

Environment Protection Authority

Guidelines for regulatory monitoring and testing – Groundwater sampling

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Abbreviations

AS Australian Standard

EPA South Australian Environment Protection Authority

EP Act *Environment Protection Act 1993*

WQ EPP *Environment Protection (Water Quality) Policy 2015*

NATA National Association of Testing Authorities (of Australia)

NEPM National Environment Protection Measure

Glossary

analyte	Refers to any chemical compound, element or other parameter as a subject for analysis.
aquifer	Permeable rock or sediment in a geological formation, or group of formations, or part of a formation that can transmit water.
biota	Plants, animals including humans, fungi or bacteria.
casing	A tube used as temporary or permanent lining for a well.
BOD	Biochemical or biological oxygen demand. A measure of the decrease in oxygen content in a sample of water—usually over five days (BOD-5).
COD	Chemical oxygen demand. The oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant.
criteria	A value (numerical or relational) set through a condition of licence that imposes a requirement on the licensee (eg that the licensee must meet or that requires the licensee to report or take other action if exceeded).
distilled water	<p>Distilled water has been used throughout this guideline for decontamination and other purposes, where water that will not impact upon the results of analysis is required. The water should have no detectable concentration of the element to be analysed, and be free of substances that interfere with the analytical method.</p> <p>The most common types used for this purpose are distilled, demineralised or deionised water. Distilled or demineralised water is the most appropriate type of water except where dissolved ionised gases are under investigation. Deionised water may not be suitable when investigating dissolved organics, particulates or bacteria.</p> <p>'Spring' water should not be used during sampling as in most cases no contaminants have been removed and high levels of some analytes (such as metals and inorganic non-metals) will be present.</p> <p>Where uncertainty exists as to the suitability and impacts of the water used, quality control blanks (as described in section 7.2) should be employed.</p>
DO	Dissolved oxygen.
EC	Electrical conductivity is the ability of water to conduct an electrical current; commonly used as a measure of salinity or total dissolved salts.
filtrate	The liquid portion of a sample after filtration.
heterogeneous	Made up of a variety of differing materials or having a number of different characteristics.
homogeneous	Having essentially uniform characteristics of composition, texture and appearance.
holding time	After taking a sample, the time by which the sample should be analysed. Exceeding the recommended holding time is likely to cause deterioration of the sample.
hydraulic gradient	The change in the static head (of groundwater) per unit distance in a given direction.

hydrogeological assessment	The study of groundwater, especially the distribution of aquifers, groundwater flow and groundwater quality.
LOR	The laboratory limit of reporting, also often referred to as limits of detection.
monitoring plan	A documented plan detailing the actions, responsibilities and timeframes that will deliver monitoring to meet the defined objectives.
monitoring program	A system developed to achieve the monitoring objectives.
NAPLs	Non-aqueous phase liquids.
packer	A device placed in a well that plugs or seals the well.
permeability	The capacity of a porous medium to transmit water.
PFAS	PFAS is an abbreviation for per- and poly- fluoroalkyl substances. These manufactured chemicals have been used for more than 50 years to make products non-stick, water repellent, and fire, weather and stain resistant. They are stable, persistent, and highly mobile chemicals.
pollutant	Something that pollutes, such as sewage, mine waste, exhaust gases, etc.
purging	The act of evacuating (removing) stagnant water from a well. This includes water in the blank casing, screened casing and filter pack.
QA	Quality assurance – the implementation of checks on the success of quality control.
QC	Quality control – the implementation of procedures to maximise the integrity of samples and data (eg cleaning procedures, contamination avoidance, sample preservation methods).
recovery	The measure of a well's return to its standing water level after purging.
RMT	Regulatory monitoring and testing. Monitoring undertaken as a condition of authorisation or in order to enable an environmental risk to be assessed, or to assess the effectiveness of risk controls and management within the scope of the EP Act.
RPD	Relative percentage difference. Refer to section 8 for equation and description.
screen	A special form of well liner used to stabilise the aquifer or gravel pack while allowing the flow of water through the well into the casing and permitting development of the screened formation.
screen interval	The area of an aquifer in which the screen has been positioned and from which groundwater may be drawn from.
spike recovery value	A percentage indicating the detected concentration of a known volume of analyte over the known value.
stygofauna	Animals that live in aquifers.
SWL	Standing water level – the depth to groundwater from the marked reference point, generally the top of casing.

water quality criteria	In relation to protecting a particular protected environmental value – means the maximum concentrations of certain substances permitted by the <i>Environment Protection (Water Quality) Policy 2015</i> to be in water or the minimum or maximum levels permitted for certain characteristics of water.
well (bore)	A hole drilled into an aquifer for the purpose of monitoring or extracting water. Another common term is 'bore'.

1 Introduction

1.1 Purpose

The purpose of this guideline is to provide any party required to carry out regulatory groundwater monitoring with a consistent approach in obtaining a representative groundwater sample.

There are a number of regulatory reasons for sampling groundwater, such as:

- meeting EPA conditions of authorisation or regulations
- gaining an understanding of hydrogeological processes in order to comprehend actual or potential impacts of activities
- assessing the extent of influence and significance of pollutants
- monitoring and assessing short and long-term trends in groundwater quality in order to comprehend actual or potential impacts of activities.

This general regulatory sampling guideline is a compilation of existing groundwater sampling documents and intended to assist people who sample groundwater and to maintain consistency, quality and traceability in their monitoring programs.

1.2 Scope

The guideline applies to the sampling of groundwater. It does not cover the sampling of surface water or wastewater, and does not provide guidance on monitoring plans, reporting requirements, drilling or sampling equipment.

1.3 Intended users

This guideline contains instructions and advice about information required by the EPA to show that groundwater samples collected for analysis are representative of the aquifer from which they were collected.

Those who collect samples for the following purposes should adhere to the approach detailed in this guideline:

- licensees sampling for compliance with regulatory monitoring and testing (RMT) requirements under the *Environment Protection Act 1993* (EP Act)
- those collecting and/or analysing samples on behalf of the EPA
- any other monitoring results submitted to the EPA.

This guideline is also intended to provide guidance for sampling and analysing groundwater for any purpose other than the above.

1.4 Legal framework

The principal legislation dealing with pollution in South Australia is the EP Act. The EPA may require water quality monitoring from a person(s) under the Act. In particular under:

- Part 1 – Preliminary, sections 5 Environmental Harm and 5B Site Contamination
- Part 6 – Environmental authorisations and development authorisations: section 52 Conditions requiring tests, monitoring or audits, the EPA can require holders of an authorisation to carry out:

... specified tests and environmental monitoring relating to the activity undertaken pursuant to the authorisation, or activities previously undertaken at the place to which the authorisation relates, and to make specified reports to the Authority on the results of such tests and monitoring.

- The monitoring and testing that is required under Part 6, section 52, and is termed ‘regulatory monitoring and testing’ (RMT).

1.5 Further guidance

The following references should be consulted for further guidance:

- [*Regulatory monitoring and testing – Monitoring plan requirements*](#) (EPA 2016)
- [*Regulatory monitoring and testing – Reporting requirements*](#) (EPA 2016)
- [*Regulatory monitoring and testing – Water and wastewater sampling*](#) (EPA 2007)
- [*AS/NZS 5667.11:1998 \(R2016\) Water quality – Sampling guidance on sampling of groundwater sampling*](#)
- [*Groundwater sampling and analysis – A field guide*](#) (Geoscience Australia 2009)
- [*Minimum construction requirements for water bores in Australia*](#) (National Uniform Drillers Licensing Committee 2012)
- [*National Environment Protection \(Assessment of Site Contamination\) Measure 1999*](#) (as amended in 2013)

For additional information not provided by the guideline, the AS/NZS 5667 series of standards can be considered for guidance on a range of hydrogeological assessments.

The methods in this guideline are consistent with the requirements of the AS/NZS 5667.11:1998 (R2016) at the time of writing. This standard is reviewed and updated regularly and it is possible that there will be discrepancies between future standards and this guideline. For the purposes of regulatory monitoring and testing, this guideline takes precedence to the extent of the inconsistency.

2 An overview of monitoring

2.1 Steps in the monitoring process

The main steps associated with monitoring are presented in Figure 1.

