

# 8. Data management, interpretation, reporting and communication



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# Introduction

## Overview of this chapter

Chapter 8 provides information on the key elements of data management, with an emphasis on data validation and confidence. It also provides advice on interpretation techniques, and how to report and communicate results effectively.

The technical information in this chapter will assist you to:

- organise and manage your data
- summarise and visualise your data
- investigate your data and explain your results
- form conclusions and make recommendations
- communicate your results to your audience
- review your project and take action if necessary.

## Why this chapter is important

Chapter 8 is important because without proper management, interpretation, reporting and communication, raw data does not serve any useful or informative purpose. However, raw data can be transformed into meaningful information that improves your knowledge of a waterway and answers specific monitoring objectives. Through proper management, interpretation, reporting and communication, the data you collect may be used

to determine the health of your waterway, monitor changes or improvements in water quality, develop strategic actions to address issues in catchments and evaluate the impacts of land-use practices.

The management, interpretation, reporting and communication of data should be considered a highly important component of your monitoring project. Regardless of the quality of data collected, if it is not adequately managed and interpreted, or the results are poorly communicated to your audience, all the effort that you put into collecting the data will have been wasted.

## How to use this chapter

Chapter 8 supports questions 10 to 12 in the development of a monitoring plan (see Table 8–1). Using this chapter during the planning stages of your project will ensure that, at the end of your project, the data you have collected is of sufficient quality and quantity for you to undertake adequate statistical interpretation to achieve your monitoring objectives.

This chapter will also be a useful reference when you reach the stage of interpreting your data and reporting your results, as it could provide some handy tips.

This chapter has been separated into four sections:

- data management
- data interpretation
- communication and reporting
- taking action.

**Table 8–1 Steps in developing a monitoring plan**

Key steps	Monitoring plan questions
Set monitoring objectives	Q1 Why are you monitoring? Q2 Who will use your data? Q3 How will the data be used? Q4 What data quality do you require?
Develop a study design	Q5 What is your study type? Q6 What will you monitor? Q7 Where will you monitor? Q8 When and how often will you monitor?
Chose monitoring methods and procedures	Q9 What methods will you use?
Plan data management, interpretation, reporting and communication	Q10 Who will be involved and how? Q11 How will the data be managed and reported? Q12 How will you ensure confidence in your data?



# Data management

## Defining 'data'

Data is any raw information that you collect in order to build a better understanding of your waterway. It can be collected from numerous sources and can be in the form of water quality monitoring results, habitat and catchment surveys, site descriptions, catchment maps, photographs, videos, oral history transcripts and notes in a diary. All of this information is valuable data and should be dated and filed in an orderly system so that it can be used to understand and explain your waterway. The different forms of information complement each other and can often provide explanations for other results. When combined, the information will improve your knowledge of the waterway. Your data confidence records, such as results of quality control checks and calibrations, are also a form of data that should be appropriately managed. This will help you to demonstrate the quality of your data.

Raw data often exists in the form of numerical values collected from monitoring physico-chemical and biological parameters, and stream condition and habitat. Raw data needs to be summarised, analysed and interpreted in context for it to be meaningful. To reveal trends—changes in water quality over time and space within your waterway—raw data needs to be collected consistently over time at the same locations and from a number of sites on the same waterway. Taking regular samples over time will enable you to determine summary measures such as averages, medians, ranges, and maximum and minimum values.

One water quality sample can give an indication of water quality at a certain place at a certain time (a snapshot). Generalisations based on limited sampling can lead to serious errors. As more samples are collected, there is more evidence for making your conclusions and errors are less likely. Sampling at the same time but at different locations along a waterway will give an indication of spatial distribution and variation in water quality along the length of the waterway. Alternatively, if samples are collected at the same site but at different times (for example, monthly), changes in water quality over time at that site can be determined.

Collecting high quality data depends on conducting complete and representative surveys and capturing accurate and precise samples. See Chapter 3 for further on details on attributes of

data. Chapters 5, 6 and 7 provide information on monitoring methods and procedures required to achieve specific levels of quality. It should be noted that not all data needs to be highly accurate or sensitive, as long as it is of appropriate quality to meet your monitoring objectives.

## Principles of data management

### 1. Data is owned by the community that collects it.

If other parties want to use the data, they must gain the permission of that community.

### 2. Data is most meaningful at the catchment scale.

Water quality data is most meaningful in the context of the catchment of that waterway, as individual catchments vary in geomorphology, climate, hydrography and ecology. Understanding the processes of the individual catchment is essential for interpreting water quality data.

### 3. Consistency is needed in gathering, interpreting and reporting data.

By gathering, interpreting and reporting data in a consistent way, data can be aggregated to report at the national scale, such for State of the Environment reports.

### 4. The quality of data being used needs to be understood.

Data users need to have confidence in the data that they use. Gathering, interpreting and reporting data in a consistent way ensures its credibility.

Data users should be aware of the quality of the data they are using, including how the data was collected and what quality control procedures were used. The best way to document this is through a project monitoring plan (see Chapter 2 for further details on developing a monitoring plan).

### 5. It is common courtesy to consult with stakeholders before reporting data.

Relevant stakeholders such as industry groups, local government, water authorities or state and federal governments, should be consulted prior to reporting the findings of the data, as they will have a vested interest in your results. This is especially true for reporting pollution incidents, where data may identify an individual or organisation.

(Waterwatch Australia Steering Committee in press)



## Recording and storing raw data

You should record your waterway monitoring results and other relevant information in a consistent and methodical way. To ensure that all necessary information is recorded at the time of monitoring, using a standard field sheet is recommended. The relevant information for each type of observation can be recorded consistently in the space provided on the record sheet. Standard field sheets allow monitoring groups to exchange and share uniform information and, at the regional scale, comparisons of data can be more easily made. Chapter 10 contains examples of standard field sheets for physico-chemical, biological, and stream condition and habitat monitoring. In addition, standard record sheets are provided for site descriptions, equipment calibrations, equipment maintenance, quality control checks and participant training details.

Other important information such as land uses in the catchment, housing developments, agricultural practices, local industries, vegetation cover and features of the waterway should have been captured in your catchment survey. Chapter 10 contains a catchment survey record sheet.

Over time, the amount of information collected will increase. You should store past information from record sheets in an accessible and safe location. A folder for each site should be set up, containing a hard copy of all record sheets and any other information on that site. It is necessary to have information such as the site description in a hard-copy format, as this page contains essential information that needs to be taken to the site each time monitoring is undertaken.

Data from record sheets should be frequently transcribed into an electronic format. A convenient and useful way to store information is to use a Microsoft Excel spreadsheet or a database in which data can be sorted, arranged and summarised. In addition, the Department of Environment and Resource Management recommends the use of the Brolga and Hydstra database systems. These may be available for use by community-based waterway monitoring groups; contact the Department of Environment and Resource Management or your regional natural resource management body for more information.

## Data validation and confidence

Refer to Chapter 3 for a description of how to ensure data confidence for the whole of your monitoring plan process. The aspects of data confidence covered here only apply to the management of data.

Errors can occur at any point in the data management process, such as when data is recorded on field record sheets or transcribed from field record sheets to a database. Data confidence procedures that relate to the data management stage ensure the reliability of reported information and assure data users that they can have confidence in the data. Data users will accept or reject data based on the level of confidence they have in its reliability.

### Data confidence procedures

In order to have confidence in your data and maintain credibility with other data users, certain procedures need to be followed during the data recording and management stage, and should be documented to demonstrate that they have been completed. Procedures to minimise errors in each of these activities are called quality control procedures. For each of the following steps, quality control procedures are outlined:

#### 1. Collecting data on site

People undertaking monitoring should be aware of baseline values for various parameters, so that they are aware of what to expect as a reasonable value for the parameter they are testing. If an unusual value is attained, the sampler should repeat the test to confirm the unusual result, and then enter the confirmed results on the record sheet. If two people are conducting monitoring at the site, the person recording the results on the field sheet should confirm the result with the sampler before recording it.

#### 2. Checking the field or laboratory record sheet

Before data is entered into a database, it should be screened for any questionable results. These may be the result of recording incorrect results on a record sheet, omitting data, using incorrect units of measurement or writing illegibly.



When validating results on a record sheet, check:

- that the decimal point is in the right place
- that results are consistent with those obtained from the various parameters tested
- whether there is an explanation to validate an unusual result—for example, there may be dead fish at a site where dissolved oxygen levels are very low.

### 3. Checking quality control record sheets

Throughout the duration of your monitoring program, it is important to record your quality control checks. If such records are not kept, it can be difficult to sustain the data quality required.

Things to look for in quality control sheets include:

- whether the equipment was calibrated
- whether the calibration results are within your tolerable error range (TER).

If calibration results do not fall within your TER you may have to discard or flag your results.

If an unusually high or low level of a parameter is recorded, you should take into account the skill levels of samplers; consider the possibility that sampling equipment was not operated correctly or that study sites were mixed up. Any discrepancy should be followed up prior to entering data into the database.

This preliminary examination is essential prior to entering the data into the database. Where a value has been recorded as below detection limits (BDL), this measurement can be replaced by the value equal to the detection limit or half the detection limit to include in statistical summaries. Where a large proportion of the dataset (for example, 25%) is below detection limits, the data should not be subjected to detailed statistical analysis as the sample variance will be underestimated and analysis will be biased or distorted (ANZECC & ARMCANZ 2000).

