 3-1: The different forms that make up the Monitoring and Quality Plan template. Minimum information requirements identified on each form must be completed to ensure monitoring data can be considered for use (or re-use).

If you are already monitoring, ensure that you have a clearly defined purpose and check that the 'what', 'where', 'how' and 'when' of your current monitoring support that purpose. For some specific purposes, advice should be sought from a specialist (e.g., if data collection is to inform regulatory processes).

There is no specific order to follow after Form A but it is likely that your monitoring purpose will lead onto selection of monitoring sites (Form B) or indicators (Form C) next, followed by measurement methods (Form D) and monitoring frequency (Form F). The template also includes forms to capture information on training and quality checks (Form E), as well as the roles and responsibilities of different group members (Form G).

Preparing your plan will very likely involve iterations between some components so that the proposed monitoring will fit with the time, resources, skills and interest that you have within your group. Depending on your monitoring purpose and methods, your group is likely to require input from someone experienced in stream monitoring to help complete the plan. Your group may also wish to approach an external organisation to independently check the plan is fit for purpose (this may or may not be the same organisation that hosts your group's Survey123 field forms).

We recommend that the electronic Monitoring and Quality Plan template is completed in full. We have highlighted a subset of questions within the template that must be answered to support re-use of your group's data. These are referred to as minimum essential information requirements and include, for example, monitoring site locations and measurement methods. The electronic template has been designed to automatically capture the minimum essential information required in a stand-alone "Essential data re-use information" form (Form H). Only this form needs to be shared with others if your group wishes to keep other details private (e.g., site access, names of group members).

A well-documented Monitoring and Quality Plan supports consistency through time and is very important for long-term monitoring programmes where group members (as well as equipment and methods) may change.

The Monitoring and Quality Plan template and an example of a completed plan are available on the Wai Connection website.

Form A: Establish your monitoring purpose (the "why")

There are many different reasons why a group may wish to monitor stream health. The focus of this national framework is therefore not on guiding what the monitoring purpose for your group is or should be, but rather ensuring that your group identifies and documents its "why" before any monitoring begins.

As a first step in identifying your why, collate some background information on your stream and catchment. Useful information includes upstream and surrounding land use, potential sources of pollution, geology, groundwater direction, and a summary of any existing monitoring data. Your regional council and other organisations may be able to assist with identifying relevant existing information and knowledge gaps. Your group may discover that monitoring isn't even needed!

The reason or purpose for monitoring should be established first because this guides what indicators of stream health you monitor, the locations at which you will monitor, the methods you will use, when you will monitor (e.g., time of day or year), and the amount of QA effort required.

The Monitoring and Quality Plan template asks the following questions to help your group identify why you are monitoring.

1. **Why are you interested in monitoring your particular stream(s)?**
Some typical reasons CBM groups monitor include:

- describing current state (is the water quality or stream condition healthy?)
- evaluating changes or trends in water quality over time (is water quality or stream condition improving or deteriorating over time?)
- determining if riparian restoration or changes in land management practices are achieving the desired water quality or ecological outcomes
- determining if specific on-farm, urban or other activities are responsible for a disproportionate amount of the contaminant load (critical source areas)
- understanding the impact of land use activity such as farming, horticulture, forestry or residential development
- determining if the water is suitable for swimming or other recreational uses
- providing a scientific basis for making decisions on the management of a stream or catchment.

There may be a number of reasons for monitoring but we recommend that your group identify one or two top reasons to develop your plan around.

2. **Are there any specific questions you want to address?**
Being as specific as possible will help with identifying what information needs to be collected.
Examples of specific questions:

- Do nutrient concentrations meet guidelines for aquatic life?
- What aquatic life does the stream support?
- Are water temperatures too high for invertebrates and fish?
- Is the water quality safe for swimming?

3. **What do you hope to achieve from your monitoring (i.e., what are your overall goals)?**
This question should consider what your group wants to do with the data you collect. Knowing how you intend to use your data will help ensure you select the most suitable monitoring indicators and methods in subsequent parts of the Monitoring and Quality Plan. Your main use of the data for will also guide the level of QA investment required.

4. **Who will use the data you collect?**
This question asks your group to identify who the data are being collected for and whether the data can be shared with other organisations. In many cases, sharing the data may be expected or required, especially if your group is receiving public funding or other assistance to support its activities. If this is the case, it is a good idea to establish at the outset with the relevant organisation how the data your group collects will be managed. See text box in Section 2.3.1 on data access, privacy and sovereignty.

5. **Do you support your data being considered for use in national environmental reporting and other applications?**
This question is an extension of question 4 and directly addresses data re-use by third parties.
A key goal of the national CBM QA framework is to promote data sharing to increase the visibility and value CBM data can provide in freshwater management. Therefore, it is important to establish early in the planning process who will use your group's data and whether your group supports the data being shared.

Form B: Identify the stream sites you will monitor (the "where")

Note: Completing Form B may or may not follow completion of Form A. In some cases, your group's monitoring question(s) may more strongly direct selection of monitoring indicators (Form C) before selection of monitoring sites.

Selecting the location of monitoring sites is a critical step in the Monitoring and Quality Plan and should link directly with your group's monitoring questions or purpose. For example, if your group is interested in what contaminant load a local stream is contributing to the river it flows into, the best site location is in the lower reaches of the stream just before it flows into the river (Figure 3-2).

Your monitoring question, as well as available resources, will also guide the number of monitoring sites you select. In the example above, if your group also wishes to compare the stream contaminant load with that in the river, then it will also be necessary to at least monitor the river just above the point at which the stream enters (Figure 3-2).

Many questions may require the inclusion of an unimpacted or reference site upstream of the main part of the catchment you are interested in. For example, if your group is specifically interested in the impact of cropping on water quality in a stream, select a site upstream of the cropping area that can represent water quality prior to the stream entering the reaches that receive runoff from cropping (Figure 3-2). This allows a comparison of water quality above and below the reach influenced by cropping.

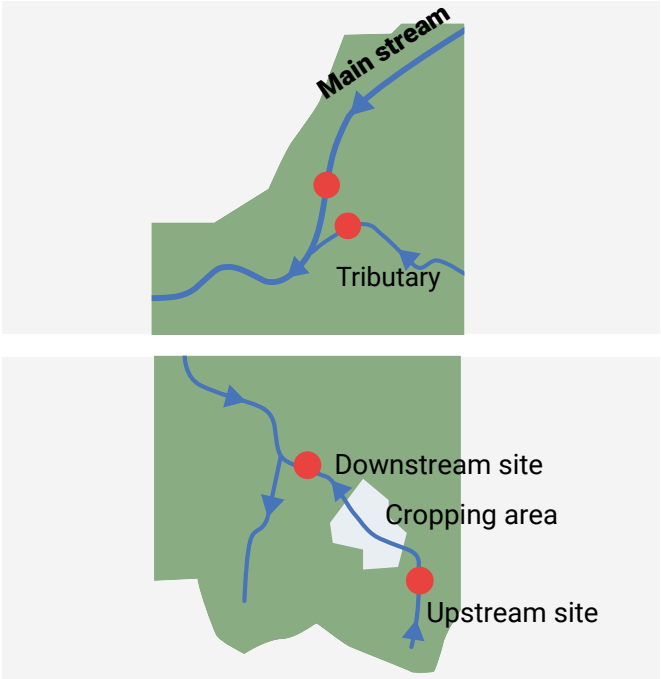


Figure 3-2: Examples of monitoring site locations. Monitoring of a tributary entering a river (top) and monitoring upstream and downstream of land used for cropping. Red circles indicate possible monitoring site locations. The blue arrows indicate the direction of stream flow.

A combination of desktop planning such as looking at maps and aerial photographs, as well as a site visit will be needed to select monitoring sites. Two important considerations when selecting sites are representativeness and safe access.

Representativeness

A monitoring site needs to represent the body of stream water that is of interest. In most cases, sites are chosen to be representative of the wider stream in that reach. Possible exceptions might be if your group's monitoring question relates to identifying differences in particular stream habitats or the influence of a stormwater outfall on stream water quality just below its point of discharge.

For a site to be representative of the wider stream area, be careful to avoid sites that are very close to stormwater outfalls, drain inputs or other point source discharges. Depending on the location of your group's sites and monitoring purpose, the influence of groundwater entering a stream and tidal backflow may also need to be considered. For example, in the example in Figure 3-2, shallow groundwater under the cropping area may be enriched with nutrients lost from the soil but, depending on the direction of groundwater flow, some of this nutrient rich water may not enter the stream for some distance downstream of the actual cropping area.

Safe access

Safe access to monitoring sites is important, particularly if sites are going to be visited regularly over an extended period of time. Key considerations include the presence of traffic, stock and other animals (e.g., dogs), and whether access will change at certain times of the year (e.g., due to lambing or unsafe access tracks in winter conditions).

Site records

It is essential to record some details about each monitoring site to correctly relocate them on future monitoring visits. These details will also assist your group – and others – to interpret and make use of the monitoring data. We refer to these details as *site metadata*.

As a minimum, Form B of the Monitoring and Quality Plan requires the following information to be captured:

- site name (incorporating the stream name), code and location (preferably in WGS84 latitude and longitude which are used by geospatial tools such as ArcGIS Survey123),
- site type (e.g., river, stream, drain), and
- whether the site is accessed from the true left or right bank (determined by facing downstream).

We strongly recommend that you also capture on Form B:

- the reason(s) for site selection,
- site access and specific health and safety notes, and
- key characteristics: streambed material, stream width, adjacent land use and the presence of any artificial structures (e.g., stormwater outfall or subsurface drain outlet) on either stream bank, and the River Environment Classification (REC) class (see information box, page 23).

How to name monitoring sites

Each monitoring site should be given a full site name and a site code in the form of a shortened abbreviation. If your group is collecting samples that will be processed in a laboratory (lab), providing the lab with both the full site name and code means you can get a report back that can be easily understood without having to check a site list.

Ideally use a site name that identifies both the stream being monitored and the location of the monitoring point. Use a landmark that is permanent or a street name or address.
Examples: Korokoro Stream at SH 2 bridge, Dry Stream 50 m upstream of Hurunui River confluence.

If the stream doesn't have a name, it can be referred to as a tributary of the stream or waterbody it flows into. *Example: Korokoro Stream tributary at Korokoro Place.*

You may also wish to record a short name.
Examples: Korokoro @ SH 2, Dry Stream u/s Hurunui R conf., Korokoro trib @ Korokoro Pl.

For an abbreviation, there are various ways this can be written but we recommend 2-3 letters that can be identified with the name of your catchment, monitoring programme or monitoring group followed by a 1-2 digit number unique to that site.
Example: If the Korokoro Stream and tributary sites above form two of three monitoring sites in the catchment, the site codes might be K1, K2, K3, or KS01, KS02, KS03.

What if my site locations are not in latitude and longitude?

Several websites allow you to enter site locations in one set of units (e.g., a NZTM or a Topo50 map reference) and will automatically convert these to your selected choice of alternative units. Try the Land Information NZ website converter: https://www.linz.govt.nz/products-services/geodetic/online-coordinate-converter

The River Environment Classification (REC)

Different parts of rivers and streams support different plant, invertebrate, fish and bird communities. Classifying river reaches into groups with similar characteristics allows comparison of 'like with like' when assessing and reporting on stream health.

The REC system was specifically developed for NZ and is based on a spatial network of river reaches (called segments) identified from maps. The classification takes into account factors which influence stream water quality and biology. These factors include climate (e.g., rainfall, temperature), the source of flow (e.g., mountain, hill, lake, lowland), geology (e.g., volcanic, alluvium gravel, greywacke) and landcover (e.g., native forest, exotic forest, scrub, pastoral, urban). Guidelines for interpreting some stream health indicator measurements vary depending on REC class.

Find out the REC class for each of your group's stream monitoring sites using the Ministry for the Environment's River Environment Classification tool. Search by stream name or address, or search the map and select your stream site with the pointer. The Monitoring and Quality Plan captures the first four levels of the REC class; climate (C), source of flow (SOF), geology (G) and landcover (L) – C/SOF/G/L.

Form B of the Monitoring and Quality Plan template includes a series of selection options to assist with recording the characteristics of each monitoring site. Depending on your group's monitoring purpose and questions, you may wish to record additional information on each site such as groundwater movement and local drainage. For long-term monitoring programmes and other situations where group members carrying out the monitoring may change over time, site cards could also be created with a location map, landowner contacts, access and health and safety details, and a photo.

Form C: Identify your stream health indicators (the "what")

Read this section first then use Tables 4.1–4.5 in Section 4 to help your CBM group complete this form in the Monitoring and Quality Plan template.

Deciding what to monitor should link directly with your group's monitoring purpose and questions, and the intended end use of the data. What resources are available will also determine what can be monitored (and how and when).

The CBM QA framework includes 28 indicators of stream health (refer Figure 2-3, page 10). These indicators include those commonly monitored by regional councils and reported in stream health and suitability for recreation assessments regionally and nationally.

Section 4 outlines each stream health indicator along with measurement methods included in the CBM QA framework. Use those details to assist your group with completing Form C. Some specialist advice may also be required.

Four example monitoring questions and possible indicators to monitor are outlined in the table on the next page – these examples can be cross referenced against the information in Section 4 to identify why these indicators have been suggested. If your group is just interested in broadly characterising general stream health, it is useful to select a few different physical, chemical and biological indicators so that multiple components of stream health are included (i.e., water quality, water quantity, aquatic life and habitat).

Example 1: Does my stream have a healthy ecosystem?	Example 2: Is it safe to swim?
Indicators of aquatic life such as macroinvertebrates and periphyton are likely to be the primary focus. If resources permit, you could select some additional indicators that are known to strongly influence aquatic life such as water temperature and stream habitat (these are also good indicators to include if you are assessing the impact of riparian restoration on stream health).	Indicators you might select include *E. coli* indicator bacteria, visual water clarity and cyanobacteria. If you are interested in other factors that can influence the swimming experience you might like to include indicators such as water temperature, periphyton cover and rubbish.
Example 3: What is the sediment load in my stream?	**Example 4: What impact is road runoff having on water quality in my stream?**
This question is specific to one type of contaminant, sediment. Measuring suspended sediment and stream flow will be required. Depending on how you design your monitoring, it may also be useful to measure turbidity and/or visual water clarity.	Indicators you might select include dissolved copper, dissolved zinc and suspended sediment. To interpret copper and zinc data against water quality guidelines, some information on pH, water hardness and dissolved organic carbon is also needed.

Form C requires, as a minimum, that you select your monitoring indicators from the list of 28. We strongly recommend that you also record a reason for selecting each indicator. The form also provides a space to capture any additional indicators you may be including that are not in the CBM QA framework. These additional indicators might relate to specific pollutants that may be present in your catchment due to a particular land use activity (e.g., pesticides) or specific stream habitat features that are important for a particular type or species of fish (e.g., suitability of riparian vegetation for Inanga/whitebait spawning or riverbed gravels for trout spawning).

Keep in mind:

- The more indicators that are selected, the more time and/or cost involved in monitoring – choose those that are most relevant to your group's needs or interests and seek specialist advice if unsure.
- Interpretation of some indicators, such as ammoniacal nitrogen, dissolved copper and dissolved zinc, requires some additional variables to be monitored (e.g., pH).
- More than one method is available to monitor most indicators – the methods selected (Form D) may ultimately determine the number of indicators your group can monitor, so be prepared to revisit Form C.

Don't forget to record and monitor indicators of action

The national CBM QA framework focuses on indicators of stream health but if your group's monitoring purpose is linked with specific catchment or riparian restoration actions to improve stream health, it is useful to record and monitor these actions (e.g., riparian planting date, length and width). See the *Healthy Waterways Register* website for more details.

Form D: Identify your measurement methods (the "how")

Read this section first then use the detailed indicator tables in Section 4 to help your CBM group complete this form in the Monitoring and Quality Plan template.

The measurement methods your group selects should primarily be guided by how the data will be used and the quality of data needed to support that use. What resources are available is also relevant but needs to be a secondary consideration to ensuring that the data will be fit for purpose. Your group should be prepared to revisit the monitoring purpose and goals on Form A.

The national CBM QA framework includes measurement methods for each of the 28 stream health indicators. In most cases, more than one method is available to measure an indicator because monitoring purposes vary across groups. These methods provide different accuracy and precision. Section 4 includes information on the general type of monitoring application each method is suitable for, based on the data categories illustrated in Figure 2-2, as well as an estimate of the time, cost and complexity involved with monitoring.

Wherever possible, a CBM QA framework method should be selected because:

- the method has been identified as being suitable for a particular type of monitoring purpose
- the use of one of the listed methods promotes consistency in data collection and therefore the ability to compare and combine data from different groups for use in environmental reporting or other applications.

Your group may have a good reason to use another method (e.g., so you can compare your results with a previous survey that used that method). Form D therefore allows another method to be listed, along with the reason for using it.

Where several methods could produce data that are suitable for your group's intended data use, the time and cost involved with each method will likely determine which option to choose. Other considerations include:

- if selecting one method over another is more likely to offer additional value or benefits, such as being directly comparable with regional council state and trend monitoring data
- whether every indicator needs to be measured to a high degree of accuracy or if some are secondary indicators where less precise data from cheaper or quicker methods are good enough
- whether the results of water sample testing are wanted immediately or your group is happy to wait for a lab report.

The driving consideration for method selection, however, should be what your group intends to use the monitoring data for. For example, if the data will be used to identify which of multiple drains on a farm has the highest nutrient concentrations, self-test kits could be used. These test kits are not as accurate as lab testing but will suffice for screening multiple sites on a farm, at least initially. In contrast, if the concentrations of nitrogen exiting a particular property drain are to be measured for comparison against a specific regional plan target or resource consent limit, lab testing will offer greater accuracy and precision, and therefore greater confidence, in the data.

CHECK: If your group's monitoring activities are funded by a particular organisation or you want that organisation to use your data, then the measurement methods may be directed by that organisation.

Types of measurement methods

Measurements of stream health indicators in the national CBM QA framework fall into three types:

Field measurements

Self-test kits

Lab testing/identification

For some indicators, there is only one type of measurement you can make. For example, water temperature and stream velocity must be measured in the field, while total nitrogen must be measured by sending a water sample to the lab. For other indicators, such as *E. coli* and dissolved forms of nutrients, you have a choice between two methods – portable self-test kits or lab testing.

There are pros and cons to each type of method (see table next page). Normally, lab testing will provide the most accurate and precise measurements of water quality.

Field measurements
Field measurements involve the use of equipment (e.g., a conductivity meter) or visual assessments (e.g., periphyton cover). Generally, the more sophisticated the equipment is, the more accurate and precise your measurements can be – provided the equipment uses proven technology and is maintained and correctly used! Similarly, using equipment such as an underwater viewer when estimating periphyton cover, and performing more observations and in greater detail, will generally offer increased accuracy and precision.

Field meter sensors require regular calibration and validation. Conductivity sensors are usually very stable and so are ideal for field use. In contrast, as well as being more expensive, both pH and turbidity sensors can drift more easily and collecting a water sample for lab testing is recommended as a first choice. See Section 4 (page 42) for more details on field meters.

Self-testing kits
Under the national CBM QA framework, your group can measure the following water quality indicators on site or at home by collecting a water sample and using a self-test kit: pH, nitrate-nitrogen, ammoniacal nitrogen, dissolved reactive phosphorus and *E. coli*.

Self-test kits use test strips (e.g., pH, nutrients), reagents (e.g., nutrients) or growth media (e.g., *E. coli*). Measurement ranges and resolution vary and are important considerations when selecting a kit. More details are provided for the relevant stream health indicators in Section 4 (pages 51–54).

Lab testing
Labs use standard test methods with strict quality checking procedures in place to provide accurate and precise measurements of water quality, and accurate identification of macroinvertebrates.

Collecting and sending water samples to a lab for testing will save your group time and effort but will cost more over the life of a long-term monitoring programme than field measurements and self-test kits. The samples must be collected, handled and transported carefully. There will also be a delay in receiving the results. See Section 4 (page 42) for more details on lab measurements.

Some pros and cons of the different types of water quality measurements are summarised in the box below. Overall, for water quality indicators, if high accuracy and precision are essential to your group's monitoring purpose or goals and there is a choice in the type of measurement that can be made, choose lab testing. The exception is conductivity where both field and lab measurements generally closely agree.

	Field measurements	**Self-test kits**	**Lab measurements**
Advantages	Immediacy of result Limited ongoing cost beyond initial purchase of equipment or test materials	Engaging and educational Immediacy of result Cheaper than lab tests	Expert advice High accuracy and precision QA/QC in place
Disadvantages	Initial expense of field meter or equipment Sensor calibration and validation required	Takes time to perform nutrient and especially *E. coli* tests Sample dilutions may be required to get a result within the measurement range Lower accuracy and measurement resolution Components of test kits have an expiry date and will need replacing Some reagents contain hazardous chemicals	Working in with courier times if a local lab isn't available It can take from days to weeks to get the results Some tests are expensive

Under the national CBM QA framework, the macroinvertebrate and fish indicators can be measured in the field or by providing one or more samples to a specialist lab for eDNA analysis. Similar to water quality, there are pros and cons of field vs lab-based measurements relating to the time, cost and information gained. See the eDNA section (page 61) for more details.

Form E: Training and quality checks

Read this section first then use the information in Section 5 to help your CBM group complete this form in the Monitoring and Quality Plan template.

Form E identifies what training your group has received or plans to receive. It also captures the internal and external quality checks your group will put in place to ensure the data collected are fit for purpose.

Training

Training in monitoring and measurement methods is critical to ensuring that data are credible and can be used for their intended purpose. It is important that all group members involved with stream monitoring are properly trained. This will increase your group's confidence in the data you collect. Being able to provide evidence that your group has received appropriate training will also increase the confidence of other potential users of the data.

Various training resources are available on-line and a range of organisations can deliver training sessions. Section 5 includes general information and resources on training in stream monitoring and sets out recommended training for measuring different stream indicators. Recommendations for refresher training are also outlined.

One advantage of sending water and biological samples to a lab for testing is that labs have existing QA systems in place to address training and quality checks. However, it is important to receive training in sample collection, preservation and handling so that your lab receives a sample that remains representative of the stream environment it was collected from.

Quality checks

Quality (or quality control) checks form a critical part of the national CBM QA framework and provide monitoring groups with confidence that good data are being collected. Because the framework seeks to support potential re-use of CBM data, it focuses on building in and capturing the results of quality checks when monitoring without dictating what those results must be for specific purposes. This allows an end user to decide if the data are of sufficient quality to meet their intended use.

A range of quality checks exist (see next page). These include internal checks your group can make and external checks made by an independent third party. External checks that indicate monitoring is being carried out correctly will increase your group's confidence in the data being collected. Section 5 outlines the quality checks that are suitable for different stream indicators and measurement methods. The number and type of checks to include should be guided by the intended end use of the data. As illustrated in Figure 2-2 (page 9), high accuracy and precision are important if the end use is to inform regulatory processes.

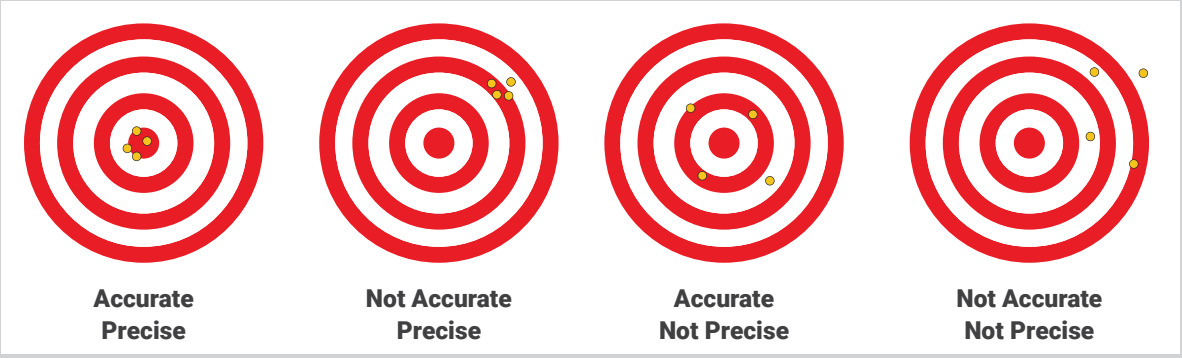
Briefly list on Form E of the Monitoring and Quality Plan template the types of checks your group intends to carry out for field measurements and sample collection and testing. The Survey123 electronic field forms include built-in checks and calculations but these can only work with the data entered. These forms cannot replace essential checks that field meters are correctly calibrated, and field measurements and water or biological samples are collected in accordance with best practice methods (Note: the field forms can capture comments for situations where your group thinks that a measurement or sample might have been compromised).

Assessing data quality

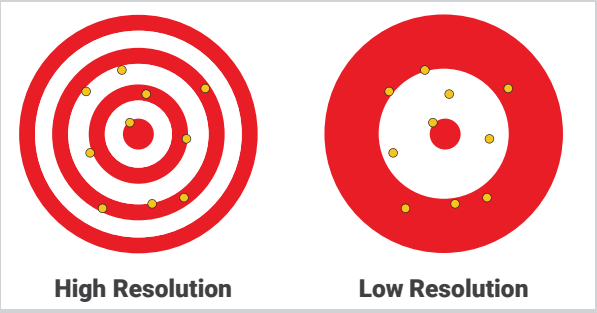
Accuracy and precision are two different but equally important aspects of data quality.

- Being accurate means that we have measured the true value.
- Being precise means that when we make repeated measurements, we consistently get the same or a similar result.

The aim is to be both accurate and precise.



Precision is often confused with measurement resolution. Resolution is the smallest unit or change that can be reliably measured. Increased resolution will improve measurement precision but it does not guarantee accuracy.



To produce credible data, CBM programmes need to adopt the same principles that are built into professional programmes to maintain data quality. These include internal and external quality checks such as:

- **standard reference solutions** – checking the accuracy, for example, of a field meter sensor using a standard solution of a known concentration
- **replicate samples** – splitting a single sample into two or more subsamples in the lab to test measurement precision
- **field blanks** – filling 'clean' samples collected in the field using distilled water to check for any background contamination arising from the sample bottle, or sample collection or handling.
- **photos** – taking photos for an expert to confirm, for example, identification of macroinvertebrates or fish
- **voucher specimens** – using preserved samples of a plant or macroinvertebrate species to verify the accuracy of an identification.

These checks are outlined in more detail in Section 5, including the types of checks that can be performed for different stream health indicators.

Form F: Identify the timing and frequency of monitoring (the "when")

When and how often your group monitors are important decisions to consider. Your group's monitoring purpose, time and resources will all influence the timing and frequency of monitoring. Form F of the Monitoring and Quality Plan template captures information on this, including any special conditions required for monitoring. The monitoring indicators are grouped by type. An example entry is given below.

Stream indicator type	Frequency and timing	Monitoring conditions	Other notes
Water quality indicators	*Every two months in the first week of the month plus a 2-week logging of water temperature in mid-summer. Monitoring will start at the first site at 10am.*	*We will sample regardless of the weather provided it is safe to do so.*	*We will target 2 rainfall events if none of our routine monitoring coincides with rainfall.*
Water quantity indicators	*We will measure stream velocity every two months when we monitor water quality.*		
Aquatic life indicators	*Periphyton cover every two months when we monitor water quality and macroinvertebrates once a year in late summer.*	*We will sample macroinvertebrates after at least two weeks of stable stream flow.*	
Physical habitat indicators	*Once a year in late summer together with the macroinvertebrate sampling.*		

Timing

In identifying when to monitor, consider the time of day, time of year and whether monitoring needs to target specific stream or weather conditions. Your group also needs to identify if and when monitoring might stop.

Time of day

Some water quality indicators, such as water temperature and dissolved oxygen (DO), vary across the course of a day. Maximum daily temperatures and DO concentrations generally occur in mid-late afternoon, whereas daily minimum values for both occur around sunrise. If your group is interested in tracking changes in these indicators through time, indicator measurements will need to be made at a consistent time of day to ensure the measurements can be compared over time. Alternatively, if the aim is to see how much these indicators vary over the course of a day, or accurately determine the effectiveness of riparian planting on reducing stream temperature during summer, it may be useful to deploy a sensor in the stream to measure water temperature at high frequency for a few weeks. Similarly, measuring DO at high frequency over at least several days or weeks in summer will provide information on whether DO is likely to drop to low levels that may impact fish and other aquatic life.

If the proposed stream monitoring includes sites located in tidal reaches, make sure to account for this in the monitoring programme. For example, if your group is interested in understanding contaminants coming from upstream and entering the estuary or coast downstream, stream water samples should be collected on an outgoing (ebb) tide at near low tide.

Seasonal cycles

Many indicators of stream health are influenced by seasonal cycles. For example, nitrate-nitrogen concentrations are generally higher in winter than summer (Figure 3-3) due to higher rainfall at this time (which flushes nitrate through the soil profile), and low uptake by aquatic plants or reduced loss to the atmosphere through a process called denitrification. Therefore, sampling throughout the winter is important if your group wants to get an accurate picture of how much nitrate-N is lost from the land to the underlying groundwater and, from there, to drains and streams.

Special conditions

Depending on your group's monitoring questions, it may be necessary to target particular stream conditions or weather events. For some aquatic life indicators, sampling is normally restricted to the warmer summer months when flows tend to be more stable and sampling is easier. If flows are particularly low, this can also provide a check on the stream ecosystem when it is under stress (e.g., from elevated stream temperatures). In contrast, if the monitoring focus is estimating sediment or nutrient loads exiting a drain or stream, then it will be necessary to collect some water samples during rain (storm) events (Figure 3-3). This is because stormflow inputs often carry the bulk of the pollutant load and this will be missed if sampling is carried out only during base stream flow conditions.

