

# 3. Data confidence



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# Introduction

## Overview of this chapter

Chapter 3 describes a range of procedures and approaches to help you incorporate *data confidence* into your waterway monitoring program. Data confidence relates to all aspects of a monitoring program, including planning, methods, quality controls and checks, equipment, participant competency, data management and documentation.

This chapter provides technical information to assist you to:

- understand the meaning of ‘data confidence’ and why it is important for your monitoring project
- ensure data confidence in your monitoring project by developing a data confidence framework for your group projects
- decide what level of data quality and wconfidence is appropriate for your objectives
- understand the importance of study design in determining data quality and confidence
- understand the importance of equipment, and the methods in which it is used, in determining data quality and confidence
- understand the importance of quality control checks and procedures
- understand that participant competency and training are critically important data confidence considerations
- practise good data entry, storage, and overall management procedures
- keep appropriate data confidence framework documents.

3-2

## Why this chapter is important

Community waterway monitoring data is a valuable but often underappreciated resource available for natural resource management. Considerable care and effort goes into the collection of community data; however, this data is often overlooked in natural resource management decision making. One of the primary reasons for this is a lack of confidence in the reliability and integrity of the data.

Using the data confidence framework outlined in this chapter will ensure that community-based monitoring groups and their stakeholders have confidence that the data collected will meet the objectives of the activity.

## How to use this chapter

Use this chapter as a source of information and planning advice for developing data confidence in your monitoring activities. The chapter is separated into two main sections. The first introduces the concepts of data confidence and data quality and explains the meaning of these terms. The second explains how to develop a data confidence framework for your monitoring projects. It covers:

- what you will need (‘inputs’)
- what you should consider
  - o planning
  - o monitoring methods and equipment
  - o quality control procedures and checks
  - o participant competency
  - o data management
- what you should document
  - o data confidence statements
  - o monitoring plans
  - o procedures
  - o record sheets.



## Defining data confidence

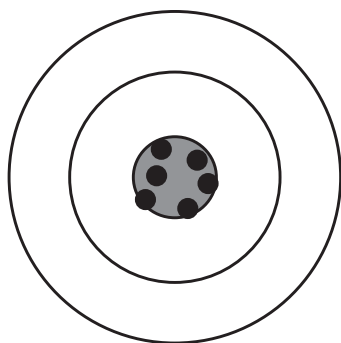
Data confidence can be defined as the confidence or certainty with which a set of data meets its defined purpose. It results from collecting appropriate quality for your project objectives, and from having a system to demonstrate this to others who may be interested in your data. This is also sometimes known as *quality assurance*.

Data quality is defined as the level of *accuracy*, *precision*, *representativeness*, *completeness*, *comparability* and *sensitivity* of your data. These terms are each defined in the text box opposite.

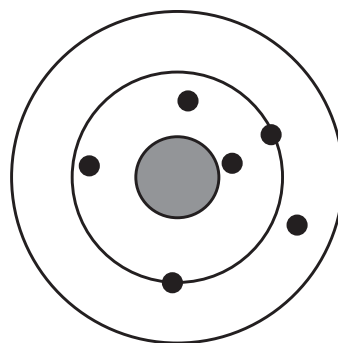
Accuracy, precision, and sensitivity relate to the quality of, or level of error in, each of your measurements. Your *measurement error* is determined by the monitoring methods, equipment and procedures you use.

Figure 3–1 represents the difference between accuracy and precision—two terms that are often confused.

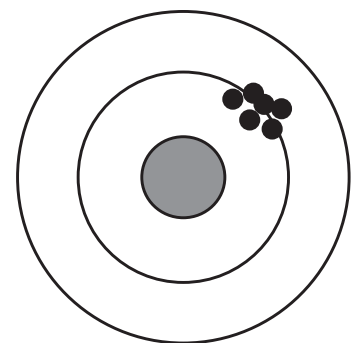
Representativeness, completeness and comparability all relate to the quality of, or level of error in, all of your measurements as a whole, and how meaningful your data is from a whole-of-study perspective. These terms relate to how well your data represents the true environmental conditions of your waterway. Your *environmental error* is determined by the locations in and along the waterway from which you take your samples, the timing and frequency of your monitoring, and the monitoring methods, equipment and procedures that you use.



Accurate and precise



Inaccurate and imprecise



Precise but inaccurate

Figure 3–1 Accuracy and precision (modified from Eaton et al. 2005)



## **Accuracy**

Accuracy is a measure of how close your measured result is to the ‘true’ or expected value. A small difference indicates a more accurate reading than a large difference, and consequently inspires greater confidence that your data adequately represents the measured characteristic. Accuracy can be assessed by analysing prepared standards from different sources.

## **Precision**

Precision is how well you are able to repeat the result on the same sample regardless of accuracy. It provides information about how consistent your equipment and sample methods are. This is important when you start to compare data with other data from different times or places.

