Government of **Western Australia**
Department of **Water**

Water quality monitoring program design

A guideline to the development of surface water quality monitoring programs

Looking after all our water needs

Water quality monitoring program design

A guideline for field sampling for surface water quality monitoring programs

Looking after all our water needs

Department of Water

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Standards

The preparation and control of this document is based on Australian Standards.

Disclaimers

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1 Introduction

Water quality monitoring is important for environmental protection, managing waterways and their catchments, identifying pollution events and community education.

Monitoring consists of making observations and taking measurements that are analysed and reported to provide information and knowledge about catchments and waterways.

Identifying a clear purpose for monitoring is the first and most critical step for an effective monitoring program and should be based on an analysis of issues affecting the catchment and/or water body.

As awareness of land-use changes and their impact on water quality has grown, there has been a corresponding growth in community participation in water quality monitoring and local action to protect local environments. Where the purpose of monitoring is to provide data for local action planning or catchment-wide decision making, it is important that the monitoring provides data of a known quality. It is essential that we know how good the data are if we are going to make good catchment management decisions or develop meaningful resource condition targets.

With the development of the monitoring and evaluation framework for the National Heritage Trust and the National Action Plan for Salinity and Water Quality co-funded regional strategies, there was an outstanding opportunity to integrate many existing, and proposed, future monitoring programs. This helps optimise the information gathered from monitoring expenditure. The eventual goal is to develop an overall monitoring and evaluation framework that:

- recognises the considerable overlap in objectives and information needs of the existing and future monitoring programs;
- supports access to monitoring data and information through the use of consistent data management protocols, such as the storage of data in a single, publicly accessible database; the Water INformation (WIN) database has been specifically constructed for this purpose;
- enables comparison of results between similar monitoring programs by establishing consistent sampling and analysis methods; this monitoring and evaluation guideline document is designed to help achieve that goal;
- ensures monitoring and reporting is compatible with a wide range of management and reporting outcomes – locally, regionally and nationally;
- supports the development of partnerships that are capable of reducing duplication of monitoring and deliver improved data quality and consistency.

This publication is designed to enable all agencies and groups involved in surface water quality monitoring to develop programs that use standard operating procedures for sample collection and analysis. This will result in data of a known quality that can be applied to a wider range of analysis and outcomes. Through this process, and by using better data management and quality assurance procedures, all stakeholders can save money.

It should be remembered that water quality is just one aspect of a catchment that you can monitor. There are other monitoring tools that can be applied to other areas within the catchment; for example, photo point monitoring to assess the establishment of revegetation is a highly effective and cost-efficient form of monitoring.

This publication provides guidance only. Should you have any problems or questions please contact your regional natural resource management catchment council, Water Science Branch (Department of Water), Measurement and Water Information Branch (Department of Water), the laboratory you are using for your sample analysis, or your local catchment group.

2 Designing a monitoring program — an overview

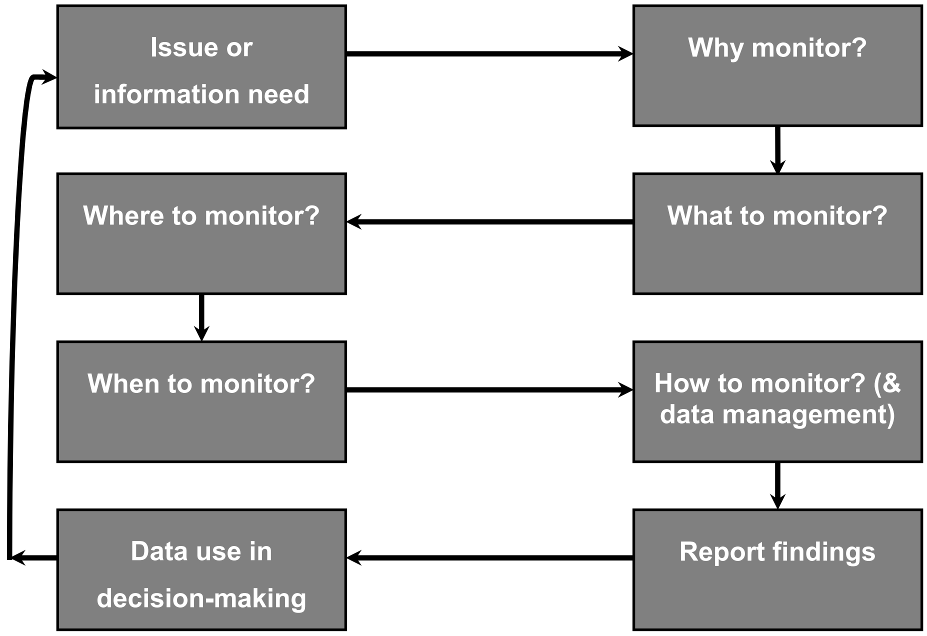


Figure 1 Overview of monitoring design

Figure 1 represents the basic steps involved in designing a monitoring program, and the structure of this document is based upon those steps. At its simplest level, a monitoring program could be described as the why, what, where, when and how of sampling; these are the questions that should frame the basis of a monitoring program. A monitoring plan is both a guide to, and record of, decisions about the design of your study. Your plan will help you choose the best monitoring tools for the task and define the scale and complexity of your monitoring work. A carefully considered plan from the start will save a lot of time, effort and money.

The starting point for any program *must* be the need for information within any given ecosystem. The evaluation of your ongoing work and any reliable past data, provides the data/knowledge/process understanding to that information need (the feedback) which then informs the next stage, which is sampling; and so the cycle continues.

It is important to note here that monitoring is the 'consistent, regular, long-term gathering of data'. Everything else is a sampling event or series of sampling events. However, whether you are conducting long-term monitoring or a one-off sampling event it is vital that adequate training is provided for the samplers and that the program has clear objectives and a sampling and analysis plan (or SAP). It is also vital that the samplers operate using standard operating procedures based on national standards, use accredited labs and quality assurance and quality control protocols, as well as employing proper data management techniques to ensure the long-term capture and preservation of data.

An important consideration about waterways is the potential for variability over time and space. This poses a challenge to the sampler who is trying to build up an accurate picture of what is happening in the waterway through a series of discrete samples, taken at fixed sampling sites at any particular time. Taking samples at a greater number of sites can reduce the effects of natural variability within waters, as can taking more samples (replicates) at each site. However, budget constraints and general practicality must temper the urge to sample every square inch of a catchment continuously.