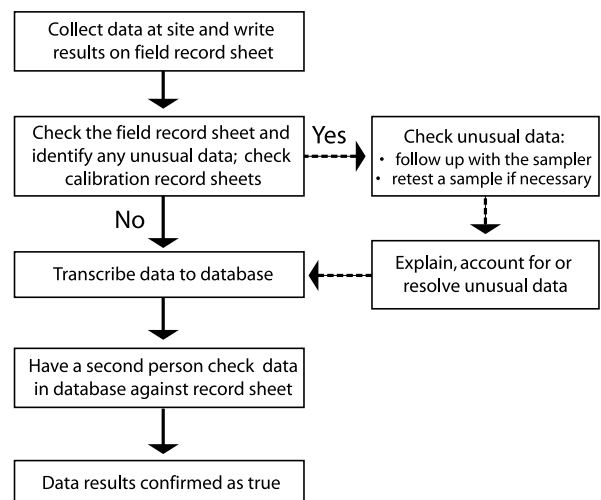
### 4. Transcribing the data to a database

Only validated data should be entered into the database. Care should be taken when transcribing data from the record sheet to the database as human errors in data entry can distort your results.

### 5. Rechecking data in the database

It is essential to compare the field results sheet with the results entered into the database or spreadsheet to ensure that they are the same. Ideally, a second person performs this task. Documentation to record this validation should include a space or tick box on each record sheet that states the name of who entered the data, who validated the entered data and the date these tasks were completed.

Your data is credible when you can demonstrate, with the aid of quality control checks, that it meets your required standards of accuracy and reliability as determined by your monitoring plan. Further assurance that results are a true indication can be obtained by comparing the current results against past results or graphing results to identify anomalies (results that fall outside the range that is normally observed).



8-5

Figure 8-1 Process for validating data



## Skills training

The skill level of the person undertaking sampling methods, using equipment and interpreting data contributes to data confidence. Some of the skills required for data management, interpretation, reporting and communication include:

- understanding basic principles of good data management
- using spreadsheets and databases
- following data management procedures specified in the monitoring plan for
  - entering data into a database
  - validating data
  - filing documents.

The people undertaking monitoring should be trained to the skill level appropriate for their monitoring plan. A logbook should be maintained as a record of skills training. Refer to Chapter 9 for further details on training and to Chapter 10 for an example of a training log record sheet.

## Documentation

Thorough documentation and record keeping will provide evidence for all quality control components and ensure data confidence.

Documentation should cover:

- field procedures—monitoring procedures and measurement procedures (instrument operation)
- quality control procedures
- data management procedures—data trails, data entry and storage, and data validation.

Copies of all record sheets should be kept, including:

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

The Monitoring Plan Tool (refer to the

CD-ROM provided with this manual) will assist you to demonstrate confidence in your data and document this process appropriately. If you have followed these steps, you will have collected and stored your data in accordance with data confidence guidelines. The next stage is to interpret your data.

## Data interpretation

Waterway data can exhibit a high degree of variation over both space and time, which can obscure any trends and patterns when you are interpreting data. Data interpretation is sometimes referred to as ‘extracting the signal from the noise’, as it identifies which aspects are important from the entire dataset. Data interpretation is therefore a critical step in your monitoring project, as it turns raw data into meaningful information that improves knowledge of a waterway and answers specific monitoring objectives. A combination of physical and chemical results, biological monitoring, and stream condition and habitat assessments, together with any extra background information collected for the site, should be used to make a judgment about the health of your waterway.

Figure 8–2 illustrates the steps involved in data interpretation. Each step within the process is described in more detail in this section.

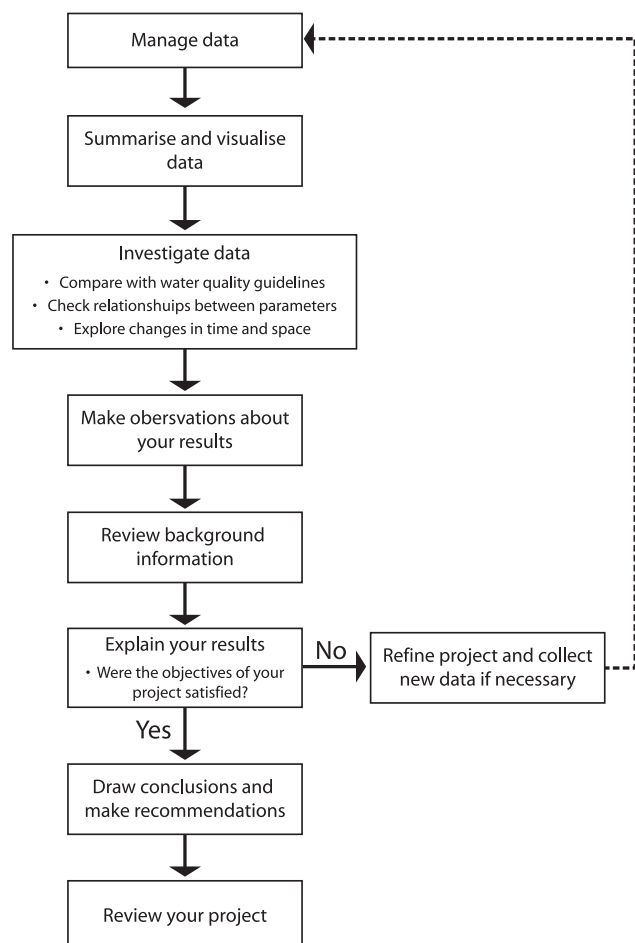


Figure 8–2 Process for interpreting data



## Summarising and visualising data

The answers to your monitoring objectives are often buried within your dataset. The objective of summarising data is to present important features of the data and identify outliers or unusual observations. A combination of statistical tools can be used including graphs, tables and numerical summary statistics.

### Using summary statistics

Table 8–2 lists some statistics that use numerical values to summarise data and convey the essential information clearly and concisely. Many computer programs, such as Microsoft Excel or the Brolga database, can be used for this function. Each statistic is explained below.

### *Mean (average)*

The average is calculated by adding all the values and dividing by the number of values. The problem with averaging a set of numbers is that very high and very low values can distort the results.

#### Example

Dataset: 2, 3, 4, 10, 12, 13, 14, 80

$$\begin{aligned} \text{Average} &= (2 + 3 + 4 + 10 + 12 + 13 + 14 + 80) \\ &\quad \div 8 \\ &= 138 \div 8 \\ &= 17.25 \end{aligned}$$

Table 8–2 Summary statistics for data

Summary statistic	What it measures	Purpose
Mean (average)	Central tendency	A value that is representative or typical of the values being summarised
Median		The middle value of the dataset (an equal number of values fall above and below)
Mode		The most frequently occurring value in the dataset
Range	Variability	The difference between the maximum and minimum value in the dataset (useful for identifying a trend over time or space)
Standard deviation		A statistic comparing how closely several results are clustered around the average value
Percentile of a distribution		A statistic showing how the data is spread above and below the average or median
Interquartile range		The value of the 75th percentile minus the 25th percentile
Relative per cent difference		A statistic comparing how close the result is to the true value



### **Median**

The median is a robust measure of central tendency as it is relatively unaffected by extremes in the dataset. Values are placed in order from lowest to highest. The median is the middle value—50% of values are below it and 50% are above.

#### **Example**

Dataset: 2, 3, 4, 10, 12, 13, 14, 80

Median = the two central numbers, which are 10 and 12

So  $(10 + 12) \div 2 = 11$

### **Mode**

The mode is defined as the most frequently occurring value in the dataset.

#### **Example**

Dataset: 2, 2, 4, 4, 4, 6, 7, 7

Mode = 4

### **Range (maximum – minimum)**

The simplest measure of variation is the range. It is the difference between the highest value and the lowest value. It is rarely used as a measure of variability as it is affected by very high and very low numbers in the dataset, however it is useful for identifying a trend over time or space.

#### **Example**

Dataset: 2, 3, 4, 10, 12, 13, 14, 80

Range =  $80 - 2 = 78$

### **Percentiles**

Percentile is a value below which a given percentage of the data lies. It is the  $p$ th percentile that is greater than or equal to  $p\%$  of all values in the distribution. For example, 25% of all values in a distribution are numerically less than or equal to the 25th percentile.

The 25th, 50th and 75th percentiles are called quartiles. The range between key percentiles is used to show the spread of the data. If the spread is narrow, it means that your dataset is relatively consistent and clustered around the median. If the spread is wide, it indicates that there is a lot of variation in your data. The percentile range is used to determine if there is a trend over time or space in your dataset. It can be shown graphically as a box and whisker plot.

### **Relative per cent difference**

Relative per cent difference is used to show how close the result from a water sample is to the true result. It is expressed as a positive or negative difference to the true result. This is often used when a blind sample test has been performed or where a calibration solution has been analysed.

#### **Example**

A field thermometer took a reading of 25.2 °C, while a certified thermometer took a reading of 24.5 °C.

The difference between the two results is  $25.2\text{ °C} - 24.5\text{ °C} = 0.7\text{ °C}$ .

This is divided by the average of the two results to calculate the per cent different, which is  $0.7 \div 24.85 = 0.028$  or 2.8%.