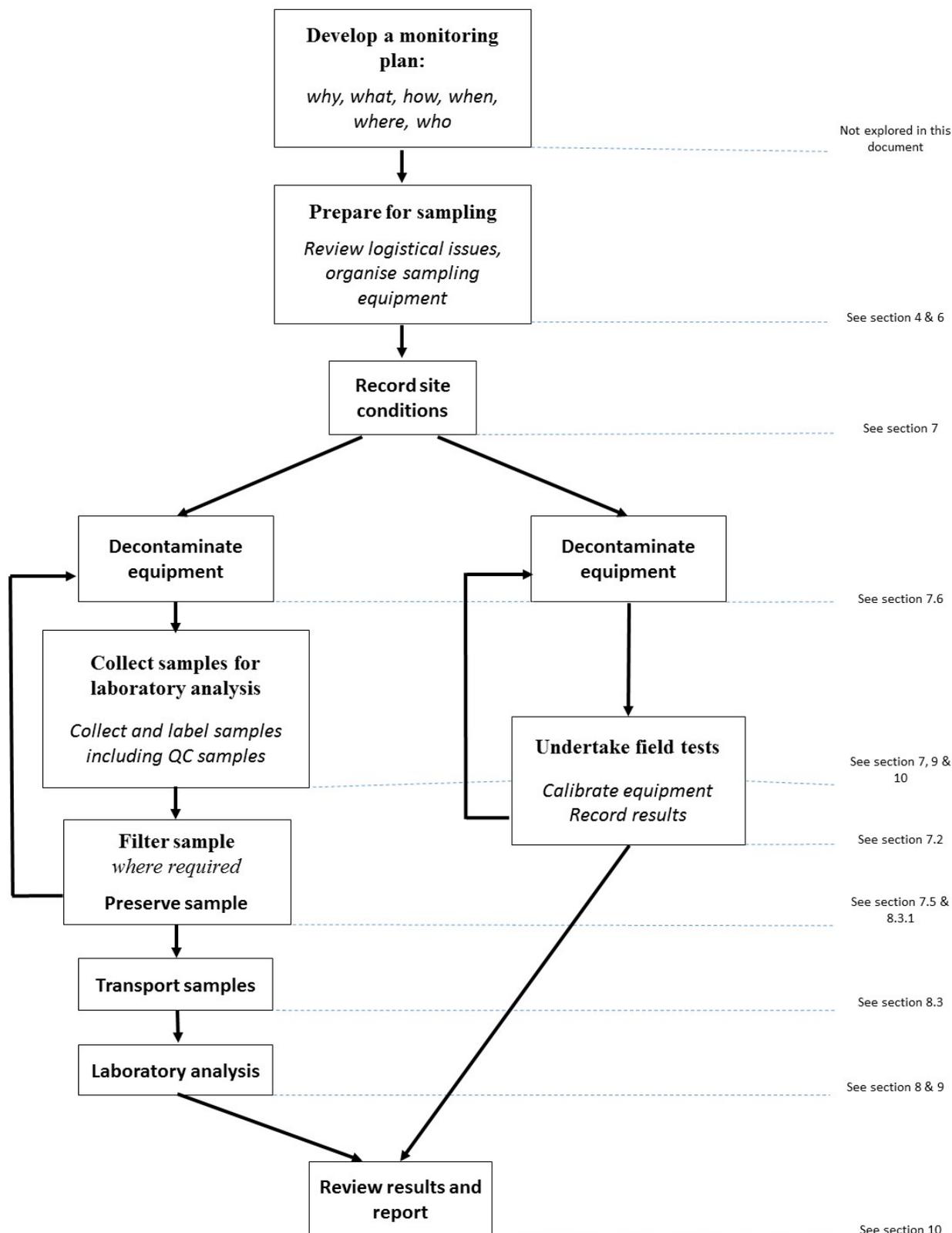


Figure 1 Stages of monitoring

2.2 Integrity of samples

To ensure that sampling is consistent, and of good quality, the samples need to be representative of the body from which they were taken. If the sample integrity is poor, the information gained could be misleading and ultimately result in mismanagement or contamination of the water resource.

The main processes that have the potential to affect the integrity of a sample are listed in Table 1. These processes are interlinked and a change in one may have a flow-on effect that will influence another process, eg a change in temperature can cause chemical reactions.

2.2.1 Contamination of samples

Contamination of a sample occurs when foreign substances are introduced into the sample, the sample is collected without the appropriate sampling method, or the physical storage conditions for the sample are inappropriate. This will lead to the sample having characteristics that are not representative of the in situ conditions. Contamination of a sample can occur at any stage of the sampling process from pumping the groundwater, to the collection of samples, through to the final analysis, and will have a direct effect on the integrity of the sample. As many results are reported in fractions of grams, even extremely small volumes of contaminants can significantly affect results. Contamination can be very costly, especially if regulatory decisions are based on unrepresentative data.

Table 1 Main groundwater sampling techniques that result in an unrepresentative sample

Processes impacting a representative sample	Comments	Impacted analytes					
		A	B	C	D	E	F
Sampling stagnant well water	<p>Water within the well is altered by a number of processes such as:</p> <ul style="list-style-type: none"> • The air–water interface: <ul style="list-style-type: none"> – oxygen gradient by atmospheric diffusion across interface – increased microbial activity (via extra O₂) – direct loss of volatile components (eg VOCs, CO₂, CH₄, H₂S). – indirect effects on redox-species (eg pH, Mn²⁺, Fe²⁺, alkalinity). • Interaction with well casing/intake material: <ul style="list-style-type: none"> – sorption to plastic casing/filter pack (negative bias) – corrosion, leaching/desorption of metals, organics and other solutes into groundwater, including pH effects (positive bias). • Contributions of contaminants/solutes above static water level: <ul style="list-style-type: none"> – condensation inside casing – addition of solutes via surface water infiltration/ leakage through seals 	•	•	•	•	•	•

Processes impacting a representative sample	Comments	Impacted analytes					
		A	B	C	D	E	F
	<ul style="list-style-type: none"> – water from non-target zones via leakage through casing defects – oxygenation by direct rainfall/surface water infiltration – addition of dust/exotic solids and biological material (if well is uncapped) – addition of volatile fractions from the vadose zone (eg landfill gases). <p>(From CL:AIRE, TB3, 2008)</p>						
Agitation/ turbidity	<p>Sources during sampling:</p> <ul style="list-style-type: none"> • Well construction: <ul style="list-style-type: none"> – from drilling (turbidity may decrease with each sampling event) – improper well design and construction (turbidity may decrease with each sampling event). • Groundwater extraction: <ul style="list-style-type: none"> – If the well is over pumped such that the water level falls to within the screened interval then the geological formation becomes aerated. <p>Consequences:</p> <ul style="list-style-type: none"> – can radically alter analytical results – increases in Fe, Al, Ca, Mg, Mn and Si – PAHs altered – radionuclides altered. 				•		•
Cross-contamination	<p>Sources during sampling:</p> <ul style="list-style-type: none"> • when there are multiple sampling points, the transfer of contaminants from one sample point to the sample of another sampling point can occur via the sampling equipment • sampling equipment comes in a variety of materials, which can be carefully paired with the chemical of concern. <p>Consequences:</p> <ul style="list-style-type: none"> • a non-representative sample that misinforms chemical and physical conditions at a particular point. 				•	•	•

Processes impacting a representative sample	Comments	Impacted analytes					
		A	B	C	D	E	F
	<p>Mitigation measures:</p> <ul style="list-style-type: none"> where groundwater is known or suspected of contamination, wells should be sampled from the least contaminated area to greatest area of contamination dedicated or disposable sampling equipment should be used decontamination protocols should be used along with equipment blank samples. <p>Example: PFAS</p> <p>A number of precautions are required when sampling for PFAS that are not necessary for other sampling:</p> <ul style="list-style-type: none"> clothing worn sunscreen wash hands before sampling and use a new pair of disposable nitrile gloves. Teflon® materials must NOT be used in the sampling process. minimising the samples to light exposure do not use plastic ice blocks, chemical or gel based products when cooling the samples. <p>For further information please refer to the PFAS National Environmental Management Plan.</p>						
Aeration/oxidation – the introduction of oxygen	<p>Sources during sampling:</p> <ul style="list-style-type: none"> Over purging: <ul style="list-style-type: none"> the target geological formation may become aerated if the well is over pumped such that the water level falls to within the screened interval. Surface sample collection: <ul style="list-style-type: none"> less significant source particularly from devices where the discharge volume is hard to control, such as bailers sampling bottles should be filled at relatively low rate, 250 ml/min or less for VOCs and 500 ml/min or less for other parameters. 			•	•		•

Processes impacting a representative sample	Comments	Impacted analytes					
		A	B	C	D	E	F
	<p>Consequences:</p> <ul style="list-style-type: none"> increased DO, pH and redox resulting in an underestimation of calcium ions, magnesium ions, heavy metals (particularly Fe and Mn), hydrogen sulfide and ammonium. Also bulk organic parameters including chemical oxygen demand (COD), biological oxygen demand (BOD) and total organic carbon (TOC). increased DO, pH and redox. 						
Adsorption/dissolution of metals	<p>Sources during sampling:</p> <ul style="list-style-type: none"> silt in water samples: <ul style="list-style-type: none"> particulate matter introduced. <p>Consequences:</p> <ul style="list-style-type: none"> alteration of trace metals, particularly iron, zinc and manganese. 				•		
Adsorption/desorption of organics	<p>Sources:</p> <ul style="list-style-type: none"> materials in the borehole: <ul style="list-style-type: none"> PVC can release trace organic substances from borehole lining. materials in the sampling equipment (primarily tubing and filters): <ul style="list-style-type: none"> inert materials should be used. <p>Consequences:</p> <ul style="list-style-type: none"> organic concentrations are affected, along with COD, BOD and TOC. 		•			•	
Pressure changes	<p>Sources:</p> <ul style="list-style-type: none"> Change in ambient pressures: <ul style="list-style-type: none"> gases and some trace VOCs may be removed from solution. Sampling methods: <ul style="list-style-type: none"> pressure changes from surging by sampling equipment pressure changes from moving parts in the equipment. 			•			•

Processes impacting a representative sample	Comments	Impacted analytes					
		A	B	C	D	E	F
	<p>Consequences:</p> <ul style="list-style-type: none"> a decrease in pressure releases gases, VOCs, chemical equilibrium changes or disturb colloidal concentrations. 						
Temperature changes	<p>Sources:</p> <ul style="list-style-type: none"> sampling methods: <ul style="list-style-type: none"> heating of sampled water during collection. sample storage: <ul style="list-style-type: none"> improperly stored samples change between sample and analysis. <p>Consequences:</p> <ul style="list-style-type: none"> heat reduces the solubility of dissolved gases, such as CO₂ and O₂ loss of CO₂ and O₂ can shift pH and redox state, causing precipitation of carbonates (Ca and Mg), and dissolved metals, most readily Fe. The precipitation of Fe can cause co-precipitation of other metals such as Ni, Cu and Cr loss of VOCs through volatilisation. <p>(Nielsen and Nielsen 2005)</p>	•					•

Key:

A: major dissolved metals and phosphate

B: COD, BOD, TOC

C: ammonia, oxidised-nitrogen, alkalinity

D: trace metals

E: trace organic compounds

F: DO, Eh, volatile organic compounds (VOCs) and dissolved gases

Altered from Environment Agency (2003, Table 9.1)

2.2.2 Quality control of samples

The collection, equipment and preservation methods used for sampling should be chosen to minimise the impacts of the factors listed in Table 1. Quality control protocols and procedures must be developed and implemented at all stages of monitoring to minimise and to quantify the impact of these processes on sample integrity,.