Generally speaking, the data collected will be more accurate if sampling is *complete* (or as complete as is practically feasible), *representative* (of the water body or catchment) and *comparable* (to other data).

Completeness refers to the amount of data required to cope with natural variability (over time and space) of the environment and accurately reflect the true conditions in the waterway.

For data to be *representative,* it has to represent the conditions at sampling sites as closely as possible. Unrepresentative samples are a major source of error that can far outweigh errors in analysis. For example, sampling from the side of a stream just below a pollution outfall may fail to detect any pollution because of lack of mixing with the main flow of the stream. Sampling at least 100 meters downstream should allow adequate mixing so that the sample is representative of the true concentration of the contaminants you are trying to measure in the water body.

Sample results are *comparable* if they have been collected under the same conditions and analysed in the same way; for example:

- using the same standard operating procedures to collect the samples;
- transporting the samples in the same container types and under the same conditions;
- using analytical laboratories that are accredited by the National Association of Testing Authorities, have been independently audited by the Department of Water, and use the same analytical methods for sample analyses.

You must also bear in mind that no sampling will be perfectly accurate (from a measurement perspective) as virtually all scientific measurements have an associated level of uncertainty.

Designing a good monitoring plan will ensure that you are asking the right questions, collecting the right data and reporting the data in an informative manner. A monitoring plan is the first key step towards data quality assurance and can be a simple or as detailed as is needed to achieve your information goals.

With monitoring there are no short cuts.

The confidence you can place in your results is directly related to how much effort is applied to planning, collecting and analysing.

Consistent monitoring yields accurate results.

The main concern is the elimination of errors, which can occur in several ways.

- Poor site selection and planning.
- Inaccurate measurement due to poorly calibrated equipment or sample contamination.
- Poor sampling techniques.
- Inaccurate record keeping and data transcription.
- Management and storage.

To reduce these potential errors we use quality assurance procedures while planning our monitoring program. These procedures can include, but are not limited to the following.

- Preparation of a sampling and analysis plan.
- Ensuring all equipment and collection containers are appropriate, clean, calibrated and in good working order.
- Ensuring samplers are properly trained and use standard operating procedures to collect samples.
- Treating samples correctly post-collection, and transporting them to laboratories under chain of custody in order to guarantee sample integrity.
- Using accredited and independently audited laboratories that use specific sample analysis methods to allow comparison of results with historical data.
- Cross-checking field records of samples with sample bottle labels (especially the sample numbers) by at least two of the samplers (to reduce the risk of human error).
- Regular data verification (from the database) to check all data (e.g. for outlying data points and data entry or transcription errors) and also that quality control data are within an acceptable range. This should be done by the project manager regularly (as they are most familiar with the project and are more likely to spot any errors or erroneous datum points) – so that if any problems are identified they can be corrected quickly.

3 The land use diagrams

The land use diagrams in Figures two, three and four have been designed to provide a guide only to some of the potential impacts certain land uses may have upon receiving waters in affected catchments, and what parameters you might consider measuring to detect those impacts if they do eventuate.

It is worth noting that land uses are often not clearly separated within catchments. Commercial (light industrial) and industrial zones can abut or be completely surrounded by urban and/or rural areas and sometimes isolated industrial activities (e.g. mining) are found in rural areas. Stormwater run-off from these differing land uses tends to become mixed in a network of drainage systems, so you may need to select monitoring sites very carefully to isolate certain land uses within your catchment – if that is the aim of your monitoring program.

It is important to note that the on-site operational practices of some industrial (e.g. mining), rural (e.g. farming) and urban/commercial (e.g. vehicle workshops, including wash-down areas) land uses will be a major factor in whether or not the particular activity associated with the land use has any impact on the catchment's waterways. A land or business owner using best management practices may have only a minimal effect (if any at all) on the water quality of local waterways.

Acid sulphate soils (ASS) and their impact (if disturbed and exposed to air) is one issue that needs to be considered in all land-use areas. Although in this document ASS have been listed under acid-based industries in Figure two, this has only been done because the potential impacts and parameters that you might select are the same for acid-based industries as they are for ASS impacts. Clearly ASS are not an industrial by-product, but rather they occur naturally and are only problematic if disturbed or poorly managed. Such disturbances can result from any activity that involves drainage, dewatering or disturbing soil, thereby exposing potential ASS to air. Clearing land for urban expansion and associated dewatering activities, or land clearing to increase areas of cultivatable land on farms, are obvious examples of where such disturbances may occur.

Sewage treatment is another potential source of contamination (as well as providing an essential service for our expanding population) that must be carefully considered. Although it has been included in the industrial land use diagram in Figure two, it is an activity that occurs anywhere there is a population over a certain size. Treatment plants are scattered across the state from rural areas to the coast, with discharges into local waterways, major rivers and the ocean, and the level of treatment applied to sewage also varies between plants. Another important consideration in this area is the impact of septic tanks in areas with no main sewerage.

Depending on the level of treatment applied to waste prior to discharge, local waterways could receive significant levels of nutrients, suspended solids, pathogens and bacteria. These alone are problematic, but their presence will also increase the biological oxygen demand of the receiving waters downstream of the treatment plant discharge point, as decomposing bacteria break down the remaining wastes. This may lead to depletion of dissolved oxygen in receiving waters and even, in extreme cases, cause or contribute to fish kills due to suffocation. If conditions are suitable, algal blooms may also occur in affected waterways.

3.1 Industrial land uses

Petroleum-based industries, such as refineries and power stations, can potentially export hydrocarbons to waterways. By following the arrow down in Figure two you can see what the potential impacts of this might be on the river and then below that, what parameters you could monitor to assess if the targeted industry is having an impact on water quality

Metal-based industries may include mining (including mineral sands) and ore processing activities (of which there are many examples in Western Australia), and some recycling industries. Mining can result in the export of sediments to waterways and other metal processing activities can result in the export of the associated metal(s) into waterways.

Acid-based industries (such as metal plating and galvanising activities) can result in acidic run-off reaching local waterways. This can result in lowered pH, increased total acidity and increased mobilisation of heavy metals into a dissolved form in affected waterways.

Sewage treatment has been discussed above.

3.2 Rural land uses

Land clearing may result in increased salinity problems in a catchment and/or the export of sediments and/or decaying organic matter to waterways. It may also result in ASS disturbance (as mentioned above) and this may lead to acidity-related problems in the catchment (e.g. low pH, increased total acidity and mobilisation of heavy metals into a dissolved, bioavailable form).

Stock control activities, such as feed lots, can result in an increased level of organic matter entering local waterways – having a similar effect on water quality as sewage treatment plants.