Hence, the field thermometer result (25.2 °C) was 2.8% above the true result (24.5 °C).

### **Standard deviation**

Standard deviation is used to compare how closely several results are clustered around the average value. Very similar results will have a small standard deviation and widely scattered data will have a larger standard deviation. It is expressed as  $\pm$  from the average value. It is suitable for reporting your quality control results and for split and replicate samples where data is expected to fit a normal distribution curve (Cassidy 2003). Standard deviation is the preferred measure of variability because it has the same units of measure as the original data (ANZECC & ARMCANZ 2000).



## Example

Five replicate temperature measurements were taken.

Dataset: 22.5 °C, 22.8 °C, 23.2 °C, 23.1 °C, 22.9 °C

Step 1: The deviation from the average is calculated by subtracting the average from the result (ignore the negative if it occurs), then multiplying this number by itself and adding it to other squared values. See the table below for details.

Sample	Result	Result – average	(Result – average) <sup>2</sup>
1	22.5	22.5 – 22.9 = 0.4	0.16
2	22.8	22.8 – 22.9 = 0.1	0.01
3	23.2	23.2 – 22.9 = 0.3	0.09
4	23.1	23.1 – 22.9 = 0.2	0.04
5	22.9	22.9 – 22.9 = 0.0	0.00
Average = 22.9		Total = 0.30	

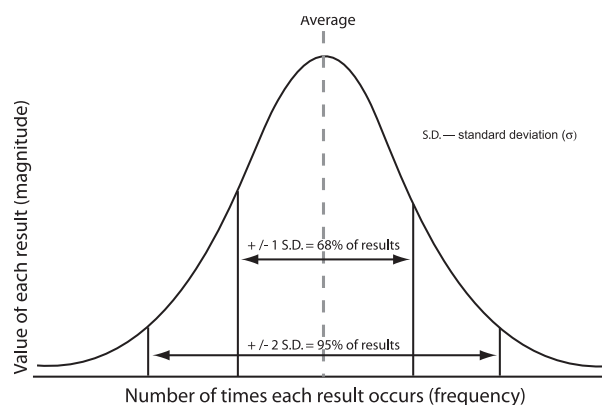
Step 2: The total is divided by the number of results minus one; that is,  $0.3 \div 4 = 0.075$ .

Step 3: Take the square root of this value,  $\sqrt{0.075} = 0.27$ .

Answer: The standard deviation for the set of temperature results is 0.3 °C.

Standard deviation assumes that if the same parameter is measured many times under the same conditions, the results will be randomly clustered around the average with more values near the average than further away. A graph of the frequency (the number of times each result occurs) plotted against its magnitude (the value of the result) should give a bell-shaped or 'normal' curve. Figure 8–3 is a normal distribution curve showing standard deviation. Approximately two thirds (68%) of your results will fall within one standard deviation of the average and 95% of results will fall within two standard deviations of the average. The height and width of the curve are determined by the average and standard deviation, respectively. The normal distribution is a continuous, bell-shaped distribution of data values. If the data values are evenly distributed about the mean, the distribution is said to be symmetrical (see Figure 8–3 and 8–4a).

When the majority of the data values fall to the left of the mean, the distribution is said to be positively or right skewed (Figure 8–4b). The mean falls to the right of the median and both the mean and the median fall to the right of the mode. When the majority of the data values fall to the right of the mean, the distribution is said to be negatively or left skewed (Figure 8–4c). The mean is to the left of the median, and the mean and the median are to the left of the mode. Standard deviation is not suitable for summarising your water quality data and biological information when water quality data can be skewed (biased) to a higher or lower value due to events such as high rainfall and flooding.



**Figure 8–3 Standard deviation in a normal distribution curve**

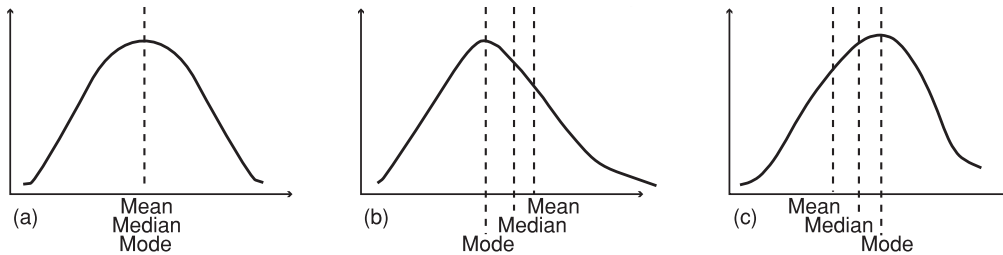


Figure 8-4 Normal (a), positively skewed (b) and negatively skewed (c) distribution curves

Table 8-3 Graphs useful for visualising data

Type of graph	Purpose	Description
Line graph	Reveals trends over time and space, and relationships	Plotted points that have been connected by a line
Bar graph	Shows value of data points	Columns of various heights
Scatter plot	Reveals trends and linear relationships	Scattered data points in graph of <i>x</i> - and <i>y</i> -axis
Pie chart	Compares categories within a whole collection	Round circle divided into wedges proportional to contribution
Box and whisker plot	Shows variability and central tendency	Graph of median, interquartile range and range of dataset

### Relative standard deviation

You may choose to express standard deviation as a percentage of the average to give it more meaning. The lower the percentage, the more precise the results are. The relative standard deviation is calculated as the standard deviation divided by the average, multiplied by one hundred. Using the standard deviation dataset in the previous example, relative standard deviation is calculated as  $0.3 \text{ (standard deviation)} \div 22.9 \text{ }^\circ\text{C (average)} \times 100 = 1.3\%$ . The spread of temperature data can be expressed as the average  $\pm$  the relative standard deviation, which is  $22.9 \text{ }^\circ\text{C} \pm 1.3\%$ .

### Visualising data

Various types of graphs can be used to summarise and visualise data and can contribute to data confidence. Graphs enhance the readability and usefulness of data and can help to identify anomalies, errors, outliers and properties of the distribution (such as skewness and dispersion). Graphs also communicate monitoring results through trends over time and space, relationships between parameters (existence of and types) and

time series analysis. Graphs allow simple analysis of several water quality parameters simultaneously, which is advantageous because important information and relationships can be missed if parameters are analysed individually.

A good graph includes:

- a title (with figure number and descriptive name)
- labelled axes (with units of measurement)
- consistent scale along axes
- appropriate size and space to clearly display data
- a legend (for example, to differentiate between categories, parameters or sites)
- a descriptive paragraph below the graph highlighting the major features, trends or relationships displayed by the graph.

Table 8-3 lists some useful graph types for visualising data. Each of these is explained in the following sections.



**Line graph**

A line graph effectively shows trends over space and time by using data points connected by a line. It emphasises trends and the relationship between the data points without giving particular attention to any specific data point. Figure 8–5 shows a pattern that would not be apparent from a data table. The two lines show an inverse relationship; as temperature increases, dissolved oxygen decreases.

**Bar graph**

A bar graph (Figure 8–6) uses columns with heights that represent the value of the data point. This type of graph can show spikes, low points and anomalies at a glance.

**Macro-invertebrate family richness**

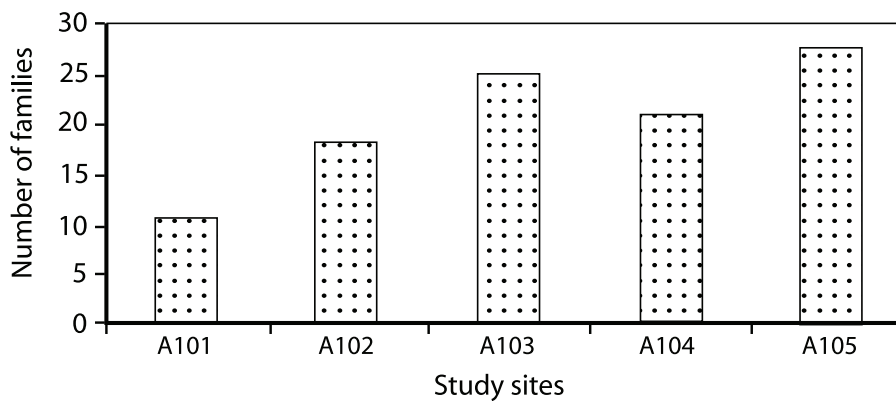


Figure 8–6 Example of a bar graph

**Dissolved oxygen and temperature at Site 1**

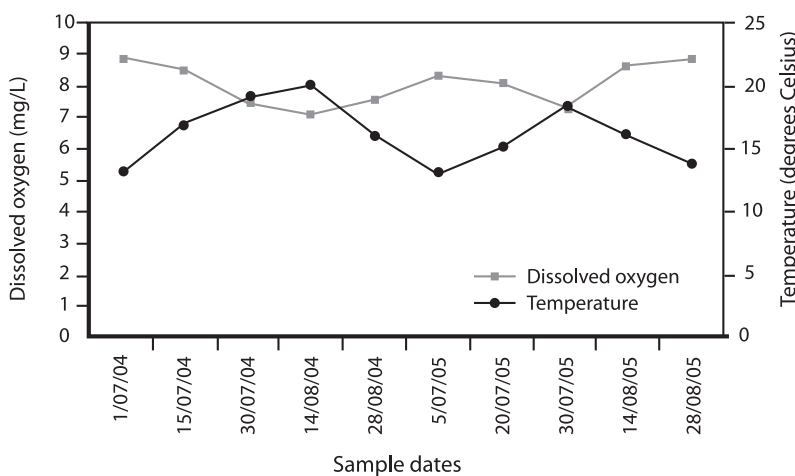


Figure 8–5 Example of a line graph



### Scatter plot

Scatter plots consist of a vertical axis representing one parameter, a horizontal axis representing another parameter and the points in the plot representing the individual results (Figure 8-7). Water quality data exhibits a high degree of variation over both space and time. This high natural variation has the ability to obscure trends in water quality. Scatter plots effectively provide a view of the trend and the surrounding natural variation ('noise') of water quality parameters. They also highlight linear relationships between the variables on the *x*- and *y*-axis, where the plotted points fall on a straight (or almost straight) line. The more the points tend to fall along a straight line, the stronger the linear relationship. The figure below shows two parameters that have a linear relationship (dissolved oxygen decreases as temperature increases).