## **Sensitivity**

Sensitivity refers to the capacity for the data to discern between two different values. The more sensitive a method or instrument, the closer the two discernable values will be. Factors that influence sensitivity include detection limit, resolution and range of the equipment or method used. Not all projects require high sensitivity—this will depend on the objectives of the monitoring project.

## **Representativeness**

Representativeness is the extent to which your measurements reflect the true condition or attribute that you are measuring. The methods used when monitoring will have the greatest influence on representativeness. For example, measuring oxygen concentration by taking a subsample in a bucket will give a less representative result than if measured by a probe submerged directly into the water body. A single measurement might not represent the true condition of a site, so multiple measurements may be required (for example, in a stratified dam).

## **Completeness**

Completeness relates to the total number of measurements obtained as a proportion of the number of measurements that were planned or required to be taken. There are many reasons why you may not collect as much data as planned, such as missed sampling opportunities and equipment failure. It is important to consider how much data is required to get a good representation of conditions. Methods and equipment should be chosen that provide sufficient levels of data completeness.

## **Comparability**

Comparability is the extent to which one piece of data can be compared with another. Comparison may be within a single project, between projects, at different times or between different organisations. The use of standardised methods and equipment will improve comparability, as will good understanding and documentation of issues such as accuracy, precision, and representativeness. The use of quality control samples (for example, certified reference materials) is regularly applied to track and demonstrate external reproducibility and comparability.



## Ensuring data confidence

Using a data confidence framework (such as the one outlined in Figure 3–2) for your waterway monitoring project will ensure that the data you collect is of appropriate quality to meet your needs. It will assist you to develop and implement data confidence measures in all aspects of your project, including planning, monitoring methods, training, data management and documentation.

This manual is an important resource for supporting the development and implementation of a data confidence framework, but should not be used as a stand-alone document. To develop a data confidence framework, the following inputs can also be useful:

- an ongoing training program to ensure that all the participants have adequate knowledge and skills
- access to adequate water quality expertise, which ensures that the waterway monitoring program is scientifically rigorous and fit for its purpose
- the *Monitoring plan tool for community-based waterway monitoring*, which provides a user-friendly and standardised framework to support the development of waterway monitoring projects.

A number of key considerations are necessary to ensure that an appropriate data confidence framework is established. These considerations can be applied to both new and existing monitoring projects and programs. Data confidence considerations include:

- planning
- monitoring methods and equipment

- quality control procedures and checks
- participant competency
- data management
- documentation.

## Planning

Careful planning will help you develop a monitoring program that collects data of a known and appropriate quality for its intended purpose. The planning phase is one of the most critical steps in any monitoring plan, but is often rushed or compromised by the perceived need to ‘get something done’. This is particularly true if the timing of data collection is considered to be critical, such as with a pollution event or high-flow event. However, if you take the time to properly define the issues and explore the strategies required to satisfactorily address them, your project is far more likely to result in a positive outcome.

Key documents generated through this planning phase include data confidence statements and monitoring plans. These are explained later in this chapter.

## Levels of data quality

The first step in the planning phase of your data confidence framework is to decide what level of data quality you require. This section provides further information on Question 4 of the guide to developing a monitoring plan outlined in Chapter 2.

You should consider how accurate and precise you require your data to be. Data is never 100% accurate or precise. It can also be very difficult, costly, and time-consuming to collect

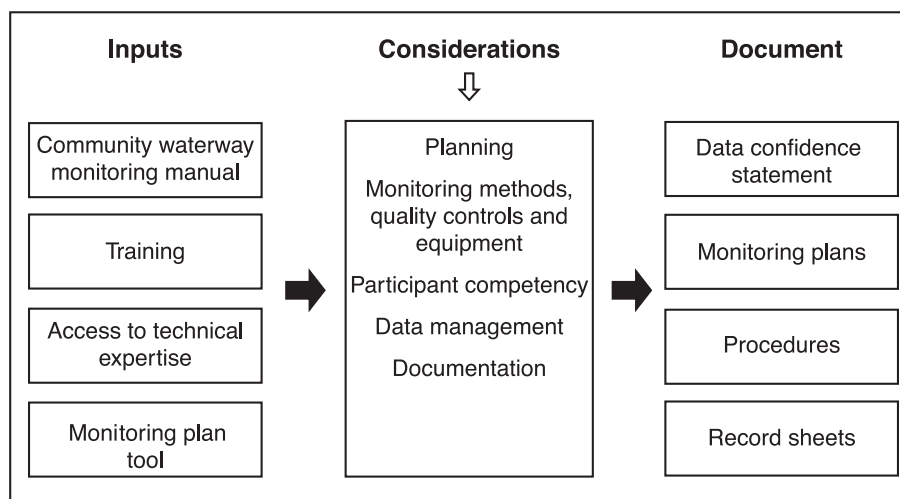


Figure 3–2 Framework for developing data confidence



measurements of very high data quality. Therefore, you need to decide what level of error or uncertainty in your measurements can be tolerated and is acceptable to the monitoring objectives of your project. This acceptable level of error is known as a *tolerable error range* (TER).