Quality control (QC) protocols that are typically used in monitoring are shown in Table 2. This table also states the minimum quality control that is required for licensees undertaking regulatory monitoring and testing (RMT), ie monitoring required as a condition of authorisation.

Table 2 Quality control in monitoring

Monitoring step	QC protocols	Purpose	Refer to	Compulsory for RMT
Develop monitoring plan (not explored in this document)	Various including multiple sample locations, duplicate samples, sampling times	Ensure sample collected is representative of aquifer from which it was taken	Section 3 of this guideline	If specified
	Review of monitoring plan by EPA	To ensure that monitoring plan is in compliance with authorisation and meets monitoring objective	Regulatory monitoring and testing – water and wastewater sampling (EPA 2007) Regulatory monitoring and testing – monitoring plan requirements (EPA 2016) AS/NZS 5667.1:1998 (R2016)	Yes
Sample collection	Appropriate containers, filling and preservation techniques	Minimise changes to sample (physical and chemical)	Section 6.2 and Appendix 2	Yes
	Sample blanks – field, transport, equipment and container	Quantify contamination of samples during sampling process	Section 8 and Appendix 1	Equipment blanks only
	Decontamination of sampling equipment	Minimise contamination	Section 7.6	Yes
Sample filtration	Filtration procedures	Minimise physical and chemical changes to sample	Section 7.5	If field filtration performed
	Filtration blanks	Quantify physical changes and contamination during filtration	Section 9.2.1 (filtration blanks)	If field filtration performed
Field testing	Equipment calibration	Minimise and quantify bias and error in field equipment	Section 7.2	Yes
Transport and storage	Appropriate preservation techniques	Minimise physical and chemical changes to sample	Section 8.3.1 and Appendix 2	Yes
Analysis	NATA lab accredited for required analysis	Ensure laboratory undertakes appropriate QC	Section 9	Yes

Monitoring step	QC protocols	Purpose	Refer to	Compulsory for RMT
		including spikes, calibration of equipment		
	Duplicate samples – intra (within) lab	Check variability in lab analysis	Section 9.2.2	Yes
	Duplicate samples – inter (between) lab	Quantify differences between laboratories' analysis methods	Section 9.2.2	Yes
Reporting (not explored in this document)	Peer review validation	Validate that sampling is undertaken as per monitoring plan and in accordance with sampling guidelines	Regulatory monitoring and testing – reporting requirements (EPA 2016)	When stated in licence

3 Developing a monitoring plan

It is important that every monitoring plan is site specific and has clear objectives of why, what, how, when and where to sample, in order to inform management decisions. The monitoring plan should be written by qualified personnel and reviewed by the EPA before implementation.

The process of developing a monitoring plan is not within the scope of this document. For further information please refer to the following documents,

- Regulatory monitoring and testing – Water and wastewater sampling (EPA 2007)
- Regulatory monitoring and testing – Monitoring plan requirements (EPA 2016)
- Groundwater sampling and analysis – A field guide (Geoscience Australia 2009)
- [AS/NZS 5667.1:1998 \(R2016\) Water quality – sampling guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples](#)

4 Planning a sampling event

Groundwater by its nature is difficult to access and sampling usually relies upon the use of constructed features (eg wells). Sampling groundwater presents unique challenges and needs careful planning and consideration. The cost of installing and sampling groundwater wells is high. Careful planning can prevent unnecessary expense and save time.

4.1 Logistics

Groundwater sampling requires the use of specialised equipment in order to have confidence in the data obtained. Careful planning and preparation of a groundwater sampling event is very important and can save time and reduce the number of difficulties that commonly occur during site work.

The basic steps for planning a sampling event are as follows:

- 1 Review the monitoring plan including monitoring locations, number of samples required, sampling methods, and occupational health and safety (OHS) issues.
- 2 Inform the client or property owner of your intended schedule and be aware of any liabilities that you may incur.
- 3 Coordinate with the analytical laboratory. Obtain appropriate sample containers (ie containers of suitable material and volume that contain preservatives as listed in [Appendix 2](#)). Discuss any problems you foresee, for example with procedures, containers or limitations of reporting.
- 4 Schedule the monitoring event, including planning how and when you will transport the samples back to the laboratory. The aim is to have all samples preserved and delivered to the laboratory as quickly as possible and within recommended holding times. This is especially relevant for samples with holding times of 24 hours or less. (Holding times are listed in [Appendix 2](#).)
- 5 Organise and review site maps and locations to determine logistics of sampling including sampling order. Sampling order should be designed to avoid cross-contamination, ie as much as practical, move from samples with lowest pollutant concentrations to highest concentrations. Be sure the diameter and depth of the monitoring wells to be sampled is known and the sampling equipment must be right for the job.
- 6 Check that you have all the equipment required for the sampling event. Select the appropriate sampling method and equipment (eg low flow pump) based on the potential contaminants and their likely distribution in the aquifer. Test that the equipment is operational and calibrated. Ensure you are able to decontaminate equipment that is to be reused between samples.
- 7 Fill out as much paperwork as practical before sampling such as preparation of labels.

4.2 Communication

It is strongly recommended that the analytical laboratory be consulted before implementing a sampling plan. Each laboratory may use different analytical techniques that require specific sampling techniques, preservatives or field treatments (such as filtering and freezing).

It is important to inform the laboratory of any analytes that may be in particularly high or low concentrations. Some analytical methods need to be modified for the extremes in concentration ranges and prior knowledge of the expected range can speed up the turnaround. Some instruments may be affected if exceptionally high concentrations of certain analytes are introduced without prior dilution. Factors such as salinity of a sample can also influence the choice of analytical methods, and some sample characteristics can cause interference with procedures for other analytes.

During the implementation of a monitoring program it is useful to stay in communication with the laboratory so they know when to expect the samples and whether there are any problems with sample collection. This is especially important with microbiological samples.

4.3 Occupational health and safety

There are many hazards to be aware of when working in any field environment. It is recommended that a specific safety plan be developed for each monitoring plan. The safety plan should be developed to address risks and may include the following:

- Hazard identification, risk assessment and hazard control measures. Typical hazards in sampling include:
 - vehicle breakdown or accident, eg bogging in wet conditions
 - exposure to hazardous substances eg decontamination chemicals, analytes, toxic products formed from sample preparation or stabilisation (eg acidification) and toxic gases such as hydrogen sulphide, bacteria in wellhead or groundwater
 - temperature hazards, typically sunburn and heatstroke
 - working in, over or adjacent to water
 - working adjacent to traffic
 - poisonous animals (spiders, snakes) and plants
 - terrain of sampling area.
- Actions to be undertaken to remove, reduce or control risk.
- Emergency procedures and information such as location of nearest medical facility.

When conducting a sampling event, the right safety equipment will make the task safer. This equipment can be preventative or provide assistance in the case of an incident. The sampling checklist (see Appendix 3) provides an example of the type of personal protective equipment (PPE) that may be required for sampling in the field. Additional protective equipment may be necessary as required by the specialist nature of a particular sampling task or the OHS policy of your employer.

5 Drilling and well construction

5.1 Permits

In South Australia a permit is required before a well is constructed. Under the *Natural Resources Management Act 2004* (NRM Act), only a licensed driller is permitted to drill a well. Applications for well permits are available from [WaterConnect](#).

Further guidance on drilling and well construction can be found in:

- Minimum construction requirements for water bores in Australia (National Uniform Drillers Licensing Committee 2011)
- Groundwater sampling and analysis – A field guide (Geoscience Australia 2009).

5.2 Screening to avoid the spread of contamination

Accurate and discrete placement of the well screen is essential to ensure the appropriate aquifer is targeted to minimise the risk of causing environmental harm to potential unimpacted aquifers or other water bearing zones.

If the screen, for example, is placed into a potentially confined aquifer and continues up through the upper confining layer and into a known unconfined aquifer or unsaturated zone, and that layer contains contamination, a number of problems can arise:

- The known unconfined aquifer (or unsaturated zone) may become saturated with groundwater, further spreading the contamination.
- The potential confined lower aquifer may be impacted through chemical diffusion from the upper layer.
- A false interpretation of contamination in the uncontaminated confined aquifer can be made due to the pump drawing in the contamination in the unconfined aquifer while sampling the confined aquifer.

5.3 The integrity of regulatory monitoring wells

When the EPA assesses a report with the results of groundwater sampling, it assumes that the integrity of the monitoring well(s) sampled is intact, and any variation in chemical trends in the samples are a result of the activity impacting on the groundwater rather than an issue with the integrity of the well.

Although there are no specific regulatory requirements for the maintenance of monitoring wells, it is in the best interest of the operator to ensure well integrity.

Poor water well construction leads to the majority of well integrity failures. Water well construction is now required to meet mandatory construction standards across Australia, unless there are state or territory exemptions (Department of the Environment 2014). All design, drilling, construction, maintenance and decommissioning of wells in Australia is governed by the document, Minimum construction requirements for water bores in Australia (National Uniform Drillers Licensing Committee 2011)

Other causes are:

- Fouling; biological, chemical and physical.
- Corrosion; of both metal and plastic screening and casing.
- Damage to the headworks and no capping of the well.