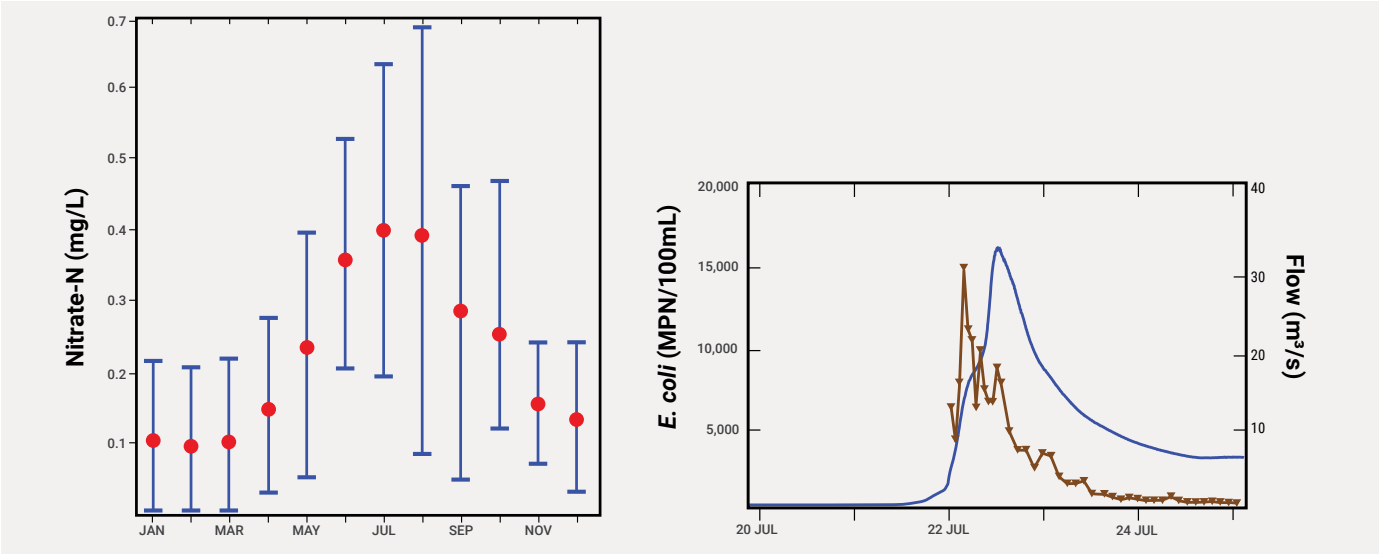


Figure 3-3: Left – illustration of typical seasonal variation seen in nitrate-nitrogen concentrations over the course of a year (note the higher concentrations during the winter months. Right – in many streams, *E. coli* indicator bacteria concentrations (brown) increase significantly with stream flow (blue) when it rains, and the peak concentration usually occurs while the river level is still rising.

It is important to remain consistent with your monitoring frequency. Create a monitoring schedule that your group can commit to.

Frequency

For general monitoring of stream health, water quality indicators are best measured at least seasonally (four times per year). Monthly measurements are common in most regional council stream monitoring programmes and are better for tracking changes in water quality over time. In contrast, stream habitat changes slowly under normal conditions, so annual assessments of habitat characteristics, including stream shade, may be adequate.

If your group's monitoring is focussed on measuring the effectiveness of actions to improve fresh water (e.g., riparian planting, stock exclusion), a tool is available online to help determine the location, frequency and duration of measurements that may be required to detect early improvements in a selection of water quality and aquatic life indicators. See: www.monitoringfreshwater.co.nz.

High frequency sensor-based water quality measurements

The number and range of water quality instruments that can be deployed in a stream to measure specific water quality indictors at high frequency (e.g., every 5 or 15 minutes) is growing. Water temperature, dissolved oxygen, conductivity, pH, turbidity and nitrate-nitrogen are examples of indicators than can be measured at high frequency.

As exciting as high frequency sensors sound, especially if set up to provide a real-time data feed to a smartphone or computer, they can be expensive and generally require a lot of checks and maintenance to get good quality data. It is important for your group to ask:

- Do we need high frequency measurements to answer our monitoring questions?
- Do we have the time and other resources to commit to this type of monitoring?
- How will we quality check, manage (and interpret!) the large volume of data?

Because of the time, expense and complexity that is generally involved with high frequency sensor-based measurements of water quality (see page 41), the CBM framework only addresses short-term deployments of water temperature and dissolved oxygen sensors (e.g., from a few days to a few weeks). If your group wishes to monitor these indicators for a longer period, or to monitor other indicators at high frequency, advice should be sought from a specialist to design and implement a suitable monitoring plan.

When to stop monitoring

An important question to address in the Monitoring and Quality Plan is how long your group will monitor for. This will help identify the resources needed and whether the monitoring programme is achievable.

Deciding how long to monitor for should be guided by your group's monitoring purpose and questions (Form A, page 19). For example:

- If the purpose is to **determine the current condition (or state)** of a stream, monthly water sample collection over a 12-month period and a summer-time assessment of aquatic life indicators will provide a reasonable indication of this, assuming rainfall and the summer reflect an 'average' year. Monitoring for a period of 3 to 5 years will reduce the effect of variability between years and provide a more robust set of summary statistics and assessment of stream condition.
- If the intention is to **assess trends** in stream health, then depending on the indicator and sampling frequency, monitoring for 5 to 10+ years may be needed. If the trends are being tracked to assess the effects of new riparian vegetation planted to improve stream health, be prepared to monitor some ecological and habitat indicators at least annually beyond 10 years. This is because it can take many years, even decades, for the full benefits of riparian plantings to take effect.
- If the purpose is to **measure the impact** of a stormwater drain discharge into a stream, the monitoring focus could be relatively short periods that target a specific number of rainfall events.

Where monitoring is related to measuring the effectiveness of a mitigation measure, specialist advice should be sought on an appropriate monitoring duration. A wetland constructed to treat overland runoff can take many years to establish and provide optimal performance. In contrast, a well-designed detainment bund is likely to be effective at retaining sediment in overland runoff from as soon as it is built.

Form G: Roles, responsibilities and review

There are many roles and responsibilities that come with maintaining a monitoring programme. It is important to share these responsibilities among group members so that no one is overloaded.

Some suggested roles and responsibilities to consider are outlined below. Form G will capture this information for each group member, including any specific tasks or relevant notes. The minimum essential information to enter on the form and make available externally is the name and a contact email for a group member that will serve as the primary point of contact for external organisations to connect with your group.

Role	Responsibility
Monitoring coordinator	Manages and oversees the monitoring programme, including Monitoring and Quality Plan completion and review.
Equipment manager	Obtains and maintains all monitoring equipment and supplies, ensuring equipment is in good working order and any standard solutions and reagents are safely stored and have not expired.
Data manager	Manages the data collected, including potential exchange of data with other parties.
Outreach/communicator	Connects with the wider local community, media or support organisation and any other external specialists or organisations that may be advising or interested in the group's monitoring activities.
Quality/Training manager	Oversees all quality assurance measures outlined in the Monitoring & Quality Plan, including preparation of written monitoring protocols and organisation of training events and refreshers.
Health and safety coordinator	Works with the equipment and quality/training managers to develop, implement and maintain health and safety procedures.
Monitoring team member	Carries out the monitoring (may be a specific component or all components).

Review and submission of the Monitoring and Quality Plan

The final two questions on Form G require a comment on what input your group has received, and from whom (job title and organisation), in preparing and finalising the Monitoring and Quality Plan.

Depending on the monitoring purpose and questions, your group may wish to approach an external specialist to independently check the plan is complete and fit for purpose. Under the national CBM QA framework, an external check is required for groups wanting to use their monitoring data to inform a specific regulatory process (see Figure 5–1, page 82). Seeking a review of some sort may even be a requirement or expectation of any organisation that is funding or otherwise supporting your group's monitoring activities.

Knowing that external specialist input has contributed to the planning of your group's monitoring serves two purposes:

- it will increase your group's confidence that a robust plan is in place to commence monitoring and collect credible data, and
- it will likely increase the potential for third parties to consider using the data.

Your Monitoring and Quality Plan should be a living document – your questions and intended data use may change once you've collected and looked at some data. Periodically re-check and, if necessary, update your plan to ensure it remains fit for purpose.

Summary

Fit for purpose monitoring starts with knowing your reason for monitoring and then planning everything so that it supports that purpose. If your group's reason can't be fulfilled with the time and resources you have, either look for additional resourcing or revise your monitoring goals so that they are achievable.

A critical part of the national CBM QA framework is completing a Monitoring and Quality Plan to capture the essential elements of your group's stream monitoring in one place. The electronic template provided is designed to ensure that your group documents:

- the critical details of why, what, where, how, and when before you start monitoring,
- the specific measures your group will put in place to assess and manage data quality, and
- who will do what in the programme.

Because this planning stage will strongly influence the success of your group's stream monitoring, the support of one or more specialists along different stages of your monitoring journey may be required to help prepare or review the plan.

To fully implement your group's Monitoring and Quality Plan under the national framework will require a host organisation to provide access to the ArcGIS Survey123 electronic field forms. The host organisation will need to be given at least a copy of Form H from the plan so that it has the minimum essential information about the proposed monitoring. Ensure that your group and the host organisation understand and agree how access to the monitoring data will be managed.

Finally, remember to keep the plan alive – review it regularly with your group, along with your monitoring results, to ensure that it remains fit for purpose.

SECTION 4

Indicators and measurement methods

Use the information provided in this section to help your CBM group complete Form C and Form D of the Monitoring and Quality Plan outlined in Section 3.

Each of the 28 stream health indicators in the national CBM QA framework are outlined in this section, grouped by indicator type (water quality, water quantity, aquatic life and stream physical habitat).

The information provided for each indicator includes:

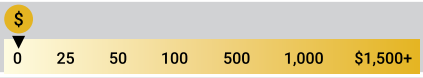
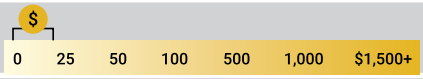
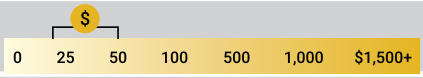
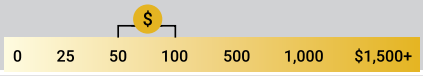
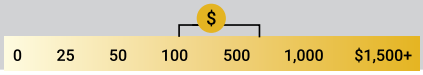
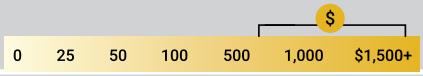
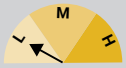
- a brief description and its relevance to stream health, and
- the different measurement methods included in the framework, including:
  - which of the three broad categories of data use each method is suitable for,
  - equipment and material requirements, and
  - an indication of the time, cost and complexity associated with measuring the indicator.

Some symbols are used in the tables presented in this section. The time and cost estimates are presented on a per indicator basis. Two types of cost are indicated:

- the initial or one-off cost, such as the cost of purchasing sampling equipment, and
- the ongoing sampling or measurement costs, such as the cost of test materials (excluding consumables such as batteries or ice) or lab testing.

In reality, the equipment costs will not apply to every indicator because some equipment items, such as a measuring tape and an underwater viewer, are used to measure more than one indicator.

Key to symbols

Data use		See Figure 2–2 (page 9) for examples of monitoring that fit into each of these broad categories. It is best to check measurement methods with the relevant regional council if collecting data to inform a specific regulatory purpose.
Time		Less than 5 minutes
		5–15 minutes
		15–30 minutes
		30–60 minutes
		Over an hour
Cost (in NZD)		None
		Up to $20
		$20–$50
		$50–$150
		$150–-$600
		Over $600
Complexity		A scale from low to high is used to indicate the complexity of carrying out each CBM monitoring method. It is indicative only, assuming little prior monitoring experience.

For many of the indicators presented in this section, there are existing videos available on-line that demonstrate how to measure them. Links to these videos are included as training resources in Section 5 and website links to them are provided in Section 7. Taking a look at these videos may be helpful for your group to understand more about the time and complexity involved with monitoring each indicator.

Expensive equipment doesn't guarantee good quality data – you must know how to use and maintain the equipment correctly. Building in good training and quality checks (Section 5) will provide evidence of this and increase your confidence in the data you collect.

Water quality indicators

Table 4-1 outlines the water quality indicators in the national CBM QA framework and their relevance to stream health. For most of these indicators you can find more detail on how they are measured and what they tell us about stream health:

- in Chapter 3 of NIWA's Stream Health Monitoring and Assessment Kit (SHMAK) manual, or
- from fact sheets available on the Land Air Water Aotearoa (LAWA) website.

Most of the water quality indicators need to be measured either in the stream with a field meter or by performing a test on a water sample collected from the stream. We therefore look at field meter measurements and water sampling methods first. Measurement methods and resource requirements then follow in table format for each of the 18 water quality indicators.

Table 4-1: Stream health water quality indicators in the national CBM QA framework.
Key: * Indicators that must be measured in the field, + Indicators that must be measured by a professional lab

Indicator	Relevance to stream health
Water temperature*	WHAT: A physical property expressing how hot or cold water is. WHY: Influences the rates of chemical and biological processes (e.g., algal growth rates) and recreational use and affects other indicators of stream health such as dissolved oxygen, conductivity and the toxicity of ammonia to aquatic life. Very high water temperatures can kill fish and invertebrates.
Dissolved oxygen (DO)*	WHAT: The amount of oxygen dissolved in water and therefore a direct indicator of a stream's ability to support aquatic life. WHY: Low levels may indicate organic pollution (e.g., from wastewater or animal effluent entering the stream) and result in release of nutrients stored in sediments on the streambed. Very low DO levels can result in fish kills.
Visual clarity* and turbidity	WHAT: Visual clarity is a measure of underwater visibility in streams that reflects the amounts of fine sediment, algae, and other particles suspended in the water. Turbidity is the murkiness or cloudiness of water, indicating, for example, the presence of suspended sediment, dissolved solids, chemicals and algae. Best used only as a proxy for visual clarity or suspended sediment. WHY: Reduced visual clarity (high turbidity) can harm aquatic animals and river birds who rely on sight to find prey and avoid predators, and swimmers who may not see underwater hazards. Reduced clarity also reduces the amount of light passing through the water to the streambed for use by plants for photosynthesis. Low visual clarity may indicate that fine sediment is getting into the stream and this is often accompanied by faecal and nutrient contamination.

Suspended sediment+	WHAT: Sediment suspended in the water column, often consisting of a mixture of inorganic clays and silts and organic particles such as algae and tiny fragments of dead leaves. WHY: As well as reducing visual clarity, suspended sediment may carry other contaminants (e.g., phosphorus, metals) and can clog the gills of fish and benthic macroinvertebrates. It can also settle out on the streambed, reducing the quality of this habitat and smothering organisms that live there.
Conductivity	WHAT: A measure of the ability of a water to pass an electrical current. WHY: A useful general measure of water quality as it indicates the concentration of dissolved substances and minerals present. Streams tend to have a relatively constant range of conductivity so, a significant change in conductivity could suggest that some source of pollution has entered the stream. Groundwater inflows and catchment geology can also influence conductivity.
pH	WHAT: The hydrogen ion concentration of the stream water, essentially representing its acidity (low pH) or alkalinity (high pH). WHY: Aquatic life can't tolerate extremely low or high pH. pH also influences the toxicity of ammonia and some metals (e.g., copper and zinc).
Nutrients – Nitrogen (N) and Phosphorus (P)	WHAT: Essential elements for plants and animals and natural components of healthy streams. WHY: As outlined below, in certain forms and amounts, N and P can impact aquatic life, recreational values and human health.
• Ammoniacal-N	WHAT: A soluble form of N in water. Rarely found in any significant amounts in natural waters so its presence most commonly indicates wastewater or animal effluent is also present. WHY: Can be toxic to aquatic life at high concentrations, especially fish.
• Nitrate-N	WHAT: Very soluble in water and forms the main component of N that is biologically available. WHY: Concentrations above natural levels (which are typically very low) can increase nuisance growths of algae and aquatic plants, provided requirements for other essential nutrients (like P) are met. Toxic to aquatic life at very high concentrations. Can also be harmful to livestock and human health.
• Dissolved inorganic N	WHAT: The sum of ammoniacal-N, nitrite-N and nitrate-N. WHY: Represents the total dissolved or soluble inorganic component of the total N in the water column. Often similar to a stream's nitrate-N concentration except where streams are impacted by high levels of pollutants and low DO levels.
• Total N+	WHAT: The sum of all forms of N present in a stream, including organic and inorganic forms organic (e.g., in suspended algae cells). WHY: Indicates how much nitrogen could potentially become biologically available instream or in downstream environments such as lakes and estuaries if the right conditions exist.

* Dissolved Reactive P	WHAT: A soluble form of P in water, making it readily available for uptake by aquatic plants. WHY: High concentrations can increase nuisance growths of algae and aquatic plants and degrade stream habitat.
* Total P+	WHAT: The sum of all forms of P present in a stream, including organic and inorganic forms. WHY: Indicates how much P could potentially become biologically available instream or in downstream environments such as lakes and estuaries if the right conditions exist. Often closely correlated with suspended sediment and turbidity as some forms of phosphorus 'stick' to fine sediment, entering streams through surface runoff and bank erosion.
Copper (dissolved)+	WHAT: Copper and zinc are natural elements that are essential for metabolism but can be toxic to aquatic life at high concentrations. Both are common urban contaminants transported to streams via stormwater from roads (zinc from vehicle tyre wear, copper from brake pad wear), buildings (e.g., zinc from galvanised roofs and copper from spouting and other fixtures) and industrial yards. Copper is also found in some antifouling paints as well as some fungicides used in residential gardens and horticultural areas. WHY: Dissolved concentrations represent the forms that are most readily available to impact aquatic life. Copper and zinc can accumulate in sediments and living organisms.
Zinc (dissolved)+	
E. coli	WHAT: Microbiological indicator bacteria for faecal contamination and the preferred indicator for determining the suitability of fresh waters for drinking and contact recreation, including food harvest. WHY: The presence of *E. coli* may indicate the presence of harmful pathogens[1] that can cause eye, ear, nose and throat infections, skin diseases, and gastrointestinal disorders – some pathogens in contaminated water can also be transmitted to livestock and affect their health. Nearly always found in high numbers in the gut of humans (i.e., present in wastewater discharges) and other warm-blooded animals (e.g., sheep, cattle, birds).
Enterococci+	Microbiological indicator bacteria for faecal contamination and the preferred microbiological indicator bacteria for assessing human health effects from recreational activities in saline waters. See also *E. coli*.

[1] Faecal indicator bacteria such as *E. coli* and enterococci are measured in water rather than the actual pathogens (e.g., salmonella, campylobacter, cryptosporidium, giardia) because pathogens are only periodically present (when a sick person or animal is shedding the pathogen). Pathogen tests are also often difficult and expensive.

Field meter measurements

Water temperature, dissolved oxygen (DO), conductivity, pH and turbidity are the five water quality indicators in the national CBM QA framework that can be measured using a field (water quality) meter. Only water temperature and DO must be measured in the field using a field meter. Conductivity, pH and turbidity can also be measured by collecting a water sample and sending it to a lab for testing.

Should my group purchase a field/water quality meter?

This depends on what water quality indicators your group wants to measure and your budget and time. A wide range of inexpensive thermometers are available for measuring water temperature if this is the only water quality indicator that will be measured in the field. Conductivity meters can be purchased for as little as $100 and are a worthwhile one-off investment for making measurements of conductivity.

At the very least access to a field meter will be needed if your group wishes to monitor DO. Any meter that measures DO, conductivity or pH will also measure water temperature (because measurements of these indicators vary with water temperature).

All field meters require regular maintenance and checks of sensor performance. This is particularly important for DO, pH and turbidity measurements because these sensors typically drift over time. Conductivity sensors are generally more stable – but a check still needs to be made with standard solutions to confirm the sensor is reading within an acceptable range.

Field meters range widely in price and performance. Some are fitted with a single sensor or probe (e.g., for measuring pH) while others are multi-sensor meters. Some meters have a fixed set of sensors while others allow different sensors to be added or swapped out for another sensor. Reliable multi-sensor meters will likely be cost-prohibitive for most CBM groups.

Field meters that measure DO, pH and turbidity can be expensive. For DO, meters with an optical sensor are the most reliable and require less maintenance than membrane-based galvanic or polarographic sensors. However, the price of DO meters with an optical sensor starts from around $1,500. One option may be to pool resources with another monitoring group or loan a field meter from a regional council or other organisation.

Similar to DO, pH and turbidity meters are generally upwards of $1,500 each. This expense, as well as the time (and cost) involved with sensor quality checks, mean that it is generally easier to collect a water sample for a lab to measure pH and turbidity. A test-strip can also be used to estimate pH if your group does not require a precise measurement. In the case of turbidity, if your group would prefer a field measurement or an immediate result over a lab measurement, then consider measuring the closely related visual water clarity indicator instead.

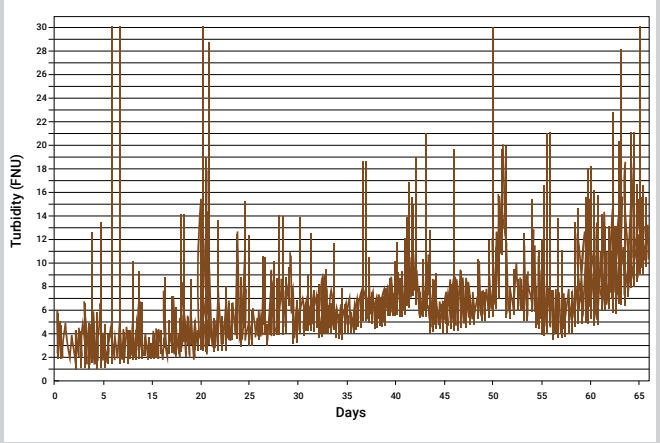
Although the national CBM QA framework provides an option to use a field meter to measure pH and turbidity, these meters can be expensive, and sensor calibration and maintenance can be time-consuming and difficult. We recommend lab testing if you need consistently accurate and reliable results, especially if you are unlikely to be monitoring for more than a few years.

High frequency sensor-based water quality measurements

Water temperature, DO, conductivity, pH, turbidity and nitrate-nitrogen are examples of indicators than can be measured at high frequency (e.g., every 5 or 15 minutes).

Sensor performance varies widely across meters and despite the "plug and play" claims of some manufacturers and retailers, most sensors can rarely be left in a stream for more than a few weeks before they will need some checking and maintenance. A common issue is sensor drift from algae growing on the sensor (biofouling). Although some instruments have mechanical wipers to clean the sensor face, the wipers are not maintenance free and will only slow rather than eliminate biofouling. This means that the raw data record from the sensor will generally need to be 'cleaned' before it can be reliably used.

Example of biofouling on a multi-sensor meter that has been deployed in the field.



Example of drift in a turbidity sensor over a 65 day deployment.

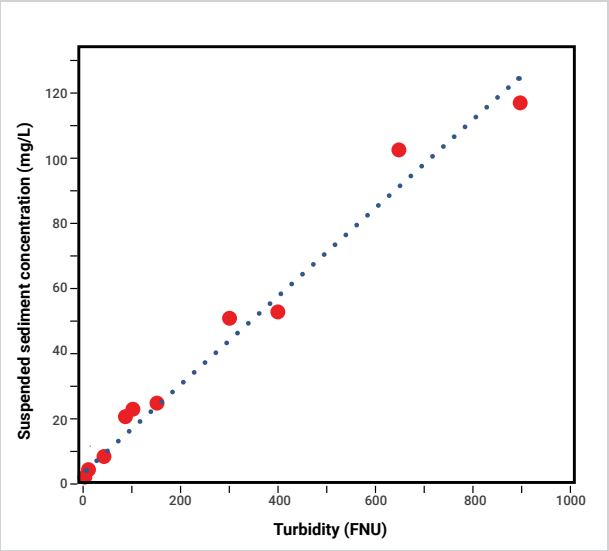
What is sensor drift and why does it matter?

Sensor drift is a common problem that can lead to inaccurate measurement readings. Drift can arise from, amongst other things, biofouling, depletion of reagents contained within the sensor, or sensor malfunction.

Drift affects the sensor's accuracy, causing it to be off target. The only way to know if a sensor has drifted is through calibration and validation using a reference instrument or standard. Unless this is done, drift will cause the measurement error to get worse over time. Sensor drift is a common issue when deploying sensors in streams for more than a few weeks.

Sensor verification

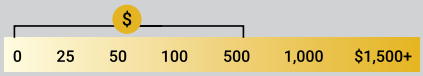
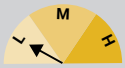
For indicators such as turbidity and nitrate-nitrogen, sensor performance will need to be verified using another sensor or lab testing of water samples collected from close to the sensor. Also, turbidity should only be measured as a surrogate for other water quality indicators, usually sediment and visual clarity. This means that these other water quality indicators will also need to measured for a period of time and over a range of stream flows to establish a relationship between turbidity and the water quality indicator(s) of interest. Only then can the high frequency turbidity measurements be used to estimate sediment concentrations or visual clarity. Stream flow data will also be needed for interpretation.



Relationship established between spot measurements of turbidity and suspended sediment.

Water sample collection and laboratory measurement

Stream water samples should be collected just below the water's surface, usually by hand (A), or with the aid of a sampling pole (B). A bucket and rope (C) may be needed when it isn't easy or possible to access a stream directly.

Collection methods	By hand or with aid of a sampling pole or bucket and rope
Method instructions available from	Instructions and videos available from various sources, such as: • Section 4 of the NEMS Discrete Water Quality (Part 2: Rivers) • NIWA SHMAK manual
Equipment	Disposable gloves (recommended), chillibin and ice or cooler pads to store and transport samples after collection
Caveats	Sampling by hand will not always be possible (e.g., when the stream is too deep, swiftly flowing or turbid for safe entry) and a sampling pole is highly recommended. A bucket and rope are usually reserved for sampling from bridges or towers when the water may be some distance down and can be difficult.
Time	
Equipment cost (initial or one-off)	
Ongoing cost	Negligible
Complexity	
Training and quality checks	See page 91

Water samples not being tested on-site need to be promptly removed from the light and chilled to preserve them until testing can be done. Some water sample tests require the water sample to be preserved with a few drops of acid or by passing it through a filter. If your samples are being tested by a lab, it can usually do these extra preservation steps for you if it receives your (chilled) samples promptly following collection. There is a charge to pay a lab to filter samples but there is also a cost to buying filtering kits and it can be difficult and time consuming to filter stream samples that contain lots of sediment or algae.

Getting a good deal from your lab

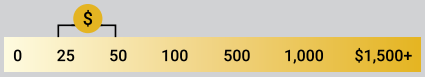
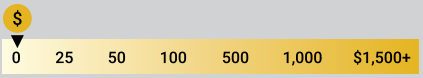
Talk to a lab (or regional council) contact about your test requirements when designing your stream monitoring programme. Labs work with lots of landowners and community groups and can offer a wealth of information on water sample testing.

- For many stream indicators, labs perform tests in large batches and may offer a lower price per test if an agreed minimum number of samples will be provided.
- Depending on the lab you may be able to get a package of tests at a cheaper price than the standard price of each test.
- Test methods for some stream water quality indicators share some common steps, such as needing to be filtered or digested in acid. This means that the cost of an additional test, especially a nutrient or metal test, may not be as much as you think.
- Some labs may be willing to offer a discount to support CBM initiatives and may assist with chillibins, labelled sampling bottles and even courier tickets.

Water temperature

Water temperature is separated into discrete and continuous sensor-based measurements.

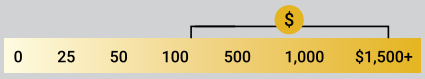
Discrete measurements

Measurement units	˚C	
Measurement type	Field measurement	
Measurement methods	Thermometer	Field meter
Data use	 Depends on specific data use	
Method instructions available from	• NIWA SHMAK manual • Wai Care manual	NEMS Discrete Water Quality (Part 2: Rivers)
Equipment	Analogue or digital thermometer	Field meter with a temperature sensor (e.g., a dissolved oxygen or conductivity meter)
Caveats	Analogue thermometers can't be calibrated and measurements are not as accurate or precise as those made using a temperature sensor on a standard field meter	Sensors should be checked with a reference thermometer at least annually
Time		
Equipment cost (initial or one-off)		
Ongoing cost	Negligible	
Complexity		* 
Measurement range and resolution	Depends on thermometer/meter. For analogue measurements, record to the nearest 0.5˚C	
Training and quality checks	See page 87	

* Assumes use of an existing field meter for DO, conductivity or pH, all of which will have a built-in temperature sensor.

Continuous measurements

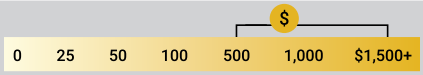
Continuous measurements are made in the same way as discrete measurements but a sensor is deployed in the stream for a period of time to record measurements at high frequency. This requires use of a temperature sensor with a waterproof logging function, such as Onset's Hobo® Pendant MX Water Temperature data logger (included in the NIWA SHMAK kit). This and other similar loggers have Bluetooth wireless access options to deliver temperature measurements directly to your mobile phone or a Windows computer. The data are delivered through an app (e.g., HOBOconnect app).

Measurement units	˚C
Measurement type	Field measurement
Measurement methods	Water temperature sensor and logger
Data use	
Method instructions available from	• NIWA SHMAK manual (Hobo pendant logger) • NEMS Continuous Water Temperature
Equipment	Temperature sensor with a waterproof logging function, and something to mount or attach this device to (e.g., waratah and cable ties or bracket)
Caveats	The NEMS Continuous Water Temperature recommends measurement intervals of no less than 5 minutes (but 15–60 minute intervals should be sufficient for many data uses and will reduce the volume of measurements to manage)
Time	
Equipment cost (initial or one-off)	
Ongoing cost	Negligible
Complexity	
Measurement range and resolution	Depends on sensor type and logging interval selected
Training and quality checks	See page 87

Dissolved oxygen

Dissolved oxygen (DO) is separated into discrete and continuous sensor-based measurements.

Discrete measurements

Measurement units	% saturation and mg/L (equivalent to g/m³)
Measurement type	Field measurement
Measurement methods	Field meter* • Optical (luminescent) sensor – recommended (see page 40) and NEMS compliant • Electrochemical, membrane-based (polarographic or galvanic) sensor
Data use	
Method instructions available from	NEMS Discrete Water Quality (Part 2: Rivers)
Equipment	DO meter (or a field meter with a DO sensor). Optical sensors are more stable and, require less maintenance and calibration than membrane-based sensors.
Caveats	NEMS requires a sensor accuracy of ± 3% and ±0.3 mg/L. Barometric pressure must be recorded if the DO sensor does not automatically measure this. Electrical conductivity also needs to be measured if the stream is influenced by coastal tides.
Time	
Equipment cost (initial or one-off)	
Ongoing cost	Periodic meter servicing required
Complexity	
Measurement resolution	Sensor dependent but generally 0 to 200% and 0–20 mg/L at a resolution of 0.1% or 0.1 mg/L (likely 0.5 mg/L if using a meter that has an analogue scale)
Training and quality checks	See page 87

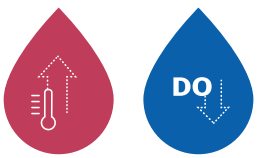
* DO can also be measured using a Winkler titration but this method is not included in the framework as it is difficult to perform reliably. See the technical guidance document for more details.

DO saturation vs concentration and important supporting measurements

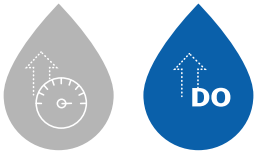
Oxygen saturation (%) and oxygen concentration both measure the amount of oxygen dissolved in water.