Your TER can be used to decide what monitoring methods and equipment are right your needs. It is also used to determine what quality control procedures you should use, such as how often to calibrate your equipment, and how to decide whether the calibration has been successful (calibration acceptance criteria).

Ideally you should set a TER, based on your monitoring objectives, for each of the parameters you will be measuring. For example, your monitoring objective could be to determine whether the physico-chemical characteristics in a creek are suitable to support fish life. According to the Australia and New Zealand Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand, the majority of fish species in fresh water can tolerate a pH range of between 5 and 9 pH units (ANZECC & ARMCANZ 2000). Due to the substantial range in pH values that fish can endure, a TER of plus or minus 0.5 pH units would be sufficient to give you confidence in your results. Therefore, appropriate measures would need to be taken prior to sampling to ensure that the methods used to monitor pH fall within the desired TER of  $\pm 0.5$  pH units. However, if the tolerable pH range for fish were smaller (for example, 6.5 to 7.5 pH units), then a smaller TER would be required to accurately meet your objectives.

Identifying TERs upfront can be very difficult for inexperienced monitoring groups. In addition, sometimes not enough is known enough about certain parts of the aquatic ecosystem to allow specific TERs to be set upfront based on monitoring objectives alone. For this reason, this manual uses a simple three-tiered system to allow community-based groups to identify their required data quality during the initial planning phase of their monitoring project. Groups simply choose whether they require *demonstrative*, *indicative* or *analytical* data. These categories each relate to a broad TER. The analytical level roughly relates to the level of data quality attained by current state agency monitoring programs. The categories are arbitrary and have simply been provided to direct

community groups in a user-friendly manner to monitoring methods and equipment that are right for their needs.

Achieving higher data quality not only depends on having accurate and precise data; it also depends on having complete, representative, and comparable data. These aspects of data quality relate to how meaningful your data is from a whole-study perspective (does it provide a good picture of what is going on?) rather than just at each single sampling point.

When developing your monitoring objectives, think about how representative and comparable you want your data to be. This will help you design your study, including where to monitor at the site, the number of sites required and the appropriate frequency of monitoring.

If you require highly accurate and precise data from each site, the time and costs involved in collecting such data may restrict the number of sites you are able to monitor. In this situation, data would have high accuracy and precision but lower completeness and representativeness. Conversely, monitoring a larger number of sites gives greater completeness and representativeness, but you may not have the time or resources to collect such accurate or precise data from each site. When planning your project, you must decide how best to allocate time and resources to meet your monitoring objectives.

Details on how to design a monitoring strategy to achieve your desired data quality are provided in the following sections of this chapter.

Once you have decided on the methods, equipment, and procedures you will be using, you should verify your TERs for each of the parameters being measured. This will involve developing an estimate of your actual level of error for each parameter based on the specific equipment and methods that you are using, the people undertaking the monitoring, and the type of waterway you will be monitoring. Your TER should take into account the error associated with both field sampling and laboratory analysis (if applicable). The TER is not simply the instrumental error, or a value provided by the instrument manufacturer; it is the error based on all of the factors outlined above.



Going through this process will assist you to check whether the TERs you have specified are actually achievable. TER verification is especially important to those aiming to collect indicative or analytical data, and applies to the monitoring of physico-chemical and biological parameters. It is difficult to estimate an error range for stream condition and habitat monitoring due to the subjective nature of this type of monitoring.

Your TERs should be verified through scientific procedures and determined prior to implementing the monitoring project. One way to verify your TERs for measuring physico-chemical parameters using field-based monitoring methods is to conduct a shadow testing workshop. To do this, you will need real samples from one of your potential monitoring sites, and control samples. See page 3–11 for more information on control samples. Select control samples that match the chemistry and typical range of values for your waterway as closely as possible. You will normally need about two or three control samples to represent the full range of typical values in your waterway. To determine your error range for:

- **accuracy**, take five to seven replicates of each control sample (Eaton et al. 2005). Examine the difference (level of error) between your measurement and the known value of each control sample and calculate the average error (standard deviation) for each. See Chapter 8 for advice on how to calculate standard deviations
- **precision**, take five to seven replicate measurements of each of your control and real samples (Eaton et al. 2005). Examine the difference (level of error) between the replicate measurements of each sample and calculate the average error (standard deviation).

Ideally, you should repeat this process for each piece of equipment and equipment operator (person undertaking monitoring) involved in the project.

You should report an estimated (and tolerable) error range for each parameter for each typical range of values in your waterway. Your estimated (and tolerable) error ranges should be expressed as  $\pm x$  units or as a percentage. For example, an estimated or tolerable error range for total nitrogen at low values (0 to 0.03 mg/L) could be expressed as  $\pm 0.005$  mg/L or  $\pm 0.5\%$ .

You can also calculate your average error range by using a control chart. See Chapter 5 of ANZECC and ARMCANZ (2000) or Eaton et al. (2005) for more information.