Indicators of poor well integrity:

- Increasing turbidity, salinity, iron and manganese over time.
- Declining SWL, flow rates and daily pumped volume over time.

Tools to inspect well integrity:

- Closed circuit TV down hole camera logging tool.
- Multi-finger calliper logging tool.
- Sonic bond logging tools or cement bond logging tools.
- Ultrasonic bond logging tools.

Essential maintenance requirements:

- Capped to prevent foreign materials entering.
- Protected from external physical damage by vehicles or animals.

5.4 Disposing of wastewater and drilling fluids

Wastewater or drilling fluids **must** be disposed of in accordance with the [Guidelines for the assessment and remediation of site contamination](#) (EPA 2018).

6 Equipment

6.1 Pumping and sampling equipment

The groundwater sampling method chosen will depend on the monitoring objective(s) and site-specific conditions. Chosen sampling methods affected by conditions include the type of (suitable) sampling device, the position of the sampler intake, and composition of the groundwater to be sampled (eg turbidity, containing high levels of volatile organics, NAPLs). All sampling methods and equipment, including pumping criteria and field readings, should be clearly documented.

The most important thing to consider when selecting a sampling device is whether it gives consistent results and disturbs the sample to the minimum extent possible.

For more information on sampling equipment, please refer to Groundwater sampling and analysis – A field guide (Geoscience Australia 2009)

Sampling equipment should be constructed from inert materials (eg stainless steel, Teflon®, glass) that will not contaminate the sample. The tendency for organics and metals to sorb into and out of many materials makes the selection of sample equipment critical when sampling trace concentrations. Please refer to the PFAS National Environmental Management Plan when sampling for PFAS where materials such as Teflon® are not suitable for use.

Some sampling equipment is disposable, while other equipment will need decontamination between samples. Decontamination is discussed further in section 7.6. If choosing such equipment, it must be disposed of in accordance with the contamination risk. Please consult the Guidelines for the assessment and remediation of site contamination (EPA 2018) for further information.

It should be noted in instances where low-flow pumping and sampling are required, the pump should have a variable flow rate. Caution should be taken with some pumps that may heat up and affect the physical and chemical properties of the sample when run at low-flow rates.

The following are important practical considerations that need to be taken into account when selecting a sampling pump:

- The depth of the standing water level (SWL) is important, as the deeper the SWL the more head the device must overcome to deliver the sample to the surface. Note also that the SWL may be increased due to draw down during pumping
- The well needs to be able to accommodate the sampling device; the smaller the diameter of the well, the more limited the options.
- Some pumps are easier to operate, clean and maintain than others.
- Being easy to service in the field is a distinct advantage.
- Reliability and durability are important as groundwater sampling devices often operate for long periods, under heavy loads and in restricted spaces.
- Decontamination between sampling each well need to be straightforward.

6.2 Sampling containers

Containers used for collecting samples must not affect the integrity of the sample. As a result, specific container types are used for different analytes. Additionally, there are a number of treatments that are applied to containers to further reduce the chance of sample contamination. The NATA accredited laboratory undertaking the analysis should always be consulted for the most appropriate sample container choice. [Appendix 2](#) provides guidance for container selection and treatments by analysis type. Sample containers are generally obtained from analytical laboratories. Please refer to the PFAS National Environmental Management Plan when sampling for PFAS, as a variety of materials are not suitable for use.

7 Sampling methods

7.1 Groundwater levels

Standing water level (SWL) should be measured before purging and sampling. The SWL should be measured with a purpose-built tape or meter, and from a permanently marked reference point, generally at the top of the casing.

Groundwater levels from different wells in the same aquifer may be used to determine the hydraulic gradient between the wells and allow the direction of lateral flow to be determined. The hydraulic gradient from wells in different aquifers should not be used to determine lateral flow. However, this information may make it possible to calculate vertical flow. Groundwater flow direction can be estimated with three or more wells, spaced roughly equally apart in a triangular arrangement. This information is used, with other supporting information, to determine the hydrogeological setting.

When calculating flow direction, water levels should be taken on the same day or at shorter intervals if they are influenced by the tide. Groundwater flows may vary significantly over time. A groundwater contour map should be generated from several sampling events to find the direction of flow and variability across the site. Groundwater contours cannot be constructed unless all the wells used have been surveyed to a common datum.

7.2 Measuring field parameters

Some parameters cannot be reliably measured in the laboratory as their characteristics change over a very short time scale. Temperature is the best example of this. Water temperature will begin to stabilise to the new ambient temperature as soon as the water is removed from the well. Water temperature must be measured in situ.

Parameters that can be measured in the field include temperature, dissolved oxygen, pH, conductivity, salinity, turbidity and redox potential. These can be reliably measured using a multi-parameter meter – usually with an electrode for each parameter. It is crucial to calibrate the meter accurately before using it, and regularly during use. Calibration procedures vary between meters and between manufacturers so it is important to follow the instructions supplied with the equipment.

Most electrodes are calibrated using standard solutions of known properties. These can be purchased from various laboratory supply companies or sourced from a National Association of Testing Authorities (NATA) accredited analytical laboratory. Standard solutions have a limited shelf life and can deteriorate if not stored correctly (away from light at 20°C for most solutions is acceptable). The quality of standard solutions will directly influence the performance of the meter so it is important that if there is any doubt, fresh standard solutions be obtained. Calibration of all meters should be routinely recorded on a standard sheet including dates, temperatures and calibration readings. This will provide a record of the performance of each meter and provide evidence that quality procedures are being employed.

Ideally, parameters should be measured in situ, using down-hole water quality meters. However, this is often impractical. A flow-through cell should be used to prevent contact between the sample and the atmosphere. A flow-through cell will also provide for continuous measurement. Where a flow-through cell is not available, the discharge tube should be placed at the base of the measuring container to minimise exposure to the atmosphere.

Some manufacturers are producing ion-specific probes that measure analytes such as nitrite, calcium, sulfide, bromide, fluoride, ammonium and chloride in the field. They may be suitable for situations where parameters are present in high concentrations, but may be subject to interference from other substances. The results produced by these field meters may not be comparable to those produced in the laboratory. Additionally, some colorimetric methods are becoming available, particularly for online applications. To apply these methods in a regulatory monitoring plan the EPA must be consulted prior to field testing.

7.3 Purging styles

The way in which a well is purged has the most significant impact on sample quality (Nielsen and Nielsen 2005).

All sampling methods assume that stagnant water has been standing in the well casing, and that this stagnant water is different, both physically and chemically, from the aquifer water. Hence some form of purging is first required to remove this stagnant water before a representative sample can be obtained. Well purging intends to introduce fresh groundwater into the well that is representative of the aquifer (or geological unit). The following sections detail purging methods.

Each method has advantages and disadvantages and should be selected based on the monitoring objective(s) and the hydrological assessment.

At sites where the purged groundwater is known, or suspected, to contain contaminants, the water must be disposed of in a manner that does not allow it to enter waterways, the stormwater system or contaminate soil. The Guidelines for the assessment and remediation of site contamination (EPA 2018) can assist with the correct disposal of purge water.

Wells can be divided into two categories when it comes to purging – high yielding and low yielding. For each type different sampling methods are recommended to obtain the most representative sample possible.

7.3.1 Purging high yielding wells

These are wells that are screened in formations with high hydraulic conductivity, and recover quickly if pumped dry.

Well-volume method

The well-volume method is a simple reproducible sampling technique that aims to provide confidence that the sample collected is representative of water quality of the screened aquifer. However, the detection of a contaminant at a low concentration in a thin, contaminated zone with long well screens may be difficult; vertical profiling techniques should be used in this case, or other sampling types considered. This technique should not be used to purge aquifers contaminated by NAPLs.

Pump placement

Where the standing water level (SWL) is above screen level, the purging pump should be above the screen. This will have the effect of vacuuming out the stagnant water and cause less stress on the screened section.

Where the SWL is within the screen, the pump should be placed at least one metre above the bottom of the well to avoid disturbing fine material on the bottom.

Purging method

To determine the volume of groundwater required to be purged the following calculation is used:

$$\text{Well volume (kL)} = h \times \pi \times \frac{d^2}{4}$$

Where h = height of the water column in the well (m)
 d = inner diameter of the casing (m)

A minimum of three well volumes are usually purged when using this method, although the actual number of well volumes removed should be based on the stabilisation of water quality parameters. It is best to use a flow-through cell when measuring the water quality parameters. Stabilisation is achieved when three successive measures of at least three parameters differ by less than the acceptable ranges listed in Table 3. Three successive measurements are defined as measurements taken at an interval corresponding with the purging of one half a well volume.

Table 3 Requirements for stabilisation – well-volume method

Parameter	EC	pH	Temp(°C)	DO	redox
Acceptable range	5%	±0.1	0.2	10%	±10 mv

Purging should be documented in the forms in [Appendix 6](#).

The main disadvantages of this method are:

- It does not take into account the yield of each aquifer. A universally accepted three-well volume is often taken, despite there not being a standard number of well volumes that suits all hydrogeological conditions (Nielson and Nielson 2005).
- Its focus is more on the removal of large volumes of groundwater, with no regard to the chemical change and stabilisation that would indicate aquifer water.
- It encourages the use of bailers and high speed submersible pumps. This leads to the mixing of different waters, where the insertion of the bailer or pump can push stagnant water into the aquifer matrix and mix it with the groundwater.
- The higher than natural flow rate pumping of groundwater introduces particulate matter and leads to the movement of contaminants into non-contaminated areas.