- Oxygen saturation is a ratio of the concentration of DO to the amount of oxygen that can potentially be dissolved in water at a given water temperature, atmospheric pressure, and salinity.
- Oxygen concentration is the actual amount of DO in the water. It is calculated from the measurement of saturated DO.

The presence of dissolved salts, such as from saline water, can alter DO saturation, as can the presence of organic matter – such as decaying vegetation, and animal or human waste.



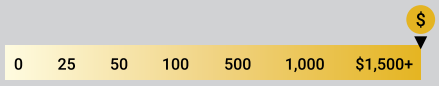
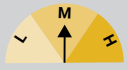
As water temperature or salinity increase, DO in water reduces. In contrast, as barometric pressure increases, DO also increases.



Continuous measurements

Continuous measurements are made in the same way as discrete measurements but a sensor is deployed in the stream for a few days or more to record measurements at high frequency. This requires use of a field meter with a waterproof logging function.

Note: This table assumes a deployment period of no more than about four weeks and so minimal or no sensor cleaning or recalibration is required.

Measurement units	% saturation and mg/L (equivalent to g/m³)
Measurement type	Field measurement
Measurement methods	DO sensor and logger (e.g., a PME miniDOT® Clear Logger, Hobo U266 DO Logger) • Optical (luminescent) sensor – recommended and NEMS compliant • Electrochemical, membrane-based (polarographic or galvanic) sensor
Data use	
Method instructions available from	NEMS Continuous Dissolved Oxygen
Equipment	DO sensor with a waterproof logging function, and something to mount or attach this device to (e.g., waratah and cable ties or bracket)
Caveats	NEMS requires a sensor accuracy of ± 3% and ±0.3 mg/L. Barometric pressure must be recorded if the DO sensor does not automatically measure this. Electrical conductivity also needs to be measured if the stream is influenced by coastal tides or other saline inputs. The NEMS recommends measurement intervals of no less than 15 minutes (but 30-60 minute intervals may be sufficient for many data uses and will reduce the volume of measurements to manage).
Time	
Equipment cost (initial or one-off)	
Ongoing cost	Periodic meter servicing required
Complexity	
Measurement range and resolution	Sensor dependent but generally 0 to 200% and 0–20 mg/L at a resolution of 0.1% or 0.1 mg/L
Training and quality checks	See page 87

Visual water clarity

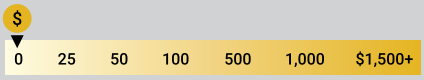
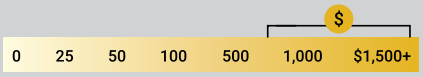
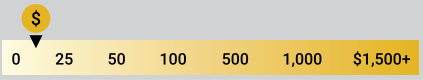
The national CBM QA framework has measurement methods for visual water clarity – the horizontal clarity tube measurement (A) and the horizontal black disc method (B).

Measurement units	m	
Measurement type	Field measurement	
Measurement methods	Clarity tube	Horizontal black disc
Data use	Unsuitable if visual clarity needs to be quantified above 0.5–1 m	Suitable for all data applications; essential where visual clarity >1 m must be quantified
Method instructions available from	• NIWA SHMAK manual • NEMS Discrete Water Quality (Part 2: Rivers)	
Equipment	Clarity tube and black target mounted on a magnet	Set of 3 x black discs, underwater viewer (with 45 degree mirror) and measuring tape
Caveats	Limited to a measurement of between 0 and 1 m and the relationship with black disc is only equivalent between 0 and 0.5 m	Unsafe in high or very turbid flows and can be difficult in shallow, weedy streams (use a clarity tube in these conditions)
Time		
Equipment cost (initial or one-off)	$ 0 25 50 100 500 1,000 $1,500+	$ 0 25 50 100 500 1,000 $1,500+
Ongoing cost	Negligible	Negligible
Complexity	L M H	L M H Easier and safer with 2 people
Measurement resolution	1% (0.01 m or 1 cm)	1% (0.01 m or 1 cm) or 0.1 m if visibility is >10 m
Training and quality checks	See page 89	

Clarity tube and black disc comparison

The clarity tube was designed by NIWA as an easy-to-use, quick method for estimating visual clarity in small, and often shallow and turbid rural streams. Although designed using the same measurement principle as a black disc, the original testing demonstrated that a clarity tube can only reliably estimate black disc visual clarity up to around 0.5–0.7 m. For clarity tube measurements over 0.5 m, the tube measurement can be converted to black disc clarity using the equation in Kilroy and Biggs (2002). This conversion is not suitable for some types of coloured stream waters. We recommend using a black disc if visual clarity is regularly greater than 0.5 m.

Turbidity

Measurement units	Various – generally Nephelometric Turbidity Unit (NTU) and the Formazin Nephelometric Unit (FNU)	
Measurement type	Field measurement or lab measurement made on a water sample	
Measurement methods	Turbidity meter (field)	Turbidity meter (lab)
	• IS0 7027 (near infra-red light, FNU) – NEMS compliant • APHA 2130 B (white light, NTU)	
Data use		
Method instructions	NEMS Discrete Water Quality (Part 2: Rivers)	
Equipment	Turbidimeter (or a field meter with a turbidity sensor)	Sample bottle, chilly bin and ice packs
Caveats	Turbidity measurements vary with sensor make and model so consistency in sensor type through time is critical. The upper range of the measurement on some sensors is only 1,000 NTU or FNU so will not return a measurement for sediment-laden/ flood water samples. Regular sensor calibration is also required.	If you need measurements from very sediment-laden (flood water) samples, ask the lab to take measurements on diluted samples
Time		
Equipment cost (initial or one-off)	Periodic meter servicing required	
Cost per sample		
Complexity		
Detection limit	Sensor dependent but generally 0.05–0.1 NTU or FNU	
Measurement range and resolution	Sensor dependent but generally a minimum of 0 to 1,000 NTU or FNU, with some field and lab sensors able to record up to 4,000 NTU or FNU without needing to dilute the sample. Report to one decimal place between 0 and 10 NTU or FNU, and to no more than the nearest whole number above 10 NTU or FNU.	
Training and quality checks	See page 97 (lab measurements)	

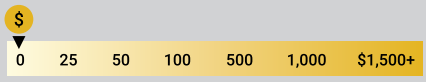
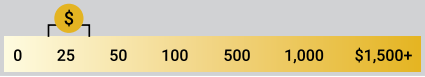
What is the difference between NTU and FNU?

Different turbidity meters measure turbidity in different ways because of differences in their design. Both NTU and FNU scales measure turbidity by the scattered light method but use different light sources to do this. Meters that measure turbidity using the visible light spectrum that the human eye can detect (400-600 nanometers (nm), referred to as white light) report in NTU, in line with the US EPA 180.1 standard. In contrast, turbidity meters that use infrared light at 860 nm report in FNU, in line with ISO 7027, the European drinking water protocol. The differences in light source between meters means that a measurement from a 'white light' meter will not be the same as that from a 'infrared light' meter.

In NZ, the NEMS recommends the use of IS0 7027 compliant sensors for river and stream measurements (i.e., FNU). Whatever meter is used, it is critical that the meter make, model and units are recorded with the measurement values.

Suspended sediment

In the national CBM QA framework, suspended sediment refers to total suspended solids (TSS), sometimes shortened to suspended solids.

Measurement units	milligrams per litre, mg/L (equivalent to g/m³)
Measurement type	Lab measurement made on a water sample
Measurement methods	APHA 2540 D
Data use	 Some specific data uses or some councils may require the suspended sediment concentration (SSC) to be measured. See information box (below).
Method instructions available from	Contact your lab. Also see NEMS Discrete Water Quality (Part 2: Rivers)
Equipment	Sample bottle, chilly bin and ice packs. May require a sample pole or similar device for sampling in high flow conditions.
Caveats	Can require a large volume of sample to be collected if a low detection limit is needed. The test may underestimate the actual amount of sediment present when a sample is very dirty.
Time	
Equipment cost (initial or one-off)	
Cost per sample	
Complexity	
Detection limit	Varies with sample volume but generally around 3 mg/L for a 1 L sample (a 2 L sample is required to achieve a limit of 1 mg/L if the water is very clean)
Measurement range and resolution	Varies with sample volume. Reported to nearest 1 mg/L when concentrations are less than 100 mg/L.
Training and quality checks	See page 97

* More complex than routine water sample collection if targeting wet weather or high flow conditions.

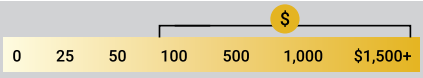
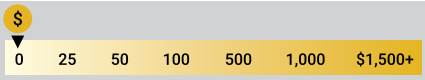
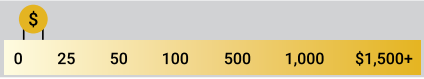
What is the difference between SSC and TSS?

Suspended sediment concentration (SSC) and total suspended solids (TSS) are both measured in a similar way and reported in the same units. However, the results from the two test methods often differ when samples contain a lot of sand. This is due to the amount of the sample that is tested. A SSC test uses the entire water sample. In contrast, unless the sample is very clear, the test method for TSS only uses a portion of the sample, called a subsample. Although the original sample is mixed before a subsample is removed, heavy sands settle out very quickly so the subsample may not be completely representative of the much larger original sample. This means that, for very dirty samples, the TSS test result will generally be lower than a SSC test result.

Should I measure SSC?

Regional councils generally use SSC testing when they want to accurately understand the amount of sediment passing through streams into lakes or estuaries downstream. It is a more expensive and time-consuming test when water samples are very dirty and is not offered by some NZ labs. A TSS test will answer most sediment-related questions but talk to your council or a specialist if more robust sediment load monitoring is a priority for your group.

Electrical conductivity

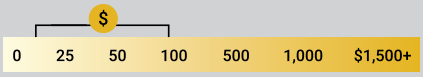
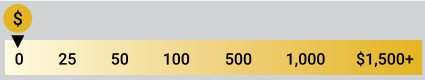
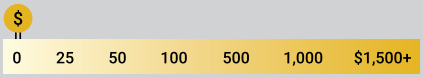
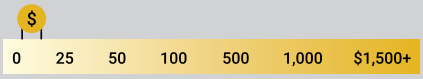
Measurement units	µS/cm @ 25˚C – although other measurement units may be used (e.g., mS/cm or mS/m)	
Measurement type	Field measurement or lab measurement made on a water sample	
Measurement methods	Conductivity meter (field)	Conductivity meter (lab) • APHA 2510 B (NEMS compliant)
Data use	 NEMS requires a sensor accuracy of ± 1 µS/cm	
Method instructions available from	• NIWA SHMAK manual and video • NEMS Discrete Water Quality (Part 2: Rivers)	
Equipment	Conductivity meter (or a field meter with a conductivity sensor)	Sample bottle, chilly bin and ice packs
Caveats	Conductivity increases with increasing water temperature and should be measured using a meter that can output the measurements at a standard reference temperature of 25˚C, in line with NEMS requirements and reporting of conductivity by NZ labs.	
Time		
Equipment cost (initial or one-off)		
Cost per sample	Negligible*	
Complexity	 *	
Detection limit	Sensor dependent but generally 1 µS/cm	
Measurement range and resolution	Sensor dependent but generally 1 to 50,000 µS/cm, which spans pure water to seawater. Some (especially low cost) sensors have a smaller measurement range of around 1-20,000 µS/cm. Reporting to the nearest 1 µS/cm is sufficient.	
Training and quality checks	See pages 87 (field measurements) and 97 (lab measurement)	

* Measurement is straightforward but the sensor needs periodic quality checks (validation and calibration) using standard solutions.

What does SpC on my meter display mean?

A reference to SpC means specific conductance. Electrical conductivity measurements vary with water temperature and so are best standardised to a specific water temperature, usually 25˚C. Many conductivity meters can report conductivity both at the temperature of the water measured as well as a standardised temperature of 25˚C (an algorithm is automatically applied). Always record the SpC measurement value so that you can compare your measurements with those from other sites and datasets.

pH

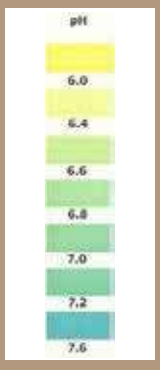
Measurement units	pH units	
Measurement type	Field measurement (self-test kit) or lab measurement made on a water sample	
Measurement methods	Field measurement (self-test kit)* • pH test strips (e.g., MColorpHast™)	pH meter (lab) • APHA 4500-H+ B (NEMS compliant)
Data use	 Depends on specific data use	
Method instructions available from	Test kit	NEMS Discrete Water Quality (Part 2: Rivers)
Equipment	Test strips	Sample bottle, chilly bin and ice packs
Caveats	Test strips have low measurement precision especially if the strips span the full pH 1–14 range, and so less precise than lab measurements. For most stream monitoring, selecting strips with a limited pH range (e.g., 5–9) will increase measurement precision and provide more useful data.	Water sample needs to be airtight (no air bubbles) and dispatched promptly to the lab
Time		
Equipment cost (initial or one-off)		
Cost per sample (Test kit includes up to 100 test strips)		
Complexity		
Measurement range and resolution	Depends on test kit - read measurement to the nearest half test strip increment	0–14, reported to 1 decimal place
Training and quality checks	See page 93 (self-test kit measurements) and page 97 (lab measurement)	

* Field meters are also widely available but are not specifically recommended in the national CBM QA framework. This is because it can be very difficult to calibrate and get accurate measurement values from pH sensors – reliable sensors are likely to be cost-prohibitive for CBM groups. However, the field forms do allow field-based sensor measurements to be captured (along with mandatory information on sensor type and calibration) should a CBM group have access to reliable sensor.

pH is measured on a logarithmic scale

The difference between a pH value of 7 vs 8 may not seem like much on a measurement scale from 0 (acidic) to 14 (alkaline) but the pH measurement scale is logarithmic. This means that a pH of 8 is ten times more alkaline than a pH of 7!

It is often best to use test strip kits with narrow measurement ranges (e.g., 5–9) that can be read in increments of say 0.2 or at least 0.5 pH units. This is particularly important when you want to compare ammoniacal nitrogen or metal test results against guidelines for aquatic ecosystem health (because toxicity guidelines vary with pH).



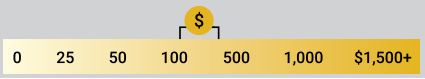
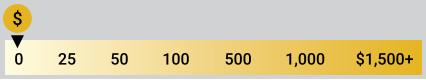
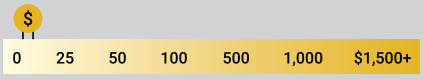
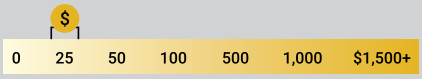
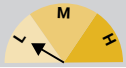
Nitrate-nitrogen (Nitrate-N)

Nitrate-N, like the two other dissolved forms of nutrients in the national CBM QA framework, can be measured using self test kits or by providing a lab with a water sample for testing.

Measurement units	mg/L (equivalent to g/m³)	
Measurement type	Self-test (in the field or at home) or lab measurement made on a water sample	
Measurement methods	Most common test kit options used in NZ • AquaSpex Microtest® Nitrate-N NED (SHMAK), colorimetric test • Hach® nitrate test strips (Auckland Council Wai Care)	Lab test method • APHA 4500 B-NO_3 I (NEMS compliant)
Data use	Suitable for general environmental screening (e.g., to identify pollution 'hotspots')	
Method instructions available from	Provided with the test kit. Also see relevant NIWA SHMAK or Wai Care manual	Contact your lab. Also see NEMS Discrete Water Quality (Part 2: Rivers)
Equipment /materials	Test kit (may include a syringe) and sample bottle	Sample bottle, chilly bin and ice packs
Caveats	If test kit does not go below 0.5 mg/L, a lab test is recommended. Turbid samples should be filtered prior to testing. A sample dilution is required if test result is above the upper end of the measurement range.	Prompt chilling and dispatch to lab required so that the sample can be filtered (preserved). NEMS requires a method detection limit of at least 0.002 mg/L.
Time		
Equipment cost (initial or one-off)	$ 0 25 50 100 500 1,000 $1,500+	$ 0 25 50 100 500 1,000 $1,500+
Cost per sample (25–70 tests included in equipment cost)	$ 0 25 50 100 500 1,000 $1,500+	$ 0 25 50 100 500 1,000 $1,500+
Complexity*	L M H *	L M H
Detection limit	Depends on test kit but 0.05 mg/L at best	0.002–0.005 mg/L
Measurement range and resolution	• AquaSpex Microtest® Nitrate-N NED (HS): 0.05–0.8 mg/L • AquaSpex Microtest® Nitrate-N NED: 0–4.5 mg/L • Hach® nitrate test strips: 0–3 mg/L In all cases, estimate the measurement to the nearest half increment	Generally from 0.002 mg/L upwards, reported to nearest 0.01 mg/L or 2 significant figures
Training and quality checks	See page 93 (self-test kit measurements) and page 97 (lab measurement)	

* Moderate/high if sample filtering and/or a sample dilution is required.

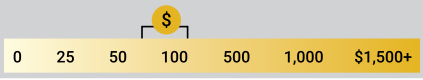
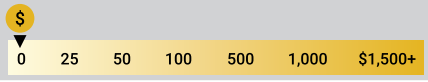
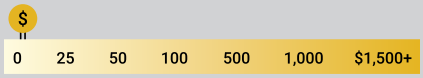
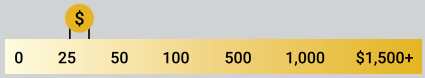
Ammoniacal nitrogen

Measurement units	mg/L (equivalent to g/m³)	
Measurement type	Self-test (in the field or at home) or lab measurement (recommended) made on a water sample	
Measurement methods	Visual test kit option (example): • CHEMets® Ammonia Test Kit K-1510 low range (0–1 mg/L), Direct Nesslerization method	Lab test method: • APHA 4500-NH_3 H (flow injection analyser) – NEMS compliant
Data use	 Generally only suitable for measurements in streams and drains with degraded water quality to confirm a suspected impact from animal effluent or human or industrial wastewater inputs	
Method instructions available from	Provided with the test kit – also see water sample collection requirements	Contact your lab. Also see NEMS Discrete Water Quality (Part 2: Rivers)
Equipment /materials	Test kit and sample bottle	Sample bottle, chilly bin and ice packs
Caveats	Turbid samples should be filtered prior to testing. Chlorine (e.g., if associated with wastewater treatment) may interfere with the results. Sample reagent contains mercury (i.e., hazardous).	Concentrations in most streams are very low, often below lab method detection limits – take extreme care not to contaminate the sample. NEMS requires a method detection limit of at least 0.005 mg/L.
Time		
Equipment cost (initial or one-off)		
Cost per sample (30 tests included in equipment cost)		
Complexity		
Detection limit	Depends on test kit but 0.05 mg/L at best	0.005–0.01 mg/L
Measurement range and resolution	Depends on test kit - read measurement to the nearest half test strip increment	Generally from mg/L upwards, reported to 2 significant figures
Training and quality checks	See page 93 (self-test kit measurements) and page 97 (lab measurement)	

Dissolved inorganic nitrogen (DIN)

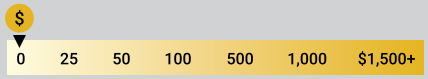
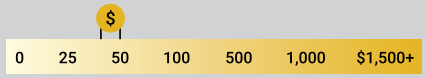
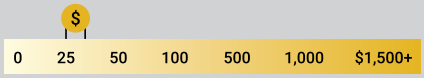
Dissolved inorganic nitrogen is the sum of ammoniacal nitrogen, nitrite-nitrogen and nitrate-nitrogen. It can be measured on a water sample submitted to the lab (see nitrate-nitrogen) and will cost around double a nitrate-N test because it involves two different measurements and a calculation.

Dissolved reactive phosphorus (DRP)

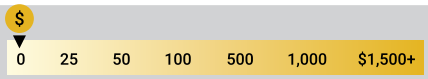
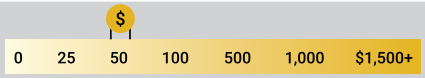
Measurement units	mg/L (equivalent to g/m³)	
Measurement type	Self-test (in the field or at home) or lab measurement made on a water sample	
Measurement methods	Test kit options (commonly used in NZ)* • Hanna® HI-713 Phosphate Pocket Checker (NIWA SHMAK) • AquaSpex Microtest® Phosphate-P MB+ (HS) (Auckland Council Wai Care) * Other kits exist	Lab test method • APHA 4500-P G, flow injection analyser (NEMS compliant) performed on a 0.45 micron filtered sample
Data use	 Depends on specific data use – see caveats	
Method instructions available from	Provided with the test kit – also see water sample collection requirements	Contact your lab. Also see NEMS Discrete Water Quality (Part 2: Rivers)
Equipment /materials	Test kit and sample bottle	Sample bottle, chilly bin and ice packs
Caveats	• Except in highly degraded streams, DRP concentrations are often lower than most test kits can reliably measure and lab measurement is recommended • Turbid samples should be filtered prior to testing (tests on unfiltered samples may not be comparable with lab tests which are always performed on filtered samples) • A sample dilution is required if test result is above the upper end of the measurement range (unlikely in NZ streams) • Some tests measure phosphate and a calculation is needed to express the measurement as DRP	Prompt chilling and dispatch to lab required so that the sample can be filtered (preserved). NEMS requires a method detection limit of at least 0.001 mg/L.
Time		
Equipment cost (initial or one-off)		
Cost per test (25–60 tests included in equipment cost)		
Complexity*	 *	
Detection limit	• Hanna® HI-713: 0.03 mg/L (as DRP) • AquaSpex: 0.05 mg/L	0.001–0.004 mg/L
Measurement range and resolution	• Hanna® HI-713: 0–2.5 mg/L, reported to nearest 0.01 mg/L as phosphate (~0.03 mg/L as DRP) • AquaSpex: 0.025–0.4 mg/L, reported to nearest half increment of the test strip	From 0.001 mg/L upwards, reported to 2 or 3 significant figures
Training and quality checks	See page 93 (self-test kit measurements) and page 97 (lab measurement)	

* Moderate/high if sample filtering and/or a sample dilution is required.

Total nitrogen (TN) and total phosphorus (TP)

	Total nitrogen	Total phosphorus
Measurement units	mg/L (equivalent to g/m³)	
Measurement type	Lab measurement made on a water sample	
Measurement methods	• Direct measurement – APHA 4500-NO3 I (NEMS compliant) following a potassium persulphate digestion (APHA 4500-N C or APHA 4500-P J digestion) • Indirect measurement – calculated from the sum of Total Kjeldahl Nitrogen (TKN, measured via APHA 4500- Norg D) plus Nitrite-N and Nitrate-N	• APHA 4500-P G (NEMS compliant) following a APHA 4500-P B 5 or J acid persulphate digestion
Data use		
Method details	Contact your lab. Also see NEMS Discrete Water Quality (Part 2: Rivers)	
Equipment /materials	Sample bottle, chilly bin and ice packs	
Caveats	The two methods often produce different results, particularly when water samples contain suspended particles. Check which method your regional council uses/requires. NEMS requires a method detection limit of at least 0.01 mg/L.	NEMS requires a method detection limit of at least 0.002 mg/L
Time		
Equipment cost (initial or one-off)		
Cost per sample		
Complexity		
Detection limit	0.01 mg/L (0.11 mg/L for indirect measurement)	Varies from 0.001–0.005 mg/L
Measurement resolution	Reported to 2 or 3 significant figures	
Training and quality checks	See page 97	

Dissolved copper and dissolved zinc

	Dissolved copper	Dissolved zinc
Measurement units	mg/L (equivalent to g/m³)	
Measurement type	Lab measurement made on a water sample	
Measurement methods	APHA 3125 B (ICP-MS) performed on a 0.45 micron filtered sample preserved with nitric acid (NEMS compliant)	
Data use	 For regulatory purposes, you should measure the supporting indicators listed in the caveats below and will likely need your samples tested at trace level	
Method details	Contact your lab. Also see NEMS Discrete Water Quality (Part 2: Rivers)	
Equipment /materials	Sample bottle, chilly bin and ice packs	
Caveats	• Samples must be dispatched promptly to the lab – otherwise they will need to be filtered after collection into a lab bottle containing nitric acid preservative. • For comparison of copper results against environmental toxicity guidelines, dissolved organic carbon (DOC) also needs to be measured. For zinc, DOC, hardness and pH also need to be measured. A DOC sample needs to be collected in a dark brown glass bottle (the lab will supply this). • NEMS requires the detection limits listed below.	
Time*		
Equipment cost (initial or one-off)		
Cost per test*		
Complexity**		
Detection limit	Varies depending on whether screen or trace level is selected* (NEMS requires at least 0.0005 mg/L)	Varies depending on whether screen or trace level is selected* (NEMS requires at least 0.001 mg/L)
Training and quality checks	See page 97	

* Assumes samples are measured at trace level for both Cu and Zn. Does not include the costs of measuring DOC, hardness or pH. Although ultra-trace tests are available, these are unlikely to be required for most CBM purposes and a very high attention to detail is required to avoid contamination during sampling (e.g., sunblock and powdered disposable gloves generally contain zinc).

** Assumes samples are filtered by the lab rather than in the field. Time is 15 minutes and complexity is moderate if field filtering is required.

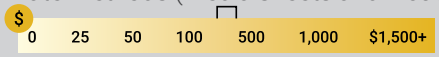
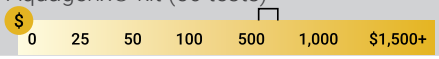
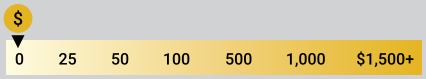
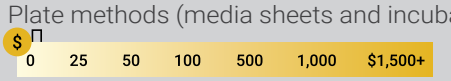
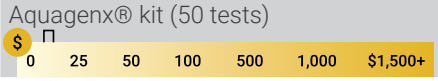
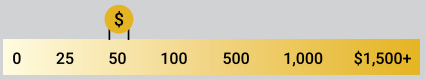
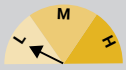
The influence of DOC, hardness and pH on metal toxicity

The toxicity of copper and zinc to aquatic life varies with the physical and chemical conditions of the stream water. For example:

- zinc toxicity is higher in soft (low hardness) and alkaline (high pH) waters
- both copper and zinc toxicity decrease as the amount of organic material in the water (e.g., from decomposing plant and animal material) increases. This is typically measured as dissolved organic carbon or DOC.

Hardness, pH and DOC are examples of toxicity modifying factors (TMFs). The correct use of NZ aquatic toxicity guidelines requires these TMFs to be measured (or at least estimated) alongside dissolved copper and zinc concentrations. More information is available in Gadd et al. (2023).

Escherichia coli (*E. coli*)

Measurement units	The number of *E. coli* colonies per 100 mL, presented as either the most probable number (MPN) or colony forming units (CFU) per 100 mL	
Measurement type	Self-test (at home) or lab test made on a water sample	
Measurement methods	Test kit options (commonly used in NZ): • 3M™ Petrifilm™ *E. coli* plates (NIWA SHMAK) • MC-Media Pad® *E. coli* plates • Aquagenx® CBT EC-TC MPN kit	Lab test methods: • APHA 9223 B, Colilert (NEMS compliant) • APHA 9222 G, membrane filtration
Data use	 Depends on specific data use. Regulatory uses will likely require testing by an accredited lab.	 Some regulatory uses may specify a minimum detection limit or a minimum number of samples
Method instructions available from	• Plate methods: See NIWA SHMAK manual • Aquagenx®: See instructions provided with the kit	Contact your lab. Also see NEMS Discrete Water Quality (Part 2: Rivers)
Equipment /materials	Test kit and sterile sample bottle plus a chilly bin, ice and an incubator for plate methods	Sterile sample bottle, chilly bin and ice packs
Caveats	• Sample must be removed from the light and tested within 24 hours • Plate methods*: Sample dilution with distilled water is required to quantify heavily contaminated waters (e.g., >8,000–10,000 *E. coli* per 100 mL) • Aquagenx®: Designed for drinking waters and can not quantify higher *E. coli* counts found in many streams as well as plate test methods. Only a single 10-fold sample dilution is possible.	• Sample must be removed from the light, chilled to below 10˚C and dispatched to the lab for testing within 24 hours • The Colilert® test method can't produce an *E. coli* count above 2,419 MPN/100 mL unless a sample dilution is performed • Membrane filtration methods may not work well on very turbid samples and a sample dilution may be needed
Time		
Equipment cost (initial or one-off)	Plate methods (media sheets and incubator):  Aquagenx® kit (50 tests) 	
Cost per test	Plate methods (media sheets and incubator):  Aquagenx® kit (50 tests) 	
Complexity	 Plate methods  Aquagenx method	
Detection limit	From 1 MPN/100 mL or 1 CFU/100 mL** for plate-based methods	
Measurement resolution and range	Depends on test method and volume of sample tested but to nearest whole number for CFU tests or as per statistical tables (MPN tests). Plate methods offer higher precision than MPN methods.	
Training and quality checks	See page 93	See page 97

* *E. coli* bacteria range from very low to very high numbers in some streams, so getting a reliable measurement using plate methods often requires multiple tests using different volumes of subsample.

** Only applies when a 100 mL sample is tested. If only a 10mL subsample is tested, both the detection limit and measurement resolution reduce to 10 *E. coli* per 100 mL.

What are MPN and CFU?

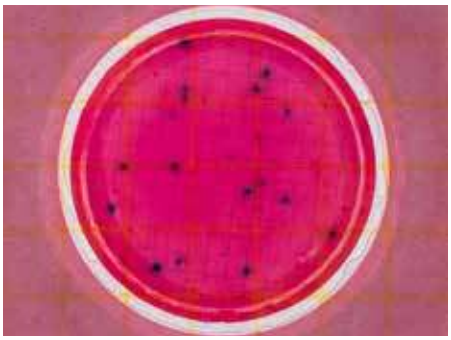
MPN stands for Most Probable Number and is a statistical estimate of the viable *E. coli* cell numbers. Methods that report MPN results for *E. coli* are based on tests that use different volumes of the sample contained in multiple wells (e.g., in a Colilert Quantitray®), compartments (e.g., Aquagenx® CBT) or in multiple tubes (e.g., 5 tubes with each tube representing a different sample dilution). After an incubation period, the number of positive wells, compartments or tubes is used to generate the MPN result from statistical "look-up" tables.

CFU stands for Colony Forming Units. Methods reporting in CFU are based on an actual count of the number of *E. coli* colonies from a membrane filtration test. A membrane filter is placed on an agar (or similar) test plate and a known volume of sample added before the plate is incubated for a period. If the test is performed on a diluted sample, the count of the *E. coli* colonies present on the plate after incubation must be multiplied by the dilution factor to express the result per 100 mL.