If you are using laboratory-based methods in your monitoring project, your laboratory should estimate the level of error, or uncertainty, for each parameter (based on the specific analysis methods being used) using a method that aligns with national and international standards.

## Other planning considerations

To achieve your desired data quality (demonstrative, indicative, or analytical), you should design your monitoring plan by carefully following the guide in Chapter 2.

Aspects of your monitoring plan that will determine whether you achieve your desired data quality are:

- where, when, and how often you will monitor (your study design)
- what methods, equipment and quality controls you use
- what data management procedures you follow
- what level of training participants will receive.

Where, when, and how often you monitor will influence your data quality as they will determine how representative, complete and comparable your data is. To ensure that your data is all of these things, follow the advice in Chapter 4 on how to design your study.

Advice on other planning aspects that are important for data quality is provided in the sections below.

## Monitoring methods and equipment

The equipment chosen, the monitoring methods used, and how these methods are carried out are extremely important in determining the data quality and confidence associated with your monitoring program. See chapters 5, 6 and 7 for information on choosing methods and equipment relevant to your desired data quality (demonstrative, indicative or analytical). These chapters also provide information on how you should undertake each method to minimise both measurement and environmental errors.



Measurement and environmental errors affect the quality of your data. Monitoring procedures should seek to minimise the influence of these on your results.

Environmental errors commonly occur during the monitoring process when a non-representative sample is taken—for example, by not allowing for spatial variation within a water body or by disturbing bottom sediments during sample capture.

A common source of measurement errors is sample contamination. Inadequate preparation of sample bottles can lead to contamination. Other forms of contamination may be caused by the manufacturing process or storage, contact with insect repellents or boat fuel (when sampling from a boat), or contamination through physical contact. Similarly, inadequately cleaning a dip net could result in an inaccurate estimation of macro-invertebrate communities.

Measurement errors can also occur due to inappropriate treatment, preservation, storage or transportation of samples, which could lead to unaccounted-for changes in water chemistry or degradation of macro-invertebrates. Using out-of-date or contaminated chemicals for calibration, treatment or preservation is common, but may result in incorrect meter readings.

When you undertake waterway monitoring, it is always best to perform your measurements on a sample of water either in situ (actually within the water body) or as soon as possible after the sample is taken, as this is when the sample is most representative of the actual conditions within the water. However, it is not always possible or preferable to get an in situ or field reading for all the required parameters, particularly if conditions are unsafe.

Laboratory analysis of a water sample will often give a more accurate and precise reading than a field instrument, and at other times laboratory analysis will be the only suitable method for deriving such data. When using laboratory analysis, the sample analysed by the laboratory should be representative of the body of water from which the sample was taken. It is also essential that

the sample is correctly labelled, as this prevents laboratory parameters from accidentally being recorded against the wrong site or sample. These issues of sample preservation, transport and storage need to be considered when developing a monitoring plan.

Variations between laboratory-measured water quality and conditions at the point of monitoring must be minimised. Possible sources of variation include:

- **contamination**—the sample may be contaminated in some way by the storage container or the process used to capture the sample
- **biological processes**—functions associated with phytoplankton, micro-organisms and bacteria (including photosynthesis, respiration, consumption, assimilation and excretion) can occur after the sample is collected
- **non-biological processes**—these include temperature variations, chemical reactions, volatilisation, absorption and sedimentation.

## Quality control procedures

Preventing or minimising these variations is possible by using a range of different quality control procedures when monitoring. Procedures can be used for each monitoring method to minimise errors and therefore increase the data quality of your project.

The quality control procedures outlined below relate to monitoring methods and equipment (that is, collecting samples or conducting surveys). Other important quality control procedures, relating to participant training and data management, are outlined later in this chapter.

### Physico-chemical monitoring

Quality control procedures for physico-chemical monitoring should account for the treatment, preservation, storage, and transportation of samples. Error considerations include:

- **treatment**—the method by which the water sample is treated upon sample capture to prevent or minimise variation from ambient conditions (for example, filtering or acidification)



- **preservation**—the method by which the sample is preserved for the period of time between sample capture and subsequent analysis (for example, chilling, freezing or using fixative solutions)
- **storage**—the conditions under which the sample is stored between sample capture and subsequent analysis (for example, placing in darkness, refrigerating or freezing). Many storage requirements are time-constrained and analysis must occur within this given time to ensure representative results. It is also worth noting that storing a sample with other material may cause contamination
- **transportation**—how the sample is moved from the site to the laboratory. Consideration must be given to treatment, preservation and storage requirements when determining a suitable method for transporting the sample to a laboratory. Of particular concern are samples with very short storage times and those that need to remain frozen.

Additional quality control procedures to increase data confidence in physico-chemical monitoring are listed below.

To minimise **environmental** errors, you should:

- capture a representative water sample using the standard procedure (see page 5–9)
- use the standard nutrient sampling procedure (see page 5–73) when sampling for nitrogen and phosphorus
- take a water sample upstream from any activities that may disturb the sediment
- collect samples using a consistent method
- sample from the same location in the stream each time
- sample under similar environmental conditions each time (for example, same time of day or flow level).