Where possible, when sampling for all but the most basic of water quality parameters, other more passive sampling techniques should be considered.

Low-flow sampling

Low-flow sampling utilises pumping at low-flow rates, and relies on chemically based evidence that groundwater, and not the stagnant well water, is being sampled.

This sampling technique minimises drawdown of the static water table, and draws the water directly from the formation, avoiding the need to remove large volumes of stagnant water. Samples are collected directly from the pumping mechanism with minimum disturbance to the aquifer.

Low-flow purging can also significantly reduce the volume of purge water produced. This method has the advantage of limiting vertical mixing and vaporisation of volatile organic compounds in solution in the well casing, or well hole as compared with high-flow pumping and sampling. The low-flow pumping method generally reduces turbidity during pumping, and is suited to situations where the target parameters could sorb to particulate matter.

Low-flow pumping is generally most effective with short screened intervals, eg 1.5 to 9 m. This pumping method is generally not suitable for:

- aquifers with very low hydraulic conductivities where minimal drawdown cannot be maintained
- long screened intervals (eg >9 m) or open-hole wells where the hydraulic flow pathways are unknown
- aquifer is contaminated by NAPLs.

Pump placement

Generally the pump intake should be positioned in the mid-point of the screened or open zone. It should be noted that the flow within a well will be dominated by the hydraulic conductivity of the aquifer layers rather than the pump position resulting in a flow weighted sample.

If the substance(s) of interest are known to accumulate either near the top or bottom of the screen, it may be appropriate for the pump to be positioned closer to this zone.

Similarly, if there is a particular geological interval of interest then the pump should be positioned adjacent to that zone.

Purging method

The following method must be followed when using low-flow pumping:

- calibrate all equipment
- remove well cap and monitor head-space if volatile organic compounds (VOCs) are suspected
- measure the SWL from a surveyed reference point
- Assemble the pump, ensuring that the pump and tubing do not come in contact with contaminated soil or other surfaces. It is preferable that the tubing length matches the required depth of the pump. Excessive tubing may cause temperature changes and chemistry changes in the sample
- place pump in the screen, taking care to minimise disturbance to the water column
- connect the flow-through cell
- Start the pump and adjust the flow so that there is minimal drawdown. The aim of low-flow purging is to establish a stabilised pumping rate while minimising the drawdown in the well. Water level needs to be measured continuously until an equilibrium between the flow rate and drawdown level is established. Flow rates are typically 0.1–0.5 L/min, with a drawdown generally less than 0.1 m (Puls and Barcelona 1996).
- Once the flow rate is established, stabilisation parameters can be measured to determine when purging is completed. It is best to use a flow cell when measuring water quality parameters. Dissolved oxygen and electrical conductivity are the most reliable indicators used to decide when stabilisation has been achieved. Indicator parameters are considered stable when three consecutive readings fall within the ranges presented in Table 4. The readings should be at least three minutes apart, or the time taken to evacuate the equivalent of one volume of the flow-through cell (whichever is greater).

When using low-flow pumping, the following details should be recorded to support the method:

- construction details of the well
- depth of pump intake during purging and sampling
- flow rate
- draw-down distance required to achieve equilibrium
- purging time
- details of the stabilised parameters.

It is recommended that the groundwater sampling record sheet in [Appendix 6](#) is used as a record for low-flow purging

Table 4 Requirements for stabilisation – low-flow sampling

Parameter	EC	pH	Temp(°C)	DO	redox
Acceptable range	5%	±0.1	0.2	10%	±10 mv

7.3.2 Purging low yielding wells

These are wells that are finished in fine grained formations, which have low hydraulic conductivity, such as clays and silts. If pumped dry, these wells are slower to recover, with groundwater moving relatively slowly through the formation. Low yielding wells are often pumped dry before the appropriate amount of purging. This introduces error in obtaining a representative sample. Even low flow sampling method is inappropriate for sampling these wells due to rapid drawdown in the well. In the past low yield wells have generally been sampled in one of two ways:

Purging the well to dryness and then sampling during recovery

The EPA does not recommend this method for water quality sampling due to the number of ways this method alters the sample from being representative of the groundwater.

Issues with this method	Effects on the sample
Drying out the formation, exposing it to atmospheric conditions before recovery	<ul style="list-style-type: none"> • Oxidation reactions, dramatically altering results for a variety of inorganic parameters • Loss of VOCs in samples after recovery (up to 70%)
The hydraulic gradient set up in the formation after the well has been pumped dry	<ul style="list-style-type: none"> • Turbidity in the formation and the well
Cascading water as the well recovers	<ul style="list-style-type: none"> • Changes in dissolved gasses and redox state • Affects concentration of analytes through the oxidation of dissolved metals and the loss of VOCs.
Trapped air in the filter pack surrounding the screen.	<ul style="list-style-type: none"> • Ongoing effects on dissolved gas levels and redox states
Insufficient well recovery	<ul style="list-style-type: none"> • Unable to take sample

Purging to the top of the well screen, then sampling in the screened area

- Where possible, a low-flow pumping method is used or pumping is carried out a number of times in order to avoid the exposure of the screen.
- Once the purging has occurred, the same device can be used to sample in the screened area.
- The risk of lowering the water level into the screened interval and dewatering the surrounding formation with this method is high.

In terms of obtaining a representative sample in low yield wells, or shallow wells with minimal screening, it is considered far more important to avoid altering the chemistry of the sample through pumping the well dry than the risk of sampling some of the stagnant well water (Nielsen and Nielsen 2005). The aim is to target groundwater moving through the screened interval, as it flows through independent of the stagnant water.

The following two sampling methods are considered more effective for sampling low-flow wells where there is insufficient water to achieve the stabilisation of parameters through purging.

Minimum purge sampling

- Where there is sufficient water in the well to ensure coverage of the pump during purging and sampling in low yield wells
- Only the water in the screened interval is to be sampled.
- Suitable for all water quality sampling except for NAPLs.
- The pump should be positioned in the well screen, but not too close to the bottom of the screen that any sediment at the bottom of the well is disturbed.
- The pump should be left in position for a short amount of time before sampling occurs, this could be several days. Dedicated pumps are often used for this reason.
- The key difference between minimum purge sampling and low-flow sampling is that the aim is to only sample the groundwater in the screened area with minimal mixing in the water column

- Bailers and inertial lift pumps must not be used for this type of sampling (Nielsen and Nielsen 2005).

Coring the screened water column

This method is carried out with a disposal grab sampling device known as a hydrasleeve.

The hydrasleeve allows groundwater to be 'cored' in the well screen interval with no pumping, and minimal disturbance to the water column. It is a flexible, lay flat PE sleeve, which is weighted at the sealed bottom and has a flexible top loading check valve. A cable is attached to a collar at the top of the device. As the hydrasleeve is slowly lowered, hydrostatic pressure keeps the sleeve collapsed and the check valve closed. The thin cross-section of the collapsed device results in minimal disturbance to the water column. Once the hydrasleeve is in position, the cabling is attached to the well head and left for an appropriate period of time to allow the water column to normalise, usually between 48 hours and a week. To retrieve the hydrasleeve it must be raised rapidly to open the check valve and fill the device.

Hydrasleeves come in different sizes, and selection will depend on the volume of groundwater required for analysis (Nielsen and Nielsen 2005).

7.4 Collecting a sample

The sampling method used will depend on the goal of the monitoring plan and should take into account possible influences on the parameters being sampled. For consistency, the same sampling and purging methods should be used each time the well(s) is sampled, unless a different method would improve sample quality and data precision.

The following matters need to be considered and will directly affect the sample quality (these are also relevant to the choice of sampling device):

- The sampling device should cause minimal physical or chemical alteration to the sample. It is important that the device does not cause degassing, aeration, volatilisation, oxidation, sorption or precipitation as a result of:
 - transporting the sample to the surface
 - the sample interacting with the materials from which the device is constructed
 - transferring the sample to its container.
- To gain the most representative data, it is recommended that sampling devices are constructed from inert materials such as stainless steel or Teflon®. Flexible components such as tubing should be PVC or polyethylene, and ideally Teflon® coated. However, the materials selected will depend on the sensitivity of the information required.
- When sampling with a pump, the flow rate should not be increased. If a flow-through cell is being used it should be disconnected or bypassed during sample collection as the water quality probe may alter the chemistry of the sample.
- Sensitive parameters, such as VOCs and trace metals, should be taken at low flow rates (generally <250 ml/min) [Nielsen and Nielsen 2005].

For a comprehensive guide to sampling individual parameters and the equipment required, please refer to Groundwater sampling and analysis – a field guide (Geoscience Australia 2009).

7.4.1 Biota (stygo fauna) sampling

The science of groundwater biota, or stygo fauna, is an emerging field and as such, there is no standard method with which to sample.

It is advisable that when sampling for biota or stygo fauna that the sampler attempt to preserve as many of the conditions in the sample container that were present in situ, for example temperature, darkness, pH, contact (or lack of contact) with air. For further information contact the EPA.

7.5 Filtration of samples

Whether samples need to be filtered depends on the monitoring objective(s). Ideally, the well construction, purging and sampling techniques used should minimise the turbidity of the groundwater sample so that there is no need to filter. However, there may be occasions when it is necessary to filter samples in the field to preserve certain parameters and prevent their alteration during the delay between sampling and analysis. Filtering may also be necessary to separate the soluble component, eg dissolved metals, from the rest of the sample.