Are Colilert (MPN) and membrane filtration (CFU) test results comparable?

Both MPN and CFU test methods are reliable and can give a good assessment of potential microbial risks of stream waters used for recreation or drinking. Both methods express an estimate of the number of *E. coli* bacteria per 100 mL of sample, allowing the results between the two methods to be compared. However, the tests work by different processes and therefore will not necessarily produce equivalent results.

For lab testing of stream (and lake) samples, the NEMS recommends the use of Colilert method. This method can quantify *E. coli* counts up to 2,419 MPN/100 mL without the need to perform a sample dilution.



From left to right: A typical sterile sampling bottle used for collection of water samples for *E. coli* and enterococci testing, preparing a test plate (membrane filtration method) before incubation, checking the temperature of the water bath in a home-made portable incubator, and the *E. coli* colonies found on a plate after incubation. For details on colony counting, see page 96.

Enterococci

Measurement of enterococci requires collection of a water sample for lab testing. Details are the same as for a lab-based *E. coli* test, except that the method options are:

- APHA 9230 D b (Enterolert) with a detection limit of 1 MPN/100 mL for fresh waters and 10 MPN/100 mL for marine waters, and
- APHA 9230 C (membrane filtration) with a detection limit starting from 1 CFU/100 mL.

An enterococci test is similar in cost to an *E. coli* test.

Aquatic life indicators

Table 4-2 outlines the aquatic life indicators in the national CBM QA framework and their relevance to stream health. More detail on the importance of these indicators, how they are measured and what they tell us about stream health can be found in Chapter 3 of the SHMAK manual.

Most of the aquatic life indicators are observation-based measurements but macroinvertebrates may also be monitored by collecting and preserving a sample for identification later by your group or a specialist lab. The national CBM QA framework also provides for monitoring of macroinvertebrates and fish through collection of stream water samples for environmental DNA (eDNA) testing. Because eDNA testing is still relatively new compared to other methods and will detect the presence of other species (e.g., plant, birds and stock), eDNA test requirements are presented first in their own table. An explanation of eDNA is also provided.

Table 4-2: Stream health aquatic life indicators in the national CBM QA framework. The specific measurement for each indicator is provided in the tables that follow.

Indicator	Relevance to stream health
Periphyton 	WHAT: Communities of algae and cyanobacteria attached to the surface of rocks, sediment or aquatic plants in streams and form part of the benthic (stream bed) community in rivers. Periphyton grows in a variety of forms from thin films to thick mats or long filaments in shades of green and brown. WHY: Periphyton provides a food source for macroinvertebrates but thick growths can lead to reduced food quality and may also change macroinvertebrate habitat. Thick periphyton growths also look unsightly and can be a nuisance, spoiling recreational activities such as swimming and fishing, and clogging water intakes and filters. Periphyton blooms are usually a symptom of a stream system stressed by factors such as nutrient enrichment, and high light and water temperatures. Thick and extensive periphyton cover can contribute to depleted night-time dissolved oxygen levels.
Microcoleus cyanobacteria 	WHAT: A specific genus of cyanobacteria or "toxic algae" that grows as dark brown-black mats on the stream bed. Originally known as *Phormidium*. WHY: Microcoleus can taint drinking water and fish with a musty odour and produce toxins that are harmful to animals and humans. In NZ, there have been over 100 dog deaths associated with Microcoleus.
Macrophytes 	WHAT: Large aquatic plants, often (but not always) with leaves and roots. Common in muddy or sandy-bottom streams. WHY: Macrophytes produce oxygen while photosynthesising during the day, provide refuge for fish and habitat for benthic macroinvertebrates, and contribute to nutrient cycling. However, in high volumes, macrophytes can impact swimming or fishing, impede river flow (increasing flooding risk), clog water intakes, contribute to depleted dissolved oxygen levels at night, and cause fine sediment to settle on the stream bed. Some macrophytes, such as hornwort, Egeria and Lagarosiphon, are invasive or noxious weeds that can quickly form large dense beds that choke waterways and outcompete other plant and animal species.

Macroinvertebrates  	WHAT: Small animals, including insects, that are part of the benthos (see information box below) of streams and lakes, and large enough to be seen with the naked eye (macro) and lack a backbone (invertebrate). Often called stream or water bugs for short, they include a range of insects (e.g., mayflies, beetles), crustaceans (e.g., kōura/crayfish and shrimps), snails, worms and leeches. WHY: Macroinvertebrates are a key part of stream food webs, feeding on periphyton, macrophytes, leaf litter from nearby trees, dead wood or each other. The aquatic larvae are an important food source for fish and the winged adults are often eaten by birds and bats. The tolerance of different macroinvertebrate types to habitat and water quality conditions is well known so the variety of bugs present in a stream can tell you about ecosystem health. Unlike water quality indicators, which only reflect one point in time, invertebrates reflect a range of habitat and water quality conditions over a longer period of time.
Fish  	WHAT: Fish are top predators in stream ecosystems, where the type and number of each species present affects macroinvertebrate abundance and some ecosystem processes. Native fish species are an important part of NZ's freshwater biodiversity. Most native species are declining in number and some are threatened with extinction. WHY: The range of fish present can tell us about stream habitat and water quality, both at a specific monitoring site and between this site and the sea. Also, about a third of native species spend some part of their lives at sea so they need to be able to travel between the sea and their freshwater habitats to complete their life cycle. This means certain species may not be present at a stream site indicate if there is a physical barrier to migration, such as a dam or culvert, downstream of the site. Other relevant factors include loss of riparian vegetation, low dissolved oxygen levels or food sources, and the presence of introduced fish species.

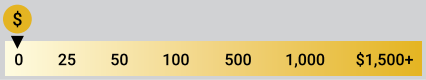
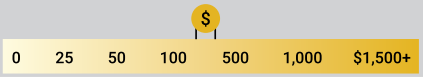
What is the benthos?

Benthos refers to the communities of bacteria, plants and animals that live on, in, or near the bottom of a stream (or lake or sea). It is common to hear freshwater ecologists use terms like stream benthos, benthic cyanobacteria and benthic invertebrates.

Environmental DNA (eDNA)

Two forms of eDNA water sample collection are included in the national CBM QA framework:

- active sampling method: water samples are filtered in the field with a syringe and filter
- passive sampling method[1]: a small filter pod is deployed for 24 hours in an area of stream with moderate to high flow to collect eDNA before retrieval and dispatch to the lab for analysis.

Measurement units	Taxonomic (e.g., species, genus or family)
Measurement type	Lab measurement made on a water sample
Measurement methods	eDNA sequencing using polymerase chain reaction (PCR) technology
Data use	 Will not be suitable for some specific science and regulatory uses (see box on opposite page). Replicate samples are required along with extreme care to avoid sample contamination.
Method instructions available from	Instructions and video available from the Environmental Protection Authority and Wilderlab websites
Equipment	Disposable gloves, special sample syringes and packaging for transport (provided by the laboratory as part of the test price)
Caveats	Test results represent a snapshot in time of what species are present or were (recently) present. They won't tell you how many individuals are present of each species, if the species are alive or dead, or where in the stream the species is located. Also, a test that is negative for a particular species of interest doesn't necessarily mean that species is not present. See box (opposite page) for more details.
Time	
Equipment cost (initial or one-off)	
Cost per sample	
Complexity	
Detection	Dependent on the eDNA library and sample volume. The patchy distribution of eDNA means that a single sample may miss many species that are present. For all data purposes other than engagement and education replicate samples will likely be needed at each site. Six 1 L samples is the optimum number to maximise the probability of species detection but three samples may be sufficient for some investigations.

[1] Wilderlab note that the passive method is still considered a development in progress. It is recommended for flowing sites with very high sediment load, sampling, and pest mammal monitoring.

What is environmental DNA and how is it measured in a stream?

Environmental DNA, or eDNA, refers to various traces of genetic material shed by living organisms as they move in, through and around the environment. Specialist labs can extract and isolate this material from samples of stream water (or sediment) and use genetic libraries or databases to identify hundreds of species, including bacteria, algae, plants, invertebrates, fish, frogs, birds and mammals.

Sources of environmental DNA. © Wilderlab

What will and won't an eDNA testing tell us about a stream?

Testing a stream water sample will give you an extensive list of the species with genetic material present. However, this list will rarely identify all of the species present as not all species are currently available in reference databases. Also, a particular species of interest that isn't listed may be actually present in the stream but there was insufficient genetic material captured in the sample to detect it.

Currently, an eDNA test also won't tell you anything definitive about:

- how many individuals are present of each species,
- if the species were dead or alive at the time of sample collection, or
- whether the species is located at the sampling site or further upstream.

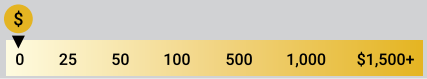
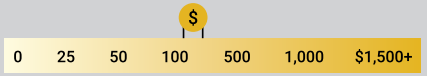
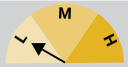
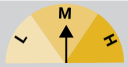
Testing of eDNA in NZ is rapidly evolving and improving. The number and types of species that can be identified will continue to increase, along with confidence in the accuracy of species identification.

Should our group use eDNA testing?

Environmental DNA is a very quick and useful screening and surveillance tool for detecting a large range of animal and plant species, including the potential presence of threatened (endangered) native species or invasive species. Filtering water samples also creates less disturbance in a stream than traditional collection of biological samples. However, in ecological monitoring programmes where current state and trends over time are often of interest, or detailed information is required on the numbers and condition of different species present in a particular stream reach, eDNA testing is best used as a complementary tool alongside traditional, longer established aquatic plant and animal monitoring methods.

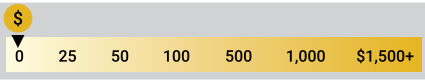
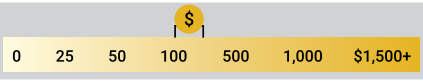
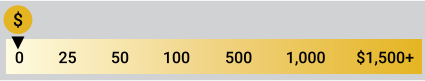
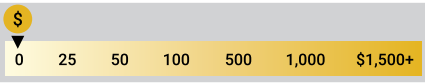
Collecting an eDNA water sample (active method).

Periphyton

Specific indicator	Percentage of the visible or wadeable streambed covered by periphyton			
Measurement type	Field measurement			
Measurement units	%			
Measurement methods	Bankside visual assessment	Instream stone method (NIWA SHMAK)	Instream visual assessment – simplified	Instream visual assessment – detailed (NEMS recommended)
	Basic estimate of percentage cover of 3 categories of periphyton: bare rock/thin films, mat-forming algae and filament-forming algae	Estimate of percentage cover across 10 stones of 6 periphyton categories: as for the bankside assessment but with *Microcoleus* (toxic algae) and Didymo in separate categories + moss/other category	Estimate of percentage cover at 10 points on the streambed, generally from 2 cross sections, of 4 periphyton categories: bare rock, thin films, mat-forming algae and filament-forming algae	As per instream visual simplified assessment but made at 20 points on the streambed, generally along 2 or 4 cross sections and to a higher resolution
Data use	 Depends on specific data use – suitable for general environmental screening		 Depends on specific data use	
Method instructions available from	CBM field form. The NIWA SHMAK periphyton identification guide may also be useful.	NIWA SHMAK guidance manual, video and periphyton identification guide	• NEMS Periphyton • NIWA SHMAK guidance manual, video and periphyton identification guide	NEMS Periphyton
Equipment	None	None	Underwater viewer recommended	Underwater viewer
Caveats	Limited by what can be viewed from the bank	Biased method because it targets stones of a certain size. Therefore, comparisons between sites can be qualitative only	Simplified from NEMS Periphyton	Additional periphyton categories may be required for some data use purposes (e.g., didymo, sludge) – see NEMS Periphyton
Time				
Equipment cost (initial or one-off)				
Ongoing cost	None			
Complexity				
Measurement resolution	Low (varies by category)	Nearest 10%	Nearest 10%	Nearest 5%
Training and quality checks	See page 99			

Microcoleus cyanobacteria

All periphyton assessment options included on the CBM field form have been designed to capture if *Microcoleus* cyanobacteria is present at the site but only the in-stone periphyton assessment method will capture information on the amount of cover. For quantitative data on streambed coverage of *Microcoleus*, select one of the two methods from the table below.

Specific indicator	Percentage of the visible or wadeable streambed covered by *Microcoleus* cyanobacteria mats ("toxic algae")	
Measurement type	Field measurement	
Measurement units	%	
Measurement methods	Bankside visual assessment Simple 4 cover category estimate	Instream visual assessment Estimate of cover at 10 points on the streambed, generally from 2 cross sections
Data use	 Depends on specific data use – suitable for general environmental screening	 Depends on specific data use. An underwater viewer is essential for robust assessments
Method instructions available from	CBM field form and Cawthron Institute video on river toxic algae to support identification	See periphyton monitoring instructions for cross section establishment and Cawthron Institute toxic algae video
Equipment /materials	None	Underwater viewer (recommended)
Caveats	Limited by what can be viewed from the bank	
Time		
Equipment cost (initial or one-off)		
Ongoing cost		
Complexity		
Measurement resolution	Four cover categories (0%, <20%, 20-50% and >50%)	Nearest 10%
Training and quality checks	See page 99	

Macrophytes

Specific indicator	Macrophyte abundance – 2 options: • Amount of water surface area occupied by macrophytes • Amount of water surface area and water volume occupied by macrophytes (recommended)	
Measurement type	Field measurement	
Measurement units	%	
Measurement methods	Bankside visual assessment	Instream visual assessment
	Estimate of abundance from 3-5 points across 5 sections of stream (minimum of 20 points)	
Data use	Depends on specific data use – suitable for general environmental screening	Depends on specific data use. A quadrat is essential for robust assessments.
Method instructions available from	NIWA SHMAK guidance manual	
Equipment /materials	Measuring tape	Measuring tape, 0.5 m x 0.5 quadrat (square frame)
Caveats	Limited by what can be viewed from the bank. Requires very clear water for the water volume component.	An underwater viewer may be needed for robust assessments of the volume component if the water is not clear.
Time*		
Equipment cost (initial or one-off)	$ 0 25 50 100 500 1,000 $1,500+	$ 0 25 50 100 500 1,000 $1,500+
Ongoing cost	None	None
Complexity	L M H	L M H
Measurement resolution	Nearest 10%	Nearest 10%
Training and quality checks	See page 101	

* Will vary depending on amount of macrophytes.

Which macrophyte indicator measurement should our group choose?

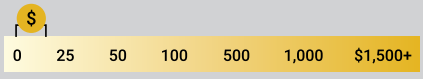
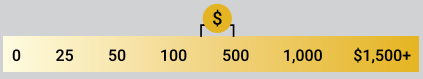
Estimating both the area of the water's surface and the amount of the water column occupied by macrophytes is the NIWA SHMAK method. This method will provide the most robust assessment of nuisance macrophyte growth and its potential impacts on stream health. However, if your group does not have the time to commit, you could just estimate the amount of stream surface cover. This option will still be useful for some applications, such as tracking over time whether stream shade provided by riparian plantings is reducing the amount of surface cover of macrophytes.

Macroinvertebrates

The macroinvertebrate indicator method has two parts (presented across two tables):

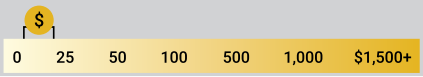
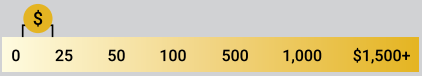
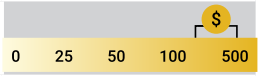
- sample collection, and
- sampling processing (macroinvertebrate counting and identification).

Part A: Sample Collection

Specific indicator	Macroinvertebrate types and abundance	
Measurement type	Field assessment or lab assessment made on a macroinvertebrate sample	
Measurement units	Taxonomic (e.g., species, genus or family)	
Measurement methods	Instream stone method – riffle habitat, stony bottom stream (NIWA SHMAK) Collection of 10 randomly selected stones	Kicknet* method – 2 options: • riffle habitat (stony bottom stream), or • mixed habitat (NEMS compliant) Mixed habitat targets the range of streambed (e.g., stone, mud, gravel) and habitat (e.g., riffles, runs, pools, macrophytes) types present across the sampling reach
Data use	 Depends on specific data use – suitable for general environmental screening and surveillance	 Depends on specific data use. Some investigative science and regulatory uses will require replicate samples and the same habitat types to be sampled between sites.
Method instructions available from	NIWA SHMAK guidance manual	NIWA SHMAK guidance manual For samples that will be processed by a lab, see NEMS Macroinvertebrates for sample sorting and preservation requirements
Equipment /materials	White ice cream container or tray to place rocks and some stream water into	Measuring tape, dish brush, white tray, bucket, sieve(s) + sample containers and preservative for samples that will be processed by a lab
Caveats	Will only find invertebrates that are clinging to the stones (if stones are present)	
Time (to collect and sort)		Riffle-habitat only 
		Multi-habitat 
Equipment cost (initial or one-off)		
Ongoing cost	None	None if field-based for Part B
		<$10 if lab-based for Part B
Complexity		
		
Training and quality checks	See page 103	

* Other sampling nets/equipment exists, such as Surber samplers. The kicknet is recommended in the national CBM QA framework because it is the most common sample collection equipment and can be used across a wider range of stream types and habitats. However, the CBM field forms do provide for the capture of data using a Surber (or other sampling equipment).

Part B: Sample processing (counting and ID)

Specific indicator	Macroinvertebrate types and abundance		
Measurement type	Field assessment or laboratory assessment made on a macroinvertebrate sample		
Measurement units	Taxonomic (e.g., species, genus or family) and abundance (actual or category-based)		
Measurement methods	Instream stone method – riffle habitat, stony bottom stream (NIWA SHMAK) Field-based identification and counting of different invertebrates	Kick-net sample method - two options • field processing • lab processing (NEMS compliant) Field and lab identification options, and different options within these	
Data use	 Depends on specific data use – suitable for general environmental screening and surveillance	 Depends on specific data use. Some specific investigation uses and all regulatory uses require accurate identification and counting in a specialist lab	
Method instructions available from	NIWA SHMAK guidance manual, macroinvertebrate ID videos and macroinvertebrate field ID guide	**Field ID** NIWA SHMAK guidance manual, macroinvertebrate ID videos and macroinvertebrate field ID guide	**Lab ID** NEMS Macroinvertebrates requirements
Equipment /materials	White tray, magnifying glass, invertebrate field guide	None	
Caveats	Will only find invertebrates that are clinging to the stones	Accuracy and precision dependent on your group's experience	
Time*			
Equipment cost (initial or one-off)			
Ongoing cost (per sample)	None	None	
Complexity*			
Taxonomic resolution	Low to moderate – limited to SHMAK macroinvertebrate classes and abundance scores	Low to high, depending on level of identification and counting applied	Very high

* Time and complexity will vary depending on the variety and number of invertebrates found.

Sorting a macroinvertebrate sample in the field

Olinga, smooth cased caddisfly larvae

Deleatidium mayfly larvae

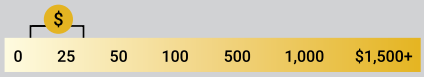
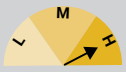
Chironomidae midge larvae

Sphaeriidae mollusc

Elmidae beetle larvae

Fish

The national CBM QA framework includes two of the three standard fish monitoring methods used in NZ; spotlighting and trapping. The third method, electric fishing, is not included in the framework because it requires a special electric fishing machine that must be used by a certified operator.

Specific indicator	Fish presence/absence and abundance	
Measurement type	Field assessment	
Measurement units	Taxonomic (e.g., species, genus or family) and abundance (actual or category-based)	
Measurement methods	Spotlighting Carried out after sunset to identify and count nocturnally active fish. Can include estimating and/or measuring fish size classes	Trapping – 2 net types: • Gee minnow traps • Fyke nets Traps and nets are set over a stream reach and left overnight before returning to identify and count captured fish. Can include estimating and/or measuring fish size classes.
Data use	 Depends on specific data use. Most investigation, surveillance and regulatory data uses will require: • net and trap dimensions (e.g., mesh size) to be consistent through time to minimise variability in sampling (catch) effort • identification of the fish by a specialist	
Method instructions available from	NIWA SHMAK guidance manual and sections 3.5 and 3.6 of the NZ Freshwater Fish Sampling Protocols (Joy et al. 2013)	
Equipment /materials	Measuring tape, torch/lamp, field form	Measuring tape, fish buckets/bins, field form, gee minnow nets, fyke nets
Caveats	Designed for wadeable streams (<1 m deep) and requires calm water conditions at low or base stream flow. Good for detecting galaxiids but less likely to detect juvenile eels and lamprey	Designed for wadeable streams (<1 m deep) and requires stable stream flows prior to and during the trapping period
Time		 (for each of trap/net setting and retrieval)
Equipment cost (initial or one-off)		• $25-80 per Gee minnow trap • >$100-$250 per fyke net
Ongoing cost	Negligible	Nil (provided no traps or nets need to be replaced)
Complexity		
Taxonomic resolution	Depends on the expertise and experience of group members	
Training and quality checks	See page 105	

Which fish monitoring method should our group choose?

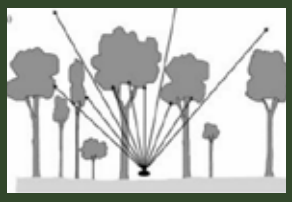
Each of the three standard fishing methods has advantages and disadvantages and none of these methods on their own will detect every species of fish present in a stream reach. If your group is interested in a specific species or type of fish, you may only need to use one method. However, if you want to know more on the range of fish present, select multiple methods and collect water samples for eDNA testing.

For more information, see Section 3.2 of the NZ Freshwater Fish Sampling Protocols (Joy et al. 2013) or talk to a specialist.

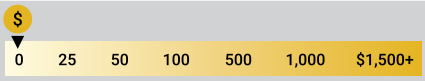
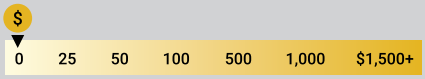
Stream habitat indicators

Table 4-3 outlines the stream habitat indicators in the national CBM QA framework and their relevance to stream health. All of these indicators are observation-based.

Table 4-3: Physical habitat indicators in the national CBM QA framework.

Indicator	Relevance to stream health
Physical habitat quality 	WHAT: The various physical features of a stream reach that influence the quality of the living space for aquatic life. These include shade and deposited fine sediment listed below as well as water depth and flow types, streambed composition, and riparian and stream bank characteristics. WHY: Degraded physical habitat reduces the range, abundance and condition of aquatic life. It can also affect the amenity and aesthetic values of streams, or their suitability for recreation and cultural uses.
Deposited fine sediment 	WHAT: Fine sediment (mud, clay and sand) that falls out of the water column and settles on the streambed. A lot of this sediment comes from overland flow or stormwater runoff during rainfall and stream bank erosion or damage, such as from flooding and stock access. WHY: Deposited fine sediment can clog the spaces between streambed gravels and cobbles used by invertebrates and fish and degrade food sources and sites used for egg laying. Excessive fine sediment can affect the types of invertebrates that live in the stream, and lead to changes in behaviour, feeding and growth. It can also affect the suitability of rivers and streams for recreation.
Shade (canopy closure) 	WHAT: The degree to which riparian trees and vegetation (or in some cases structures) block natural light from directly reaching the water surface and bed of a stream. WHY: Riparian shading keeps stream water cool and helps reduce the growth of nuisance algae and plants.
Rubbish 	WHAT: A physical pollutant such as aluminium cans, glass bottles, plastic packaging and food waste. WHY: Often impacts amenity and recreational values, can pose a human health hazard (e.g., broken glass, soiled nappies) and may harm aquatic life and birds (e.g., through leaking of toxic contaminants or entrapment in plastic). A lot of rubbish is eventually transported downstream to estuaries or out to sea where it can continue to impact the environment.

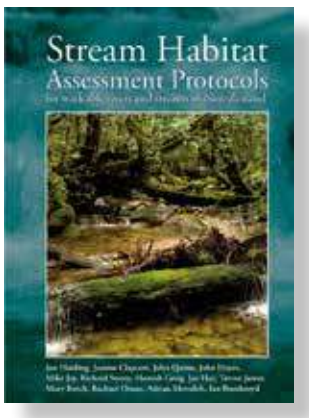
Physical habitat quality

Measurement type	Field measurement	
Measurement units	None (point-based score)	
Measurement methods	SHMAK visual habitat assessment Scoring of 8 habitat variables	National Rapid Habitat Assessment (RHA) (recommended) Scoring of 10 habitat variables
Data use	 Depends on specific data use – suitable for general environmental screening	 Depends on specific data use. A survey that collects quantitative data will be essential for robust assessments of habitat quality.
Method instructions available from	NIWA SHMAK guidance manual	National RHA protocol (Clapcott 2015)
Equipment /materials	Measuring tape (recommended)	
Caveats	Not completely comparable with the National RHA method which is widely used by regional councils	
Time		
Equipment cost (initial or one-off)		
Ongoing cost		
Complexity*		
Measurement scale	Produces a total score between 0 and 64	Produces a total score between 10 and 100
Measurement resolution	Each variable is scored between 0 and 8	Each variable is scored between 1 and 10
Training and quality checks	See page 106	

* Complexity depends on stream type and characteristics.

The Stream Habitat Assessment Protocols (Harding et al. 2009) detail both rapid and more advanced methods for assessing physical habitat quality. Examples of completed assessment forms are also provided.

Note: The RHA method features as Protocol 1 but the RHA method included in the CBM framework is a revised and updated version by Clapcott (2015) that includes scoring of habitat variables.



Components of the physical habitat quality indicator

The national rapid habitat assessment (RHA) method provides a quick way to measure the quality of the physical habitat at a stream site. It involves assigning a score between 1 (poor) and 10 (excellent) for each of 10 habitat variables:

- deposited sediment
- invertebrate habitat diversity
- invertebrate habitat abundance
- fish cover diversity
- fish cover abundance
- hydraulic heterogeneity (range of water depths and flow types)
- bank erosion
- bank vegetation
- riparian width
- riparian shade.

A stream bank with significant erosion

The sum of these scores is then added to give a total habitat quality score out of 100. It can be useful to compare scores between different sites in a catchment, especially against a score from a suitable reference site(s) to understand how far away these sites are from the 'best' site.

Provided the stream is not too wide and the water is clear enough, both the RHA and the SHMAK surveys can be done from the stream bank in less than 15–20 minutes. A survey is best done after completing other biological monitoring and should be done with macroinvertebrate monitoring because the results will help with interpreting the macroinvertebrate data.

Understanding stream habitat modification

The RHA survey provides a measure of the current state or condition of stream habitat. A national protocol (see Holmes 2022) is also available to rapidly assess how much the stream habitat has been modified or the pressure it is under from further modification – for example, from bank engineering, vehicle access or intensive land use. The protocol includes 12 pressure variables and, like the RHA, ranks each variable on a scale of 1 to 10. The higher the score, the higher the pressure.

Deposited fine sediment

Indicator	Percentage of the visible streambed covered by fine sediment < 2 mm in diameter	
Measurement type	Field measurement	
Measurement units	%	
Measurement methods	Bankside visual assessment Simple 4 category estimate of cover in run habitat	Instream visual assessment Semi-quantitative assessment of cover at 20 points on the streambed in run habitat, generally from 5 cross sections
Data use	Depends on specific data use – suitable for general environmental screening	Depends on specific data use. Some specific investigative surveillance and regulatory purposes may require quantitative measurements of deposited sediment.
Method instructions available from	CBM form: Simplified from Protocol 1 of the national Sediment Assessment Methods	Based on Protocol 2 of the national Sediment Assessment Methods (SAM)*
Equipment /materials	None	Underwater viewer (recommended)
Caveats	Limited by what is visible from the bank. Requires very clear water	Use of a viewer essential to support data use in regulatory applications. SAM Protocol 2 requires cover to be estimated to the nearest 5%
Time		
Equipment cost (initial or one-off)	$ 0 25 50 100 500 1,000 $1,500+	$ 0 25 50 100 500 1,000 $1,500+
Ongoing cost (per sample)	None	None
Complexity	M	M
Measurement range and resolution	0 to 100%, in 25% increments	0 to 100%, in 10% increments
Training and quality checks	See page 107	

The national Sediment Assessment Methods (Clapcott et al. 2011) detail six different protocols for assessing both deposited and suspended fine sediment in streams as well as guidance and supporting information on the effects of fine sediment on aquatic life and stream values.

Rubbish (litter)

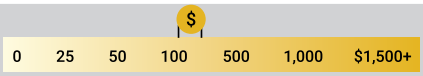
Assessments of rubbish (litter) in the national CBM QA framework adopt existing NIWA SHMAK kit and Litter Intelligence methods.

Measurement type	Field measurement	
Measurement methods	Visual reach assessment (NIWA SHMAK Level 1 method) Screening of five aspects of rubbish, including the amount, likely sources and impacts on aquatic life and human health	Rubbish tally method (NIWA SHMAK Level 2 method – equivalent to the Litter Intelligence protocol for fresh water) Collection, identification and counting of different types (e.g., plastic, rubber, cloth, paper, metal) of rubbish in the stream and on the stream banks using the Litter Intelligence categories
Data use	General environmental or hotspot screening	Some specific data uses may require other types of measurement or detail
Method details	SHMAK guidance manual	SHMAK guidance manual and Litter Intelligence website
Equipment /materials	Tape measure (30 m)	Tape measure (30 m) rubbish bags, gloves and pick-up claw or kitchen tongs
Caveats		Requires at least 2 people
Time*		Over 1hr
Equipment cost (initial or one-off)	$ 0 25 50 100 500 1,000 $1,500+	$ 0 25 50 100 500 1,000 $1,500+
Ongoing cost	None	
Complexity*	M L H	M L H
Measurement scale	Assigns a score from 1 (poor) to 8 (excellent) to 5 variables	Lists over 100 rubbish items for collected rubbish to be recorded against (as a count and/or estimated weight)
Training and quality checks	See page 110	

* Time and complexity will vary depending on the site characteristics and amount of rubbish present.

Shade (canopy closure)

The physical habitat quality indicator (page 71) included in the national CBM QA framework includes a basic assessment of riparian shading that may be sufficient for many groups monitoring needs. For groups that want a more robust way to track changes in shade over time (e.g., arising from maturing of riparian stream plantings), the method below captures quantitative data on stream canopy cover closure, as an indicator of stream shade.