To minimise **measurement** errors, you should:

- use a sample container free of contaminants and rinsed prior to sampling
- check, maintain and repair field equipment on a regular basis
- repeat readings taken from probes
- label sample bottles clearly and accurately
- use standard field record sheets.

Details on how to design a monitoring strategy to achieve your desired data quality are provided in the following sections of this chapter.

## Biological monitoring

Quality control procedures to increase data quality for biological (macro-invertebrate) monitoring are listed below.

To minimise **environmental** errors, you should:

- collect samples using a consistent method
- sample from the same location in the stream each time
- sample under similar environmental conditions each time (for example, same season or flow level)
- ensure that the location of sampling is representative of the typical environmental conditions and characteristics of the waterway
- compare results of samples collected from the same habitat type only (for example, do not compare edge samples with riffle samples)
- compare results of samples collected by the same type of method only (for example, do not compare sweep samples with kick samples).

To minimise **measurement** errors, you should:

- regularly maintain sampling nets—check for holes, tears, debris or leftovers from previous sampling sites
- ensure that other equipment for the collection, storage, sorting, and analysis of macro-invertebrates is clean and free from leftovers from previous sampling sites
- use good quality taxonomic keys and a reference collection of macro-invertebrates identified by a local expert to assist with accurate macro-invertebrate identification. A reference collection can be built by placing three or four specimens of a macro-invertebrate of each taxonomic level (family/species) into an alcohol-filled vial. Reference specimens should be in good condition and large enough for all identifying features to be observed. Each vial must be labelled to record the type of macro-invertebrate and the date and site of collection. The size of a reference collection should increase with time
- use standard field record sheets.

See Chapter 6 for further information on recommended quality control procedures for biological monitoring.



## Stream condition and habitat monitoring

Quality control procedures to increase data confidence in stream condition and habitat monitoring are listed below.

To minimise **environmental** errors, you should:

- conduct assessments using a consistent method
- conduct assessments from the same location on the waterway each time
- conduct assessments under similar environmental conditions each time (for example, same season or flow level)
- ensure that the location of assessment on the waterway is representative of the typical environmental conditions and characteristics of the area.

To minimise **measurement** errors, you should:

- use local vegetation guides and reference books to help identify plants
- use reference photographs to ensure consistency and accuracy in assessment (for example, images of a ‘very poor’ waterway to a ‘very good’ waterway that are representative of your region). Such images will also assist to ‘recalibrate’ the human eye to a consistent standard
- have groups of people carry out the same survey and ask them to discuss their assessment prior to recording the data
- use standard field record sheets.

See Chapter 7 for further information on recommended quality control procedures for each stream condition and habitat monitoring.

## Quality control checks

*Quality control checks* involve activities that measure and control the quality of data. They include a range of specific checks that let you know what level of errors have occurred in your results and whether they are outside your TER. Quality control checks also provide a means of demonstrating to other data users that your monitoring project is collecting data of the appropriate quality. Including quality control procedures and results will increase the data confidence associated with your monitoring project.

Listed below are the key quality control checks that you should undertake. When and how often you should use these checks will depend on the data quality you are aiming to achieve. For demonstrative data quality, quality control checks are generally not necessary. For indicative and analytical data, a number of quality control checks should be undertaken.

The specific quality control checks recommended for each data quality level are detailed in chapters 5, 6 and 7 but are introduced below.

## Physico-chemical monitoring

### *Calibrations and calibration checks*

Calibrations are one of the most important and commonly used quality control procedures and are vitally important in ensuring that your equipment produces data of sufficient accuracy to comply with your TERs. Calibrations are used to reset the accuracy of your sampling equipment to a known standard. This is necessary because all equipment will suffer from the influence of ‘drift’, where the equipment’s ability to measure accurately is eroded over time. This occurs due to a range of external and internal processes such as ongoing use, change in conditions under which the equipment is used, and exposure to the environment.

Calibration checks are carried out through the use of *control samples* (see below for a full explanation of these). The control samples used should reflect the chemistry make-up and typical range of values for your waterway as closely as possible. If the equipment is not reading within your TER, you



will need to complete a calibration before further credible data can be collected. A calibration check should be carried out prior to every calibration and can be as easy as recording the pre-calibration reading for each calibration standard used. If the calibration check is frequently failing the TER it is likely that the intercalibration period for the meter (the time between each calibration) is too long and some of the data being collected may not be meeting your quality requirements. If this is the case, you should carry out calibration checks more frequently to check for drift, and recalibrate as necessary.

### **Controls**

*Control samples* are samples that have a known value that are used to test the accuracy of your methods and equipment.

There are various standards of control samples. They can be prepared by a laboratory accredited by the National Association of Testing Authorities (NATA) or an internationally accredited laboratory. Those prepared by an internationally accredited laboratory are known as *certified reference materials* (CRMs). However, CRMs are very expensive and are only relevant to those aiming for a very high level of data confidence. Most community-based groups should aim to use those prepared by a NATA-accredited laboratory. These are often known as *in-house reference materials* (IHRMs).