It is acknowledged that field filtering of very turbid samples may be problematic and it may be more practical for filtering to occur in the laboratory. If samples are laboratory filtered this should be annotated on your results appropriately. Contact your laboratory for instructions on collecting samples for laboratory filtration (eg if sampling for dissolved metals analysis should not be acidified as required in [Appendix 2](#)).

There are various methods and equipment available for field filtration from simple gravity or syringe pressure systems to more complex pump operated pressure or vacuum systems. The best method to use will depend upon the analysis to be performed.

Pressure filtration is preferable over vacuum filtration where the drawing off of volatiles may compromise results. This is likely to be the case when analysing for nutrients and volatile organics.

When filtering with a syringe, the sample should be drawn into the syringe directly from the sample container (and discharged to flush the syringe). A second sample is then drawn into the syringe and a 0.45- μm filter attached to the syringe. A pre-filter is recommended for turbid samples to avoid clogging the 0.45- μm filter. The sample can then be passed through the filters and the filtrate retained in a clean container. Care should be taken to ensure that the filters are changed as they have a tendency to clog. Excessive force may rupture filters or affect the properties of the sample.

Open sample containers are prone to contamination, particularly in dusty and dirty field environments. It is important when filtering samples in the field to take care to minimise the chance of contamination by selecting a clean work environment and replacing caps on sample containers immediately.

7.6 Decontamination

Decontamination is the cleaning of sampling equipment to remove trace analytes and avoid cross-contamination of samples. Reliance should not be placed solely on decontamination procedures. Minimise the chance and consequence of contamination with good sampling design and equipment. When planning sampling consider:

- eliminating the need of multiple-use equipment, eg collect sample directly into container rather than using a bucket to collect and then transfer
- using disposable equipment instead of multiple-use equipment, eg disposable syringes for field filtration
- undertaking tasks within a sterile laboratory rather than in the field, eg requesting that a laboratory undertake filtration rather than attempt field filtration
- reducing the risk of contamination by, as much as practical, sampling from locations with lowest concentration of analyte to highest concentrations
- dedicating equipment particularly the purging system, for each well to reduce the risk of cross contamination.

Any equipment that comes in contact with groundwater must be thoroughly decontaminated between sample collection and at the end of each sampling trip.

The following methods should be used when decontaminating sampling equipment:

- The equipment should be cleaned with decontamination solution and water, followed by multiple rinses with distilled water.
- Decontaminate the pump away from the sampling site.

- Place plastic sheets around the sample site to prevent contamination from ground material.
- Wear clean, sterile gloves and protective clothing when decontaminating.
- Prepare detergent solution in a large container or bucket followed by putting the pump into container and pumping until the hose is full of detergent solution.
- Specific cleaning solutions will depend on the contaminants being investigated, as follows:
 - phosphate-free detergent should be used for a general range of analyses
 - a solvent should be used for oil and grease, hydrocarbons, pesticides, PCBs or PAHs. Rinse equipment with acetone then solvent such as methylated spirits
 - washing solution of 10% nitric acid is recommended for metal analysis acid.
- When sampling for microbiological parameters, bleach should be used to sterilise equipment between sample points (bleach is not to be used if sampling for chlorine). Subsequent to flushing with bleach, pump distilled water through the pump and line and rinse the external hose. Similarly, rinse the bailer. If distilled water is not available, then potable water may be used as a second choice.
- If using a bailer, run several litres of detergent solution through the equipment.
- Collect an equipment blank sample, ie a sample of contaminant-free water after it has been pumped through the system. This is part of the QA/QC procedure to check on the effectiveness of the decontamination process (see section 9.2).
- If contamination is suspected, the wastewater from the decontamination process may need to be contained and disposed of to a treatment facility. If this is the case, the water must not be disposed of to groundwater or surface local drainage.

8 Sample identification, transport and storage

8.1 Labelling and identification

Samples need to be labelled so they can be readily identified at all times. Sample containers should be marked in such a way that they can be clearly identified and distinguished from other samples in the laboratory. Without appropriate labelling, all samples may look alike. Labels will need to be durable. Most samples will be preserved in ice so labels and the ink used will need to be insoluble in water. It is important to take care when packing samples, as these are often subject to vibration during transport causing identification to rub off or become illegible.

It should be noted that xylene in permanent markers can contaminate samples intended for organic analysis. Biro or pencil should be used for organic samples.

Sample labels should contain as much information as practical, and these **must** specify a clear and unique identifying code that can be cross-referenced to the monitoring location and time of sampling (eg via sampling record sheet – see example in [Appendix 6](#)).

Labels may also contain:

- date of sampling
- time of sampling
- location and name of sampling site (include GPS coordinates if available)
- job or project number
- name of sampler
- container pre-treatment and preservations added
- other observations that may affect the method or results of the analysis.

The information above should be recorded on a sampling record sheet and retained as a permanent record.

Hazardous or potentially hazardous samples (such as solvents) should be clearly marked. Similarly, any samples that could reasonably be expected to have particularly high concentrations of a particular analyte should be brought to the attention of the laboratory, as this may affect the analytical technique.

8.2 Chain of custody

Chain of custody procedures and documentation demonstrate sample control. This gives confidence that the sample integrity has not been compromised and imperative if the samples are to be used in legal proceedings or if there is any suspicion that the samples might be tampered with at any stage of the process. The chain of custody documentation is a record used to trace possession and handling of a sample from the time of collection through analysis, reporting and disposal.

The basis of chain of custody control is that a sample is always in someone's custody and as such they are responsible for it. It is important to realise that couriers will often not recognise the contents of a sample container, but only take responsibility for the container itself. As such, the item (eg esky) should be secured with tape so that it would be obvious if the items had been tampered with.

The sampler should complete the chain of custody forms prior to packing the samples. The original form must remain with the sample at all times to enable the completion of custody details at each stage of progression through transportation, analysis and reporting (see [Appendix 7](#) for a sample chain of custody form).

A copy of the final completed form should be obtained from the laboratory to confirm receipt and appropriate transfer and handling. The analytical laboratory should also include a copy as part of the analytical report.

8.3 Transport and storage

During sample transport and storage it is vital that all procedures are followed to ensure that samples are not significantly altered in condition and are in a state fit for analysis at the laboratory. Contamination of samples can easily occur during transport due to container cross-contamination, packaging material or chilling products. During sample storage, degradation can occur due to lack of appropriate preservation, inappropriate storage conditions, excessive storage times and sample cross contamination.

The key aspects of effective transport and storage are to:

- ensure samples are appropriately packed to avoid breakage and cross-contamination
- reduce sample degradation through appropriate preservation
- ensure time between sampling and analysing does not exceed holding time
- Sample containers should be sealed, carefully packed with an appropriate packing material, chilled or frozen (as required) and transported in an appropriate cooler (esky) or fridge. It is sometimes necessary to take further action to prevent cross-contamination, either between samples or from ice, during transport. This could include placing sample containers in snap-lock bags or airtight, plastic tubes with screw caps before transport.

If a courier is to be employed, sample security, chain of custody and refrigeration issues need to be considered prior to transporting the samples. If a courier is not able to meet all the requirements an alternative form of transport should be found.

A basic list of equipment required for sample transport and storage is listed in the Sampling Checklist (see [Appendix 3](#)) and includes labels for sample containers (if not already on containers), snap-lock bags or tubes if required, esky or fridge, ice bricks or crushed ice, packing material (eg foam packing), packing tape, consignment note for external courier and chain of custody forms.

8.3.1 Preservation techniques

Preservation techniques are vital to minimise changes to the sample following sampling. Changes that may occur if poor or incorrect preservation occurs are summarised in section 2.2. Required preservation techniques for specific analytes are detailed in [Appendix 2](#). Some common preservatives are described below.

Refrigeration: Keeping samples between 1°C and 4°C will preserve the majority of physical, chemical and biological characteristics in the short term (<24 hours) and as such is recommended for all samples between collection and delivery to the laboratory. It is recommended that microbiological samples be refrigerated between 2°C and 10°C (as per AS/NZS 2031:2001). Ice can be used to rapidly cool samples to 4°C before transport. Ice bricks are preferred over loose ice or dry ice.

Freezing: In general, freezing at <-20°C will prolong the storage period. However, the freezing process significantly alters some nutrients and biological analytes such as chlorophyll, and the laboratory should be consulted before samples are frozen. Filtering samples in the field before freezing may be required. This is usually done for soluble nutrients, particularly when same-day delivery to the laboratory is not possible.

Chemical addition: The appropriate chemical preservative and dose rate can vary between analytes and according to container size. The analytical laboratory should always be consulted to establish which chemical preservative is appropriate for the analytical technique employed by that laboratory. Preservatives include acidic and basic solutions, and biocides. It is important these are used in the form of concentrated solutions so that the volume of preservatives required is minimised. This will minimise the dilution effect the preservative has on the sample. Chemical additives are normally added by the laboratory and supplied pre-prepared. When sampling this way, it is important that the bottle is not flushed during sampling and to minimise the amount of spillage from the bottle during collection.

All preservation procedures employed should be recorded such as on the field sheet or chain of custody form. Some preservatives need to be removed or negated before analysis (eg pH corrections) and are required to be considered by the laboratory before analysis. It is crucial that a clear record of any sample treatments is available to the laboratory.

8.3.2 Holding times

While preservation techniques can reduce degradation rates they may not completely halt such changes. All analytes therefore have a holding time, which is the maximum time that can elapse between sampling and analysis, and where the sample is unlikely to be significantly modified under the recommended preservation conditions. Holding times for each analyte are included in [Appendix 2](#). Samples must be delivered to the laboratory within the required holding times.

9 Quality

9.1 Quality assurance

Quality assurance (QA) is the policies, procedures and actions established to provide and maintain a degree of confidence in data integrity and accuracy.