### Pie chart

A pie chart (Figure 8-8) is used to compare categories within the whole collection of data. The proportion of each category is represented by the size of the wedge. Pie charts are popular due to their simplicity and clarity and should be limited to five or six wedges.

8-12

Relationship between temperature and dissolved oxygen

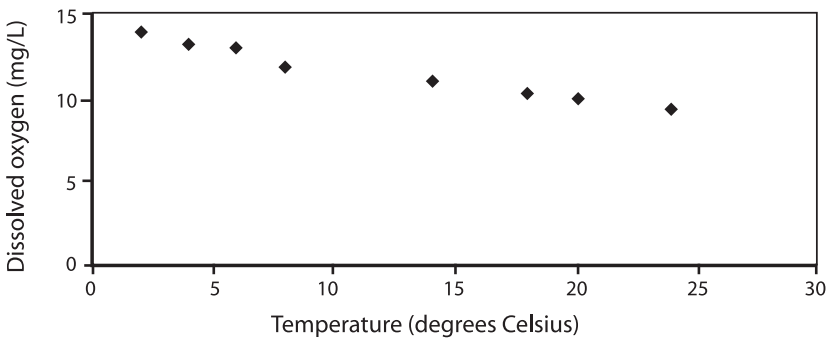


Figure 8-7 Example of a scatter plot

Summary of site condition ratings

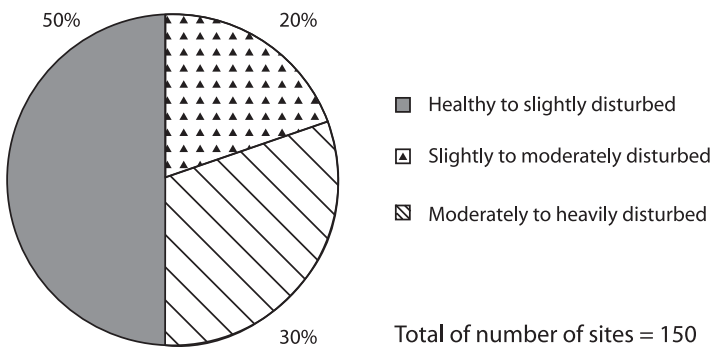


Figure 8-8 Example of a pie chart



### *Box and whisker plot*

A good method for presenting certain types of waterway statistics is a box and whisker plot (Figure 8–9). One plot can display the median and variability of data around it, as well as the skew, range and size of the dataset. You can use a statistical software package to construct a box and whisker plot by following these steps:

1. Enter the data from lowest to highest value.
2. Plot the lowest and highest values on the graph as short, horizontal lines; these represent the maximum and minimum values of the dataset (between these lines is the range). The line lengths (and therefore box width) can be used to indicate the relative size of the dataset. For example, a dataset with 20 values would be twice as wide as a dataset with 10 values.
3. Determine and plot the median of the dataset (Q2), which divides the data into two parts with an equal number of values above and below the median line.
4. Determine and plot the first quartile (Q1), which is the median of the lower part of the dataset.
5. Determine and plot the third quartile (Q3), which is the median of the upper part of the dataset. The range between the first and third quartiles is known as the interquartile range.
6. Draw vertical lines for the sides of the box, and to join the box to the lines for maximum and minimum values.

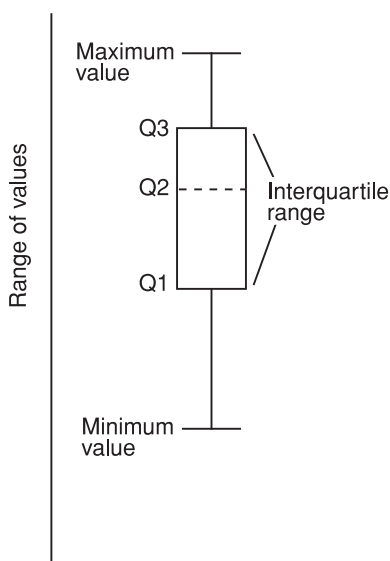


Figure 8–9 Example of a box and whisker plot

### **Choosing an appropriate summary method**

It is important to choose the appropriate statistical measure for your dataset and for the questions you want to answer, as different statistical measures are used for different purposes. For example, minimum and maximum values may appropriately answer basic monitoring questions, as some water quality standards are based on the number of times a measurement may exceed a set level, while the range of readings throughout a day may be appropriate for monitoring other parameters. Summary statistics are important for comparisons between months, seasons or years for the same site, or for comparisons between sites. For indicators that vary naturally with seasons (for example, temperature and dissolved oxygen), separate summaries should be calculated for each season.

Follow these general rules when choosing appropriate statistical tests:

- If data contains very high or very low values, the median should be used instead of the average (due to the skewed distribution).
- If data does not contain very high or very low values, the median or average can be used as they may be very similar (due to the normal distribution).

Table 8–4 lists some summary statistics appropriate for physico-chemical parameters collected on an ambient monthly basis; however, you should check historical datasets to see how the parameters have been summarised to allow for comparison.



**Table 8–4 Suggested summary statistics for physico-chemical data collected on an ambient monthly basis (Cassidy 2003)**

Parameter	Suitable summary statistic
Temperature (water or air)	Seasonal average Seasonal median Maximum Range Percentiles
Dissolved oxygen (mg/L)	Seasonal median Minimum Percentiles
Dissolved oxygen (% saturation)	Seasonal average* Seasonal median Percentiles
Turbidity	Median Quartiles
Nutrients (e.g. nitrate or phosphate)	Median Percentiles
Conductivity or salinity	Median Percentiles
pH	Median Percentiles

\* if values are fairly stable

Ambient (routine) monitoring of biological (macro-invertebrate) and stream condition and habitat indicators is usually done only on a yearly or less frequent basis so you may not need to or be able to calculate the summary statistics suggested for physico-chemical indicators. However, you should still graph your data to allow comparison of results from year to year and between sites, depending on what is appropriate to your monitoring objectives.

For examples of the summary methods used for different monitoring projects, refer to the case studies in Chapter 11.

Remember that before you undertake any data interpretation, such as graphing your results or calculating any summary statistics, you may need to perform some extra calculations on your raw data. For example, if you are using Method 3 in Chapter 6 for biological (macro-invertebrate) monitoring, you will need to calculate your taxa and index scores such as SIGNAL 2, total family richness and PET (stonefly, mayfly, caddisfly) family richness. If you are using Method 3 in Chapter 7 for stream condition and habitat monitoring, you will need to calculate your index score or rating for each parameter (bank and bed stability condition rating, stream habitat diversity ratings and riparian vegetation disturbance rating). For monitoring of some physico-chemical parameters, you may need to do some extra calculations such as the calculation of per cent saturation for dissolved oxygen. For guidance on how to perform such calculations, refer to the relevant monitoring methods chapter.

It is important to note that summary statistics only describe the data. These statistics do not investigate the data to find out answers to your monitoring questions or provide explanations for your results. Information on how to investigate and analyse your data in relation to your monitoring objectives and how to explain your results is provided in the following sections.



## Investigating data

Depending on the objectives of your monitoring plan, statistical summaries may be enough to give you an indication of the health of your waterway, but will not answer specific monitoring questions. Some monitoring plan objectives may require comparisons with known guidelines or you may need to undertake more rigorous statistical analyses such as hypothesis testing, relationships between variables and changes in time and space. A brief description of each type of data investigation is given below. Further information and examples can be found in ANZECC & ARMCANZ (2000b) or any introductory statistical analysis textbook. Some suggested texts are listed at the end of this chapter.

### Considering your objectives and study design

The way in which your data will be interpreted will largely depend on your study type and monitoring objectives.

The different types of monitoring you may be doing include:

- ambient (routine) monitoring to monitor trends through time and detect a decline or improvement in condition. This type is also used to detect pollution events and pest species outbreaks or to develop local waterway guidelines

- load-based monitoring to estimate sediment and nutrient inputs during high-flow events
- impact assessment to assess the impact of a land use or pollution source
- restoration assessment to assess the effectiveness of a management action
- compliance monitoring to assess compliance with guidelines—for example, for drinking water or recreation
- investigative studies to investigate causes of a water quality problem.

Each of these will have different study designs and will therefore require quite different forms of data investigation and interpretation. See Chapter 4 for more details on study design.