Pest and weed control activities (e.g. crop dusting and spraying) can introduce the applied pesticide and/or herbicide into waterways, especially if the application is not precise, or if it rains shortly after application is carried out.

Fertilizer application can result in nutrients leaching into local waterways (e.g. if the application rates are too high, the soils have a poor nutrient retention, or if it rains heavily shortly after application).

3.3 Urban land uses

Land clearing activities present the same potential risks to the water quality of local waterways as listed above under rural land uses.

Lawn, park and garden care may lead to applied fertilisers, herbicides and pesticides being leached through soil or stormwater drainage into waterways. This includes individual household lawns and gardens as well as larger-scale public open spaces. It is widely acknowledged that urban catchments generally contribute more nutrients to local waterways per hectare than rural catchments do.

Light industry and commercial activities (e.g. petrol stations and vehicle workshops) can lead to a range of contaminants being carried from hard surfaces (including roads) in stormwater run-off into waterways, via urban stormwater drainage, normally to the nearest river or wetland. This problem can be heightened if individual businesses do not employ best management practices for on-site chemical storage, vehicle wash-down areas and stormwater retention systems. Potential contaminants could be almost anything, depending on the precise nature of activities in a given light industrial area and materials used (information that should be available from the local government authority). However, hydrocarbons and heavy metals are a good starting point for a parameter list for such areas and for drains receiving a lot of stormwater from roads.

Household chemicals, detergents and other cleaning products can also be a problem if disposed of incorrectly or irresponsibly. Pesticides and surfactants are just two groups of chemicals used in homes, which can find their way through urban stormwater drains to local waterways and rivers, where they can pose a risk to public and environmental health.

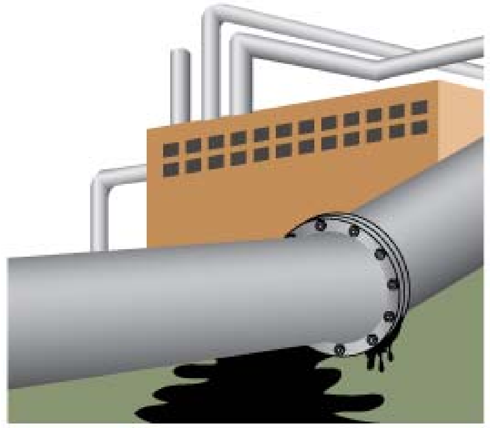
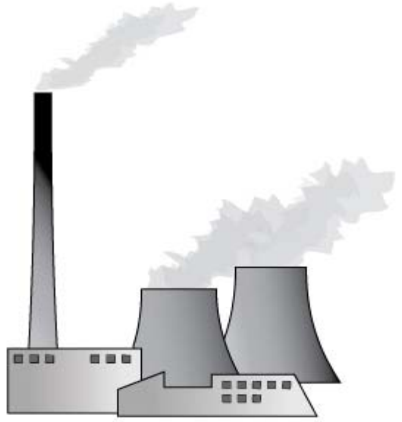
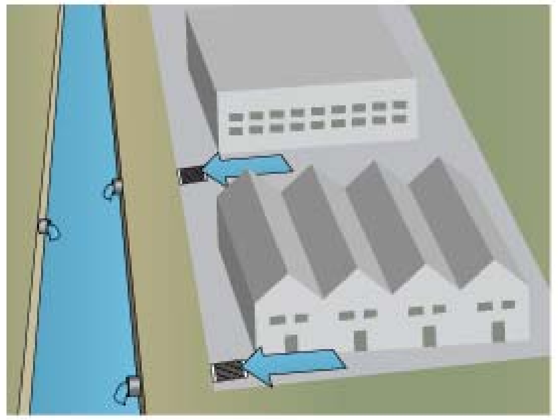


Figure 2 Identify industrial uses that may be impacting on your river and/or catchment





Petroleum based industry:

- Oil refineries
- Degreasers from manufacturing, fabrication, motor vehicle repairs
- Combustion processes (waste incinerators, power generation)

Potential exports from land to river

Hydrocarbons

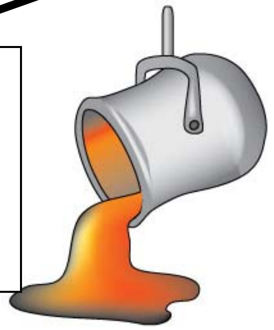
Potential river impact

- Loss of species
- Threat to public health

Total recoverable hydrocarbons
Oil and grease
Total petroleum hydrocarbons
BTEX compounds
PAHs

Metal based industry:

- Mining
- Mineral sands
- Computer recycling



Potential exports from land to river

Heavy metals

Potential river impact

- Degraded habitat
- Loss of species
- Threat to public health

Heavy metals (e.g. Aluminum, Arsenic, Cadmium, Chromium, Copper, Iron, Mercury, Nickel, Lead, Zinc)

Sediments

Potential river impact

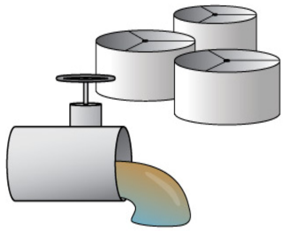
- Degraded habitat
- Reduced biodiversity

Turbidity

Total suspended solids (TSS)

Sewage Treatment:

- Due to urban (population) pressures (include areas on septic systems)



Potential exports from land to river

Nutrients (N & P)
Suspended solids
Pathogens

Potential river impact

- Excess nutrients
- Algal blooms
- Threat to public health

Nutrients (TN & TP), plus soluble fractions of N and P
Chlorophyll *a*
TSS
Bacteria
Dissolved oxygen

Acid based industry:

- Metal extraction (mining)
- Metal plating

Acid sulphate soils

Potential exports from land to river

Acidic solutions

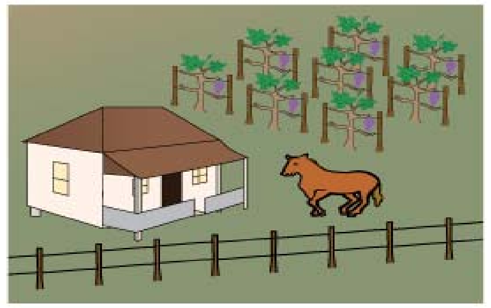
Potential river impact

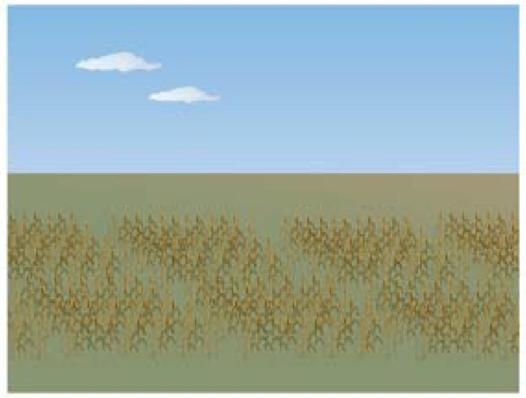
- Degraded habitat
- Loss of species
- Threat to public health

pH
Heavy metals (e.g. Aluminum, Arsenic, Cadmium, Chromium, Copper, Iron, Mercury, Nickel, Lead, Zinc)
Total acidity