Specific indicator	Canopy closure
Measurement units	%
Measurement type	Field measurement
Measurement method	Spherical densiometer, modified for stream assessments (see box, opposite page)
Data use	 Depends on specific data use. Data use for some investigative, surveillance and regulatory purposes may require direct measurements of shade using light sensors.
Method instructions available from	See box (opposite page) and the U.S. Fish and Wildlife Service video: Measuring stream canopy closure using a spherical densiometer
Equipment	Spherical densiometer, tape and measuring tape. A tripod is also recommended to ensure the densiometer is kept level and read at a consistent height (0.3 m) above the water's surface.
Caveats	Requires safe access across the entire stream reach and width. The same stream reach should be assessed over time and at the same time of year (ideally by the same observer(s)). Precision is less than that achieved using a traditional 24-square densiometer.
Time	
Equipment cost (initial or one-off)	
Ongoing cost	None
Complexity	
Measurement range and resolution	0 to 100%, in increments of approx. 6%
Training and quality checks	See page 109

Measuring stream shade using paired PAR-light sensors

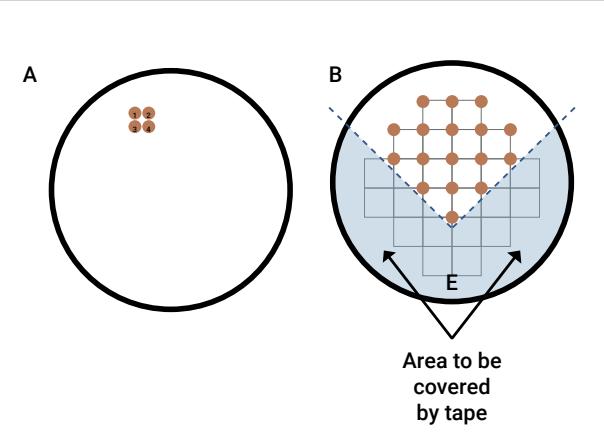
If your group needs a direct measurement of shade that can produce accurate and precise data, twin photosynthetically active radiation (PAR) sensors should be used. These sensors measure light intensity at frequencies associated with photosynthesis and so provide the information on light levels that are most relevant for instream plant growth.

Some further information on these sensors is provided in the companion background report. Because PAR sensors are expensive and require calibration, your group will likely need to loan these sensors and have a scientist experienced in their use help you to calibrate and use them in the field.

What is a densiometer and how do you use it in a stream environment?

A densiometer is a small instrument containing a concave or convex piece of mirrored metal with 24 squares engraved on its surface that reflect the incident light at an angle of 180°. This mirror is fixed into wooden housing with an in-built bubble to level the equipment at the time of its reading. The canopy image is reflected in the densiometer and a count is made at four points (quarters) in each square if vegetation (as opposed to sky) is showing.

Originally developed for assessments of canopy closure in forestry blocks, the traditional method has the observer make four counts within each grid (A) giving a maximum count of 96. The count is then multiplied by 1.04 to present a canopy closure as a percentage.



Traditional measurement (A) and modified assessment (B)

How many measurements are required?

Aim for 20 measurements which are made at multiple locations along a stream reach and across the width of a stream. This involves:

1. Laying out a series of 3-5 cross sections along the length of the selected stream reach.
2. At each cross section, making one observation of canopy closure at the stream edge facing the left bank, four observations from the centre of the stream (facing upstream, downstream, the left bank and the right bank) and one observation at the opposite stream edge facing the right bank.
3. Taking a photo of the stream canopy closure looking upstream from the bottom of the reach and downstream from the top of the reach.

A convex densiometer with tape added to adapt for canopy closure estimates in stream environments.

The CBM approach uses the Strickler (1959) modification adopted for monitoring stream canopy closure by the US Wildlife Service. The lower portion of the densiometer is taped off to stop your reflection being seen on the surface when making a reading. This approach emphasises overhead vegetation and counts of vegetation 'hits' are made at the 17 points that intersect squares in the upper portion of the densiometer (B). The count (out of 17) is then converted to a percentage canopy closure. See the companion background report (Milne et al. 2023) for more details.

Water quantity indicators

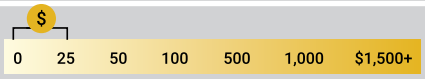
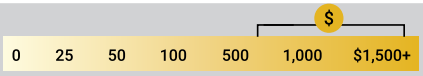
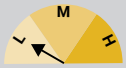
Table 4-4 outlines the water quantity indicators in the national CBM QA framework and their relevance to stream health. More detail on the importance of stream velocity and flow indicators, how they are measured and what they tell us about stream health can be found in Chapter 3 of the SHMAK manual.

Table 4-4: Stream health water quantity indicators in the national CBM QA framework.

Indicator	Relevance to stream health
Water velocity	WHAT: The speed at which the water moves in a stream, usually measured in metres per second (m/s). Also known as current velocity, it is greatest in the middle of a stream channel, near the water's surface. WHY: Current is an important aspect of aquatic habitat and affects the mixing and dilution of contaminants. Fast currents bring more food to aquatic animals and can help aerate the water.
Stream flow	WHAT: The volume of water flowing past a point in a stream. Also called stream discharge. Measured in litres per second (L/s) or cubic metres per second (m^3/s). WHY: Many other indicators of stream health, including most water quality indicators, change with stream flow. Multiplying stream flow by the measured concentration of a particular water quality variable (e.g., total nitrogen or suspended sediment) gives the total load of the contaminant in the stream. Understanding contaminant loads is important because this can influence the health of lakes and estuaries downstream. For aquatic life indicators like periphyton and macroinvertebrates, it is the flow conditions in the days or weeks before monitoring that can influence when best to sample and what you may find. A stream with a highly varying flow may be a more difficult habitat for aquatic plants and animals to live in than a more stable stream.
Rainfall	WHAT: The quantity (in millimetres) of rain that falls within a given area, such as a stream catchment, in a given period of time (e.g., 11 mm in 24 hr). WHY: Rainfall is an important source of water for recharging stream flows but, depending on how heavy it is (intensity) and long it lasts (duration), rainfall also flushes sediment, nutrients, microbes, metals and other contaminants from the land into streams. Sharp increases in stream flow can occur after heavy rainfall and this can increase bank erosion, resuspend contaminants in the streambed sediments, and wash periphyton and invertebrates away.

Water depth or level is one of the measurements required to estimate stream flow. Water level recorders (or staff gauges, left) are surveyed into the beds of some streams to support measurements of stream cross sectional area and flow.

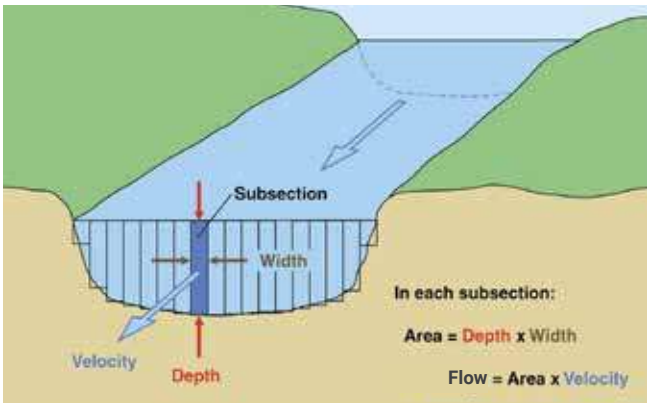
Water velocity

Measurement type	Field measurement	
Measurement units	Metres per second (m/s)	
Measurement methods	Float method Time taken for a floating object to travel a known distance	Current meter (instream) Measurements at one or more points across the width of a stream
Data use	 Likely to be limited to coarse environmental screening	 Depends on specific data use and the number of point measurements made. Specific meter models or specifications may also be required.
Method instructions available from	NIWA SHMAK guidance manual	NIWA SHMAK guidance manual and current meter instructions
Equipment /materials	Measuring tape, stopwatch/timer and a tennis ball (or other float)	Current meter, measuring rod/ruler, stopwatch/ timer
Caveats	Measures surface velocity and a standard correction factor is used to convert this to average stream velocity. Requires a relatively straight reach of stream.	Must know the meter's coefficient number to convert meter readings to velocity. Requires a relatively straight reach of stream.
Time		
Equipment cost (initial or one-off)		
Ongoing cost	None	Negligible
Complexity		
Measurement resolution	Low	Depends on number of point measurements
Training and quality checks	See page 111	

Stream flow

Stream flow in the national CBM QA framework is calculated from measurements of water velocity and the cross-sectional area of the stream. This is known as the velocity-area method.

The accuracy and precision of the estimated average stream flow is strongly influenced by the number of water velocity and especially depth measurements made across the stream channel. Fewer measurements are needed if the stream reach is relatively straight and has a consistent width and depth.

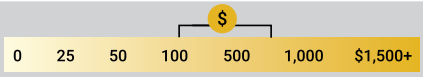
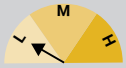


Measurement units	Cubic metres per second (m^3/s)	
Measurement methods	Float method As per water velocity above but includes an estimate (or measure) of average water depth	Current meter As per water velocity above but includes measurements of water depth at one or more points across the stream

Rainfall

Regional councils, MetService and NIWA operate networks that measure rainfall across much of NZ.

Check your regional council or the LAWA website as a starting point to see what rainfall data might be available in the vicinity of your group's stream catchment. If the stream drains a remote rural or bush area or your group specifically wants to measure rainfall, the table below sets out details for measuring daily rainfall with a standard (manual) rainfall gauge.

Measurement units	Millimetres per day (mm/day)
Measurement type	Field measurement
Measurement method	Manual rain gauge
Data use	 Suitability for some specific applications, especially regulatory processes, may require the use of a specific rain gauge and/or the rain gauge to be calibrated or verified by an independent specialist
Method instructions available from	NIWA's instructions for rainfall observers (Harper 1994)
Equipment	A graduated cylinder rain gauge and a bracket and stake (or equivalent) to secure it in place
Caveats	Rainfall should be read at 9 am each day
Time	
Equipment cost (initial or one-off)	
Ongoing cost	None
Complexity	
Measurement range and resolution	Typically 0 to 180 mm, with measurements recorded to the nearest 0.5 mm
Training and quality checks	See page 112

* For measurements only (i.e., excludes rain gauge installation).

Why measure rainfall at 9 am?

Across NZ, daily rainfall is usually reported over the 24-hour period ending at 9 am. Reading a rainfall gauge daily at 9 am will therefore allow your group's daily rainfall measurements to be compared to, or added to, the daily rainfall measurements from other nearby gauges.

Both NIWA and MetService invite CBM groups to share their rainfall data.

SECTION 5

Training and quality checks

Training and quality checks form critical components of any good monitoring programme that seeks to produce fit for purpose data.

In this section we outline:

- training resources and common types of quality checks for monitoring stream health,
- important observations of weather and stream conditions to record on each monitoring occasion, regardless of which stream health indicators are being measured,
- in table and diagram format for each stream health indicator in the national CBM QA framework:
  - recommended training requirements,
  - what measurement and supporting information (metadata) your group must record, and
  - recommended internal and external quality checks.

The ArcGIS Survey123 electronic field forms included with the national CBM QA framework (Section 6) will automatically prompt your group to capture the necessary measurement supporting information, and assist with some of the quality checks.

Use the information provided in this section to help your CBM group complete Form E of the Monitoring and Quality Plan outlined in Section 3. When deciding what training and quality checks to adopt, keep in mind your primary monitoring purpose and intended data use (Figure 5-1).

Training, good documentation and commitment to routine quality checks is essential if your group wants the data collected to be considered for use in regulatory processes (e.g., when your regional council sets or revises limits or rules on catchment water quality).

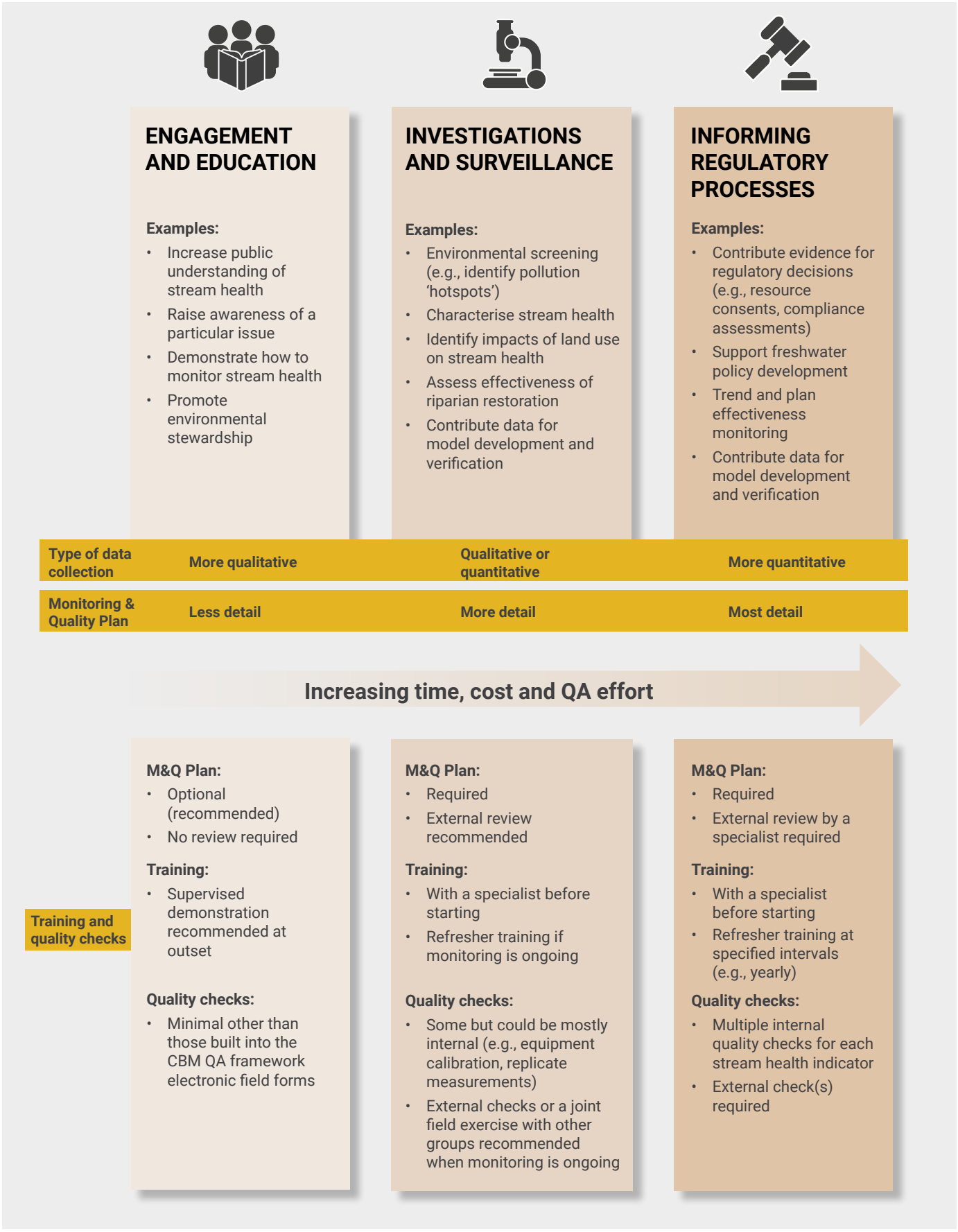


Figure 5-1: Main data use categories in the national CBM QA framework (with examples of possible data collection purposes that sit in each) and the recommended investment in planning, training and quality checks associated with each. Your group's monitoring questions and intended data use should guide the investment level required.

Training

There are currently no formally recognised national training courses or accreditation available in NZ that specifically target community-based stream monitoring. However, many regional councils and not-for-profit organisations such as the Mountains to Sea Conservation Trust and NZ Landcare Trust have staff that train community groups to use freshwater citizen science tools and resources, such as NIWA's SHMAK and Auckland Council's Wai Care kits. Some scientists in research organisations (e.g., NIWA, Cawthron Institute, universities) and consultancies also support community and iwi-based groups interested in monitoring stream health.

As well as printable user manuals such as those which come with field meters, self-test kits and NIWA's SHMAK kit, a range of short videos are freely available on-line that demonstrate how to monitor different stream health indicators. These videos are useful for supporting hands-on training and are useful as refresher training resources. Examples of the most relevant videos are included in the indicator tables later this section and are collated in table form in Section 7.

If your group is embarking on a long-term monitoring programme, it is a good idea to develop some standard operating procedures, or SOPs. As shown in the monitoring process diagram in Section 2 (page 8), SOPs form an important part of QA in environmental monitoring, particularly in maintaining consistency in long term monitoring programmes where group members carrying out the monitoring may change over time.

SOPs are a set or manual of step-by-step, easy to understand instructions that CBM groups can follow safely and correctly to carry out various monitoring activities. They are a mix of the relevant details from manufacturer instructions or standard methods but are tailored to each group's specific monitoring sites, equipment and needs. They are also a place to record contact details for equipment suppliers and your council and lab, as well as how the monitoring data will be managed.

Refresher training is important to factor into your programme, especially if your group intends to monitor over many years. Some indicators may only be monitored once a year and it can be easy to forget some important details. Also, some group members may not be involved in the monitoring regularly enough to remember how to carry out some tasks. Think about how you will manage this, such as through holding annual or seasonal group training sessions or re-watching instructional videos. Having an independent specialist check on your field and measurement activities ensures your SOPs are robust.

Attendees at a Mountains to Sea Conservation Trust training event learning to estimate macrophyte cover and volume.

A community group with NIWA and Greater Wellington Regional Council science staff learning to use an underwater viewer to estimate streambed periphyton cover.

Quality checks

The purpose of quality checks is to minimise errors when monitoring and ensure that your group's results are representative of the overall condition of the stream monitoring site. They include internal and external checks.

Internal quality checks

A large range of internal quality checks can be made. The more common checks that CBM groups can carry out are outlined below. If the samples collected are being sent to a lab for testing (e.g., nutrients) or identification (e.g., macroinvertebrates), the lab will carry out its own internal quality checks (see page 109).

- **Equipment checks:** Ensuring that all the necessary pieces of equipment are available for use and maintained in good working order. Examples include checking the condition of your group's visual clarity tube, black discs or sampling net, and checking the expiry dates of reagents used in self-test kits and standard solutions used to calibrate field meters.
- **Calibration standards:** Usually a lab-prepared chemical solution of a known concentration (e.g., a pH standard of 7.0). These standards are used to check (validate) the accuracy of field meter sensors or lab instruments. If the sensor or instrument reads too high or too low, it can be corrected or adjusted (calibrated) to read the value of the standard.
- **Field replicates:** Two or more field measurements (e.g., visual water clarity, dissolved oxygen), or water or biological samples collected and tested from the same site. These measurements are usually made independently by different group members to assess how closely their results agree (i.e., a check of precision or repeatability). When replicate samples are sent to the lab as a check on their testing performance, the samples should be collected by the same person and given a false site name ('blind samples') so that the lab does not know a quality check is being made.
- **Field blanks:** Commonly used in monitoring of water quality, these are samples of pure water that, when tested, are expected to return a "zero" measurement for the indicator of interest (e.g., *E. coli*, nutrients). A field blank helps check for contamination of the samples during sample collection, transport and testing. It is a useful quality check when sampling streams with very low nutrient or faecal bacteria concentrations (e.g., forested headwater reaches). Take some pure water into the field and then fill a clean, unused sample bottle in the field with that water at the location where you are collecting your stream samples. See the information box (top right).

Making a field or lab blank

Blanks are artificial samples made up of ultra-pure MilliQ water used to trace sources of contamination which may be introduced to samples. Although not 100% pure, distilled water is also often used a blank. A lab or a local research organisation should be able to supply your group with some water for use in blank samples.

If your group only needs a blank for *E. coli* self-tests and can't access a pure water source, bottled or tap water from a town supply should be suitable.

- **Lab replicates:** A single field sample that the lab splits into two or more subsamples to test their measurement precision. Most labs routinely perform replicate testing as part of their own internal quality system. Groups using self-test kits to measure for nutrients or *E. coli* under the CBM QA framework should also adopt this practice.
- **Lab blanks:** Similar to field blanks but only used to check possible sample contamination during lab testing. Groups using self-test kits under the CBM QA framework should also perform lab blanks, particularly for *E. coli* testing.
- **Voucher specimens:** Physical preserved specimens or sample(s) of a plant or animal species used to confirm taxonomic identification (i.e., they can verify the accuracy of identification). In CBM, voucher specimens can also be used as a 'mystery box' in training sessions to check the skill levels of group members.
- **Photographs:** Used to help confirm species identification (e.g., macrophytes, macroinvertebrates) or check point-based observations of stream health indicators such as the percentage of the streambed covered in fine sediment or periphyton.

External quality checks

External quality control in the national CBM QA framework involves an independent external organisation checking that your group is correctly carrying out measurement, sampling and testing or identification activities. This process is known as external verification. External verification adds credibility to your monitoring efforts and provides reassurance that your group is collecting good quality data. It can also help identify when training refreshers might be needed, and to keep your group up to date with new or emerging monitoring methods.

Three types of external verification are included in the national CBM QA framework:

- **Field verification:** An independent freshwater scientist or monitoring officer, or a suitably trained coordinator from another community monitoring group, checks the field measurement and sampling techniques of your group's members to confirm these are correct. This may involve them collecting their own field measurements or samples to compare the results against those of your group.
- **Taxonomic verification:** The organisms (taxa) in one or more biological samples your group collected can be independently identified (and sometimes counted) by a specialist to confirm the accuracy of your group's identification (and counting). This check is often carried out on macroinvertebrate samples.
- **Lab verification:** If your group is monitoring water quality indicators using field meters or self-test kits, you could periodically send a water sample to a lab to check how well your measurement(s) agrees. Lab verification can also be used to check on the performance of your lab. This option generally won't be necessary given labs have extensive quality check programmes in place. However, it might be worth considering if you are using a lab that isn't accredited to perform a particular test. In this case, your group would collect a single "bulk" water sample and split this into two subsamples. One subsample would be sent to the regular lab and the other to another lab as an independent check.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Environmental monitoring staff from NIWA and Otago Regional Council carrying out side-by-side field measurements (left) and water sample collection (right). The two samples were sent to the lab for nutrient testing to check there was close agreement in the results (as would be expected).

General weather and stream observations (metadata)

Regardless of which stream health indicators your group is measuring, there are some quick and important observations that should be recorded on every monitoring visit. These observations are known as *site visit metadata* and relate to weather and stream conditions. Recording whether it has rained recently, if the stream is flowing lower or higher than usual, or if birds or animals are in or near the water, is important because these things will often influence some of the indicator measurements. Capturing these observations will therefore be very useful when it comes to interpreting your group's monitoring data.

The ArcGIS Survey123 electronic field forms included in the national CBM QA framework capture the observations listed in Table 5-1. The forms also allow photos to be uploaded of the site or any unusual or concerning feature (e.g., bank collapse, algal bloom) and text comments of any additional notes. No formal training is necessary to make the observations. Many of the observations have tick box options to select from so it should take less than 5 minutes to complete them.

Table 5-1: Site visit metadata that must be captured on the Survey123 field form on every visit to a monitoring site, in addition to site location, date, time and observer name(s). Unless indicated otherwise, only one option can be selected.

General conditions	Options
Weather	Partly cloudy, Overcast, Drizzle, Rain
Wind	Calm, Light, Moderate, Strong
Rain in last 24 hr?	Yes, No, Unsure
Stream conditions	**Options**
Stream water level	High, Normal (or base flow), Low
Stream observations *(select all that apply)*	Stock on banks/in water, Wildfowl in water, Local bank erosion, surface scums/oils, Rubbish on banks/in water, Periphyton, Macrophytes, Fish
Stream odour	Yes, No
Stream water appearance	Clear and colourless, Slightly murky, Turbid, Humic-stained, Other

How do we know if the water level is low or at base flow?

This isn't always obvious if it's not summer and your group hasn't been monitoring for long but look along the stream bank and edges for signs of recently exposed plants, algae, gravels or sediment. Often there is a visible line along the bank indicating the water level is lower than usual. A nearby council flow or rainfall monitoring station may also be helpful (including for interpretating the monitoring data later). Check the LAWA website for rainfall data.

Low flows in the Kopuaranga River, Wairarapa – note the reduced wetted width and the exposed algae at the water's edge.

Water quality indicators

Field meter measurements

The table below addresses training, records and quality checks for discrete (spot) measurements of water temperature, dissolved oxygen (DO) and conductivity. Measurement resolution and metadata records for field measurements of pH and turbidity are also included but as the national CBM QA framework recommends that these indicators are measured in the lab, training and quality checks are not included here.

Instruction videos are provided with most continuous water temperature and DO sensors. Ensure that the sensor installation is safe from high flows, vandalism or other interference (e.g., stock).

Training	In-field demonstration and practice based around the quality checks below
Method information	See pages 40–41, 43–46 and 50
Resources	• NIWA e-Learning training videos (YouTube): – WQ Rivers – field measurements – WQ Rivers – field measurements from a bridge
Refresher frequency	Annually
Records	
Measurement resolution	• Water temperature: nearest 0.1˚C (or 0.5˚C for an analogue thermometer) • DO: 0.01 mg/L and 0.1% • Conductivity: nearest 1 µS/cm (or 0.1 mS/m) • pH: nearest 0.1 • Turbidity: 0.1 FNU or NTU between 0 and 10, otherwise nearest 1 FNU or NTU
Supporting metadata	• Measurement device used, including field meter make and model* • Sensor validation and calibration details* • Barometric pressure (for DO and only if the meter does not compensate for this)
Quality checks	*Equipment checks*
Internal checks	• Sensor accuracy: – Water temperature: 0.5˚C – DO: 0.3 mg/L and 3% – Conductivity: 1 µS/cm at 25˚C (or 0.5% of full scale) • Membrane is intact (no bubbles) – applies to galvanic and electrochemical DO sensors only • Sensor validation and calibration (see box opposite page)
	Field measurement checks • Sensors deployed in running water and allowed to stabilise before measurements are read • DO: Corrected for barometric pressure (if correction not built-in) • Conductivity measurements are recorded at 25˚C • A repeat measurement (using the same sensor) is periodically made by a second, independent observer – the original and repeat measurements should agree within ± 5%
External checks	• The same checks as listed above made by an independent (trained) observer or specialist • Side-by-side measurement with a specialist using pre-calibrated sensors – measurements should agree within ± 5%

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

Sensor validation and calibration requirements

The NEMS for discrete measurements of river water quality sets the following requirements for data of the highest quality. The checks are important if your group wants very accurate measurements to support trend detection over time but will add time and effort. However, most conductivity sensors are quite stable over time and for most data uses, it may be sufficient just to check the sensor at the start of the day at three-monthly intervals against one standard solution.

Indicator	What?	How often?
Water temperature	Check (validate) the sensor against 2 traceable reference thermometers (a lab may be able to check this for you)	At least once every 12-monthly. Replace sensor if it fails.
DO	Before monitoring, check the sensor is within the valid range of ± 0.5% saturation using 100% saturated air or water. If the measurement is outside of this range, calibrate the sensor following the manufacturer's instructions.	On each day the sensor is used.
Conductivity	Before monitoring, check the sensor's accuracy against at least 2 lab standard solutions: • standards ≤ 10 µS/cm: measurement should be within ± 25% • standards 10-200 µS/cm: ± 15% • standards >200 µS/cm: ± 5% If the measurement is outside the accepted range, calibrate the sensor following the manufacturer's instructions.	On each day the sensor is used. *(The NEMS also requires the sensor to be re-checked at the end of the day in a 148 µS/cm standard solution (should agree within ± 15%) and a note recorded with your measurements if this end of day sensor check is outside of the accepted range)*

Good sensor maintenance is critical to ensuring accurate and reliable measurements. The NEMS recommend that sensors are rinsed daily after use to keep them clean. Optical DO sensors should be stored with a damp sponge to keep them fully saturated – this will make sensor validation and calibration much easier. Also, sensor caps will need to be periodically replaced – check the manufacturer's instructions.

Visual water clarity

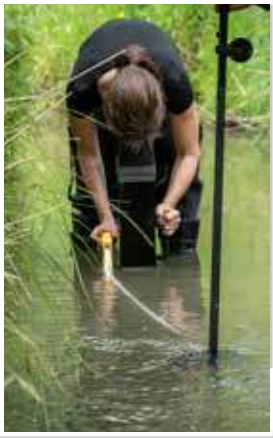
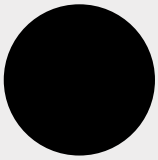
Training	In-field demonstration and practice based around the quality checks below
Method information	See page 47
Resources	• NIWA SHMAK videos: Water quality – visual clarity • Environment Canterbury video: Visual clarity tube measurements • NIWA e-Learning training videos (YouTube): WQ Rivers – black disk or visual clarity measurements
Refresher frequency	Annually if not regularly making visual clarity measurements or if regular measurements are made without a check by a second observer
Records	
Measurement resolution	Nearest 0.01 m (1 cm) or nearest 0.1 m if visibility using a black disc is >10 m
Supporting metadata	• Measurement device used (i.e., clarity tube or black disc)* • General lighting conditions (sun, shade, mixed)* • Appearance and reappearance distances* • Disc size used (black disc only)*
Quality checks	
Internal checks	*Clarity tube and black disc* • Path of sight uniformly lit (avoid shadows) • Measurements collected without being affected by a sediment/disturbance plume • Observer's eyes are snug to the tube end/viewer and time is allowed for eyes to adjust to stream lighting • Appearance and reappearance distances measured and recorded • A repeat set of measurements is made by a second, independent observer (the two average values of the appearance and reappearance distances should agree within ± 10%)* *Black disc only (additional to above)* Equipment checks • Discs painted in black matte with no chipped or worn areas • Viewer window and mirror are clean and scratch-free Measurement checks • Measurement made in flowing water, preferably in a run • Appropriate diameter disc size is used:* – 200 mm: where visibility is >1.5 m – 60 mm: where visibility is 0.5-1.5 m – 20 mm: where visibility is ≤0.5 m (or a clarity tube is used) • Measurement tape is pulled tight and kept straight
External checks	• The same checks as listed above made by an independent (trained) observer or specialist • Side-by-side measurement with a specialist – measurements should agree within 10%

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

Tips for visual clarity measurements

- Make sure you are downstream of the disc
- Keep your eyes snug to the viewer
- Let your eyes adjust to the stream lighting
- Ensure the measuring tape is kept tight

A clarity tube that comes with 1 cm increments printed along its length will make it easier to read distances.

Black disc	Whick black disc size to use?			
				
	Disc size (diameter)	200 mm	60 mm	20 mm
	Use if clarity is:	>1.5 m	0.5 to 1.5 m	<0.5 m

Why is it important to use the right size black disc?

The black disc method estimates visual clarity horizontally through the water column, which makes it more useful in shallow rivers and streams compared with the vertical Secchi depth method that is commonly used to measure water clarity in lakes and coastal waters. However, a bias arises when horizontal visual clarity measurements extend only a short distance from the underwater viewer. The black disc method accounts for this bias by using smaller diameter discs when the visual clarity is low (0.5–1.5 m) and very low (0.5 m).