For a monitoring program to successfully meet its objectives, a rigorous and thorough program of checks, comparisons and communication must be implemented. In order to achieve consistent data collection, a QA system must be followed.

Figure 2 outlines a systematic approach to the development of a QA program for sampling.

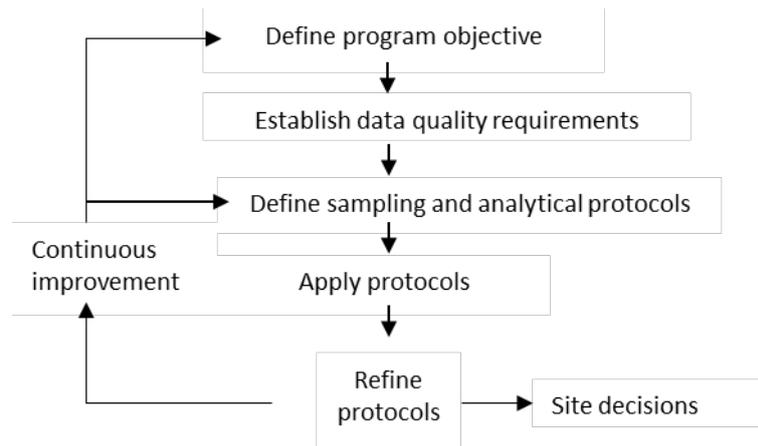


Figure 2 Quality assurance framework (Puls and Barcelona 1996)

To control errors in field sampling to a level acceptable to the data user, various aspects of a QA program should be implemented from the monitoring program design stage through to delivery at the laboratory. Table 2 outlines typical quality assurance protocols for monitoring.

9.2 Quality control

Quality control (QC) is a sample or procedure intended to verify performance characteristics of a system. Water sampling quality control ensures that the monitoring data sufficiently represents the condition of the target waters when the sample was collected. That is, that any significant change in, or contamination to, the sample due to containers, handling and transportation is identified through the incorporation of QC samples.

The type and number of QC samples collected should be based on data quality objectives. The required confidence in results will be reflected in the quantity of QC samples. The greater the number of QC samples the greater the degree of confidence in the reliability of results. The most common types of QC samples are blanks, spikes and duplicates, which are described in the following section.

[Appendix 6](#) states the minimum type and number of sample blanks and duplicates that must be taken for monitoring and testing required by the EPA (ie regulatory monitoring and testing or RMT). When stricter or less stringent requirements are appropriate, the requirements may be modified through licence conditions (EPA) or by approval of monitoring plan. Discussions must be held with your licence coordinator prior to developing a monitoring plan with QC that does not conform to the requirements within this guideline.

9.2.1 Blanks

QC blank samples are typically made from high purity water. The extremely low level of all analytes in high purity water enables identification of any contamination. If an elevated result of a particular analyte is found in a blank, it is reasonable to assume that similar contamination may have occurred in other samples.

Each type of blank is designed to assess the contamination from a particular part of the process and together a system of blanks isolates contamination from the sampling, transport and analytical process.

If elevated concentrations of target analytes are detected during the analysis of a blank sample, a thorough review of the areas of the sampling plan that may be introducing the contamination must be undertaken to determine the effect on the results and corresponding conclusions.

Field and transport blanks

Field blanks are designed to illustrate the effect of handling on sample integrity. They detect contamination from sources such as dust and atmospheric fallout. To collect field and transport blanks, high purity water is poured into three sample containers prior to going on site. If the water to be sampled is known to be saline the blanks should be of corresponding salinity. Two of the sample containers are taken to the site and one is sent to the laboratory. At the site, the cap of the field blanks should be removed and replaced at the end of sampling. During transport and storage the containers should be treated as if they hold a real sample. The transport blank need not be opened but should be carried with the rest of the samples.

Container blanks

Container blanks show if there has been any contamination of the sample from the container itself, the washing process or any preservation techniques. Containers are selected randomly, filled with distilled water in the laboratory and the appropriate preservation applied. These blanks should be held in the laboratory for the same time as the samples before analysis. They are particularly important when the holding time is in the order of several days or weeks.

Equipment (rinsate) blanks

Contamination introduced into the sample through contact with sampling equipment is measured using an equipment blank. Ideally, an equipment blank is prepared before sampling to show contaminants have not been introduced and at the conclusion of sampling to show the effectiveness of the decontamination procedure. The equipment should be decontaminated in the usual manner. The final rinse with distilled water (or similar) in the decontamination process has completed preparation of the equipment blank. If the washing process is cleaning the equipment sufficiently, the equipment blanks should show no change in composition from the rinse water.

Filtration blanks

Some parameters require a sample to be filtered in the field. A filtration blank allows determination of contamination from the filtering process. This can be from dust and atmospheric fallout during the filtration process or from the filter and filtration equipment. After the filtration equipment has been decontaminated in the usual manner, process a blank of high purity water through the filtration apparatus in the same way that the sample would be. The filtrate should then be collected in a normal sample container, preserved as appropriate and transported to the laboratory with the other samples.

9.2.2 Duplicates

Field duplicate samples are obtained by dividing a sample collected from a sampling point. They can be used to measure the precision or repeatability of the analytical process in the laboratory.

Duplicate samples should be blind-coded so that the laboratory cannot tell which primary samples they correspond to. Remember the corresponding sample to the duplicate needs to be recorded on the field sheet. Note that duplicate analysis is generally targeted at the contaminants of concern and will not necessarily consist of a full set of analytes.

There are two types of duplicate samples:

- Intra-lab duplicates, where the duplicate sample is transported to the same laboratory (primary laboratory) as the bulk of the samples – these duplicates measure the precision/variation of the primary laboratory's analytical methods.

- Inter-lab duplicates, where samples are sent to a different laboratory (often called secondary or QA laboratory). These duplicates give an indication of the variability between laboratories which can provide a degree of confidence in the accuracy of the laboratories.

The duplicate samples should produce identical results within the specific tolerances of the analytical procedure.

9.2.3 ‘Spikes’ or sample spiking

Spiked samples have a known amount of a particular analyte added to a sub-sample. This is generally done in the laboratory but can be undertaken in the field. Spikes are used to determine the effectiveness of the overall sampling and analysis program including all of the QC samples described earlier (as per AS/NZS 5667.1). As the final concentration of that analyte is known, spiked samples can be used to check the analytical process. It is important that the person analysing the spiked samples is not aware of the spiked value to ensure they are treated in the same way as regular samples. They are usually prepared in the analytical laboratory by trained personnel but can be prepared in the field if required.

If used, the concentration of the spiked samples should be within the general range of the contaminant expected in the real water samples.

10 Analysis, documentation and reporting

10.1 Sampling documentation

The following minimum information must be recorded on a groundwater sampling record sheet:

- location and well identification
- time and date of sampling
- weather conditions such as rain, sun and wind
- standing water level and well depth
- calculations of well volume (if applicable)
- purging and sampling method used
- field measurements and stabilisation criteria
- physical properties of the sample – turbidity, odour and colour
- flow rate of purging and volume purged, with the corresponding purging time
- well construction details
- sample code.

An example of a groundwater sampling record sheet is provided in [Appendix 6](#).

10.2 Data review

It is important that the data obtained is reviewed prior to assessment and interpretation. Simple reviews can be undertaken that will highlight major issues in the quality of sampling or analysis and provide useful information on accuracy and precision of sampling and analytical methods. The reviews should be carried out in the following ways.

10.2.1 Compare duplicate samples results

As duplicate samples are a sub-sample of the same initial sample the variation between samples should be within the tolerances for the analytical procedure. Differences between duplicates are often quantified as relative percentage difference (RPD).

The relative percentage difference (RPD) of each field duplicate set can be calculated to assess the overall sample precision by using the formula:

$$RPD = \left[(R_1 - R_2) \div \frac{(R_1 + R_2)}{2} \right] \times 100$$

Where R_1 = result of sample, R_2 = result of duplicate sample

If an RPD is >20%, or if the RPD of intra-laboratory duplicates is much greater than the RPD of inter-laboratory duplicates, an investigation as to the cause should be investigated and documented.

10.2.2 Review spike recovery values

Spiked samples have a known amount of an analyte added to them. This is generally done in the laboratory. Laboratories should report the results of spiked samples. As the actual concentration of the analyte is known, spiked samples are used to check the analytical process. Spike recovery values should be within the 80–120% range. Consistently high or low spike recovery values indicate that there may be bias in the analytical process.

10.2.3 Review blank samples results

Blank samples should have low or zero concentrations of the analytes of concern. If high concentrations of analytes are detected, the monitoring should be thoroughly reviewed to determine whether there is a problem with contamination.

10.3 Reporting

When submitting groundwater data to the EPA, the data **must** be accompanied by supporting information. When submitting a report, refer to the Regulatory monitoring and testing: Reporting requirements (EPA 2016).

The supporting information must include:

- site identification, including site plan and survey data
- the monitoring objective
- reference to the monitoring plan
- sampling methodology (see section 7)
- geological setting including local lithology (where available)
- groundwater level results including survey data (mAHD) and flow direction
- assessment criteria
- QA/QC evaluation
- interpretation and conclusions of results.