Table 8–5 suggests statistical measures for different types of monitoring; however, this is merely a guide. Data investigation methods should be selected to answer your monitoring plan objectives and will vary from project to project.

Table 8–5 Suggested data investigation methods based on study design

Study design	Comparison with guidelines	Development of local guidelines	Relationships between variables	Changes in time and space	Hypothesis testing
Ambient (routine) monitoring	✓	✓	✓	✓	
Load-based monitoring			✓	✓	
Impact assessment			✓	✓	✓
Restoration assessment			✓	✓	✓
Compliance monitoring	✓			✓	
Investigative studies			✓	✓	✓



## Comparing with guidelines

Comparing your water quality results with known standards of acceptable or desirable conditions for various water quality parameters can tell you a lot about the health of your waterway. The *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ 2000a) were prepared as part of Australia's National Water Quality Management Strategy, by the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ). These guidelines provide water quality values (numbers) for different indicators relating to the protection of aquatic ecosystems and human uses (such as drinking water, recreation and food production). If water quality results exceed these measurements, the parameter has the potential to cause a problem and consequently should trigger a management response. For further information on the ANZECC and ARMCANZ guidelines, go to <[www.deh.gov.au/water/quality/nwqms](http://www.deh.gov.au/water/quality/nwqms)>.

While the ANZECC and ARMCANZ guidelines provide default guideline values, it is strongly emphasised that locally relevant guidelines should be developed to adapt the guidelines for local environmental conditions. The *Queensland water quality guidelines* (Environmental Protection Agency 2006) were developed for this purpose.

The Queensland guidelines aim to provide regional and subregional guideline values that are tailored to specific water types, as well as providing a process or framework for deriving local, more specific guidelines for waters in Queensland. These guidelines are structured on:

- levels of aquatic ecosystem protection—high ecological or conservation value ecosystem, slightly to moderately disturbed ecosystem and highly disturbed ecosystem
- regions and subregions—different guidelines have been developed for seven different regions across Queensland based on major drainage divisions: South East Queensland, Central Queensland, Wet Tropics, Eastern Cape York, Gulf, Lake Eyre and Murray–Darling. Subregions will be determined if there are clear differences in water quality between parts of a region

- water types—including upland fresh water, lowland fresh water, lakes, wetlands, estuaries, inshore marine and offshore marine. Guideline values are being developed for each water type in each region (and in the future this will include subregions)

Values are provided for physico-chemical, biological and habitat indicators. The guidelines can be downloaded from the Department of Environment and Resource Management website <[www.epa.qld.gov.au/environmental\\_management/water/water\\_quality\\_guidelines](http://www.epa.qld.gov.au/environmental_management/water/water_quality_guidelines)>.

Regional guideline values for macro-invertebrate indicators and riparian habitat indicators are currently available for South East Queensland only. It is intended that these indicators for the other regions will be included in future versions of the Queensland guidelines. Until regional guidelines for these indicators become available, rating and index score systems can provide some form of data interpretation. These include the SIGNAL index and AUSRIVAS rating systems for macro-invertebrate monitoring, and the State of the Rivers rating system for stream condition and habitat monitoring. For guidance on how to use these ratings systems, refer to the relevant monitoring methods chapter.

The Queensland guidelines are for base-flow conditions. No guidelines are currently available for event (flood) conditions.

The Queensland guidelines should be used when local guidelines are not available. Use the ANZECC and ARMCANZ guidelines where Queensland guideline values are not available.

Community-based waterway monitoring groups can potentially contribute data to the refinement or development of local guidelines. If your group is interested in contributing to the refinement of existing Queensland guidelines, contact the Department of Environment and Resource Management Freshwater and Marine Sciences Division on (07) 3896 9245 to find out the data quality and quantity criteria for contributions, or refer to the Queensland guidelines. If your group is interested in developing new local guidelines, see the next section, 'Developing local guidelines'.

The Queensland guidelines (section 4.3) also outline how the guideline values can be used as a technical input for deriving water quality objectives



or targets (agreed levels of water quality for various parameters that will be achieved through waterway management). Water quality objectives are designed to protect the environmental values of a waterway, such as its uses as drinking water, for human recreation, for food production or as aquatic ecosystems. Water quality objectives are determined by local communities and take into account social, economic and environmental considerations. While water quality guidelines are an important technical input to the development of water quality objectives, the objectives may adopt a different set of values. This is often the case if the relevant water quality guidelines are deemed to be economically or technically unachievable. The National Water Quality Management Strategy requires state and regional organisations to set water quality objectives based on the environmental values of the waterway. In Queensland, regional natural resource management bodies are also required to set resource condition targets for waterways in their region—see ‘Setting targets’ on page 8–26 for further information.

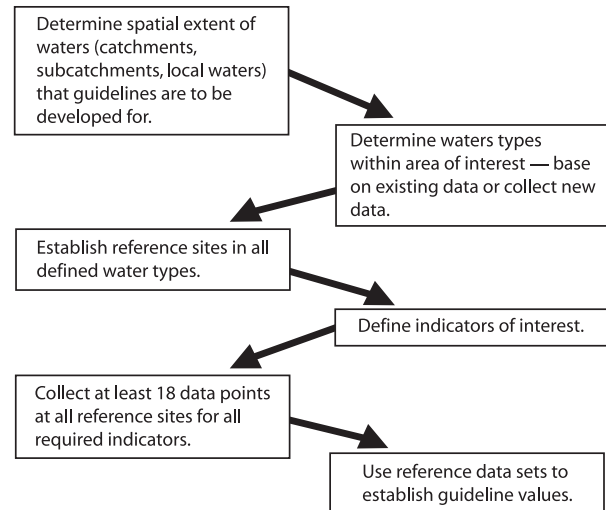
If your group wishes to compare its waterway monitoring data to the relevant guidelines to assess compliance, you should refer to sections 4.1 and 8.4 of the Queensland guidelines. These sections outline the ANZECC and ARMCANZ compliance assessment protocols and the statistical approaches needed to determine compliance. These approaches are especially useful if you have a long-term (at least one year) dataset and wish to determine whether your waterway complies with the relevant guidelines. The Guideline Assessment Tool (see page 8–27) can also assist with this process.

### Developing local guidelines

Local guidelines are specific to a region or a catchment. They take into account the geography, climate and other natural features of an area. In certain parts of Queensland, local water quality guidelines have not yet been established. Your group may therefore wish to contribute to developing local guidelines for your area.

The Queensland guidelines outline a process for developing local guidelines (section 3). This is shown in Figure 8–10.

**Figure 8–10 Process for developing guidelines at a local level** (Environmental Protection Agency 2006)



For detailed information on the process of developing local guidelines, refer to section 3 of the Queensland guidelines or volume 4 of the ANZECC and ARMCANZ guidelines. Alternatively, contact the Department of Environment and Resource Management or your regional natural resource management body.

An additional consideration in the process of developing local guidelines is the quality of data used to derive the guideline values. The Queensland guidelines recommend that all reference site monitoring programs (for the purpose of developing local guidelines) have quality assurance programs in place that:

- are well documented
- keep sampling errors at a minimum
- allow these errors to be quantified.

In order for local water guidelines to be included in future versions of the Queensland guidelines, the data used may need to meet additional quality and quantity requirements. Refer to the Queensland guidelines or contact the Department of Environment and Resource Management on (07) 3896 9245 or <epa.ev@epa.qld.gov.au>.



## Hypothesis testing

Hypothesis testing involves structuring your monitoring plan on the basis of two statements (hypotheses). Traditionally, a *null hypothesis* ( $H_0$ ) assumes no change or no relationship between the tested parameters, while the *alternative hypothesis* ( $H_a$ ) assumes that there is a change or relationship between the parameters. A test statistic is chosen and the level of acceptable error (denoted by  $\alpha$ ) is selected (for example, 0.05). The result is given as a  $p$ -value. A  $p$ -value greater than the chosen value of  $\alpha$  suggests that  $H_0$  is true, indicating a non-significant result (there is no difference). A  $p$ -value of less than the chosen value of  $\alpha$  suggests that  $H_0$  is false and  $H_a$  should be accepted, hence it is a significant result (a significant difference exists). The  $p$ -value indicates the level of statistical significance;  $p < 0.05$  (significant difference),  $p < 0.01$  (very significant difference) and  $p < 0.001$  (highly significant difference).

For example, if you wanted to determine whether a sewage treatment plant was having an impact on water quality, you would take replicate water samples above and below the sewage treatment plant. As nitrate is an indicator of pollution, you could set up a hypothesis to determine whether nitrate levels are significantly different upstream (Site A) from downstream of the sewage treatment (Site B). This is stated as:

$H_0$ : Nitrate at Site A is not significantly different from nitrate at Site B.

$H_a$ : Nitrate at Site A is significantly different from nitrate at Site B.

The  $H_0$  (null hypothesis) assumes that there is no pollution and hence no difference in nitrate levels above and below the sewage treatment plant. The  $H_a$  (alternative hypothesis) assumes that there is pollution; therefore Site B would have significantly higher nitrate levels than Site A. For methods of testing hypotheses, refer to the descriptions of  $t$ -tests and ANOVAs in the following paragraphs.