Water sample collection

Note: The table below is for grab (discrete) water sampling for measurements of water quality indicators. Collection of water samples for eDNA testing is outlined on page 98.

Training	In-field demonstration and practice based around the quality checks below
Method information	See page 42
Useful resources	• NIWA e-Learning training videos (YouTube): – WQ Rivers – bottle sampling methods – WQ Rivers – sample handling and dispatch • NEMS Discrete Water Quality: Part 2 Rivers • NIWA SHMAK video: How to collect a water sample
Refresher frequency	Annually
Records	
Supporting metadata	• Collection method* (e.g., grab sample by hand, sampling pole) • Stream water appearance* (e.g., clear and colourless, slightly murky) • Sample collection time* • If the sample might be compromised in any way (e.g., if sediment on the streambed was disturbed and entered the sample bottle, a non-sterile sample bottle was used collect a sample for *E. coli* testing)
Quality checks	
Internal checks	• Water sample(s) are representative of the site, taken ~0.2 m below surface in flowing water away from immediate contamination sources • Correct lab sample bottle(s) used for the indicator(s) to be measured and correctly rinsed and/or filled (see box opposite page) • Sample bottles clearly and permanently labelled with an identification code • Samples promptly removed from light and placed in chilled containers • Completed Chain of Custody form accompanies water samples sent to a lab, including site name (or code), date and time of sample collection and dispatch, and anything unusual about samples (e.g., if they are brackish) • Field replicates[1] • Field blanks[1]
External checks	• The same checks as listed above made by an independent (trained) observer or specialist • Side-by-side water sample collection with a specialist, with samples sent to the same lab or processed using the same test kit. Measurements should agree within the range specified for the relevant indicator in this section (e.g., ± 5% for conductivity).

*The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

[1] Annually if samples are going to a lab but at least quarterly if self-testing for ***E. coli*** or nutrients.

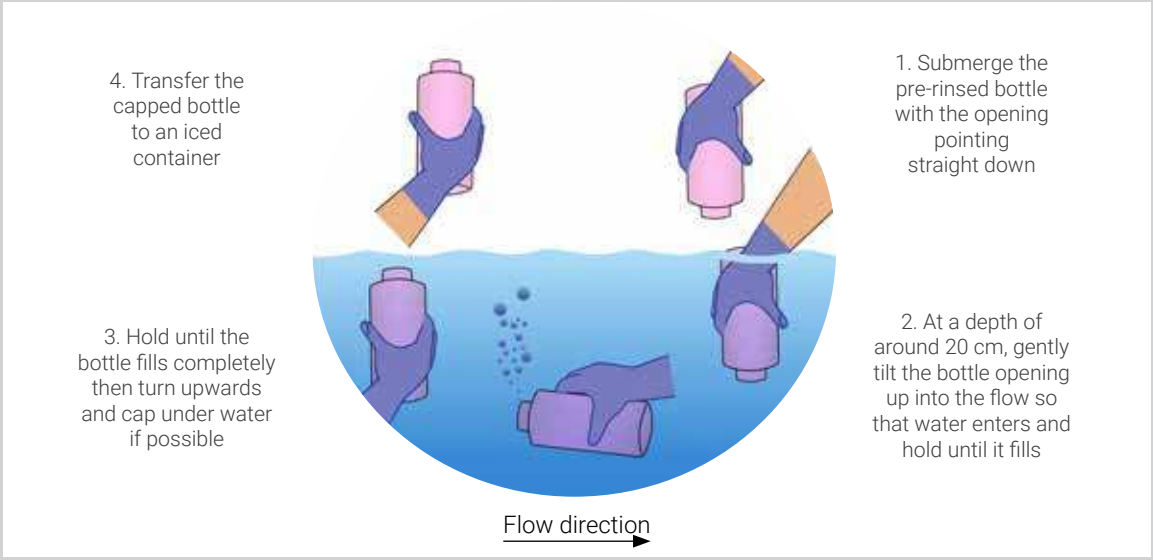
Sampling a stream is more than just dipping a bottle in at the stream bank and sending it to a lab for testing. Sampling is the first step in measuring water quality and any errors caused by incorrect sample collection or handling cannot be fixed by the lab.

It is important to ensure that the sample your group collects represents the larger body of stream water of interest and is safely handled and delivered in good condition to the lab.

Remember to check your group has the right bottles for the tests to be done – talk to the lab well ahead of time and to confirm any special delivery or other requirements.

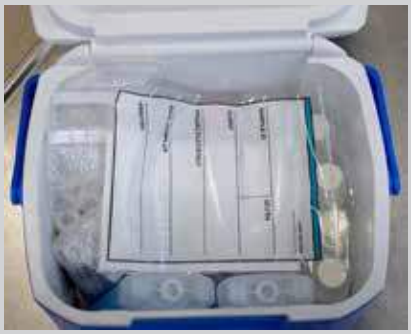
Golden rules for collecting stream water samples

1. Label each sample bottle with your monitoring site name (or code), your initials and the date and time of sample collection.
2. Collect samples in the main flow of the stream, about 20 cm below the water's surface – if it isn't safe to enter the stream, use a sample pole.
3. Approach your sampling location from downstream so that the flow carries any disturbed bottom sediment downstream away from your (upstream) sample collection area.
4. Remove the cap of the sample bottle just before sampling and avoid touching the inside of the cap or bottle.
5. Sample bottle filling
   - *Sample bottles that contain no preservative* – rinse the bottle three times in the stream water and then fill completely to the top as shown in the diagram below.
   - *Sample bottles that contain preservative* – fill the bottle to shoulder from a triple rinsed unpreserved bottle, cap it, and then invert gently to mix the preservative and sample.
   - *Sterile sample bottle for E. coli or other microbiological indicator testing* – fill the bottle directly and leave a small air gap at the top.
6. Remove samples from the light and cool promptly in a chilly bin to <10˚C. Do not let the samples freeze! (If your sample needs to be filtered, see the guide under self-nutrient test kits, page 94.)



Sampling technique for sample bottles without preservatives.

Examples of different bottles used for water sampling. The yellow top bottle is a sterile and should be filled without rinsing, with a small air gap left at the top. The green-labelled bottle contains acid preservative which will be lost if the bottle is submerged – fill this bottle from another bottle to the shoulder, cap and invert to mix.



A packed chilly bin for samples destined for overnight courier delivery. Keep sample bottles upright and tightly packed to avoid movement (sometimes extra packing may be required on top). Cooler pads have been added and the Chain of Custody form is included in a zip-lock bag on top.

Self-test kits

pH and nutrients

Training	Demonstration and practice based around the quality checks below, including practice with sample filtering and dilutions if these are likely to be used
Method information	See pages 51–54
Useful resources	• NIWA SHMAK video: Water quality – nitrate • NIWA SHMAK video: Water quality – phosphate
Refresher frequency	Annually
Records	
Measurement resolution	To nearest half increment of the test strip measurement range (e.g., for a measurement that lies between test strip increments of 0.1 and 0.2, enter 0.15)
Supporting metadata	• Water sample collection method* • Water sample condition* • Test kit make, model and measurement range* • If a sample was filtered prior to testing (nutrient kits only)* • Details of any sample dilution performed prior to testing (nutrient kits only)*
Quality checks	
Internal checks	***pH*** • Expiry date of test strips • The test strip reading is made within recommended timeframe and verified by a second observer • A repeat test is performed by a second, independent observer* (the two results should agree within the same measurement increment) • Measurement performed on a standard solution of known pH and agrees within the same measurement increment • The test strip reading is made within recommended timeframe and verified by a second observer ***Nutrients*** • Expiry date of test strips or reagents • Turbid water samples are filtered* • Sample test made at ambient air or water temperature • Reading of the test measurement is made within recommended timeframe (e.g., 60 seconds for Hach nitrate-N strips) and verified by a second observer • Results presented as nitrate or phosphate are converted to nitrate-N or DRP* • A repeat test is performed by the same or a second (different) observer* (the two results should agree within the same measurement increment or 10%) • A standard solution of known concentration is tested using the kit and the measurement falls within the correct measurement increment (or 10%)
External checks	• Side-by-side sample testing with an independent specialist – measurements should agree within the same measurement increment or 10% • A sample is sent to the lab for testing (note the lab will filter the sample and the test method may differ but if the sample was relatively clear and colourless, the lab measurement should fall within the same increment range of the test kit)

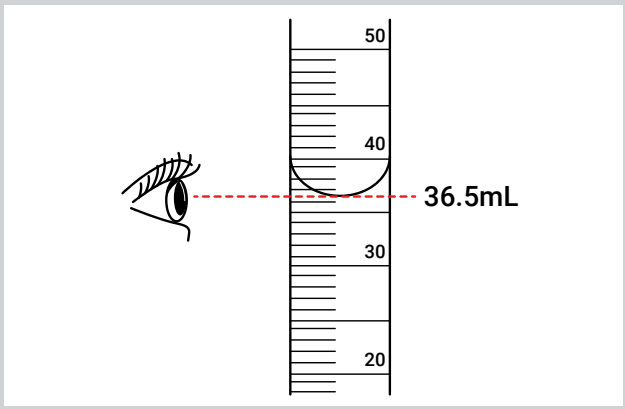
* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

How to get the best results with nutrient test kits

Reading a Hach test strip – avoid touching the test pads on the end of the strip. Make your reading in good light and within the required timeframe by holding it against the colour chart.

With powder-based reagents, form a spout in the reagent packet by pressing on each side to help with pouring the powder into your test vial. Using a funnel will further help avoid spillage.

Reading a colour comparison chart. On a flat surface under good natural light, look straight down, sliding the vials from left to right until you get the best colour match (top row). If the colour lies between two colours, record the midpoint value.



To accurately read a sample volume, place your measuring or test vial on a flat surface and at eye level, imagine a line across the lowest point (called the meniscus).

Field filtering samples

The testing of water samples for dissolved forms of nutrients and metals is carried out on filtered water samples. Unless there is going to be a delay in getting samples to the lab, we recommend your group asks the lab to do the filtering. Filtering can be done in the field or at home with the right equipment and taking care to avoid introducing any contamination. The lab can supply syringes, filters and instructions. Instructions are also available in NEMS Discrete Water Quality: Part 2 Rivers.

If your group is using a nutrient self-test kit and the water samples are turbid, they will need to be filtered first or sent to a lab for filtering and testing. Strictly speaking, all samples for self-testing should be filtered to ensure that only the dissolved inorganic nutrient fraction is measured.

E. coli

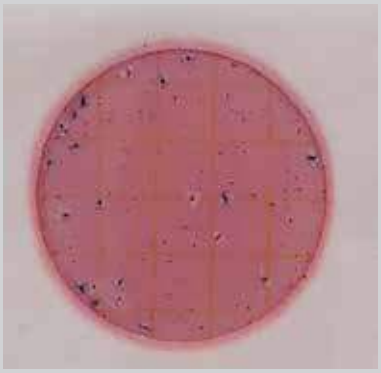
Training	Demonstration and practice based around the quality checks below, including practice with sample filtering and dilutions if these are likely to be used
Method information	See page 57
Useful resources	• NIWA's SHMAK kit is supported by 3 short videos demonstrating: – How to analyse a water sample for *E. coli* with 3M™ Petrifilm™, using the direct plating method for high concentrations. – How to analyse a water sample for *E. coli* with 3M™ Petrifilm™, using the filtering method for low concentrations. – How to count and report the *E. coli* colonies on a 3M™ Petrifilm™ gel. • The Aquagenx® website has a video demonstrating *E. coli* testing using the Compartment Bag Test (CBT) EC-TC MPN kit
Refresher frequency	Annually
Records	
Measurement resolution	To nearest whole number (CFU tests or as per the statistical tables for the test (MPN test)
Supporting metadata	• Water sample collection method* • Water sample condition* • Water sample testing date* • Test method used* • Details of number of test plates and any sample dilution performed prior to testing* • Sample incubation temperature and timeframe (CBT) EC-TC MPN test kit only)* • Plate/bag *E. coli* count, including if the *E. coli* colonies were "too numerous to count"* and which plate(s) were used in calculating the final measurement*
Quality checks	
Internal checks	• Sterile sample bottle used* and filled directly, with a small air gap • Water sample removed from light and chilled promptly following collection • Plates/CBT kits have not expired • Sterile pipette and tweezers used (plate methods only) • Sample blank tested and no *E. coli* colonies found after incubation • More than one plate is prepared and, where *E. coli* is abundant, one plate has *E. coli* present in the optimum range for counting by eye (20 to 80 colonies, see box opposite page) • The *E. coli* plate count (and expression per 100 mL*) or CBT reading is verified by a second observer • A repeat test is performed by a second, independent observer* – the two measurements, after translation to a Log value, should agree within around ± 0.5 Log value**
External checks	• Side-by-side sample collection with a specialist followed by paired testing – measurements, after conversion to a Log value, should agree within around ± 0.5 Log value** • A duplicate water sample is collected, with one of the samples sent to a professional lab for testing using a similar test method (the self-test and lab measurements, after conversion to a Log value, should agree within around ± 0.5 Log value**)

*The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

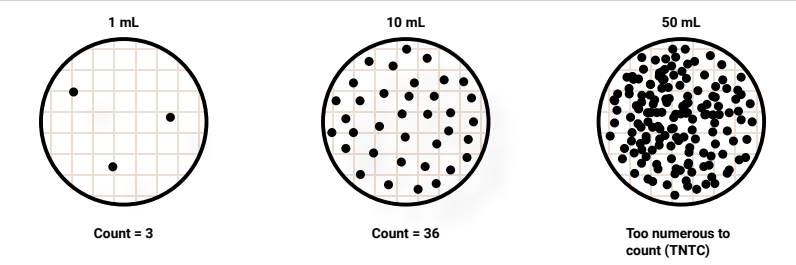
** Microorganisms such as *E. coli* multiply exponentially and so a logarithmic scale is used to assess an acceptable level of variation between repeated tests.

How to get the best results with plate-based *E. coli* testing

1. Ensure the sample bottle and testing equipment are sterile.
2. Once collected, remove the sample from the light and cool (below 10˚C, but do not let it freeze!)
3. Test the sample promptly after collection, ideally on the day of collection (otherwise keep it cool in a chilly bin or place it in the fridge and test the next day).
4. Invert the sample container gently several times to mix the sample before removing your subsample(s) for testing.
5. Ensure all subsamples are accurately measured – check the readings of your pipette and filter cup at eye level.
6. Check the incubator has stabilised at the target temperature before placing your sample(s) inside.
7. Double check your identification and counting of *E. coli* colonies.
8. Consider which plate(s) is best for calculating the official *E. coli* result.
9. Check the final calculations are correct so that the *E. coli* count is reported per 100 mL.



E. coli are the blue colonies (the small red colonies are total coliforms)



E. coli colonies after incubation on three test plates that received different subsample volumes. Plate A (left) is easy to count but there are too few colonies for a robust assessment. Plate B has *E. coli* within the optimal counting range of 20 to 80 colonies. Plate C is crowded with colonies making it very difficult to accurately count the total number. In this case, Plate B is best used to calculate the official *E. coli* result as follows: 36 x 10 = 360 CFU/100mL).

If only 1 mL of sample is tested and an error is made in identifying or counting just one *E. coli* colony this will translate to a 100-fold error in the final result!

Deciding on volumes of subsample to test

The number of *E. coli* bacteria in some streams can range from very low to very high, so getting a reliable measurement often requires testing multiple subsamples.

Determining the number and volume of subsamples to test is not a perfect science! However, the more faecal contamination a stream is expected to have, the smaller the volume of sample that needs to be tested. For example:

- stream sites that are in native or forested headwaters usually have very low *E. coli* counts and at least 50 mL of sample may need to be tested
- stream sites near or downstream of farming and urban areas often have multiple sources of faecal contamination – so using the direct plate test method of 1 mL should ensure that the *E. coli* colonies that form on the test plate are within a countable range.

Where stream sites have less intensive land use activities in the upstream catchment (e.g., lifestyle or exotic forestry areas), it is a good idea to test different subsample volumes (e.g., 1 and 10 mL or 1 and 20 mL).

As a general rule, when the water is very turbid, start with testing 1 mL of sample. This is best done in duplicate or triplicate. The *E. coli* colony count on each plate for a 1 mL subsample will need to be multiplied by 100 to report as *E. coli* CFU per 100 mL.

Laboratory (lab) testing

Lab testing is required for some indicator measurements and is an option for others. Labs have dedicated quality assurance procedures that address training and both internal and external quality control measures. Many labs have their methods IANZ accredited which is a useful quality check – and essential if your group wishes to collect monitoring data to inform regulatory processes.

One way to test the lab's performance for yourself is to periodically collect and split a sample into two bottles. Send these duplicate water samples to the lab under a dummy site name: the results should generally agree closely (within 10-15% for most indicators).

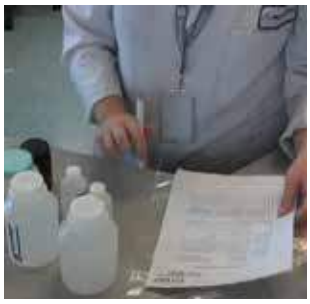
There is also information that the lab needs to provide to confirm your group's samples were received in an acceptable timeframe and condition for testing. You can get this information by completing a Chain of Custody (CoC) sampling form (supplied by the lab). Also check the final lab test report for any special notes about the measurements made. For example, sometimes a lab can't achieve its standard detection limit (e.g., if there wasn't enough sample provided or something in the sample interfered with the testing).

Quality checks	Comment
The lab confirms receipt of the samples within appropriate timeframes for testing	Information provided by return of your group's CoC form
The lab confirms the samples were in acceptable condition for testing (e.g., samples were below 10˚C on arrival)	Information provided by return of your group's CoC form
The lab is IANZ accredited to perform the selected test method	This is recommended if your group wish to use the data in regulatory processes and is consistent with NEMS requirements
The lab records on its report if any issues may have affected the quality of the test results (e.g., labs will note any water samples that arrive for *E. coli* testing outside of the recommended 24-hour processing time)	This information should be provided as a note on the bottom of the lab test report

Lab QA/QC

Accredited labs have a detailed QA system that includes a large range of internal and external quality control (QC) measures. These include some of the examples given on pages 84–85 (e.g., equipment or lab blanks, testing samples in duplicate or triplicate) as well as other checks. For example:

- **Spiked water samples:** A known quantity of the indicator being measured is added to the water sample to increase its concentration in the sample by a known amount. This check is normally used by a lab to assess the accuracy of a test method but it can also be used to check measurement accuracy for CBM self-test kits.
- **Standard reference materials (SRM) or "knowns":** This is a sample of known chemical or biological composition and/or physical properties tested alongside 'regular' samples. It is used to confirm the accuracy of a test or measurement method.



Recording arrival of samples at the lab (top) and checking the temperature inside the chilly bin.

Aquatic life indicators

eDNA water sample collection

Sterile gloves are used when collecting and handling eDNA samples to avoid sample contamination.

Training	In-field or video demonstration
Video resources	Video available from the Environmental Protection Authority and Wilderlab
Refresher	Annually
Records	
Supporting metadata	• Sample collection method* • Number of samples* and sample identification number* • Volume of stream water filtered *(for active/syringe samples only)** • Deployment time *(for passive samplers only)** • If the sample might be compromised in any way*
Quality checks	
Internal checks	• Samples are not collected immediately after heavy rain • Sterile gloves are used during sample collection and handling • Replicate samples, where collected, are collected from downstream to upstream • Water sample(s) are representative of the site, collected below the surface in flowing water and facing upstream • Samples have a unique code • 1 L of stream water is filtered or, if the water is turbid, filtering continues until the filter is clogged • Completed Chain of Custody form accompanies water samples sent to the lab, including site name (or code), date of sample collection and dispatch, and anything unusual about samples (e.g., if they are brackish) • Field blank collected[1]
External checks	Side-by-side water sample collection with an independent person experienced in sample collection, with both samples sent to the same lab for testing

*The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

[1] Depends on the intended end use of the data but an option if replicate samples are not collected and an extra check on lab performance is wanted.

Periphyton and *Microcoleus* ("toxic algae")

Periphyton streambed cover

Training	Field demonstration with an experienced specialist, followed by practice, identifying different types of periphyton and estimating their streambed coverage with an underwater viewer
Method information	See pages 63–64
Useful resources	• NIWA National River Water Quality Network periphyton ID guide • NEMS Periphyton – includes photos of the different periphyton categories and details on how to use a viewer • NIWA SHMAK video: Stream life – periphyton
Refresher frequency	Annually for instream cross section methods
Records	
Measurement resolution*	• Bankside estimate: Not applicable – selected from cover category options in survey • Instream stone method: nearest 10% • Instream cross section method (simplified): nearest 10% • Instream cross section method (detailed): nearest 5%
Supporting metadata	• Viewer method (for instream visual assessments)* • The side of the bank observations are made or started from (true left or true right)* • The number of cross sections surveyed* • Estimate of shade cover at survey area* • Estimate of stream width surveyed* • Presence of *Microcoleus* (toxic cyanobacteria) mats exposed at or near the stream edge*
Quality checks	
Internal checks	• Correct use of a viewer (for instream visual assessments), viewer window positioned horizontally under water to up to 20 cm depth • Survey commences from downstream and moves upstream • Some observation(s) are repeated by a second, independent observer to verify the periphyton types identified and cover estimates (cover estimates for the most dominant types should agree within 10-20%. Comparisons should be made over the same area(s) of streambed as far as possible. • Supporting metadata are recorded
External checks	• Photographs are taken for an independent specialist to verify the dominant periphyton types present • The same checks as listed above are made by an independent specialist

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

Microcoleus cyanobacteria streambed cover

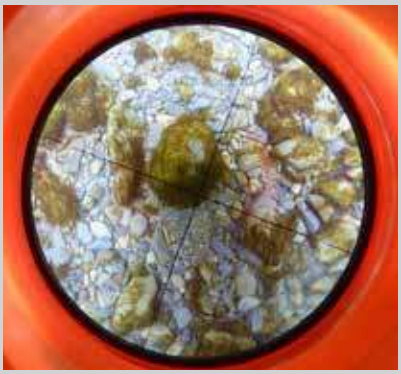
Cyanobacteria is one of the categories included in two of the periphyton cover measurement methods (instream stone and instream cross section detailed).

Where cyanobacteria cover is selected as a standalone stream health indicator (i.e., assessed independent of periphyton cover), the training and quality checks should be the same as for periphyton cover above except that the focus is on identifying and estimating coverage of *Microcoleus* to the nearest 10%.

The Cawthron Institute has made a short video to support identification of *Microcoleus* in rivers.

Tips for visual estimates of streambed periphyton cover

An underwater viewer gives the clearest view of streambed periphyton cover. Dividing the end of the viewer into quadrants using thin black tape, a vivid marker or paint will help improve the accuracy of your cover estimates. Try to keep your face snug to the viewer and let your eyes adjust before you make your estimates.



Demonstrating the correct technique for use of an underwater viewer to estimate streambed cover (middle) and (right) the streambed as seen from looking down the viewer (showing 60% filamentous cover)

Green filaments

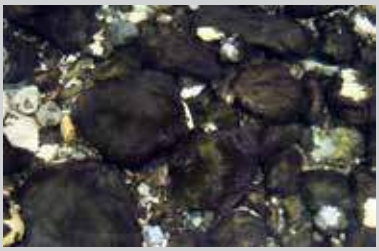
Mats

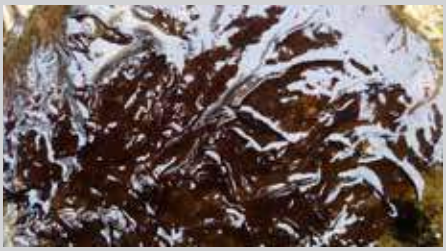
Thin films

Didymo

Sludge

If long term trends in periphyton cover is of interest, it can be useful to leave markers on the bank to indicate cross section locations – or, as shown here, use markers (painted rocks) on the streambed to indicate observations points





Microcoleus cyanobacteria – look out for dark green to black mats with a musty odour. The mats can grow very thick and may resemble black tar.

Macrophytes

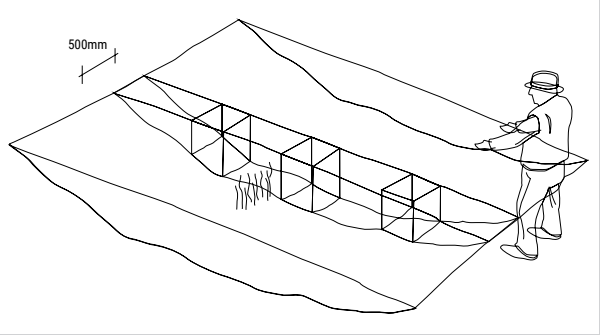
The information below will assist with cross section-based assessments of the amount (as a percentage) of:

- water surface area occupied by macrophytes, and
- water surface area and water volume occupied by macrophytes (recommended).

Training	Field demonstration with an experienced specialist, followed by practice, estimating macrophyte abundance and volume
Method information	See page 65
Useful resources	NIWA SHMAK video: Stream life – macrophytes
Refresher frequency	Annually
Records	
Measurement resolution*	• Water surface area: Nearest 10% • Water volume occupied: Nearest 10%
Supporting metadata	• Assessment method (e.g., bankside vs instream)* • Length of stream reach assessed* • The side of the bank observations are made or started from (true left or true right)* • The number of cross sections surveyed and point observations made* • Comments (e.g., if only part of stream width assessed, presence of exotic or pest species, if known)*
Quality checks	
Internal checks	• For bankside estimates, the water is clear enough to see the stream bottom • Survey starts from downstream and moves upstream • Some abundance estimate(s) are repeated by a second, independent observer and these agree within 20% • Supporting metadata are recorded
External checks	• Photographs are taken from the bank of each cross section for an independent specialist to verify the water surface cover estimates • The internal checks as listed above are made by an independent specialist

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

How to estimate macrophyte abundance



For bankside estimates (above), imagine a 0.5 m wide band across the stream. Within this band, estimate the percentage of water surface and water volume occupied by macrophytes. Where the stream is wider than 3 m, picture 3-5 columns, each 0.5 m wide going down to the stream bed and make the assessment within these.

For instream macrophyte assessments (left), a quadrat will make it easier to estimate surface cover and an underwater viewer can improve estimates of the water volume occupied by macrophytes.

Problem macrophytes

Depending on your group's monitoring objectives, it can be useful to comment on the field form if any of the macrophytes present are a pest species. Some examples of macrophytes are shown below. Various identification tools and guides are available on-line (e.g., NIWA macrophytes plant ID guides, NZ Plant Conservation Network).

If you are unsure, take a photograph and see if a freshwater plant ecologist can look at it for you.

Hornwort
(Ceratophyllum demersum)

Curly pondweed
(Potamogeton crispus)

Lagarosiphon
(Lagarosiphon major)

Eel grass
(Vallisneria spp.)

Macroinvertebrates

Sample collection

Training	Field demonstration with an experienced specialist, followed by practice, to collect and either: • sort and identify the invertebrates in the sample, or • sort and preserve a sample for laboratory identification.
Method information	See page 66
Resources	• NIWA SHMAK guidance manual • NIWA SHMAK videos – Stream life – collecting benthic macroinvertebrates using the stone method – Stream life – collecting benthic macroinvertebrates using the kicknet method – Stream life – collecting benthic macroinvertebrates in muddy bottomed streams • For samples that will be processed by an external lab, see NEMS Macroinvertebrates for sample sorting and preservation requirements
Refresher frequency	Annually prior to sampling
Records	
Supporting metadata	• Name of group member collecting the sample • Sample collection method* • Number of kicks made (kick net method only)* • Streambed habitat types sampled* • Whether samples are being processed live or preserved for identification later* • Rapid habitat assessment (see pages 71–72 and 106)
Quality checks	
Internal checks	• Kick net is clean and any holes have been repaired before use • 0.5 mm mesh is used • There has been about 2 weeks of stable stream flows prior to sample collection • Sample collection starts downstream and moves upstream • A good seal is made between net and streambed • The streambed is disturbed sufficient to dislodge invertebrates into the net, including use of hands if need be • Habitats sampled match the method selected • Samples are sorted for either processing live or preservation, with large sticks, stones and leaves discarded once attached macroinvertebrates have been removed • Where samples are preserved: – a sample label is included inside and outside the container, and – sufficient preservative is added to the sample container to achieve a concentration of at least 70% (allowing for stream water already present) • Supporting metadata are recorded
External checks	• The internal checks listed above are made by an experienced independent specialist

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

Sample processing (macroinvertebrate identification and counting)

The information presented here is for groups that are identifying and estimating macroinvertebrate abundance on live samples. If samples are being sent to an external lab for identification, the lab will have internal QA and QC requirements to ensure the sample is processed correctly. The NEMS Macroinvertebrates includes requirements for labs processing samples for state and trend assessments.

Training	Demonstration followed by practice with an experienced specialist to identify and count (or estimate) the number of the invertebrates in a sample followed by practice
Method information	See page 67
Resources	Various macroinvertebrate identification guides are available – for example; • NIWA SHMAK guidance manual • NIWA SHMAK videos – Stream life – how to get your benthic macroinvertebrate sample ready for sorting – Stream life – how to sort and identify your benthic macroinvertebrate sample • NIWA SHMAK invertebrate guide
Refresher	Annually prior to sampling
Records	
Supporting metadata	• Name of group member(s) processing the sample* • Macroinvertebrate types identified* • Estimate or count of macroinvertebrates present* • Comments on any problems with macroinvertebrate identification*
Quality checks	
Internal checks	• Macroinvertebrate identification guides are used to confirm identifications • Another group member independently checks the identifications made
External checks	• The identification of selected macroinvertebrates is confirmed by sending photographs of them to an experienced independent specialist • The internal checks as listed above are made by an experienced independent specialist • Voucher specimens (or entire sample) preserved and sent to an external specialist or lab for identification

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

Sorting a macroinvertebrate sample

Take care not to lose any invertebrates when turning the net inside out over the sorting tray. Use tweezers to carefully pick out any that are caught in the net. A white tray with compartments, such as an ice cube tray, can be useful for sorting different invertebrate types before identifying and counting them.