The process used to prepare all control samples should be documented and traceable to the international system of scientific units (SI units).

The control samples you use should match as closely as possible the chemical make-up and typical range of values of the waterway you will be monitoring in your project.

Control samples are used for calibrating equipment and for shadow testing (quality control) workshops. Shadow testing workshops often use *blind control samples*, where the relevant concentrations of a solution are known but not disclosed to the user to ensure unbiased reporting of the obtained result. Blind samples are sometimes also called mystery samples.

### **Blanks**

*Blanks* are analyte-free solutions, usually deionised or distilled water, that have a value of zero for the parameter being assessed. They are substituted for a sample to test for contamination associated with the sampling process.

*Field blanks* are those that are treated and handled in exactly the same manner as other samples collected in the field. They are sent for processing at the same time to the same laboratory and should record a 'below detection limits' result when analysed. If they do not, it indicates the possibility that the water quality values of interest are changing between sample capture and analysis.

*Equipment blanks* are those that are used to test equipment to ensure that contamination is not occurring during the sampling process. For example, the blank may be used to test for contamination due to residual material associated with the manufacturing process for sample containers.

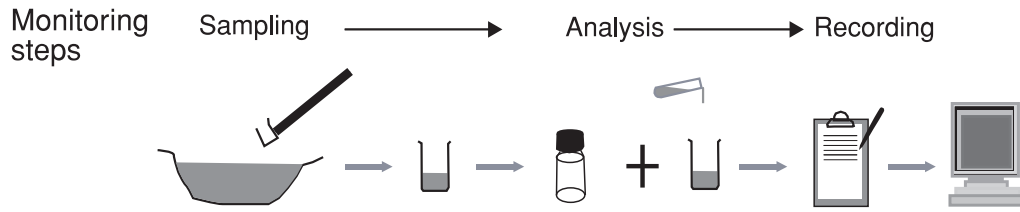
### **Replicates**

Replicate samples allow you to test the precision of your monitoring methods and equipment.

A *field replicate* is where two or more measures are taken of the same parameter at the same time and location using the same methods. Replicate measures may be used to measure background variability within the water body as well as the precision of the sampling and analytical methods being used. Replicate readings are required for certain statistical analyses such as analysis of variance.

A *duplicate measure* is performed by dividing a single sample into a number of subsamples. Each subsample is analysed and the results compared. Duplicates can be used for comparing results between methods, equipment or people (for example, to compare a field measure against laboratory analysis). Laboratories routinely use duplicates to undertake internal quality control checks to ensure that their results remain precise. The differences between duplicate measures are analysed in the same manner as for replicates (see above). Shadow testing is a form of inter-operator comparison that uses duplicate samples.

Chapter 5 outlines which of the above quality control checks are recommended to achieve your desired level of data quality.



Common errors at each step	Water body sampling errors	Contaminated sample bottles	Expired/contaminated chemicals. Operator method errors	Data recording errors	Data entry errors	
Common QC checks for each step						Expected Result
	Replicate samples					Within TER*
	Field blank					Zero
		Duplicate samples				Within TER*
		Calibration blank				Zero
		Mystery solution				As per mystery conc.
			Reagent and equipment maintenance check			All items serviceable
			Quality control workshop			Trained operators
				Confirmation by second operator		Agreement on read out
					Data entry check for outliers, etc.	Agreement with field result sheet

TER\* - tolerable error range

Figure 3-3 Standard sources of error for monitoring of physico-chemical parameters in water bodies and associated quality control checks with expected results (Cassidy 2003)



## Biological monitoring

To check the level of accuracy and representativeness of the data, a *subset* of biological samples (that is, 10%) should be re-collected, repicked and/or reidentified by an expert or experienced person, on a periodic basis. Any discrepancies between the standard and expert samples contribute to the overall error range in your data. Quality control checks using sample subsets can be divided into three parts:

- **macro-invertebrate field collection**, in which two samples are collected, one by the expert and the other by the person being assessed. Both are sorted by the expert to check that the person being assessed is collecting a representative sample
- **macro-invertebrate field picking**, in which two samples are collected by the expert. The expert 'picks' (sorts) one of the samples and the person being assessed picks the other. The picked samples are compared to check that the person being assessed is picking a representative sample. Another way to check the quality of a person's picking skills is to check the residue left over from their picked sample to determine whether any key macro-invertebrate taxa have been missed
- **macro-invertebrate laboratory identification**, in which two samples are collected and picked by an expert. One is identified by the expert and the other by the person being assessed. The results are compared to check that the level of accuracy is within the TER.

*Blind samples* should also be used to test the accuracy of macro-invertebrate identification on a periodic basis. The contents of the blind sample are known but not disclosed to the person undertaking identification, to ensure unbiased reporting of the obtained result.