Select water quality measurement below to determine likely impact of industrial land use on river ecosystem

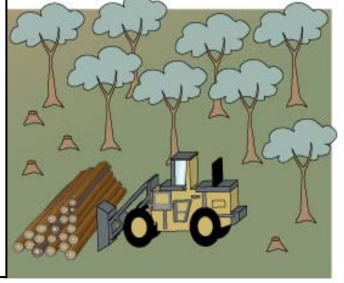
Figure 3 Identify rural land uses that may be impacting on your river and/or catchment





Land clearing:

- Conversion of rural to residential
- Tree clearing to improve farm production



Potential exports from land to river

Sediments

Saline waters

Organic matter (decaying vegetation)

Potential river impact

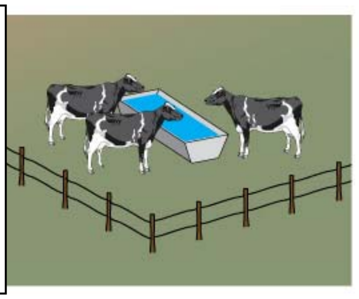
- Degraded habitat
- Loss of species

Potential river impact

- Fish kills
- Excess nutrients
- Algal blooms

Stock control:

- Sheep and cattle in rivers
- Feed lots



Potential exports from land to river

Organic matter (faecal matter)

Potential river impact

- Fish kills
- Excess nutrients
- Algal blooms

Pest and weed control:

- Crop dusting
- Weed spraying

Potential exports from land to river

Pesticides and herbicides

Potential river impact

- Degraded habitat
- Loss of species
- Public health

Fertiliser application:

- Improve crop yields
- Soil improvement (micronutrients)

Potential exports from land to river

Nutrients (Phosphorus & Nitrogen)

Potential river impact

- Excess nutrients
- Algal blooms

Select water quality measurement below to determine likely impact of rural land use on river ecosystem

Turbidity

Total suspended solids (TSS)

Conductivity

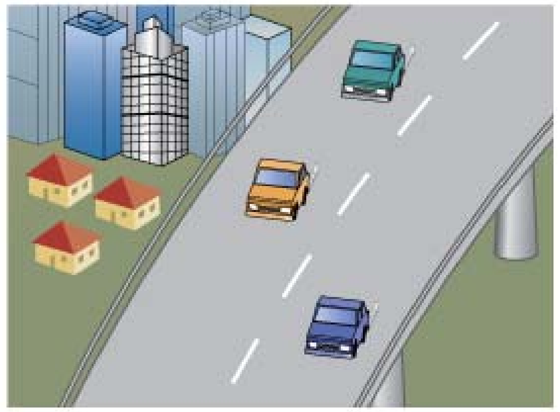
Dissolved oxygen (DO)
Dissolved organic carbon (DOC)
Biochemical oxygen demand (BOD)
Nutrients (total Nitrogen (TN), total phosphorus (TP), plus soluble fractions of N and P)
Chlorophyll *a*

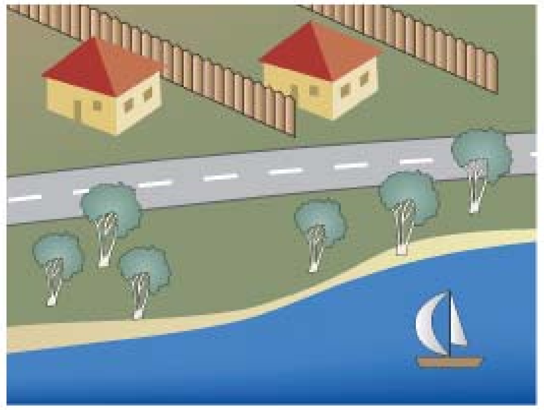
Dissolved oxygen (DO)
Dissolved organic carbon (DOC)
Biochemical oxygen demand (BOD)
Nutrients (total Nitrogen (TN), total phosphorus (TP), plus soluble fractions of N and P)
Chlorophyll *a*
Bacteria

Pesticides and herbicides (organochlorine and organophosphate, atrazine)

Nutrients (total Nitrogen (TN), total Phosphorus (TP), plus soluble fractions of N and P)
Chlorophyll *a*

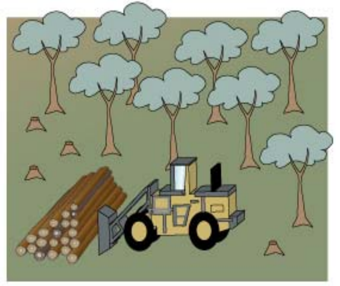
Figure 4 Identify urban land uses that may be impacting on your river and/or catchment





Land clearing:

- Conversion of rural to residential
- New housing development



Potential exports from land to river

Sediments

Lawn and park care:

- Fertilisers
- Weed control

Potential exports from land to river

Nutrients (phosphorus & nitrogen)

Herbicides & Pesticides

Light industry:

- Petrol stations
- Car workshops
- Spray painting
- Metal fabrication

Potential exports from land to river

Hydrocarbons

Heavy metals

Household chemicals:

- Weed and pest control
- Washing detergents
- Cleaning products

Potential exports from land to river

Herbicides & Pesticides

Surfactants

Potential river impact

- Degraded habitat
- Reduced biodiversity

Potential river impact

- Excess nutrients
- Algal blooms

Potential river impact

- Degraded habitat
- Loss of species
- Threat to public health

Potential river impact

- Degraded habitat
- Loss of species
- Threat to public health

Potential river impact

- Degraded habitat
- Loss of species
- Threat to public health

Potential river impact

- Degraded habitat
- Loss of species
- Threat to public health

Potential river impact

- Degraded habitat
- Loss of species
- Threat to public

Select water quality measurement below to determine likely impact of urban land use on river ecosystem