Preserving and labelling a macroinvertebrate sample

If sending a sample to a lab for processing, ensure that you:

- remove any large rocks, twigs and leaves
- do not have sample content that fills more than half of the container
- minimise the amount of stream water so that the preservative is not diluted
- label the container inside and out with the site name, site code and sampling date

Fish

Training	Demonstration with an experienced specialist, followed by practice, to identify and count (or estimate) the species and number of fish seen (spotlighting) or caught (trapping)
Method information	See page 68
Resources	• NIWA online freshwater fish ID guides and Atlas of NZ Freshwater Fish • NZ freshwater fish sampling protocols (Joy et al. 2013)
Refresher training	Annually prior to sampling
Records	
Supporting metadata	• Method(s) of fishing* • Stream and weather conditions* • Name of group member(s) that carried out the fishing* • Whether a freshwater fish ecologist or monitoring officer assisted with the survey and fish identification* • Supporting water quality measurements (optional to collect)* • Water depth range* • Length of stream reach surveyed* • Stream reach habitat types surveyed* • GPS coordinates for downstream end of reach* • Details of traps used (type, number, mesh size)* • Fish identified* • Estimate or count of fish sizes and abundance (optional to collect)* • Comments on any pest fish or problems with fish identification*
Quality checks	
Internal checks	• Fish identification guides are used to confirm identifications • Unexpected fish are compared against existing records for the catchment/area (e.g., the NZ Freshwater Fish Database, regional councils)
External checks	• The identification of selected fish is confirmed by sending photographs of them to an experienced independent specialist

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

Minnow trap set in a stream. Placing rocks inside the trap will help weigh it down and the trap should be tied to a rock or wooden stake at the stream bank to ensure it remains secure.

Regional council science staff demonstrating how a fyke net works. These nets should be set with the mouth facing downstream to minimise leaves and other debris from entering.

Stream habitat indicators

Physical habitat quality

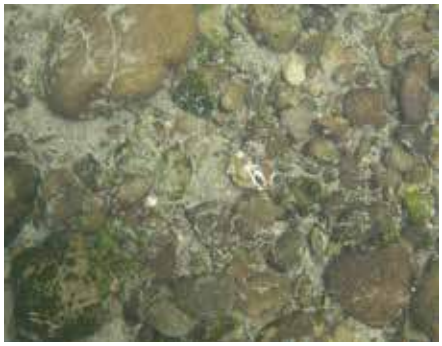
Training	Field demonstration with an experienced specialist followed by practice running through each of the different habitat variables and how to score them)
Method information	See page 71
Resources	• NIWA SHMAK habitat video – visual habitat assessment (8 variables) • Cawthron National RHA method videos
Refresher frequency	Annually
Records	
Supporting metadata	• Habitat assessment collection method* • Names of group members completing the assessment* • Width of wetted stream channel* • Length of stream reach assessed* • Photograph(s) taken
Quality checks	
Internal checks	• Correct use of a viewer (for instream visual assessments), viewer window positioned horizontally under water to up to 20 cm depth • Survey commences from downstream and moves upstream • Some observation(s) are repeated by a second, independent observer to verify the cover estimates (estimates should agree within the same cover category or 20%) • Supporting metadata are recorded
External checks	• Photographs are taken for an experienced independent specialist to verify some of the percentage cover estimates made • The survey is completed side-by-side by an experienced independent specialist and scores agree within the same category or 20%

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

See the national Rapid Habitat assessment protocol (Clapcott 2015).

It can be helpful scoring stream habitat features in pairs.

Deposited fine sediment



Examples of different amounts of fine deposited sediment cover. From left to right: 30%, 50% and 100%.

Training	Field demonstration with a specialist followed by practice estimating the percentage of the streambed covered in deposited fine sediment with an underwater viewer
Method information	See page 73
Resources	Cawthron Institute video of national RHA method video (includes commentary on sediment cover assessments)
Refresher frequency	Annually for instream cross section methods
Records	
Measurement resolution*	• Bankside estimate: Not applicable – selected from cover category options in survey • Instream cross section method: nearest 10%
Supporting metadata	• Viewer method (for instream visual assessments)* • The side of the bank observations are made or started from (true left or true right)* • The number of cross sections surveyed* • Estimate of stream width surveyed*
Quality checks	
Internal checks	• Correct use of a viewer (for instream visual assessments), viewer window positioned horizontally under water to up to 20 cm depth • Survey commences from downstream and moves upstream • Some observation(s) are repeated by a second, independent observer to verify the cover estimates (estimates should agree within the same cover category or 20%) • Supporting metadata are recorded
External checks	• Photographs are taken for an experienced independent specialist to verify some of the percentage cover estimates made • The survey is completed side-by-side by an independently experienced specialist and the cover estimates agree within the same cover category or 20%

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

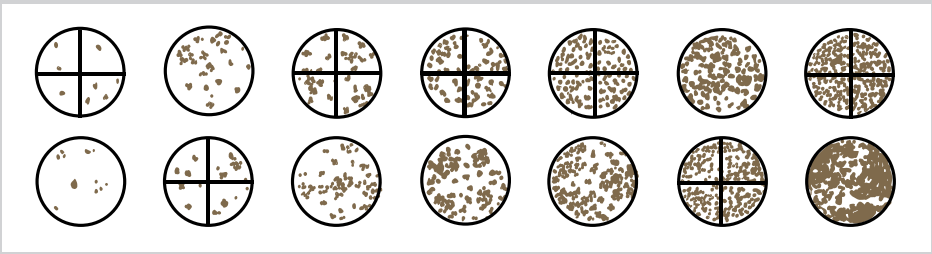
See the National Sediment Assessment Methods (Clapcott et al. 2011)

Tips for sediment cover assessments

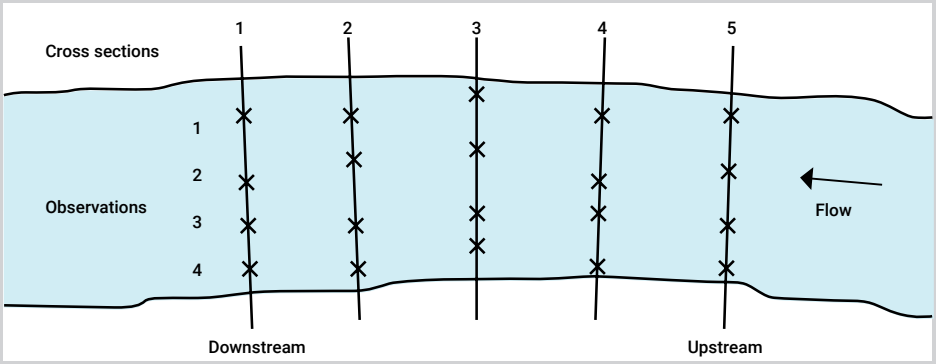
1. Where possible, complete the assessment after a period of stable stream flow.
2. For instream assessments, use an underwater viewer for a clear view of the streambed.
3. Work from downstream to upstream, approaching your observation point from downstream so that any disturbed bottom sediment is carried downstream away from your sample collection area (upstream).
4. Only assess the portion of the streambed you can actually see (e.g., wadeable, clear water that is not obstructed by aquatic plants or algae).
5. Focus on sediment particles less than 2 mm in diameter – sand, silt or mud.
6. Don't record thin films of fine sediment that forms over the top of coarser substrate or streambed periphyton (because this is not a permanent habitat feature).

Dividing an underwater viewer into quadrants and estimating the cover in each is often easiest. At each observation point, take the average of these four estimates to arrive at your streambed percent cover of fine sediment

A mixture of sand and silt that indicates the upper range of fine sediment



Examples of fine sediment cover on the streambed as seen looking through an underwater viewer.

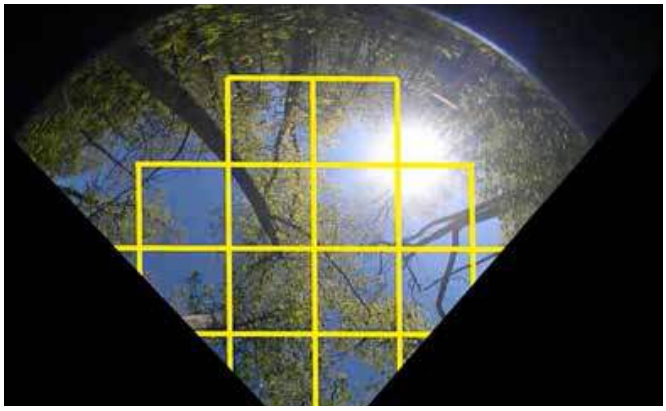


Possible layout of observations points across five cross sections. Always start at the most downstream cross section.

Shade (canopy closure)

Training	Field demonstration with a specialist experienced in assessing stream shade or habitat, followed by practice
Method information	See page 75
Video resources	U.S. Fish and Wildlife Service video: Measuring stream canopy closure using a spherical densiometer
Refresher frequency	As required
Records	
Supporting metadata	• Type of densiometer used* • If a tripod was used to take measurements* • The length of stream reach surveyed* • The number of cross sections surveyed* • Name of group member making the observations* • Number of vegetation 'hits'* • Photos of canopy cover looking upstream and downstream*
Quality checks	
Internal checks	• Correct densiometer set-up – Strickler modification (see page 76) • Tripod used or otherwise kept level at a consistent height ~0.3 m above the water's surface   • Measurements correctly taken in all four directions from the centre of the stream (A) and (especially for wide streams or where data on overhanging vegetation is wanted) facing each stream bank (B) • A second set of measurements is made by a second group member to verify the cover estimates. Cover estimates should agree within around: – 10-15% when canopy cover is very sparse (<20%) or dense (>80% and 20%) – 15-25% when canopy cover is between 20% and 80% • Supporting metadata are recorded
External checks	• Photographs looking up at the canopy from the centre of the stream are taken for an experienced independent specialist to review • The survey is completed side-by-side by an independently experienced specialist and cover estimates agree within the same ranges specified for the internal checks above

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.



- Make sure the densiometer is held level and your head is positioned so that it is just showing close to the top edge of the grid
- Count the number of intersection points covered by canopy, called vegetation 'hits' (in this image, only two in points are not covered)
- The canopy closure (%) is calculated for each observation points as follows:

$$\%\ canopy\ closure = \left(\frac{\#\ hits}{total\ observations}\right) x\ 100$$

$$\%\ canopy\ closure = \left(\frac{15}{17}\right) x\ 100$$

Rubbish (litter)

Training	Field demonstration with a specialist experienced in assessing rubbish followed by practice. Litter Intelligence offers training workshops (funding dependent).
Method information	See page 74
Video resources	SHMAK guidance manual and video
Refresher frequency	As required
Records	
Supporting metadata	• The length of stream reach surveyed • Name of group member(s) making the observations • Site photos (upstream, left bank, right bank) • GPS coordinates
Quality checks	
Internal checks	• An additional group member independently verifies the rubbish types identified
External checks	• Photographs are taken to verify the rubbish types present • 10% of surveys are audited whereby: – the survey area is re-searched and the number of missing items is recorded (the number of missing items should be <10% of the total count), and – the rubbish items collected are re-counted and re-weighed (the count and weight error should be <10%)

Examples of some different types of rubbish found in and along stream margins.

Water quantity indicators

Stream velocity and flow

Training	Field demonstration followed by practice (use of a current meter should include a demonstration with a specialist in stream flow measurement). *Note: Although the necessary calculations to arrive at velocity and flow are performed automatically in the ArcGIS Survey123 field forms, CBM groups should be familiar with what these calculations involve.*	
Method information	See page 78	
Resources	• NIWA e-Learning training videos (YouTube): – Float gauging method – Reading an external staff gauge – Current meter gauging practice • YouTube videos - for example: – How to Measure Stream Velocity – How to Measure a Stream Cross Section – Measuring River Velocity (with a basic flow meter)	
Refresher frequency	As required, potentially annually for current meter measurements	
Records		
Supporting metadata	<u>Float method</u> • Float device* • Length of measurement reach* • Timing device used* • Stream wetted width*	<u>Current meter</u> • Current meter make and model* • Meter's coefficient number
	• Description of measurement reach charactteristics* • Depth measurement method*	
Quality checks		
Internal checks	• One person manages the flow and another measures the travel time • Velocity measurement repeated three times • Multiple depth measurements made across the width of the stream	• The observer is positioned downstream of the current meter and in a way that does not impact the flow • The current meter is positioned directly into the flow at the correct depth (0.6 of the depth from the water's surface) • The current meter is operated for 60 seconds at each point to calculate the average velocity • Multiple current and depth measurements are made across the width of the stream
	 *Aim for 10 measurements across a stream unless the stream is very narrow or has a uniform channel (A)* • The measurement reach is relative straight, free of obstacles and has a uniform width and depth • Supporting metadata are recorded • If a council (or other) water level monitoring site is operated at or near the site, a photo is taken to verify the water depth and/or the estimate is compared with that of council	
External checks	• The same checks as listed above and, where a current meter is used, a second set of measurements are made by an experienced independent specialist (velocity and flow estimates should agree within approximately 10% and 20%, respectively)	

* The electronic ArcGIS Survey123 field forms in the national CBM QA framework will prompt collection of this information.

Rainfall

Training	Demonstration with a specialist or self-instruction
Method information	See page 79
Video resources	UK Met Office you-tube video: Measuring rainfall
Refresher frequency	As/if required
Records	
Measurement resolution	To the nearest 0.5 mm (4 inch plastic gauge) or 0.1 mm (5 inch gauge)
Supporting metadata	• Type of rainfall gauge • Rain gauge set up details, including height above ground • Whether the rain gauge location and set-up has been externally checked • Date and time of rainfall measurement period recorded
Quality checks	
Internal checks	• The rainfall gauge is positioned in open space, away from buildings, trees and other objects that may interfere with rainfall collection, as well as excessive wind • The rainfall gauge is located at least 0.3 m off the ground and is confirmed level (e.g., using a spirit level) • Measurements are made at regular intervals, ideally at 9 am each day • The rainfall measurement is read at eye level and at the bottom of the meniscus (see the diagram on page 94 showing how to accurate ready a sample volume) • A second person periodically verifies the primary observer's rainfall measurement
External checks	• The rainfall gauge set-up and water level reading procedure are checked by an experienced independent specialist, either in person or through supply of photographs

Summary

Training and quality checks form a critical part of the Monitoring and Quality Plan in the national CBM QA framework. While nothing will replace hands-on experience with monitoring equipment and demonstration of monitoring methods by a specialist, some excellent videos and guides are available on-line that will support training and individual or group refresher training. When planning refresher training, remember that the frequency and timing may be determined by changes in your group's monitoring programme, such as monitoring indicators and team members or roles. This is another reason why it is important to regularly review the details of your group's Monitoring and Quality Plan.

Quality checks go hand in hand with training and training refreshers and ensure that any errors that could impact data quality are identified and rectified before or during data collection. The ArcGIS Survey123 field forms, outlined next in Section 6, have been designed to assist with some of these quality checks.

SECTION 6

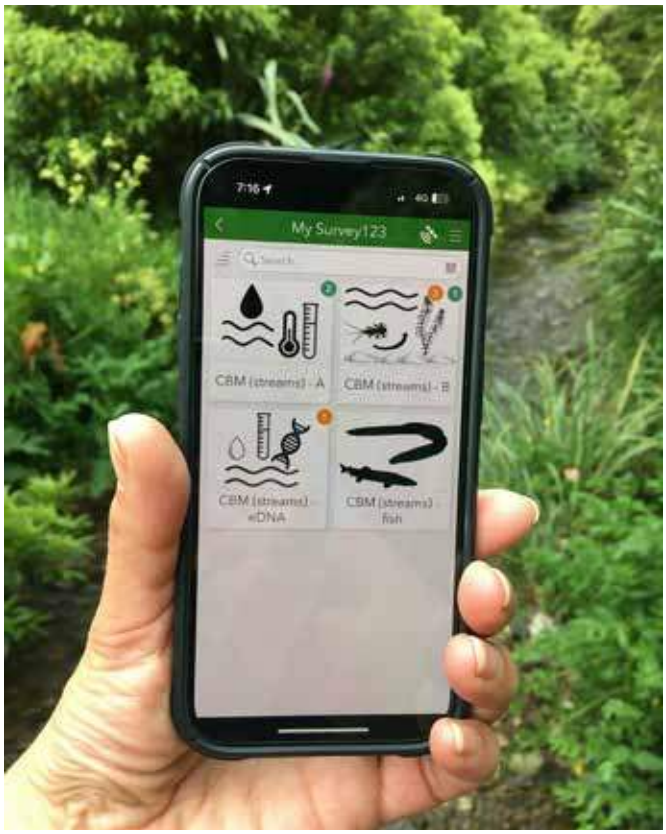
Data collection

The national CBM QA framework has been designed with the purpose of capturing stream monitoring data electronically at the time of collection.

Electronic data collection ensures that field measurements and observations can be captured in a standardised, timely and efficient way. Another advantage of electronic data capture is that it allows the data collection software to automatically complete specific calculation and quality checks.

As outlined in Section 2, electronic field form templates have been created using Esri's ArcGIS Survey123 software. Survey123 works on smart phones, tablets, laptops and desktop computers. Provided the software and field form templates are downloaded onto your device in advance, data can be captured in the field regardless of whether you have an internet connection at your stream location.

In this section, we take you through the key steps in using the field forms. A short instructional video is also available on the Wai Connection website.



Electronic field forms

The steps outlined below start at the point your group has already:

- completed the seven forms of the Monitoring and Quality Plan (see Figure 3-1, page 18),
- provided a copy of at least Form H ("Essential data re-use information") of the Plan to an organisation with an ArcGIS licence to host your group's stream survey forms, and
- agreed with the host organisation on how the data your group collects will be managed and accessed (see page 15).

Step 1: Receiving the survey form link(s) from your host organisation

Your host organisation will email you a link(s) to the CBM field forms that cover the stream health indicators your group will monitor. These forms are standard templates but will be customised at the front end so that:

- your monitoring group name appears (this may be in a dropdown selection), and
- your monitoring site names and codes are available in a dedicated list for your group to select from.

Depending on how your host organisation operates its ArcGIS system and what you have agreed to around data management, you may also receive a password to ensure only members of your group can enter data against your sites.

Click on the first survey link you receive from your host organisation.

- If you are a first-time user of ArcGIS Survey123, your smart phone or other device will prompt you to download and install the ArcGIS Survey123 app. This is free and quick to do.
- If you already have the ArcGIS Survey123 app, you will be taken to a sign in page. Because your host organisation is granting your group access, select "Continue without signing in" (if you happen to have an ArcGIS licence, you can log on via your licence).

The ArcGIS Survey123 sign-in page – you do not necessarily need to sign in

Step 2: Download your survey form(s)

Once you have passed the sign-in page the survey you received the link to will automatically download and open on the first page, ready for data entry. If you have received multiple links, exit the survey and click on the next link to download that survey. At most, you will repeat this process four times because the CBM stream health indicators are spread across four different forms:

- **CBM (streams) – A:** the main survey that contains all the water quality and other indicators likely to be measured the most frequently
- **CBM (streams) – B**: a survey that contains indicators likely to measured only once a year (e.g., physical habitat quality, macroinvertebrates)
- **CBM (streams) – eDNA**: a short survey only for collection of filtered water samples for eDNA testing
- **CBM (streams) – fish:** a survey only for fish monitoring data.

Ensure you have downloaded the relevant survey(s) onto your phone or device before you go out into the field. You only need to do this once, but you will need to periodically check for any updates to the survey and download these (see page 119).

The four CBM survey forms downloaded in ArcGIS Survey123

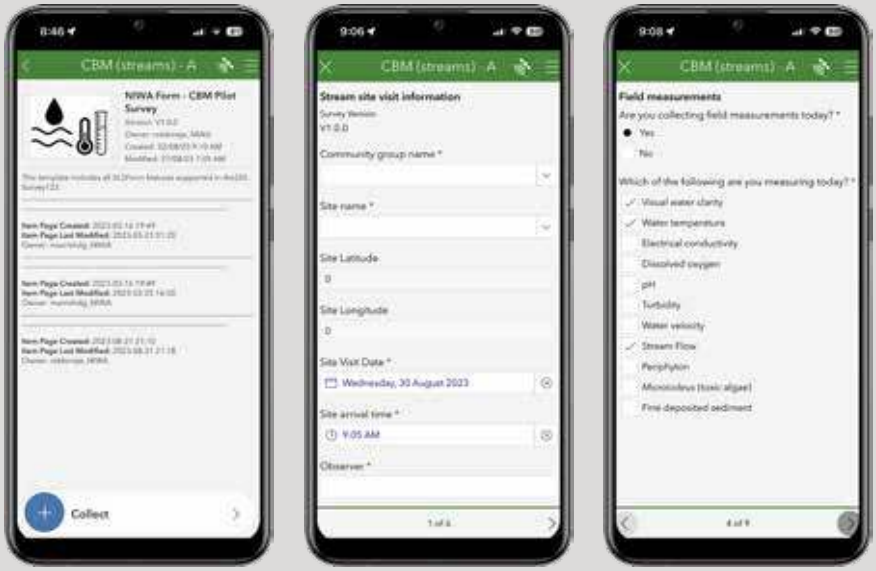
Step 3: Capture your survey data

Select the relevant survey from your menu in ArcGIS Survey123 and press the *Collect* button to begin the survey at your chosen monitoring site. A separate form will be completed in full for each monitoring site.

The survey will work through a series of questions to answer and data entry fields to complete. These begin with details around your site visit, including the site, date, time and weather and stream conditions (all four surveys ask for this site visit metadata, listed in Table 5-1, page 86).

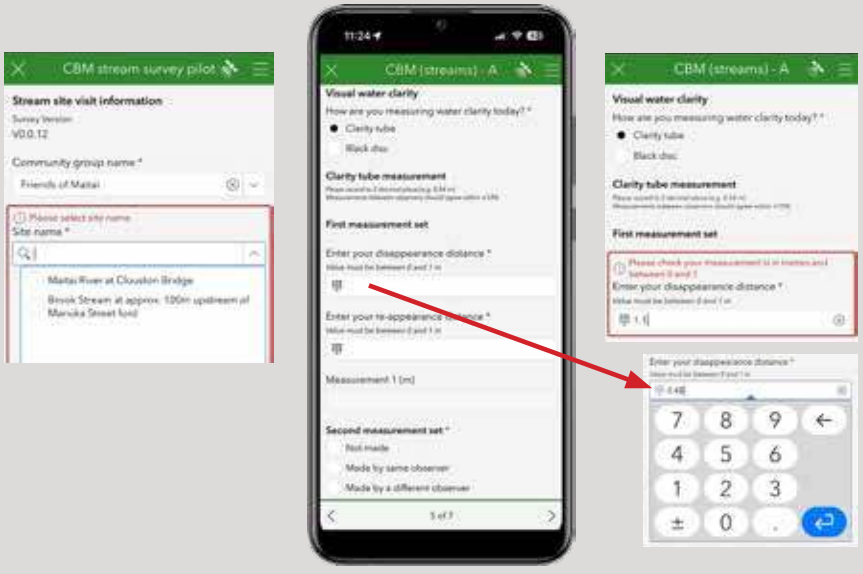
For the two main surveys, a menu-like page will appear (after the metadata) for you to select the specific stream health indicators you are measuring at the site. What you select here should align with your Monitoring and Quality Plan. In the background, Survey123 will load the relevant questions and details for the selected indicators.

You will then complete these questions and details for each stream health indicator. Most questions have a short set of options to select from to speed up data entry, standardise responses and reduce spelling errors. In some cases, a keypad will pop up to enable numbers to be entered.



Screen shots showing the collect button to launch data collection (left), the first page of the survey (middle) and the field measurements menu page (right).

Any question or field marked with a red asterisk indicates a mandatory requirement that must be completed. If you don't complete a mandatory requirement, Survey123 will not let you submit your data to the host organisation. In some cases, you will not be able to move on to the next question or a different part of the survey unless a field is completed.



Screen shots showing some features of the survey forms. On the left, is an example of a warning that appears when a mandatory question or selection has not been completed (questions/fields marked with an * must be answered). On the right is an example of a keypad button for easier entry of numeric data and also an example of a warning that pops up if an impossible measurement value is entered (because it is outside of the valid range).

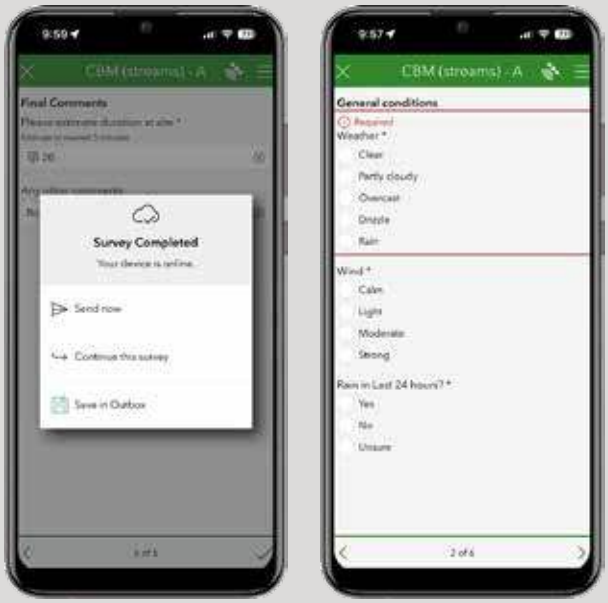
Step 4: Complete and send off your survey

After you have completed the survey questions for the stream health indicators you selected, a final page will require you to enter the time you spent at the monitoring site. There is also an option to add any final comments.

If you have correctly completed the survey, you will be able to select the tick at the bottom right corner of the page. A box will then appear telling you if you are online or offline. If you are online, you can send the survey data to your host organisation. If you are offline, wait until you have internet access to send your data.

Even if you are online, you will not be able to submit your survey if:

- you missed completing a mandatory field or entered a response that the built-in quality check process has identified as being incorrect (such as a value outside the possible measurement range) – Survey123 will prompt you to address these errors
- you are offline – in this case, wait until you have internet access to send your data
- you are measuring *E. coli* with self-test kits which require some parts of the testing to be completed at home – in this case, save the survey in your outbox and retrieve it later to complete the missing fields (this may also apply to nutrient self-testing if performed at home)
- you have surveyed fish – details about fish species and numbers are probably easier to capture on the CBM-based paper form and will need to be entered into Survey123 when you are back at home.



On the left is a screen shot of a successfully completed survey that is ready for sending to the host organisation. On the right is an example of a warning that pops up when an attempt was made to send off an incomplete survey. Survey123 will direct you to address any missing fields so that only a complete survey is sent. If you need to check some details back at home you can save the survey and open it again later.

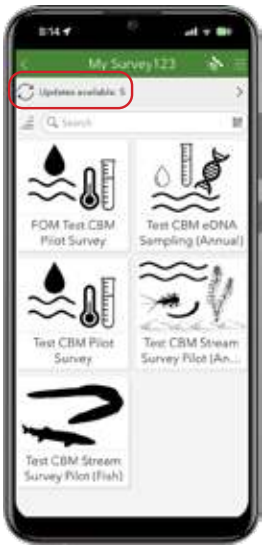
Important notes

Survey updates

Two important types of updates may occur from time to time:

1. ArcGIS may release an update to the Survey123 app (e.g., to reduce bugs or improve functionality)
2. Your host organisation may add monitoring groups or sites, or release a revised version of the template with new features or improved functionality.

Make sure to look out for notifications about these updates and download them to ensure that you are using the latest app and survey versions. Using old versions could create difficulties when it comes to submitting survey data to your host organisation.



Paper-based data capture

If your monitoring group wants to record details on a hard copy form, hard copy templates can be downloaded from the Wai Connection website. These templates only capture essential field-based data. These data will then need to be re-entered into the electronic form on the Survey123 app for the automated calculations and quality checks to run.

For community groups monitoring the rubbish and rainfall indicators, we encourage these groups to capture their data using the following existing, well-established citizen science apps:

- Rubbish: Litter Intelligence
- Rainfall: NIWA citizen science rainfall

You will need to register to use these apps (free). See page 125 in Section 7.

We also encourage groups to enter their fish monitoring data into the NZ Freshwater Fish Database maintained by NIWA.

Continuous-based water temperature and DO measurements

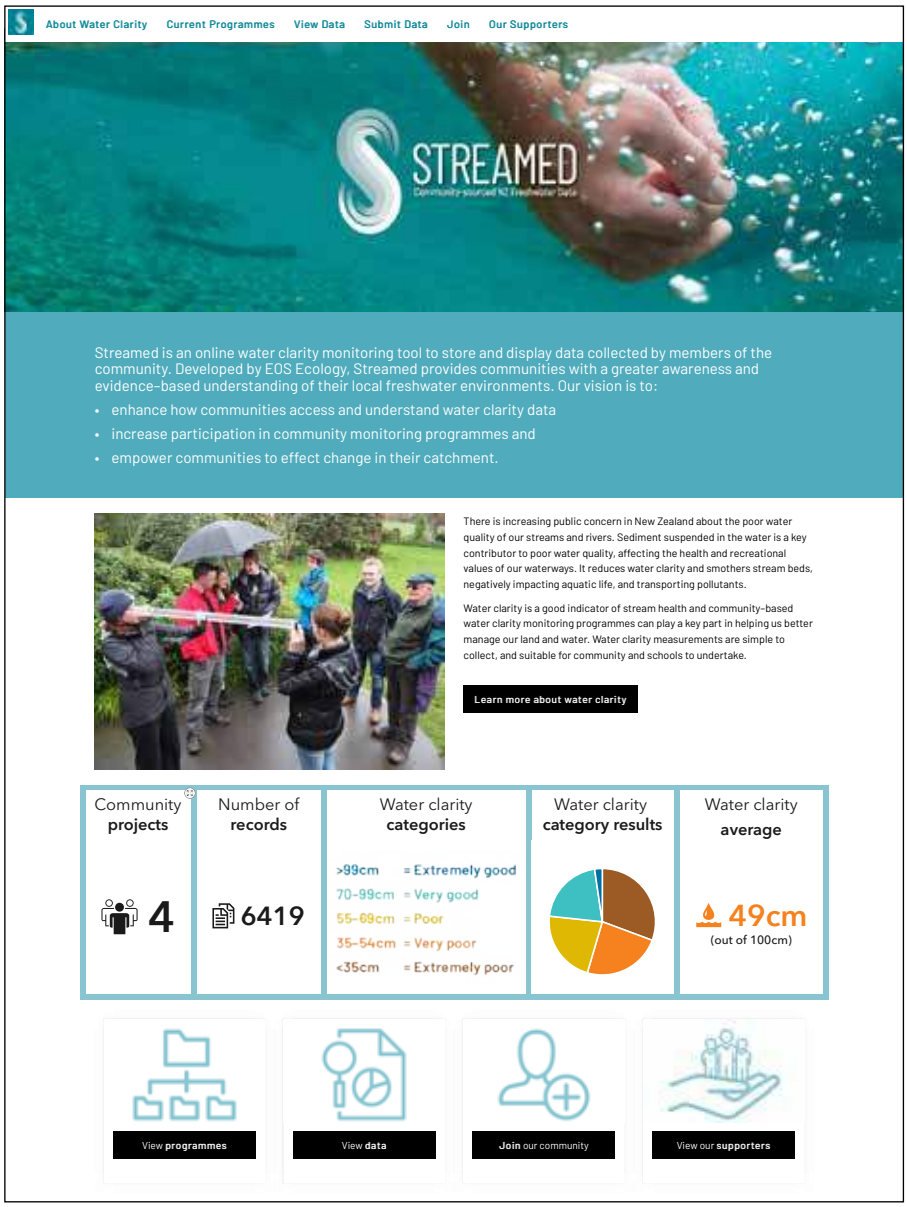
The Survey123 field forms do not include capture of continuous-based measurements. If your monitoring group has installed a logging device at one or monitoring sites to measure water quality at high frequency, the device will come with a software package and instructions that allow the data to be download and viewed. For example, the Onset HOBO® TidbiT water temperature data loggers available as part of NIWA's SHMAK kit are supported by a free HOBOconnect app and step-by-step instructions that will allow download of measurements onto a smart phone or a Microsoft Windows-compatible laptop or computer. From there you can view, export and share the data with others.