A two-sample  $t$ -test is used to compare the mean value of a water quality parameter between two water bodies, two sample sites within the same water body or samples taken at two different times within the same site. This test is used to investigate hypotheses. A  $p$ -value less than the chosen value of  $\alpha$  suggests that a significant difference exists

between the parameters, while a  $p$ -value greater than the chosen value of  $\alpha$  suggests that no significant difference exists.

A  $t$ -test can be used to test the hypothesis in the above example of the sewage treatment plant. Using a statistical computer package to perform a  $t$ -test involves entering your data from Site A and Site B and creating an output of statistics, including the mean nitrate level of Site A and mean nitrate level of Site B. Perform a  $t$ -test comparing the means, and if they are statistically different at the 0.05 level the result will be a  $p$ -value of less than 0.05. You can then accept  $H_a$  (that sites A and B are significantly different) and if Site B (downstream) has a significantly greater level of nitrate, you can assume that the sewage treatment plant is leaking effluent into the waterway, increasing nitrate levels and degrading water quality. Further water quality testing would be required to confirm this.

*Analysis of variance* (ANOVA) is an extension of the  $t$ -test to include simultaneous testing of more than two water bodies, sample sites, or times of sampling. ANOVAs test within variables and between variables. A  $p$ -value of less than 0.05 initiates further tests, such as *Tukey's test*, to identify where the significant differences lie (for example, determining which water bodies are significantly different from each other and which are not).  $P$ -values greater than 0.05 indicate that there is no significant difference.

Statistical formulas will calculate these values and computer software packages will undertake these statistical methods. These 'crunch the numbers' in your dataset to provide you with a significance value or critical number. It is then up to you to interpret that result in the context of your waterway.

## Identifying relationships between variables

A convenient first step in identifying relationships between water quality parameters is creating a scatter plot and inspecting it for relationships. Following this, the *Pearson product-moment correlation coefficient* ( $r$ ) can be calculated. This is a numerical measure of the strength of the linear relationship between two variables and is reported as a value between  $-1$  (negative relationship) and  $+1$  (positive relationship).



The value of  $r$  indicates the strength of the relationship as follows:

- A value of 0 to 0.3 indicates little or no relationship.
- A value of 0.5 to 0.7 indicates a moderate linear relationship.
- A value of 0.7 to 1.0 indicates a strong linear relationship.

Regression analysis attempts to describe the relationship between a dependent parameter ( $y$ ) and several independent variables ( $x_1, x_2, x_3$ ). It is also used to predict the value of a dependent variable based on the linear relationship with the independent variable.

### Identifying changes in time and space

According to ANZECC and ARMCANZ (2000b), formal statistical analysis of time series data can be complex and requires a degree of skill in identifying suitable models. Testing for trends can be undertaken using the seasonal Kendall Test (among others), which is a non-parametric test. To find further information and specific examples of these data analysis techniques, use the reference list at the end of this chapter, or refer to any introductory statistical analysis or statistical methods textbook.

### Making observations about your results

Making observations about your data involves highlighting important points, but not attempting to explain them. Observations do not mean anything unless more specific questions are asked, but they allow you to form a thorough and accurate understanding of the data. Trends and patterns—or, just as importantly, lack of patterns—are identified in the data. For example:

- salinity at Site A was higher in summer
- pH at Site B was much higher than the pH of all other sites on the waterway
- dissolved oxygen was consistently low at all sites.

A consideration when interpreting data is the degree of change that is significant for each parameter; most parameters vary naturally over time and space due to trends, seasonal changes, groundwater inflow and surface run-off. As some equipment and methodologies can detect small changes, the significance of the changes needs to be interpreted in the context of natural variation and baseline levels of that particular indicator.

### Reviewing background information

After summarising your data, you can take steps to interpret it in the context of your waterway. Background information is important because your data must be examined in the context of the catchment it is located in. This information can include:

- maps of the catchment with study sites marked
- study site results with correct units of measurement
- general observations
- habitat and weather conditions for each sampling date and site
- site description including habitat condition and type
- historical and current information from other sources
- land-use information from past and present
- knowledge of the acceptable range of water quality measurements from guidelines.

For a specific waterway and for the normal flow regime of that waterway, water quality measurements fall within a particular range. These measurements cannot be compared from catchment to catchment unless other conditions are similar. Consequently, it is important to be familiar with the expected natural water quality measurements for your individual catchment and consider your data in the context of the catchment and level of flow at the time of sampling before making conclusions about water quality problems. Quality and quantity of water is dependent upon the topography, soil, vegetation and rainfall in your catchment area. Activities within the catchment, such as urbanisation, agricultural or forestry practices, construction of urban areas and road building have the potential to alter the physical condition of the catchment through soil erosion, sedimentation and salinisation, so it is vitally important that you consider all of this background information when interpreting your monitoring results.



## Explaining your results

You should complete the following, if you have not already done so, to explain your results:

- Compare the results with water quality standards or guidelines—for example, the *Queensland water quality guidelines* (Environmental Protection Agency 2006)
- Check relationships between parameters.
- Explore changes over time and space for each parameter (for example, upstream and downstream, shallow and deep).
- Compare your results with historical monitoring data from other sources that was collected using comparable field and laboratory methods (that is, compare with state reports or other similar waterway documents).
- Consider the background information of your catchment and interpret results in this context.

Consider the following when explaining your results, in order to come to a conclusion:

- which sites had the highest or lowest readings of a certain parameter
- which dates had the highest or lowest readings of a certain parameter
- whether your results show a consistent pattern of change upstream to downstream or close to and further apart
- whether the data clusters around an average value, or has occasional very high or very low values
- whether changes in one indicator coincide with changes in another indicator
- if weather appears to influence your results
- whether high or low measurements coincide with heavy rainfall
- whether the time of day you sampled affected your results
- whether your anecdotal notes or field observations explain any unusual results
- whether natural changes could explain your results
- whether there are any trends over several years of data
- whether changes in one indicator explain changes in another
- whether flaws in your sampling methods explain your results
- whether you need to conduct additional monitoring to answer your monitoring questions.

You also need to review your data and consider whether it has satisfied your monitoring objectives. Within your monitoring plan you would have specified review dates when the project would be evaluated to ensure that it was meeting your monitoring objectives. If the data you collected did answer your monitoring questions, you can draw conclusions about what you discovered and make recommendations about what action should be taken and what further information is needed.

In some cases, however, the data collected may not adequately answer your monitoring objectives and therefore the results should not be reported or communicated. This could have occurred due to flaws in your sampling methods, inadequate training of monitoring personnel for required data quality, equipment failure or difficulties during monitoring such as seasonal variation. In these cases, it may be necessary to:

- refine the project objectives
- conduct training with monitoring personnel
- maintain and calibrate equipment
- undertake additional monitoring and collect new data.

## Drawing conclusions and making recommendations

Conclusions are answers to the questions you have asked of your data and in your monitoring plan. Your conclusions are explanations of your data, and all acquired information should contribute to drawing your conclusion. If monitoring has just started in a waterway, your data may be inconclusive until several years of monitoring data is available for interpretation. The following is an example conclusion:

- Nitrate and phosphate levels are elevated at sites downstream of the sewage ponds. This suggests that the sewage pond is leaking and emptying into the creek.

Recommendations describe what action should be taken and what further information should be gathered. The following are example recommendations for action:

- Bring elevated nitrate and phosphate levels to the attention of local council.
- Get the sewage pond fixed.

The following are example recommendations for gathering further information:

- Sample sites again after the sewage pond is fixed, to compare water quality.
- Conduct interviews of local residents to determine the history of the waterway before the sewage pond was introduced.



## Communication and reporting

Once your results have been interpreted and you have drawn conclusions and provided recommendations, the next step is to report and communicate these to your audience. Reporting needs to accurately and appropriately present the information to the audience. The way you present the information will depend on the level of understanding that your audience has of the issue, and on what you want to achieve. Good communication involves knowing your audience and how they will use your data, knowing what you want them to do as a consequence of your information and communicating the message to them in the most appropriate way.

### Identifying your audience

When designing your monitoring plan objectives, you would have considered **why** you are monitoring. For example, you may want to:

- increase community awareness
- enhance community skills
- provide learning opportunities
- measure water quality
- compare water quality against guidelines
- identify trends through time
- identify trends through space
- evaluate on-ground works.

You would have considered **who** will use your data. For example, your data may be relevant to:

- landholders
- catchment groups
- teachers and students
- environmental organisations
- regional natural resource management bodies
- media organisations
- industry groups
- consultants
- local and state government
- universities.

You also would have considered **how** your data will be used; this is dependent on the category of the data you collected. Demonstrative data is used for training or educational purposes or to capture basic information that can be used to demonstrate the principles of water quality or

general waterway condition.

Indicative data is used to give a general indication of water quality or stream condition, rather than a precise measurement of water quality. This type of data can be shared in an informal way to give a general indication of conditions, but you cannot be absolutely sure about the data values.