Turbidity
Total suspended solids (TSS)

Nutrients (total Nitrogen (TN), total phosphorus (TP), plus soluble fractions of N and P)
Chlorophyll *a*

Herbicides (especially glyphosate and simazine)
Pesticides

Oil and grease, BTEX and PAHs
Total recoverable hydrocarbons (TRH)
Total petroleum hydrocarbons (TPH)

Heavy metals (e.g. Aluminum, Arsenic, Cadmium, Chromium, Copper, Iron, Mercury, Nickel, Lead, Zinc)

Pesticides and herbicides (organochlorine and organophosphate, particularly glyphosate found in Round-Up)

Surfactants (anionic, cationic and non-ionic)

4 Why monitor?

The first, and undoubtedly the most critical, stage of the planning process is to determine why you are monitoring. This defines the questions to which you are seeking answers. Without this step in the monitoring plan, you should go no further. It is crucial in this planning phase to consider the issues and information needs within your catchment. Consider land uses and their potential impact upon receiving waters (Figures two, three and four for industrial, rural and urban land use impacts, respectively).

- Will your program distinguish between one land-use impact and another?
- Are you trying to identify point source pollution or more diffuse sources of pollution?
- Are you trying to monitor contaminants across a catchment to identify sources, or just monitor bottom of catchment contaminant concentrations?
- Are you trying to identify changes over time in concentrations of particular parameters (trends)?
- Are you trying to determine if a particular rehabilitation activity or catchment management action is having the desired affect? It is important to note here that there are several different activities (e.g. community education like the ‘fertilize wise’ program, tree planting or artificial wetland construction) and your monitoring must be tailored to meet the specific information needs you are trying to quantify.
- Are algal blooms* a problem in your catchment? They tend to be more of a wetland and estuarine issue.

These questions are just a few examples of the many questions that will help you develop your monitoring program so that it will meet your information needs.

Also, consider how the information you gather will be used and who will be using it. If the data are to be used mainly for educative purposes, then the quality of the data gathered is secondary to the process of collecting it. However, if samples are to be collected to use the data for informing catchment management, or environmental management decisions, then you should plan to collect data with a demonstrable level of quality. This involves building quality assurance procedures into the design of your monitoring program (this will be discussed in more depth later in this document).

*Please note that when this document refers to algal blooms it specifically means nuisance algal blooms that pose an environmental and/or public health risk and these are normally micro algal species, i.e. those species that are microscopically small (e.g. blue-green algal species).

5 What to monitor?

Water quality indicator selection is very important and depends on several factors, which are ultimately driven by the overall purpose of the monitoring program. What you monitor will depend on why you are monitoring.

Here again you may find Figures two, three and four useful as they relate certain land uses and their impacts to lists of potential parameters to measure. Start at the top of the diagram with land uses that represent activities within your area of investigation and follow the arrows down the page and you will find a list of potential parameters listed at the bottom of the page.

The selected indicators must be suitable; that is to say they should be responsive to changes in the catchment you are trying to measure. For example, a major issue in many Western Australian waterways is the number and severity of algal blooms. In order to reduce the number and severity of these blooms a level of ecosystem process understanding is required; i.e. what factors influence the number and severity of algal blooms? It is understood that nutrient levels in the estuary are a major contributing factor to the problem; therefore, the concentrations of key nutrients (nitrogen and phosphorus) and chlorophyll *a* are monitored. When selecting indicators there is a need to understand the underlying ecosystem processes, but these may not always be clear or even consistent.

Our ability to measure parameters accurately is another factor to consider when selecting a suitable water quality indicator. Using the example of algal blooms again, the selected indicators (nitrogen, phosphorus and chlorophyll *a*) can be measured accurately by analytical laboratories analysing water samples collected from the river.

Finally, cost is an unavoidable factor and your budget may have a strong bearing on what parameters you can and cannot analyse, since lab analysis costs vary greatly from one parameter to another.

This is another area where a partnership-monitoring framework could be advantageous. By streamlining and coordinating our monitoring effort between all agencies and community groups, for example within any river catchment and estuary, we can develop a coherent, well-planned approach that will eliminate duplication of monitoring efforts and deliver more data for our dollars.

6 Where to monitor?

It is important to point out here that this document is aimed only at assisting in developing surface water monitoring programs, and particularly snapshot monitoring programs designed to identify 'hotspots' in your catchment.

Site selection depends primarily on your reasons for monitoring in the first place. Where you will monitor in the catchment depends on the spatial extent of the program (i.e. how big your area of 'study' is) and then the individual sites that you select must be representative of the spatial extent of your monitoring program. For example, are you interested in nutrient concentrations across your catchment or are you trying to identify if there is pollution from particular point sources?

Once you have defined the spatial extent, you need to select individual sampling sites. While ease and reliability of access are important considerations, the most critical factor in selecting sampling sites is that they are representative of the spatial extent of your monitoring activities. The reason for doing this is so that your monitoring activities answer the questions that you set out to answer, and so that people analysing the data in the future can see what area the sampling sites are meant to represent. For example, were you trying to get a picture of what is happening at a whole catchment scale or just in a small section of a river?

If you are interested in catchment scale issues, then you must have enough sites to attempt to represent the whole catchment. This is very difficult to achieve as, generally speaking, single sites will represent only conditions at that site, and not the wider catchment. Most sites are single points, and are only representative of conditions at that particular site. They are often selected on a judgement basis, in other words they are chosen using local knowledge, or because they are at the bottom of catchments or sub-catchments, or downstream of suspected point sources. This method of site selection is common for snapshot monitoring programs designed to identify 'hotspots' (areas of elevated levels of pollutants).

River features and biological factors that may influence your results must also be considered when selecting sampling sites. These include weirs, riffles, backwaters, confluences and cattle crossings, as well as macrophytes (large aquatic plants seen without the aid of a microscope), algal blooms and floating macrophytes. In these situations, you need to make a judgement call as to where to sample. Some suggestions are in an associated document titled *Field sampling guidelines – a guideline for field sampling for surface water quality monitoring programs*.

In most cases, sampling will occur at a number of non-randomly sampled, 'fixed' sites that need to be registered with the Measurement and Water Information Branch (Department of Water) along with the submission of the sampling and analysis plan, before starting the monitoring program. However, there are alternatives such as systematic random sampling where one, or a few, randomly selected sites are selected from a list of several sites. This is a good method when you have either limited resources (human or financial) or a very large area to cover. However, the drawback is that it takes longer to build up a data set.