What happens next after data collection?

Once your CBM group has completed the survey and hit "send now", the entered survey data are transferred via the cloud to the host organisation's ArcGIS system (refer to Figure 2-4, page 12). From there, many options to store, share and view the data are possible depending on what data access and sharing arrangements your group has made with the Survey123 host organisation, and what ArcGIS licence, internal systems and resources the host organisation has.

As a starting point, unless otherwise agreed between the CBM group and the host organisation, the host organisation should promptly download data submitted via ArcGIS Survey123 and return this to your CBM group. The default ArcGIS data output is a Microsoft Excel csv file but customised data reports can be made. Check the Wai Connection website for details.

Although the national CBM QA framework does not include a database or portal to store or display CBM group data, it was developed with ArcGIS Survey123 templates to support sharing of data in a standard format between different organisations and feed into a potential future on-line portal(s). The development of on-line portals has already started to increase regionally and nationally. Check the Wai Connection website for details and updates of relevant tools and resources, including those that will assist your CBM group with data interpretation.



An example of an online NZ tool that has been created specifically to store and display monitoring data collected by community groups. This tool focuses on one stream health indicator and measurement method, visual water clarity measured using a clarity tube. Community groups enter their measurements into a desktop-based ArcGIS Survey 123 form that is hosted by EOS Ecology.

SECTION 7

Online resources and further reading

This section provides details of the various stream health monitoring guidelines, videos and other online resources referred to or referenced in Sections 4 and 5.

The web links will likely change over time as the resources or websites that host them are revised. Keep up to date by checking the separate on-line resource list on the Wai Connection website.

General resources

Resources	Details
SHMAK – Stream Health Monitoring and Assessment Kit (NIWA)	• Main website: https://niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit • Manual: https://niwa.co.nz/our-science/freshwater/tools/shmak/shmak-manual • Training videos: https://niwa.co.nz/our-science/freshwater/tools/shmak/videos • NZ Water Citizens https://www.nzwatercitizens.co.nz/
Wai Care (Auckland Council)	• Main website: https://waicare.org.nz/Resources/wcpublications.aspx
Wai Connection	• Main website: https://www.waiconnection.nz/
National Environmental Monitoring Standards (NEMS)	• Main website: https://www.nems.org.nz/
Land Air Water Aotearoa (LAWA)	• Main website: https://www.lawa.org.nz/ • Fact sheets on stream indicators: https://www.lawa.org.nz/learn/factsheets/
NIWA e-learning videos	• Main website (YouTube): https://www.youtube.com/user/NIWAeLearning
River Environment Classification (Ministry for the Environment)	• User guide: https://environment.govt.nz/assets/publications/acts-regs-and-policy-statements/rec-user-guide-2010.pdf • On-line tool: https://data.mfe.govt.nz/layer/52364-river-environment-classification-catchment-order-4-2010/
Monitoring Freshwater Improvements	• Main website: https://www.monitoringfreshwater.co.nz/
Freshwater Biodiversity Monitoring Guide (Department of Conservation and Cawthron)	• Main website: https://j4n-monitoring-guide.cawthron.org.nz/
Cultural health monitoring	• Iwi and hapū-based tools, frameworks and methods for assessing freshwater environments (Rainforth and Harmsworth 2019): https://www.nrc.govt.nz/media/n0ip2ksp/kaupapa-maori-assessments-final-jan-2019.pdf
ArcGIS Survey123 (Esri)	• Main website: https://survey123.arcgis.com/ • Eagle Technology (NZ distributor) information: https://www.esri.com/en-us/arcgis/products/index
Health and safety in the field	• NIWA SHMAK video: https://niwa.co.nz/videos/health-and-safety-in-the-field • NEMS Code of Practice for Safe Acquisition of Field Data in and Around Fresh Water: https://www.nems.org.nz/documents/safe-acquisition-of-field-data-in-and-around-fresh-water/

Indicator-based resources

Resource	Details
Information on various indicators and/or measurement methods	• NIWA SHMAK Manual: Chapter 3 (Monitoring indicators) and Chapter 4 (Field manual) • Wai Care Manual (Book 3 – Field Manual) and monitoring instructions • LAWA indicator fact sheets
Water quality indicators	
Discrete (spot) field measurements, observations, and water sampling collection and testing • water temperature • dissolved oxygen • conductivity • visual clarity	• NEMS *Discrete Water Quality*: https://www.nems.org.nz/documents/water-quality-part-2-rivers/ • NIWA e-learning training videos (YouTube): https://www.youtube.com/user/NIWAeLearning – WQ Rivers – field measurements – WQ Rivers – field measurements from a bridge – WQ Rivers – black disc or visual clarity measurements – WQ Rivers – bottle sampling measurements • NIWA SHMAK training videos: – Visual clarity: https://niwa.co.nz/videos/shmak-water-quality-%E2%80%93-visual-clarity – Stream site assessment: https://niwa.co.nz/videos/stream-site-assessment – How to collect a water sample: https://niwa.co.nz/videos/how-to-collect-a-water-sample • Environment Canterbury visual clarity tube monitoring measurements: https://esccanterbury.co.nz/project/monitoring-performance-sampling/
Water temperature and dissolved oxygen (continuous)	• NEMS: https://www.nems.org.nz/documents/water-temperature-recording/ • NEMS: https://www.nems.org.nz/documents/dissolved-oxygen/ • Onset HOBO® webinars for choosing and deploying temperature sensors: https://www.onsetcomp.com/resources/webinars/new-hobo-tidbit-mx2205-external-temperature-data-logger • PME miniDOT® Clear Logger: https://www.youtube.com/watch?v=X5JcFCyFvVg
Nutrient self-test kits	• NIWA SHMAK training videos: – Nitrate-N https://niwa.co.nz/videos/shmak-water-quality-%E2%80%93-nitrate – DRP: https://niwa.co.nz/videos/shmak-water-quality-%E2%80%93-phosphate
E. coli self-test kits	• *E. coli* testing using NIWA's SHMAK kit: – Video 1 - How to analyse a water sample for *E. coli* with Petrifilm™, using the direct plating method for high concentrations: https://vimeo.com/265095657/fc5c7e8f51 – Video 2 - How to analyse a water sample for *E. coli* with Petrifilm™, using the filtering method for low concentrations: https://vimeo.com/265095807/51153560cd – Video 3 - How to count and report the *E. coli* colonies on a Petrifilm™ gel: https://vimeo.com/265095852/929898c29c • MC-Media Pad® *E. coli* and coliform test – brochure and interpretation guide: https://www.merckmillipore.com/NZ/en/products/industrial-microbiology/culture-media/culture-media-for-food-and-beverage-industry/convenient-culture-media/z6mb.qB.lSQAAAFbMcgTzOk4,nav • *E. coli* testing using the Aquagenx® Compartment Bag Test (CBT) EC-TC MPN kit: https://www.aquagenx.com/videos/

Aquatic life indicators	
eDNA sample collection	• Environmental Protection Authority and Wilderlab video: How to collect and analyse eDNA: https://www.epa.govt.nz/community-involvement/open-waters-aotearoa/collect-and-analyse/ • Wilderlab videos: https://www.wilderlab.co.nz/more-info – eDNA active (syringe) samplers – eDNA passive samplers (the Cawthron and NIWA websites also provide information on eDNA testing services)
Periphyton	• NIWA SHMAK video: https://niwa.co.nz/videos/shmak-stream-life-%E2%80%93-periphyton • NIWA Periphyton Identification Guide: https://niwa.co.nz/sites/niwa.co.nz/files/Periphyton%20ID%20Guide.pdf • NIWA Periphyton Field Identification Chart – Appendix 3 of NIWA Stream Monitoring Periphyton Monitoring Manual (Biggs and Kilroy 2000): https://niwa.co.nz/sites/niwa.co.nz/files/import/attachments/peri_complete.pdf • NEMS *Periphyton*: https://www.nems.org.nz/documents/periphyton/
Microcoleus cyanobacteria (toxic algae)	• Cawthron Institute toxic algae in our rivers video (includes identification tips): https://vimeo.com/245848255
Macrophytes	• NIWA SHMAK training video: https://niwa.co.nz/videos/shmak-stream-life-%E2%80%93-macrophytes • NIWA identification guides: https://niwa.co.nz/freshwater/management-tools/identification-guides-and-fact-sheets/macrophyte-plant-id-guides • NZ Plant Conservation Network on-line flora species search tool: https://www.nzpcn.org.nz/flora/species/
Macroinvertebrates	• NIWA SHMAK training videos: – Stone method: https://niwa.co.nz/videos/shmak-stream-life-%E2%80%93-collecting-benthic-macroinvertebrates-using-the-stone-method – Kick-net method: https://niwa.co.nz/videos/shmak-stream-life-%E2%80%93-collecting-benthic-macroinvertebrates-using-the-kick-net-method – Sampling muddy-bottomed streams: https://niwa.co.nz/videos/shmak-stream-life-%E2%80%93-collecting-benthic-macroinvertebrates-in-muddy-bottom-streams – Preparation for sample sorting: https://niwa.co.nz/videos/shmak-stream-life-%E2%80%93-how-to-get-your-benthic-macroinvertebrate-sample-ready-for-sorting – Sample sorting and identification: https://niwa.co.nz/videos/shmak-stream-life-%E2%80%93-how-to-sort-and-identify-your-benthic-macroinvertebrate-sample • NIWA SHMAK Benthic Macroinvertebrate Field Identification Guide: https://niwa.co.nz/sites/niwa.co.nz/files/Benthic%20Macroinvertebrates%20ID%20Guide.pdf • NEMS *Macroinvertebrates*: https://www.nems.org.nz/documents/macroinvertebrates/ • Landcare Research's online Freshwater Invertebrates Guide: https://www.landcareresearch.co.nz/tools-and-resources/identification/freshwater-invertebrates-guide/
Fish	• NIWA fish identification guides: https://niwa.co.nz/freshwater/nzffd/identification-guides-and-keys • NIWA Atlas of NZ Freshwater Fish: https://niwa.co.nz/freshwater/nzffd/NIWA-fish-atlas • DOC website: https://www.doc.govt.nz/nature/native-animals/freshwater-fish/ • NZ Freshwater Fish Sampling Protocols (Joy et al. 2013): https://niwa.co.nz/static/web/New_Zealand_Freshwater_Fish_Sampling_Protocols.pdf • NZ Landcare Trust 'Hooked on Native Fish': https://landcare.org.nz/resource/hooked-on-native-fish/

Stream habitat indicators	
Physical habitat quality	• Cawthron National Rapid Habitat Assessment (RHA) method videos: https://www.cawthron.org.nz/research/our-projects/rapid-habitat-assessment-protocol/ • NIWA SHMAK Visual Habitat Assessment training video: https://niwa.co.nz/videos/shmak-habitat-%E2%80%93-visual-habitat-assessment • National Rapid Habitat Assessment Protocol (Clapcott 2015): https://envirolink.govt.nz/assets/Envirolink/1519-NLRC174-National-Rapid-Habitat-Assessment-Protocol-for-Streams-and-Rivers.pdf • NZ Stream Habitat Assessment Protocols (Harding et al. 2009): https://www.envirolink.govt.nz/assets/Envirolink/Stream20Habitat20Assessment20Protocols.pdf
Deposited fine sediment	• National Sediment Assessment Methods (Clapcott et al. 2011): https://environment.govt.nz/publications/sediment-assessment-methods/
Shade (canopy closure)	• U.S. Fish and Wildlife Service video: Measuring stream canopy closure using a spherical densiometer: https://www.youtube.com/watch?v=A4K7zr4IAmU • Clean Water Team Video: 17-point spherical convex densiometer modification: https://www.youtube.com/watch?v=gI2RIlao6Vs
Rubbish (litter)	• SHMAK training video: https://niwa.co.nz/videos/shmak-habitat-rubbish. • Litter Intelligence method details: https://litterintelligence.org/about/freshwater-monitoring/
Water quantity indicators	
Stream velocity and flow	• NIWA e-learning training videos (YouTube): https://www.youtube.com/user/NIWAeLearning – Float gauging method – Reading an external staff gauge – Current meter gauging practice • How to Measure Stream Velocity video (YouTube): https://www.youtube.com/watch?v=eKYrHc0pjxs • How to Measure a Stream Cross Section video (YouTube): https://www.youtube.com/watch?v=7gFzC_bX7Tw • Measuring River Velocity (with a basic flow meter) – YouTube video: https://www.youtube.com/watch?v=tiLjZN9Irxk
Rainfall	• UK Met Office Measuring rainfall video (YouTube): https://www.youtube.com/watch?v=JVOxLrMaWA8 • NIWA NZ citizen science rainfall monitoring network: https://niwa.co.nz/climate/information-and-resources/citizen-science-new-zealand-rainfall-monitoring-network

References

Listed below are the references that are not already included in Section 7 (online resources and further reading).

Gadd J, Hickey C, van Dam R, Milne J, Wood D. (2023) Implementing bioavailability-based toxicity guideline values for copper and zinc in Aotearoa New Zealand: Interim technical guidance for scientists and practitioners, focusing on freshwater applications. NIWA Client Report No. 2023249AK prepared for MBIE Envirolink and Horizons Regional Council. 93 p. plus appendices.

Harper A. (1994) Instructions for rainfall observers. NIWA, Wellington. 16 p.

Holmes R. (2022) Rapid river habitat pressures assessment protocol for rivers and streams. Cawthron Report No. 3801 prepared for Hawke's Bay Regional Council and Envirolink. 17 p. plus appendices.

Kilroy C, Biggs BJF. (2002) Use of the SHMAK clarity tube for measuring water clarity: Comparison with the black disk method. *New Zealand Journal of Marine and Freshwater Research*, 36:3, 519–527.

Kukutai T, Campbell-Kamariera K, Mead A, Mikaere K, Moses C, Whitehead J, Cormack D. (2023) Māori data governance model. Te Kāhui Raraunga. 66 p. plus appendices.

Milne J, Valois A, Robbins J. (2023) Make your stream monitoring data count! A national quality assurance framework for community-based monitoring in Aotearoa New Zealand. Part 2: Background report. NIWA Client Report 2023347WN prepared for MBIE Envirolink. 93 p + appendices.

Strickler GS. (1959) Use of the densiometer to estimate density of forest canopy on permanent sample plots. USDA Forest Service, Pacific Northwest Forest and Range Exp. Sta. Research Note 180, Portland, Oregon, 5 pp.

Valois A, Milne J. (2021) Quality assurance for community-based freshwater monitoring in Aotearoa New Zealand. NIWA Client Report 2021048WN prepared for Hawke's Bay Regional Council and MBIE Envirolink. 64 p.

Glossary

The terms listed in the table below are explained as they relate to stream monitoring. See Tables 4.1 to 4.5 in Section 4 for explanations of each of the stream health indicators (e.g., conductivity, dissolved oxygen) included in the national CBM QA framework.

Term/acronym	Explanation
Accuracy	Closeness of agreement between a measurement of a stream health indicator (e.g., total nitrogen concentration) and the stream's true (unknown) value for that indicator.
Attribute	A term in the NPS-FM 2020 for a specific and measurable characteristic of a variable or parameter that can be measured to tell you something about the condition of fresh water (e.g., the concentration of nitrate-nitrogen or the quantity of periphyton growing on a streambed are specific measures of nitrogen and periphyton that are used to understand the ecological condition of a stream).
Bias	The difference between true values and those values measured by an observer or instrument (e.g., sensor). Measurement bias (error) affects the accuracy of a measurement and is often due to the measurement process.
Blind sample	A sample with a 'dummy' name so that the laboratory or person testing/identifying it does not know where it was collected from or its likely composition. Blind samples can provide a check on the performance of a lab or taxonomist.
Calibrate (in relation to a sensor)	The process of adjusting a sensor so that its measurement values align with traceable standard of known accuracy. (See also 'standard solution', 'traceable standard', 'validation' and 'verification'.)
Catchment	A basin shaped area of land that captures water from rainfall and below surface drainage that flows into a stream. A stream is only as healthy as its surrounding catchment.
Community-based monitoring, CBM	A form of citizen science where members of the public, as individuals or organised groups, collect scientific data. Alternative terms to CBM include 'volunteer monitoring', 'locally based monitoring' or 'participatory monitoring'.
Censored value	Measurement values reported by the laboratory as less than some value (e.g., < 0.01 mg/L) or greater than some value (e.g., > 10,000 *E. coli* per 100 mL). See also 'method detection limit'.
Cover (of streambed)	The amount, usually expressed as a percentage, of visible streambed area that is covered by an indicator of interest (e.g., periphyton, fine sediment). Bankside cover estimates are limited to the area of streambed that is visible while instream cover assessments are limited to the area of stream that can be safely waded (typically 0.6 m deep).
Credible (data)	Data with traceable origins of collection (i.e., who collected the data, when, where and how) that are reliable and trusted as being fit for their intended purpose.
Cross section	Also referred to as a transect – a straight line across (the width) of a specific section of a stream along which a series of observations or measurements are usually made.
Current meter	An instrument for measuring water velocity.
Data	The results from observations or measurements (often used interchangeably with results, observations or measurements). May be referred to as a dataset or time-series when there are multiple observations or measurements over time.
Data quality	The suitability of data for an intended purpose. This may be indicated through assigning a quality code to the data.
Discharge (in relation to stream flow)	The volume of water flowing through a cross section of stream in a specific unit of time (e.g., litres per second, cubic metres per second, cubic metres per day).

Discrete measurement/ sample	A measurement/sample or set of measurements/samples taken from a body of water at a defined time (as opposed to continuous measurements/sampling). Discrete measurements/samples may be collected once, regularly (e.g., weekly or monthly), or irregularly (periodically).
Drift (in relation to sensors)	A continuous and gradual change in a sensor's readings that isn't related to a real change in the indicator being measured (e.g., algae growing on a turbidity sensor installed in a stream may lead to turbidity measurements drifting upwards over time).
Duplicate	A (bulk) sample split (or subsampled) into two in the field or lab to provide an estimate of measurement precision.
Ecosystem health	A broad concept that describes the condition or ability of a stream to support aquatic ecosystems. Ecosystem health is a compulsory national value for managing fresh water in NZ under the NPS-FM and includes five biophysical components: aquatic life, water quality, water quantity, physical habitat and ecological processes.
Field meter (water quality)	An instrument fitted with a sensor or multiple sensors to measure one or more characteristics of water quality variables, such as water temperature, pH or turbidity.
Flow	The quantity of water in a stream that passes through a particular point in the stream over a certain amount of time. (See also 'discharge').
Flushing flow	A high flow of sufficient magnitude to scour or otherwise remove periphyton from the streambed. The flow required to achieve this will vary from stream to stream but a common 'rule of thumb' is that a flushing flow equals three times the median stream flow. It will be large enough to carry a suspended sediment load but too small to be regarded as a flood.
Fouling (of a field meter sensor)	An accumulation of unwanted biological (e.g., algae) or chemical (e.g., salts and oxides) material on a sensor lens or other equipment that has an adverse effect on measurements.
Full-scale error (FS)	Relates to sensor-based measurements – the absolute error divided by the measurement range of the sensor, often expressed as a percentage of full scale (%FS). The error is a fixed value and so is less by proportion when the sensor is operating near its maximum range than when operating lower in its range.
Habitat	The environment or places within a stream that periphyton, plants, macroinvertebrates, fish and other organisms live.
Hard-bottomed stream	A stream with a bed substrate dominated by gravel, cobble, boulder or bedrock (i.e., particles of 2 mm or greater in size).
Indicator	A variable or parameter that is used to indicate some aspect of stream health (e.g., dissolved oxygen is an indicator of the ability of the stream to support aquatic life).
Kick-net	A triangular or D-framed mesh hand net with a pole handle that is used to collect aquatic macroinvertebrates. The CBM QA framework and NEMS *Macroinvertebrates* specify a mesh size of 0.5 mm.
Macroinvertebrates	Small animals, including insects, snails, worms and crustaceans, living in a stream that lack a backbone and are large enough to see without using a microscope.
Macrophyte	A vascular aquatic plant growing in or near the water. Typically classified in a stream as emergent (i.e., with upright portions above the water surface), submerged, or floating.
Measurement	A value obtained from a visual observation/estimation, reading or test.
Metadata	A set of data that describe and give information about the primary data of interest. In stream monitoring, general metadata, such as weather and stream conditions, are important for interpreting stream measurements. Some metadata may be specific to a particular stream health indicator (e.g., the diameter of the black disc used to measure visual water clarity). Descriptions of site locations, measurement methods and data quality are also types of metadata.
Method detection limit, MDL	The lowest concentration that can be measured by a lab within a stated confidence limit. Also known as the limit of detection (LOD). When a raw measurement value is less than the MDL, the laboratory will round the value up to the MDL and report it as < MDL value. This is known as a censored value.

Monitoring	Observations and measurements made over time to assess one or more aspects of stream health. Ongoing monitoring programmes are typically reviewed on a regular basis to ensure they remain fit for purpose.
Monitoring & Quality Plan	A plan that establishes the reason(s) for steam monitoring and intended use of the monitoring data, along with details of the monitoring (e.g., what will be measured, where, how, when and by whom), and training and quality checks that will be implemented to ensure the resulting data are credible and fit for purpose.
NEMS	National Environmental Monitoring Standards. A series of environmental monitoring standards prepared to consistency in environmental monitoring throughout NZ.
NPS-FM	National Policy Statement for Freshwater Management – mandatory national policy direction for managing freshwater introduced by the Government under the Resource Management Act (RMA) 1991.
Observer	A person making or collecting a stream observation, measurement or sample.
Observation	An individual estimate made at a fixed location, such as the amount of periphyton cover at a specific point on a cross section. Many indicators, including periphyton cover, are based on taking the average of a series of observations made at selected points along a stream reach. The term observations may also be used to refer to comments about weather and stream conditions recorded at a monitoring site.
Pathogen	A microorganism that can cause illness and disease. Common pathogens in NZ fresh waters include campylobacter, giardia and cryptosporidium.
Periphyton	The community of organisms, including algae, cyanobacteria, fungi and detritus, that is attached to the bed or submerged surfaces of streams.
Pool	An area of stream characterised by deep, slow-moving water, usually where the stream widens and/or deepens, often on the outside of bends. (See also 'riffle' and 'run'.)
Precision	The closeness of two or more repeated measurements (see 'replicates') collected under the same conditions. Sometimes referred to as repeatability. (See also 'repeatability' and 'reproducibility').
Professional/expert	See 'specialist'.
Quality Assurance (QA)	The overall planning put in place before monitoring starts to manage quality throughout the monitoring process. It includes monitoring design, sampling protocols, training, quality control and data management.
Quality Control (QC)	Activities put in place to detect or measure and correct any errors while you are monitoring (e.g., calibration of sensors on water quality meters, collection of replicate measurements or samples). Includes internal and external activities.
Quality check	A term used in the CBM QA framework for internal and external quality control (QC) measures.
Reach (of stream)	A defined length of stream channel (e.g., 50 or 100 m) selected for monitoring. Many ecological and habitat indicators are assessed over a stream reach. A 'rule of thumb' to define a reach is 20 x the stream width or a minimum of 50 m and maximum of 150 m.
Reading	The value (e.g., water temperature) displayed on a field meter or test kit when a measurement is being made.
Repeatability	The closeness of agreement between the results of repeated measurements by the *same observer* under unchanged conditions (e.g., one person taking repeated measurements of water temperature using the same sensor). (See also 'precision').
Replicate	Two (duplicate) or more measurements or samples taken under comparable conditions.
Representative	Taking a measurement or sample that reflects the conditions in the stream reach of interest. Samples need careful preservation and handling to ensure they remain representative through until they have been tested or identified.

Reproducibility	Closeness of agreement between results of measurements of the same indicator carried out by *different observers* (e.g., two people carrying out side by side measurements of visual water clarity), working independently. Good reproducibility implies (but does not quite prove) accuracy. (See also 'precision'.)
Resolution	The smallest change in a measured variable that a particular instrument can detect and/or represent.
Riffle	Short segments of stream characterised by shallow depths and fast, turbulent water flowing over boulders and cobbles which break the water surface. (See also 'run' and 'pool'.)
Riparian zone	The strip or area of land along the margins of a stream. It is the interface between land and water ecosystems.
River Environment Classification (REC)	A classification system for NZ rivers and streams based on factors which influence water quality and biology. The primary factors include climate, source of flow, geology and landcover.
Run	Segments of stream characterised by low to moderate depth, a moderate current, and a smooth or slightly rippled surface. Located between pools and riffles. (See also 'riffle' and 'pool'.)
Sample	A small amount of stream water, sediment or aquatic life that is representative of the larger stream reach from which it is collected. One or more variable(s) of interest will then be measured or identified and counted from the sample.
Sample blank (water quality)	A sample that does not contain any of the indicator or analyte of interest. Distilled water is commonly used for sample blanks.
Sampling/ measurement location	The location of a stream site where sampling or measurements are made. This may extend along a reach of stream.
Sampling point	The exact location within a stream reach at which a sample is collected (or measurement made).
Saturation	The degree or extent to which something is dissolved or absorbed compared with the maximum possible. The dissolved oxygen content in a steam is commonly expressed as a percentage saturation.
Sensor	A device that detects or measures a physical (e.g., water temperature) or chemical property (e.g., pH). Sometimes called a probe and often attached to a larger field meter/instrument.
Soft-bottomed	A stream or river in which the bed substrate comprises more than 50% sand/silt/mud/clay. These streams are typically low-gradient, slow-flowing and often dominated by macrophytes in unshaded reaches and woody debris in shady forested reaches.
SHMAK	Stream Health Monitoring and Assessment Kit. A scientific tool designed by NIWA for landowners, iwi, and community and school groups to monitor stream health in NZ.
Significant figures	The digits of a real number that are known with some degree of reliability and are therefore meaningful to express a measurement (e.g., pH is normally expressed to 2 significant figures, such as 7.1).
Site visit	The act of going to and spending time at a site to carry out one or more of measurement, observation, inspection and/or maintenance.
Specialist (or subject matter specialist)	Someone who is sufficiently qualified and/or experienced in a particular subject or topic such as water quality, freshwater ecology, hydrology or catchment management. The national CBM QA framework recommends that community groups approach a relevant subject matter expert(s) for advice when designing or reviewing a monitoring programme.
Specific conductivity	Electrical conductivity corrected to a specific temperature (e.g., 25°C in the NEMS *Discrete Water Quality* and national CBM QA framework).
Split sample	The dividing of a bulk water sample into two or more portions. Also see 'duplicate' and 'replicate'.
Spotlighting (fish)	A standard method for making observations of nocturnally active fish carried out after dark using a spotlight or torch.
Stand-down period	The period of time after a high or flushing flow event before macroinvertebrate sample collection can proceed.

Standard Operating Procedure (SOP)	The series of ordered steps, or a detailed method, followed to execute a process (e.g., to collect, sort and identify a macroinvertebrate sample).
Standard solution	A solution of precisely known concentration of a substance into which the sensor(s) of an instrument are immersed to check their performance (validate) and/or adjust (calibrate) them.
Stream health	A broad term used in the national CBM QA framework that refers to the suitability of a stream to support a healthy aquatic ecosystem and safe recreational use. It is assessed using different variables, called indicators (e.g., visual water clarity, macroinvertebrate diversity), that can provide a measure of how well these freshwater values are being met.
Subsample	A representative portion of sample taken from a larger sample. Also see 'split sample', 'duplicate' and 'replicate'.
Temperature compensation	Adjustment of water quality measurements to minimise or remove the influence of changes in water temperature on the measured values. Many water quality sensors automatically adjust to a common temperature (e.g., pH and conductivity to 25°C).
Test (water quality)	A measurement made on a water sample that often involves some form of physical or chemical testing or analysis.
Test result (water quality)	The final measurement value (result) arising from testing or analysing a water sample.
Trapping	A standard fish monitoring method that involves setting one more nets in a stream for a period of time (usually overnight). Common nets used in NZ include gee minnow and fyke nets.
Tributary	A stream that flows into a larger stream or river, or a lake. The catchment of a tributary is usually referred to as a subcatchment.
Uncertainty (of measurement)	An estimate of the variability that exists in any measurement due to various causes such as sampling technique, instrument and equipment calibrations, and human factors.
Validation (of a sensor)	A quality check to determine if a sensor is performing to specification or calibration. If sensor validation fails or cannot be performed, calibration is required. (See also 'verification' and 'calibration'.)
Variable	A property, parameter, determinant or analyte that is measured within the stream or from taking and processing a sample (e.g., water temperature, nitrate-nitrogen, macrophyte cover). In the national CBM framework, a variable is generally referred to as an *indicator*.
Velocity	The speed at which water flows.
Verification	A quality check to determine whether a measurement device (e.g., water quality sensor) or observer is performing and meeting expected accuracy as required. (See also 'validation' and 'calibration'.) Verification checks usually involve comparisons between independent measurements obtained using a reference instrument or between the observer and an independent subject matter expert.
Voucher specimen	A representative, preserved individual specimen of an organism (e.g., a specific macroinvertebrate or species of periphyton) that is used as a reference to support or verify the accuracy of identification of an organism present in a sample.
Wai Care	A water quality monitoring, education and action programme for landowners, communities and schools in the Auckland region delivered by the Auckland Council. It includes a monitoring kit, similar in concept and design to the NIWA SHMAK, for assessing stream health.
Water quality	The condition of stream water that includes physical, chemical and biological characteristics. Water quality is usually described and assessed in terms of its suitability to support particular uses or values (e.g., recreation, ecosystem health, food gathering).

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