Field replicate samples should be taken and the same field and laboratory methods should be used, to determine the level of precision in the data and any variability in results between different identifiers or samplers.

Chapter 6 outlines which of the above quality control checks are recommended to achieve your desired level of data quality.

## Stream condition and habitat monitoring

A site should be surveyed by both project staff and an expert or experienced operator at exactly the same time and the data compared. This will assess the operator's proficiency as compared to an expert assessment.

Field replication should be undertaken at the same monitoring sites. At least two people should undertake the same surveys (to allow for the subjective nature of the assessment) to demonstrate the degree of variability between results obtained by different people undertaking the monitoring.

**Note:** Quality control checks for monitoring stream condition and habitat are limited due to the subjective nature of this monitoring method.

Chapter 6 outlines which of the above quality control checks are recommended to achieve your desired level of data quality.

## Participant competency

Participant competency and training are critically important data confidence considerations. The best equipment, protocols and documentation will not provide quality data unless monitoring participants know how to use these tools and techniques in an appropriate manner.

The impact of insufficiently trained participants on data quality can be very difficult to measure as it will influence all aspects of data quality. This impact is also likely to be highly variable from task to task and inconsistent through time. In particular, inadequately trained participants will have difficulty dealing with situations that are outside their immediate experience, such as unexpected conditions, readings and equipment failure. This inability to recognise and adequately manage contingencies can severely affect the quality of the data collected, particularly during critical events such as flood or pollution event monitoring.



The only possible way to determine the influence of insufficient monitoring competency is through very close scrutiny of monitoring methods and techniques. A cost-effective option for avoiding this process is to implement a suitable training program with an assessment component. Assessment of the competency of participants is especially important for ensuring data confidence. Without assessment, it is difficult to tell whether the training has been successful.

Selecting the most appropriate training strategy will depend on factors including the prior experience of the participants, the complexity of the training task, the uniformity of training and the need for formal recognition of achievement. Training strategies include:

- **peer-based on-the-job training**—this is an informal training style where participants learn from their peers through the process of observation of and participation in work-based tasks
- **specific task-based training**—this involves explicit training on a specific task. It is likely to be more formal and detailed than peer-based on-the-job training as it focuses on all aspects of a given task and is likely to include both theoretical and practical components. An example would be holding a workshop on how to use a new piece of equipment
- **shadow testing workshops**—by using real-time samples, control samples, calibration check samples or certified reference materials, an individual's competency in measuring various parameters can be assessed
- **formal accredited training**—this involves certified training and assessment by a qualified assessor using accredited course material that complies with the Australian National Training Authority (ANTA) requirements.

Further information on training is outlined in Chapter 9.

## Data management

Collecting good quality data involves a lot of time and effort. All of this hard work can be undone by poor data management and documentation strategies. Using quality control and data validation procedures can ensure that such errors are minimised. Only data that meets your project's data confidence standards should be added to your database or used for interpretation of waterway condition.

### Data trails

Data trails are a documented representation of the various steps each piece of data goes through, from its initial capture to long-term storage in a database or filing system. Data trails are important as they enable you to identify and manage each step in your monitoring project, and to develop quality controls to ensure that the data does not become corrupted as it progresses through each step. Therefore, all data trails need to be transparent and auditable.

Data trails should be developed for each project and should include:

- each of the steps the data goes through from capture to storage
- a description of each step
- the format that the data is in
- who is involved in the step
- any quality control procedures applied
- chain of custody, signatures and records.

### Data recording

Participants should be trained in collecting and recording data. A field record sheet should be developed, and used every time data is collected. Minimum details should include:

- time and date
- location of site
- names of people sampling
- indicators, parameters, methods and equipment used
- units of measurement
- comments or notes regarding data collection
- other information such as site descriptions and climatic descriptions.

See Chapter 10 for field record sheet templates.



Many errors are made when transcribing data from the readout on meters to field data sheets. This can be a difficult source of error to control. The best protection against such errors is to provide participants with detailed training in data capture and to develop robust and secure on-site procedures that minimise the risk of inadvertent errors and misinterpretation.

### Data entry

Data entry involves collating information on field data sheets and entering it into a spreadsheet or database. During data entry there are many possible opportunities for error.

Errors are often made in field data sheets, so sheets need to be reviewed for anomalies and errors before the data is entered. Potential errors include:

- incorrectly recording time or date
- not detecting or providing possible explanations for unusual or unexpected results
- recording decimal points in the wrong place.

If two people are conducting monitoring at the site, the person recording results on the field sheet should seek verbal confirmation of each result by repeating it back to the sampler before recording it.

Errors can also occur when entering data into a database or spreadsheet. The entered data needs to be compared with the original data to ensure that no errors have occurred during transcription. It is best to have a second person, who was not involved in the data entry, do this. If errors are found and rectified, repeat the process to ensure that no subsequent errors have been made.