7 When to monitor?

Sampling frequency, again, depends on your reasons for monitoring and the information you are trying to collect. For example, to see if fertiliser application is having a long-term effect on nutrient levels in catchment waters, you might sample monthly to quarterly over five to ten years to observe any trends in water quality.

For trend analyses particularly, you need long-term data sets so that, as much as possible, the variation between seasons and annual rainfalls are ‘averaged out’. For example, if you were looking at nutrient concentrations over several years, you need to correlate your data to the rainfall so you could say that the trend you see was due to a reduction of fertilizer application in the catchment, rather than just a dry winter. Statistics are also often applied to data sets to allow us to iron out these variations over time and get a more accurate picture of what is happening. You often need at least three years of continuous data before meaningful statistical analyses can be applied to the data.

To assess if rain run-off washes nutrients into a river, the sampling might be event-driven (i.e. go out sampling while it is raining (the event), whenever that may happen). This requires good preparation and planning to be ready for sampling events. However it is important to remember that you need baseline data (collected outside of ‘events’) against which you can compare the data gathered during the event driven sampling.

If you wanted to investigate the transportation of nutrients within, or from your catchment, then rainfall is an important factor and its seasonal nature needs to be taken into account when deciding upon sampling frequency.

Often the resources available, both in terms of personnel and finances, will help determine the timescale of monitoring activities i.e. how often and for how long you monitor.

8 How to monitor?

The ‘how to’ of monitoring is often overlooked, meaning that the resultant data may have a very limited application.

It is crucial to use standardised methods and protocols for data collection and analysis. By doing this, we produce data of known quality that can be compared to past data collected in a similar fashion, and we can use that data to make sound, defensible decisions based on good science. By collecting data and managing data with a strong emphasis on quality assurance and quality controls, the same data can be used for several outcomes, in addition to the outcome for which it was collected originally. Data management will be covered in more detail later in this publication, as it is very important.

Basically, the sampler in the field must follow the sampling and analysis plan, which is the overarching document that lays out sampling objectives, sampling methods, costing, site details, sampling frequency, lab analysis methods and limits of reporting, data analysis and management, quality assurance and quality control measures, reporting, stakeholder roles and responsibilities, etc. Preparation of sampling and analysis plans are covered in more detail later.

The samplers must be trained and be familiar with the standardised sampling methods as laid out in another guidance document titled *Field sampling guidelines – a guideline for field sampling for surface water quality monitoring programs*. These guidelines are based on national standards and are one part of the process of ensuring high quality data. The other components of that process are as follows.

- Documenting all the steps taken to collect, analyse, store, manage and present the gathered data by preparing a sampling and analysis plan, as part of the quality assurance process, and following those steps throughout the monitoring program.
- Providing adequate training of all personnel involved in sample collection, including training in the maintenance, calibration and correct usage of the equipment being used.
- Using an analytical laboratory that is both accredited by the National Association of Testing Authorities, and also audited by an independent auditor on behalf of the Department of Water, for the analysis of your samples.
- Using quality control checks to minimise sample contamination and ensure data are of sufficiently high quality.
- Reviewing data regularly to validate the data early and often, including the quality control sample results. This will ensure any problems can be resolved while the project is still running; rather than after all data has been gathered and it is too late to correct the identified problem. The project manager should carry out this data review.

9 Data management

As previously mentioned, good data management allows us to make defensible decisions based on good science, using data of a known quality. It allows central availability so that the data can have multiple uses and it allows for querying and manipulation of data while preserving the raw data. Finally, it provides long-term security of data, in which considerable time and money has been invested from the planning stages through to collection, analysis and reporting.

Good data management begins before samples are collected and should be applied throughout the process. It is based on standards, follows an established process and is a good investment as it results in data that can be trusted, and becomes more valuable over time.

On the other hand, poor data management can result in data that are incomplete or lost completely, of dubious quality, not traceable to original collection sources or standards, isolated and not centrally available to those to whom it may be of use, without context, and difficult or impossible to query or manipulate. Poor data management is a waste of valuable time and resources in terms of the original sampling costs and effort, the need to gather the data again, and inadequate environmental management. In short, *‘poor quality data are worse than no data’.*

Experience has shown that if data are not correctly managed at the time of collection, it will invariably be lost, or be impossible to capture in the database later because of missing information. This is why it is important to have the management principles in place *before* sampling begins, and apply them consistently throughout the lifetime of the project.

The Measurement and Water Information Branch manages the WIN database, which is designed to meet the data management needs of the Department of Water. At the time this document was written it contained over 12 million readings, including contextual information. The data on WIN is publicly available (unless otherwise specified) and it serves about 200 data requests per month from the Department of Water, Department of Environment and Conservation, local government authorities, community groups, members of the public, universities, students and consultants.

The basic standards on which WIN data management is based are as follows.

- Standardised sampling procedures (based on national standards – AS/NZS 5667.1:1998: *Water quality – Sampling – Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples – National Water Quality Management Strategy guidelines*).
- The use of laboratories, which are accredited by the National Association of Testing Authorities and independently audited by the Department of Water.
- The use of standard operating procedures during sample collection.
- The database itself enforces these data requirements and so data of indeterminable quality is not entered onto the database.

9.1 The process of data management

The basic process to ensure that data standards are met is as follows:

- Before sampling:
  - document project planning in a sampling and analysis plan;
  - register with the Measurement and Water Information Branch (sampling and analysis plan, project, sites and sampling regimes), and;
  - ensure adequate training of sampling personnel.
- During sampling*:
  - maintain and calibrate equipment (pre- and post-field);
  - sample documentation and security (chain of custody form, field observation forms and remember to make comments on field observation forms for contextual information), and;
  - using quality control samples to check that the sampling results are of an acceptable quality (mark on yellow copy of chain of custody form).
- After sampling:
  - fax a copy of white chain of custody form (yellow if quality control samples have been included) and the field observation form to the WIN team;
  - send chemistry samples to the analytical lab with white and pink copies of chain of custody form, and;
  - E-mail electronic file (e.g. physical data) to WIN team.

The WIN team will track the sample batch, collate results and verify the data (and check that it is complete, correct and what was requested) before committing it to the database. All data and contextual information is included and quality assurance checks are carried out.

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* See *Field sampling guidelines – a guideline for field sampling for surface water quality monitoring programs*, for more details on completing chain of custody forms, field observation forms and on quality control sampling.

9.2 Data verification and validation

Once data is in the database, it should be verified and validated by an expert user (e.g. project manager). This should be done early and often so any problems can be rectified while the project is still running, rather than after the sampling has finished and the money has been spent.