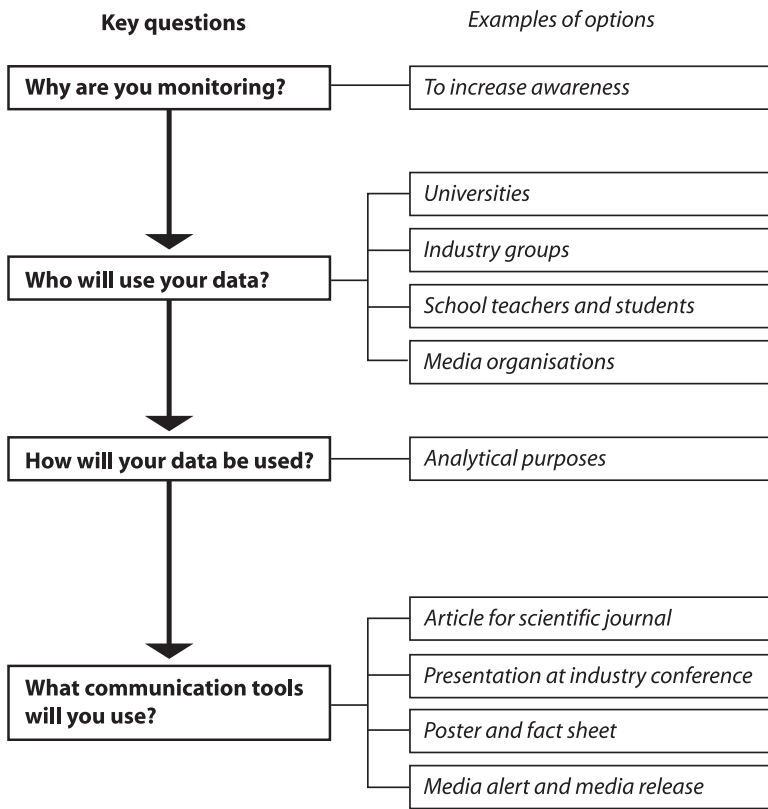
Analytical data is collected when you need accurate numerical values for your selected water quality and stream condition parameters, such as for publishing the data or undertaking statistical or numerical analysis. This type of data is most appropriate when sharing the data with other groups and organisations.

Depending on your reasons for monitoring, and the expected audience and uses for your data, you should consider **what** communication tools will best present the data to your audience. Tools include:

- reports
- television interviews
- scientific journals
- technical reports
- conferences, seminars or workshops
- presentations, open day activities or demonstrations
- newsletters
- fact sheets
- posters
- maps
- Internet web pages
- media releases.

Your audiences will have different levels of knowledge and will differ in the way that they like to receive information. The communication tool used should be the best method to catch and maintain the interest of your audience. Most audiences will respond better to pictorial or graphical representations of the overall health of a site than to numerical information. Maps and reports are commonly used as they can be easily modified to suit various audiences.

Figure 8–11 shows an example of tailoring information to the needs of the audience via appropriate communication tools.



8-22

Figure 8-11 Examples of how to target information to an audience

## Reporting

### Maps

Data will be meaningless unless the audience has a spatial understanding of the catchment or region. Maps vary from very basic, to sophisticated topographic maps showing layers of information that collaboratively tell a story about your waterway. For example, your water quality information could be presented as small pie charts (indicating poor, fair, good and excellent water quality condition) for each parameter, at each study site, on top of a catchment map.

The *Ambient surface water quality in Queensland 2003-04 summary report* (Grinter & Hunter 2005) includes water quality results for 187 sites in South East Queensland. Figure 8-12 shows these results on a land-use map.

Each site is shown as a small circle divided into quarters, with each quarter representing a different water quality parameter. The parameters are (from top right) turbidity, electrical conductivity, total nitrogen and total phosphorus. A colour coding system is used to show monitoring results for each parameter:

- green—water quality indicates that the site is ecologically healthy or shows only a slight impact
- yellow—site shows a slight to moderate impact
- red—site shows a moderate to heavy impact
- grey—site was not sampled or insufficient data was collected.

This technique allows visual comparisons to be made between the health of different sites, and patterns to be easily identified.

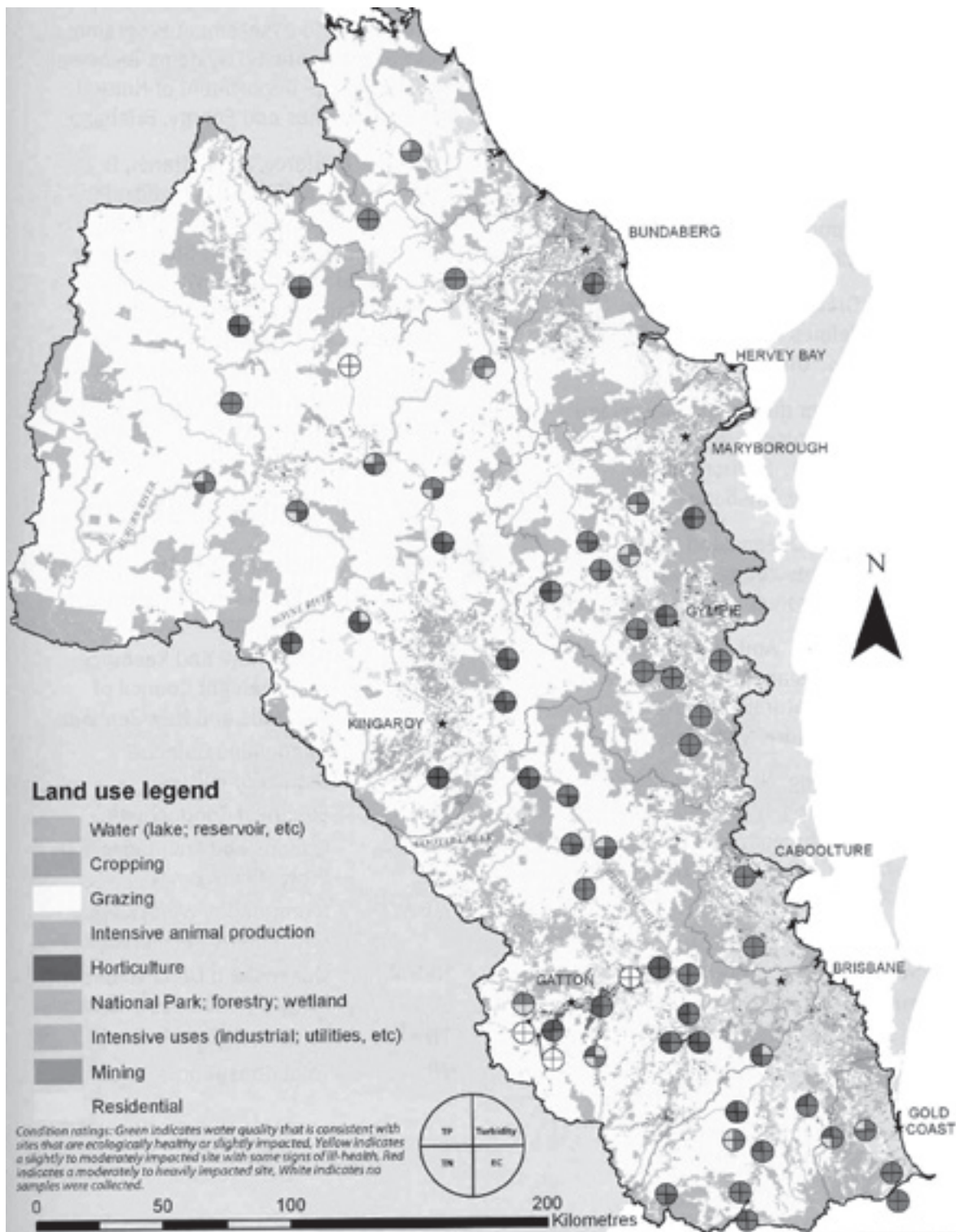


Figure 8-12 Map showing water quality and land uses in South East Queensland (Grinter & Hunter 2005)



## Reports

Reports are a good communication tool for providing an overview of your results. Reports can vary in detail, from general informative reports for the community, to detailed technical reports for state water quality agencies or planning professionals. Any report unofficially becomes a public document once it is distributed, so all reports require careful review for accuracy before distribution.

Report design for state water quality agencies or planning professionals should include the following essential elements:

- an executive summary at the start of the report describing technical findings in relation to project objectives
- an introduction outlining previous studies in the area or related field
- the purpose of the study (including objectives)
- experimental detail including descriptions of methods and sampling as well as of study location and study design
- a description of the quality assurance and quality control measures taken
- a summary of data and interpretation of your results including tables, graphs and maps
- your findings, and their implications for management
- conclusions drawn from the results and recommendations for further studies or actions
- reference details for literature cited in the report
- appendixes providing laboratory results, data tables and other information that is too detailed to be included in the body of the report.

Report design for the general public should be concise and direct, with non-technical language and definitions of unfamiliar terms and concepts. Photographs, simple charts, tables and maps with accompanying explanations are useful. The report should include a brief description of the program, the purpose for monitoring, the parameters monitored, the location of sample sites and the results and recommendations.

## Communication

Although reporting is important because it contains the monitoring results, the communication of the results and communication during the monitoring project are just as important. Reporting and communication will have limited impact if used in isolation from each other.

It is important to gain the cooperation and understanding of all stakeholders near your monitoring project including residents, workers, students, business owners, government land and water managers, natural resource management groups, local government and conservation groups. If you use a cooperative approach, most people will respond positively and participate when they are made aware of water quality issues.

Findings from the *State of Region reporting scoping project* (Chinn et al. 2006) confirmed that regional natural resource management bodies value the process of undertaking natural resource management projects over producing a report. These groups regard participatory information-sharing through engaging key audiences, contributors and stakeholders as highly important. Additionally, the scoping project found that meaningful information presented in an appropriate way has the potential to promote two-way dialogue and consequently promote awareness of issues and lead to further action.