Be aware of any unusual data, such as a reading that conflicts with what is usual or expected. Such data might be quite valid or it may be erroneous. Compare the result with existing data from that site on a graph, and determine whether the data is likely to be correct. Look for other parameters that are behaving in an unusual way or additional notes that suggest something out of the usual (for example, an algal bloom). For parameters that fluctuate little over time it may be useful to return to the site and take a second reading.

### Data storage

You should carefully consider where and how your monitoring data will be stored. Ideally, any data should be stored in both hard copy and digital format.

For hard copies, consider where your field sheets will be kept. Sheets should be photocopied and copies secured in a safe location away from the originals (for example, in another office location). This provides protection in case a copy is accidentally destroyed.

Digital copies of data must be stored securely and maintained. Consider:

- what software will be used
- what the file structure for storage will be
- how the files will be backed up and where those files will be kept
- how you will manage software and hardware updates
- who can access the data.

### Documentation

Documentation is one of the most important considerations when developing and implementing a data confidence framework. Data users need to be sure of the quality of your data so that it can be used confidently for other purposes.

Record keeping ensures that results are traceable and that errors can be detected and addressed early on. Accurate records of all stages of a monitoring program should be kept, from forming your group and setting objectives through to reporting and reviewing. Documenting these steps shows how you have considered and managed the risk of data errors at each stage. Thorough documentation and record keeping will provide evidence for all quality control components, ensuring that your project maintains a defined level of data confidence.



Key documents to support your monitoring program include monitoring plans and data confidence statements. Other examples of key documents include records of equipment calibration or training. Record sheet templates are provided in Chapter 10 and are important forms of documentation.

The following sections describe some of the important forms of documentation that your group should develop.

### Data confidence statements

A data confidence statement provides others with confidence that the data you collect meets its defined purpose and is of appropriate quality.

A data confidence statement demonstrates your group's capacity to capture and manage data. It includes information about the group, its participants, projects, resources, data management and reports. Specific project information should be contained in the monitoring plan(s).

A data confidence statement is particularly useful to groups undertaking simultaneous monitoring projects. To avoid repeating the same information (such as your data management procedures) in each project monitoring plan, you may find a group data confidence statement useful for documenting a standard set of procedures that are simply referred to in each of your project monitoring plans.

The recommended format and content for data confidence statements is presented in Table 3–1.

Table 3–1 Recommended format and content for data confidence statements

Section	Possible content
About the group	Specific interests and goals Geographic boundaries External relationships and partners Sponsors Clients and data users
Members and participants	Names and contact details Roles and responsibilities for each position Competency, training and skills
Projects	Current projects (all projects should have a monitoring plan detailing further specific details) Completed projects
Resources	Sampling equipment Maintenance and calibration Contacts for instrument servicing, repairs and advice
Methods and procedures	<b>Field procedures</b> Sampling Measurement procedures (instrument operation)  <b>Maintenance</b> Preventative actions Repairs and servicing  <b>Data management</b> Data trails Data entry and storage Data validation
Reports	List of reports and documents
Review	Required frequency of review Participants involved in the review process



Data confidence statements should be living documents and should be updated as necessary (at least annually but more frequently if required) to reflect changes to your group's participants, equipment and skills. In many circumstances, the data confidence statement will refer to other documents, such as procedures and monitoring plans, for any detailed information.

## Monitoring plans

A group may be involved in a number of projects that will differ in terms of their specific issue of concern, area of interest, indicator of interest, and required data quality. Due to this variability, groups need to develop monitoring plans to support specific project objectives.

Monitoring plans can be a very effective data confidence tool. They combine all relevant information about a project, including details of monitoring procedures, into one easily managed document. They also ensure a level of critical thought in project planning so that the project meets the intended objectives and data of suitable quality is collected. See Chapter 2 for a detailed description of how to develop a monitoring plan.

## Procedures

Well-documented procedures are critical to ensure adequate data confidence. Specific procedures may be required for a broad range of monitoring activities, including:

- monitoring procedures (including instrument operation)
- quality control check procedures
- data management procedures
  - o data trails
  - o data entry and storage
  - o data validation.

Monitoring method, quality control and data management procedures have been outlined previously in this chapter and are described further in chapters 5, 6, 7 and 8.

## Record sheets

Record sheets are critical for the adequate collection and documentation of data, as they contribute to data confidence.

Record sheets are required for a range of steps in a monitoring program, including:

- site description record sheets
- monitoring methods record sheets
- equipment calibration and maintenance log sheets
- quality control checks log sheets and control charts
- training log sheets
- health and safety records.

In particular, your equipment calibration, equipment maintenance, quality control check and training log sheets are the main mechanisms by which you can demonstrate the quality of your data. It is also a good idea to plot the results of your equipment calibrations and quality control checks onto a graph. This is known as a control chart and is another useful way of demonstrating the quality of your data. For further information on control charts, refer to ANZECC and ARMCANZ (2000) or Eaton et al. (2005).

A range of record sheet templates is provided in Chapter 10. For health and safety record sheets refer to the *Health and safety guidelines for community-based waterway monitoring* (Department of Natural Resources and Water 2006).



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