Validation asks the question, ‘Given that the data are verified (that it is complete, correct and to requirements) is it *valid* to have it say what it says?’ For example, the lab may have reported a low chlorophyll result, and it may have been captured accurately and completely into the database, but other measurements taken on the day (e.g. phytoplankton samples or dissolved oxygen measurements) indicate there should have been a higher result. This needs to be followed up.

Quality control results, both those that you submit to the lab and those carried out by the lab itself, should also be checked. Report any errors you discover to the WIN team who will follow up with the lab; samples may need to be re-analysed and hard copies of lab reports checked. Data deemed invalid can either be deleted or deactivated while remaining in the database. This means the data will not be available in reports, but can be queried in WIN if people want to see what went wrong.

10 Quality assurance and quality control in measuring water quality

Quality assurance and quality control are often treated as the same thing – but they are not:

10.1 Quality control

Quality control is the generation of data to assess and monitor how good the sampling and analysis methods are and how well they are operating. It is basically the set of specific *controls* that are applied to ensure quality assurance objectives are being met. One practical application of this is the collection of quality control samples.

10.2 Quality assurance

By contrast, quality assurance is the overall *system* put in place to *assure* a required level of quality for an undertaking. It includes such things as the definition of standards and data quality objectives, and the documentation of the system itself. It assures those using the data that the data are real, meaningful and of the required quality.

Quality assurance encompasses quality control but also includes many other aspects; including, but not limited to:

- a fully documented quality system (the Department of Water’s system is available on bookshelf or by request);
- the preparation of a documented sampling and analysis plan;
- conducting sampling using standardised and consistent procedures that are documented in the sampling and analysis plan;
- ensuring that equipment is well-maintained, cleaned and fully calibrated before use by means of specific, fully documented procedures;
- ensuring that individuals that carry out the sampling are competent and trained to do so, and;
- having dedicated systems, such as the Water Information database, that carefully process and store data via standardised procedures, and allow data retrieval later.

11 Collection of quality control samples

Determine which quality control samples to collect at the planning stage of the sampling program, i.e. when preparing the sampling and analysis plan.

It is important to collect quality control samples (where possible) in your monitoring. Firm conclusions cannot be drawn from sampling data unless the quality of the data is known. The number and the types of quality control samples you collect depend on the final use of the data, as well as the amount of time and money (again!) that you have available for your project or monitoring program.

11.1 Blank samples

Blank samples (or blanks) are clean samples of de-ionised or distilled water, introduced at various stages of sampling. They are collected to detect and measure contamination in the sampling process as a result of ineffective field procedures, containers, equipment and transport.

Often it is not possible to achieve absolutely no contamination, but rather only stable, minimal contamination levels. You need to set acceptable limits for these contamination levels, and when blanks are collected that fall outside this, you have a contamination issue that will require further investigation.

De-ionised, distilled or purified water is used for the collection of blanks in fresh water. Blanks must be prepared with solutions that are free from analytes of interest. As discussed previously, care must be taken that the de-ionised, distilled or purified water used to prepare your blank sample is not contaminated in anyway. Periodically, check the unit (if you have one) that produces your purified water. An even better practice is to get the purified water from the same analytical lab that is carrying out your sample analysis. In addition, take special care with the containers you use to store your de-ionised water (in terms of the chemical stability of the container material). As a general rule of thumb, don’t store de-ionised or purified water for more than about a week.

The following list of quality control samples and explanations of why they are collected has the name of the quality control sample followed by a code in brackets. This code is used to identify the quality control sample on the yellow copy of the chain of custody form only. See section 11.3 titled Recording of quality control samples on the chain of custody form on page 23 for more details.

Field blanks (FB)

Extra containers are taken to the site. Take a stock container of de-ionised/distilled water. On site, containers are opened and closed and the contents handled just as if these were normal samples being collected during transfer and storage, except they are filled with de-ionised/distilled water (leave or add appropriate preservative in the bottle if required – depending on which parameters the field blank is checking). These detect mainly contamination of sample during the collection procedure. Ideally, at least one of these is collected per sampling team, per sampling trip, for all measured analytes.

Trip blanks (TB)

Trip (or transport) blanks are simulated samples created in the office laboratory with de-ionised/distilled water before going out in the field to sample. They are stored, transported and preserved in the same manner as the normal field samples; i.e. they accompany the sampler into the field, but do not undergo sample collection or filtration procedures in the field.

These samples are used to assess gross-contamination of samples during transport and storage from the time of sampling till the time of analysis. Ideally at least one of these is collected per group of samples.

The following blanks are often used to isolate sources of contamination further.

Container blanks (CB)

A container of the type used is selected at random and filled with de-ionised/distilled water (leave or add appropriate preservative in the bottle if required, depending on which parameters the container blank is checking). A container blank is stored in the office while the field sampling is carried out (do not take out to the field). These samples are used to determine contamination in the container, which may occur from the internal walls of the container and from any sample washing procedure.

Rinseate blank (RB)

Rinseate (or equipment) blanks are created from de-ionised/distilled water that is used to rinse the sampling equipment between samples at various sites. They are stored, transported and preserved in the same manner as the normal field samples. They are collected after the sampling equipment is fully cleaned via the standard cleaning procedure. They measure contamination introduced through contact with the sampling equipment or sampler.

11.2 Other quality control samples

Replicate samples (RS)

Replicate samples are two or more samples collected from the same site and time, using exactly the same method. They can indicate the natural variations in the environment and variations caused by the field sampling method. They provide the experimental error and thus a measure of sampling accuracy. Two replicates will only indicate that variation exists (if there is any), but three replicates will enable some assessment of precision and bias.

Field duplicates (FD)

Field duplicates (or split samples) are samples split into two or more sub-samples and submitted as separate samples for analysis. They reflect the magnitude of errors (contamination, both random and systematic) occurring between sampling and sample analysis. They test the accuracy and the precision of sampling and analysis.

11.3 Recording of quality control samples on the chain of custody form

It is important that the analytical laboratory *cannot* identify samples that are introduced in the field to test lab performance. As a good general practice, quality control samples must be marked on the chain of custody form in some way so that they cannot be identified by the laboratory. The sample should be recorded as a normal sample using sample number, site, date, time, depth, method etc. on the chain of custody form; then mark the yellow copy only with the indicator code beside the sample number (see the label in brackets above each type of quality control sample type, e.g. RS for replicate sample). This will enable these samples to be identified during the data import stage.