It is also highly important to communicate the results back to the volunteers who have undertaken the monitoring activities. To demonstrate the value of their efforts, volunteers should receive timely feedback on how useful their monitoring efforts have been in contributing to improved water quality or influencing regional natural resource management planning. This feedback is crucial for maintaining an enthusiastic and motivated monitoring group and encouraging participants to undertake further monitoring projects.



## Taking action

The desire to address an obvious waterway issue or a potential problem is a major motivator for people to monitor the condition of their waterway. Taking action aims to facilitate a change or improvement in resource condition and can range from educational events and field days, to on-ground works and partnerships with industries and businesses. Actions could include promoting better farming practices, replanting trees, removing litter or lobbying government agencies or politicians. The nature of the waterway problem will usually determine the most suitable action to take; however, actions will depend on the interest, objectives and capacity of your group. Good planning is required to ensure that the actions taken will be appropriate, effective and long-lasting.

For example, a community group sampled at twelve sites across a catchment. At one site, three herbicides were found, while at the other sites no presence of herbicides was detected. Locals believed that the results were caused by the nearby forestry activities, as there were no other major potential sources of herbicides in the subcatchment. The monitoring was then refined to be more intense in that particular subcatchment in order to narrow down the source.

Before deciding on the action that your monitoring project should initiate, you should consider:

- what issue you want to act on. Based on the conclusion and recommendations of your waterway monitoring, choose an issue that meets the goals of your monitoring plan and is of interest to your community, and is one that you are able to influence
- what outcome or behaviour you want to change. Some examples include changing the behaviour of individuals or influencing local council to pass a regulation. Identifying the specific outcomes you want to achieve will define your audience and dictate the most effective tools and methods to use
- what the key message is. Keep it clear and simple and tailor the wording to the audience

- who the target audience is and what tools you will use to reach them. Plan your action to influence the decision makers who can make the desired changes. Identify key people at whom you will target your efforts (for example, members of local council, business owners or state agency staff). Choose an appropriate method to disseminate your message to your audience
- what tone and manner you will use. This can be friendly, formal, neutral or technical; however, keep in mind the relationship you want to have with your audience when the action is complete
- what resources you have for planning and implementing your action and what role you want to play. Identify partnerships, materials and services that need to be involved in your action to make it effective
- how you will implement your action. Describe the goals of your action, with steps to achieve it and the date for accomplishment. Each step should be clear and definite, achievable within the time-frame and of interest to the audience, and should have a noticeable outcome
- how you will evaluate your project. Reflect on the project once it is complete to improve future projects and make them more efficient, considering achievements and challenges.

The following actions are suggested to influence individuals:

- Maintain and restore buffer strips of natural vegetation along banks of waterways.
- Educate your community about simple water pollution reduction practices.
- Organise a clean-up day along your waterway.
- Distribute your monitoring report with conclusions and recommendations to key decision makers in your community.

Some suggested actions to influence local government and organisations:

- Give presentations to local decision makers and conservation committees.
- Help develop a catchment management plan.
- Report evidence of pollution such as waste spills or sewage to local officials—for example, environmental health officers or conservation committee members.
- Organise a forum and invite local decision makers to participate and learn about the results of your monitoring program.



The following actions are suggested to influence local businesses:

- Help local farmers control livestock access to streams by raising funds for fencing materials, helping to install them and arranging an alternative water source for livestock.
- Create a vegetation-planting plan and plant trees to establish a buffer between waterways and business districts.
- Give a presentation to the local chamber of commerce with results of your monitoring program and recommendations.

The following actions are suggested to influence state and federal government:

- Explore project ideas with state agency staff for a joint project.
- Find out about initiatives that you could help with to improve waterway health.

## Aligning with regional priorities

To ensure that your waterway monitoring is relevant, you should aim to align your actions with current regional natural resource management priorities. The *State of Region reporting scoping project* (Chinn et al. 2006) identified the common key drivers of State of Region reporting for regional bodies. These were to:

- support and inform planning, decision making and prioritisation within an adaptive management framework
- identify and communicate the state of key assets, threats to assets and gaps in knowledge
- enable the integration and exchange of information and knowledge across a broad range of natural resource management stakeholders
- build ownership and encourage alignment of effort in terms of monitoring and managing natural resources
- engage the broader community, influence stakeholder behaviour and inform community expectation.

Another priority is to reassess if there is a change in waterway condition over time due to management actions. Assessment will determine whether the trend is due to intervention (actions), or to an external influencing factor or 'background noise'. A commonly acknowledged challenge in evaluating the effectiveness of regional natural resource management planning and investment is that any measurable change in the condition of environmental assets may not occur for years.

## Setting targets

Each of the 14 regional natural resource management bodies across Queensland has a plan for their region, in partnership with regional stakeholders and government agencies. Implementing these plans involves prioritising investment over a range of different targets with varying time frames of achievement. These include:

- *management action targets* for the next 1 to 5 years
- *resource condition targets* for the next 10 to 20 years
- *aspirational targets* for the next 50+ years.

Your project can contribute to regional natural resource management planning by aligning with investment priorities. Targets should be specific, measurable, achievable, relevant and time-bound. Further information on targets can be found by downloading the *National natural resource management monitoring and evaluation framework* (Natural Resource Management Ministerial Council 2002a) and the *National framework for natural resource management standards and targets* (Natural Resource Management Ministerial Council 2002b) from <[www.nrm.gov.au/monitoring](http://www.nrm.gov.au/monitoring)>. These frameworks specify the minimum set of matters for which regional targets must be set.

Management action targets are short-term targets relating to management action or capacity building, and contribute to achieving longer-term targets. For example, *x* kilometres of riparian vegetation should be replanted by year *y*. Management actions for achieving this target include:

- identifying and protecting critical assets
- developing and implementing water allocation plans
- adopting improved land and water management practices.

Resource condition targets are specific, time-bound, measurable targets. For example, *x* stream sites within the region should be in a specific river condition category by year *y*. Resource condition actions for achieving this target include:

- reducing land salinity
- improving soil condition
- maintaining integrity of native vegetation communities
- maintaining integrity of inland aquatic ecosystems (rivers and other wetlands)



- maintaining integrity of estuarine, coastal and marine habitats
- reducing nutrients in aquatic environments
- reducing turbidity and suspended particulate matter in aquatic environments
- reducing surface water salinity in freshwater aquatic environments
- protecting significant native species and ecological communities
- removing ecologically significant invasive species.

Aspirational targets are the regional visions or goals about the condition of natural resources in the longer term. For example, regional native vegetation cover should be increased by 30%.

National outcomes include:

- minimising, avoiding or reducing the impact of salinity on land and water resources
- maintaining or rehabilitating biodiversity and the extent, diversity and condition of native ecosystems
- maintaining or rehabilitating populations of significant species and ecological communities
- maintaining or rehabilitating ecosystem services and functions
- maintaining or enhancing surface water and groundwater quality
- avoiding or minimising the impact of processes threatening locations and systems that are critical for conservation of biodiversity, agricultural production, towns, infrastructure or cultural and social values
- securely allocating surface water and groundwater for sustainable production purposes and to support human uses and the environment, within the sustainable capacity of the water resource
- developing sustainable production systems and putting management practices in place that maintain or rehabilitate biodiversity and ecosystem services, maintain or enhance resource quality, maintain production capacity and prevent and manage degradation.

(Natural Resource Management Ministerial Council 2002)

## Using tools and products

The Queensland water quality program—part of the National Action Plan for Salinity and Water Quality—has developed products aimed at a variety of audiences. These are based on four outcomes that collectively enhance the ability of regional

bodies, community groups, government agencies and scientists to address water quality issues. These outcomes are:

- access to information and data
- tools and software for interpreting water quality data and making decisions
- monitoring partnerships
- integrated regional condition assessments.

See the National Action Plan *Water quality online* website <[www.wqonline.info](http://www.wqonline.info)> for a full list of products.

### Guideline Assessment Tool

This is a software system that will take an entered time series of water quality parameters and compare it to a value chosen by the user from a library of guidelines. The procedure for setting guidelines follows statistical principles to provide the user with an indication of whether the monitoring site complies with the guideline. To access a copy of the Guideline Assessment Tool, visit *Water quality online* <[www.wqonline.info](http://www.wqonline.info)> or contact the Department of Environment and Resource Management, Marine and Freshwater Division, on (07) 3896 9250.

### Loads Tool

The Loads Tool provides guidance on a series of alternative techniques for calculating sediment loads. It is a decision-based tool with the ability to provide a comparative assessment of the load calculation techniques. To access a copy of the Loads Tool, visit *Water quality online* <[www.wqonline.info](http://www.wqonline.info)> or contact the Department of Environment and Resource Management, Marine and Freshwater Division.

### Natural Resource Info Pool

The Natural Resource Info Pool is a metadata database. It is a web-based tool that has been designed for storing and searching information and data on water quality. It is a pool of contact information that allows non-government organisations to contribute their datasets and resources and share their information. To access the Natural Resource Info Pool, visit *Water quality online* <[www.wqonline.info](http://www.wqonline.info)>. For further information on the Natural Resource Info Pool, contact the Department of Environment and Resource Management, Marine and Freshwater Division.



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