Labs see only the white and pink copies. Make sure the white and pink copies on the chain of custody form are not identified in any way that could allow the laboratory to identify the quality control sample. The yellow copy of the chain of custody form must be faxed to the WIN team so that data processors can identify quality control samples. If the yellow copy is faint, or otherwise hard to read, please also fax the white copy (before you send the samples to the lab).

11.4 Frequency of quality control sample collection

The Measurement and Water Information Branch recommends taking a field blank, two or three replicates and a duplicate at the beginning of a monitoring program and then again once every four or five sampling runs.

If you require assistance in determining quality control sampling frequency, please contact the Measurement and Water Information Branch (Department of Water).

12 Sampling and analysis plans

A sampling and analysis plan is simply the documentation of the development of your monitoring program. From a data management perspective the plan is essential as it ensures continuity of data quality, no matter who is sampling. Consider what would happen if you, as a program manager, were to leave your current position and none of the current projects were documented? Preparing a sampling and analysis plan also gives all team members involved in a program, the same level of understanding of what is to be done and what is involved in the project. The development of the plan provides an opportunity to work through all the important aspects of the project; the importance of this process should not be underestimated.

As an absolute minimum, a sampling and analysis plan must contain the following information.

- Why the sampling is occurring (sampling rationale).
- The history of the project (i.e. when sampling techniques have changed; when sites have been added, moved or removed from the project; and when analytes have been added or deleted and also the rationale behind any changes).
- What parameters are being measured (what to collect/measure).
- How often those parameters are being measured (sampling frequency).
- Where those parameters are being measured (sampling site location).
- How the data will be managed and reported.
- How the parameters will be collected/measured (standard operating procedures).
- Which National Association of Testing Authorities accredited and independently audited analytical laboratory is analysing your water samples and which analytical methods they use.

WIN sampling and analysis plan templates (with and without instructions) can be obtained by contacting the Measurement and Water Information Branch (Department of Water). Contact details are listed in section 14, titled “useful contacts”.

To ensure compliance with WorkSafe legislation, it is extremely important that the project manager prepares a thorough safety plan before field work starts and ensures that all staff members going into the field are suitably trained to do so safely and have all the necessary equipment to do the job safely. The safety plan should include a site-specific safety assessment of each ‘workplace’, as well as a more general consideration of actual and potential (reasonably foreseeable) hazards. Emergency contact phone numbers and directions to the nearest emergency department are also required; for country and more remote areas adequate phone coverage and a ‘phone-in policy’ should be included in the safety plan.

Your final task will be to prepare bottles and paperwork and ensure that all personnel are adequately trained in standardised sampling techniques and fully informed of when they will be sampling. *Field sampling guidelines - a guideline for field sampling* *for surface water quality monitoring programs,* addresses all the required aspects of field sampling techniques as well as paperwork and equipment protocols.

13 Reporting and data use

Once monitoring (or a period of monitoring activities) has concluded and the data has been entered onto the database (and validated), you need to analyse your data and probably compare it to something for purposes of reporting.

Examine the data and ask yourself some (or all) of these questions.

- Is the water quality data the same for all sites? If not, what could be some of potential reasons (for example, consider land uses, flow variation and rainfall patterns) for any variation in water quality?
- Is the water quality the same at each site over time, both seasonally (over a single year) or over the longer-term (need long-term (at least 3–5 years) data sets to calculate trends)?
- How does the data you have generated compare to other data from the same catchment (either current or past data)?
- How do the results compare to national guidelines (e.g. Australian and New Zealand Environment and Conservation Council (ANZECC) water quality guidelines)?
- How do the results compare to catchment resource condition targets? (If you have sufficient data to generate targets for individual catchments).

The link to: <http://www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality> (ANZECC & ARMCANZ, 2000) may prove useful. The guidelines contain trigger values for both ecosystems and human health protection. They also provide water quality guidelines for the following environmental values: aquatic ecosystems; primary industries; recreation and aesthetics; and drinking water.

The guidelines recognise three levels of protection for aquatic ecosystems: areas with high conservation value; slightly to moderately disturbed ecosystems; and highly disturbed ecosystems.

The report can be an interim report (like a progress report), an annual report or a final report at the conclusion of monitoring; but it must address the initial reasons for monitoring.

The report should cover the following broad areas.

- *Summary:* a brief summary of the report can be very useful for people who don't have time to read the entire report.
- *Introduction:* why did the monitoring occur? Plus any contextual background information.
- *Sampling sites and extent of sampling:* site locations, time of year and sampling frequency and for how long sampling occurred.

- *Methods:* list the methods used to collect samples in the field; both for general water collection and how samples were treated, handled, stored and transported on a parameter basis. The laboratory used for sample analysis should also be included in this section.
- *Results:* display your results in the most appropriate way (e.g. graph or table).
- *Discussion:* here you could compare your results between sites and/or also against guidelines or targets. How do the results at different sites compare to each other? Do the results at any site vary over time (either seasonally or between years) Are the results above or below guidelines? Are the results meeting or failing targets?
- *Conclusions:* does the data you have gathered answer the questions you originally set out to answer when planning your program? For example, has a particular land use had an impact on water quality at sites within the catchment?
- *References:* be sure to list any documents or sources you have used in preparing the report and acknowledge any help you may have received throughout the project.

14 Useful contacts

If you have any questions relevant to surface water sampling, monitoring program design, chemical or physico-chemical analysis or quality assurance and quality control please contact the Department of Water staff listed below.

Dom Heald (Water Science Branch): (08) 6364 7836

Kelli O’Neill (Water Science Branch): (08) 6364 7824

Emma van Looij (Water Science Branch): (08) 6364 7855

Steve Fisher (Water Science Branch): (08) 6364 7868

Trish Bunting (QA Officer, WIN): (08) 6364 7449

John Patten (WIN database manager): (08) 6364 7455

15 Glossary

ANZECC	Australian and New Zealand Environment and Conservation Council
AS/NZS	Australian/New Zealand Standard
DEC	Department of Environment and Conservation
SRT	Swan River Trust
WIN	Water INformation database

16 References

National Water Quality Management Strategy (2000). *Australian Guidelines for Water Quality Monitoring and Reporting.* Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ).

Department of Environment (2005). *Hydrological measurement process: Quality control samples guidelines – draft.* Department of Environment, WA.

Water and Rivers Commission (2002). *A community guideline to surface water quality investigations – version 1.0.* Water and Rivers Commission, WA.

Waterwatch reference manual (2001)

WIN database presentation – delivered by John Argus on behalf of the Department of Water.