References

- NUDLC 2012, *Minimum construction requirements for water bores in Australia*, National Uniform Drillers Licensing Committee 2011, Western Australia, viewed 23 January 2019, https://www.water.wa.gov.au/data/assets/pdf_file/0005/1796/Minimum-construction-guidelines-for-water-bores-in-Australia-V3.pdf.
- Artiola JF, Pepper IL and Brusseau M 2004, *Environmental monitoring and characterization*, Elsevier Academic Press, Massachusetts.
- Australian Standards 2016, *AS/NZS 5667.11:1998 (R2016) Water quality – Sampling guidance on sampling of groundwaters*, viewed 23 January 2019, <https://infostore.saiglobal.com/en-au/standards/as-nzs-5667-11-1998-r2016--387183/>.
- Australian Standards 2016, *AS/NZS 5667.1:1998 (R2016) Water quality – Sampling guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*, viewed 23 January 2019, https://infostore.saiglobal.com/en-au/Standards/AS-NZS-5667-1-1998-R2016--115978_SAIG_AS_AS_242380/
- CL:AIRE 2008, TB 03 – *Principals and practice for the collection of representative groundwater samples*, Contaminated Lands: Applications in Real Environments, viewed 23 January 2019, <https://www.claire.co.uk/component/phocadownload/category/17-technical-bulletins>.
- Department of the Environment 2014, *Bore integrity – Background review*, prepared by Sinclair Knight Merz Pty Ltd and revised by the Department of the Environment following peer review, viewed 23 January 2019, <https://www.environment.gov.au/system/files/resources/00f77463-2481-4fe8-934b-9a496dbf3a06/files/background-review-bore-integrity.pdf>.
- Environment Agency 2003, *Guidance on monitoring of landfill leachate, groundwater and surface water*, TGN02, viewed 23 January 2019, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/321602/LFTGN02.pdf.
- EPA 2018, *Guidelines for the assessment and remediation of site contamination*, South Australian Environment Protection Authority, Adelaide, viewed 23 January 2019, https://www.epa.sa.gov.au/environmental_info/site_contamination/assessment_and_remediation.
- 2016, *Regulatory monitoring and testing – Monitoring plan requirements*, South Australian Environment Protection Authority, Adelaide, viewed 23 January 2019, https://www.epa.sa.gov.au/environmental_info/waste_management/liquid_waste/wastewater.
- 2016, *Regulatory monitoring and testing – Reporting requirements*, South Australian Environment Protection Authority, Adelaide, viewed 23 January 2019, https://www.epa.sa.gov.au/environmental_info/waste_management/liquid_waste/wastewater.
- 2007, *Regulatory monitoring and testing: Water and wastewater sampling*, South Australian Environment Protection Authority, Adelaide, viewed 23 January 2019, https://www.epa.sa.gov.au/files/8494_guide_wws.pdf.
- Geoscience Australia 2009, *Groundwater sampling and analysis – A field guide*. Australian Government, Record 2009/27, viewed 23 January 2019, <https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search?node=srv#/metadata/a05f7892-ee1f-7506-e044-00144fdd4fa6>.
- NEPC 1999, *National Environment Protection (Assessment of Site Contamination) Measure 1999*, as amended in 2013, National Environment Protection Council, Adelaide, viewed 23 January 2019, <http://www.nepc.gov.au/nepms/assessment-site-contamination>.

Nielsen DM and Nielsen GL 2005, *The essential handbook of ground-water sampling*, CRC Press, Taylor & Francis Group, LLC, viewed 23 January 2019, <https://epdf.tips/the-essential-handbook-of-ground-water-sampling.html>.

Puls RW and Barcelona MJ 1996, *Low flow (minimal drawdown) ground-water sampling procedures*, US Environment Protection Agency, EPA/540/S-95/504, viewed 23 January 2019, <https://www.epa.gov/sites/production/files/2015-06/documents/lwflw2a.pdf>

HEPA 2018, *PFAS National Environmental Management Plan*, Heads of EPAs Australia and New Zealand, viewed 23 January 2019, <https://www.epa.vic.gov.au/your-environment/land-and-groundwater/pfas-in-victoria/pfas-national-environmental-management-plan>

Further reading

Schwartz FW & Zhang H 2003, *Fundamentals of groundwater*, John Wiley & Sons, New York.

Appendix 1 Summary of quality control samples

QC sample type	Quantifies contamination from:	Action in the laboratory	Action in field	Number	
				Recommended by AS5667.1 and ANZECC/ ARMCANZ 2000	Minimum requirement if monitoring as condition of authorisation
Field and transport blanks	Contamination due to the field conditions	Select three identical sample containers. Fill all with distilled water (or water of corresponding salinity to sample). One sample is left in the laboratory as a control sample. Two samples are taken to the field – one as a field blank and one as a transport blank. The actions in the field are then carried out.	Field blank – open container in the field for a similar period of time as is required to take sample. Re-cap container and transport to laboratory for analysis.	1 set (of 3 containers) per sampling trip ^a 1 blank per 10 samples ^b	Nil
	Contamination during transport		Transport blank – Carry a sealed sample container in the cooler with other samples. No other action necessary in the field. Return to laboratory for analysis.		Nil
Container blanks	Contamination due to the container, washing process and preservatives	Fill a sample container with distilled water – do not rinse. Apply the preservation appropriate to samples taken in that container type. The sample is to be held in the laboratory for a similar period of time as the majority of samples are held before analysis.	None	1 per batch of containers ^a 1 per 10 samples ^b	Nil
Equipment blanks	Residue on sampling equipment	Nil	Wash sampling equipment as required. Collect final rinse water as the blank.	No specific recommendation	1 per sampling event if equipment is used

QC sample type	Quantifies contamination from:	Action in the laboratory	Action in field	Number	
				Recommended by AS5667.1 and ANZECC/ARMCANZ 2000	Minimum requirement if monitoring as condition of authorisation
Filtration blanks	Contamination or changes during field filtration	Nil	After washing the filtration equipment as required filter distilled water using filtration apparatus as for a normal sample. Collect filtrate for analysis.	No specific recommendation	1 per sampling event (if sample is field filtered)
Duplicate samples – to primary laboratory	Variability of analysis within laboratory	Nil	Split a sample into two sub-samples and preserve as required. Ensure samples are labelled uniquely. Transport to laboratory as required.	1 per 20 samples (5% of samples) ^b	1 per year or 1 per 20 samples (whichever is greater) ^c
Duplicate samples – to secondary (QA) laboratory	Variability of analysis between laboratories	Nil	Split a sample into two sub-samples and preserve as required. Transport one sample to primary laboratory and one sample to secondary laboratory.	No specific recommendation	1 per year or 1 per 20 samples (whichever is greater) ^c

Recommendations sourced from:

^a AS/NZS 5667.1:1998

^b ANZECC/ARMCANZ 2000

^c Note that duplicate analyses should be targeted at the contaminants of concern and will not necessarily consist of a full set of analytes

Appendix 2 Containers, preservation methods and holding times

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
Physical and aggregate samples						
acidity and alkalinity	plastic or glass	500	fill container completely to exclude air	refrigerate	24 hours	preferable to analyse sample in field
colour—true	plastic or glass	500	fill container completely to exclude air	refrigerate and store in the dark	2 days	
conductivity (at 25°C)	plastic or glass	100	fill container completely to exclude air	none required	24 hours	preferably carried out in field for samples of low conductivity (<20 µS/cm)
oxygen, dissolved	glass			fix oxygen in the field and store in the dark (as per method of analysis used)	24 hours	preferably determined in the field
pH	plastic or glass	100		refrigerate	6 hours	carry out test as soon as possible and preferably in situ
solids (dissolved or suspended)	plastic or glass	500	dissolved: fill container completely to exclude air	refrigerate	24 hours	
turbidity	plastic or glass	100	fill container completely to exclude air	none required	24 hours	preferable to analyse sample in field or in situ

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
Metals						
aluminium barium beryllium cadmium chromium cobalt copper lead manganese molybdenum nickel silver tin vanadium zinc	acid washed, plastic or glass	100		acidify with nitric acid to pH 1 to 2	1 month	
antimony	acid washed, plastic or glass	100		acidify with nitric acid or hydrochloric acid to pH 1 to 2	1 month	hydrochloric acid should be used if hydride technique is used for analysis – consult laboratory
arsenic	acid washed, plastic or glass	500	fill container completely to exclude air	acidify with nitric acid or hydrochloric acid to pH 1 to 2	1 month	hydrochloric acid should be used if hydride technique is used for analysis – consult laboratory
boron	plastic	100	fill container completely to exclude air	none required	1 month	
chromium (VI)	acid washed, plastic or glass	100	fill container completely to exclude air	refrigerate	1 day	sample container should be rinsed thoroughly

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
iron (II)	acid washed, plastic or glass	500	fill container completely to exclude air	acidify with hydrochloric acid to pH 1 to 2	24 hours	
iron, total	acid washed, plastic or glass	500		acidify with nitric acid to pH 1 to 2	1 month	
lithium	plastic	100		none required, but may acidify with nitric acid to pH 1 to 2 and refrigerate	1 month	acidification allows the sample to be analysed for lithium as well as other metals
magnesium	acid washed, plastic or glass	100	fill container completely to exclude air	none required	1 week	samples with pH >8 or high carbonate content to be analysed solely for calcium, magnesium or hardness should be acidified
				acidify with nitric acid to pH 1 to 2	1 month	acidification permits determination of other metals from same sample
mercury	acid washed, glass	500		acidify with nitric acid to pH 1 to 2 and add potassium dichromate to give a 0.05% (m/v) final concentration	1 month	particular care is needed to ensure that the sample containers are free from contamination
potassium	acid washed, plastic or glass	100		none required/acidify with nitric acid to pH 1 to 2	1 month	acidification allows the sample to be analysed for potassium as well as other metals
selenium	acid washed, plastic or glass	500		acidify with nitric or hydrochloric acid to pH 1 to 2	1 month	
uranium	acid washed, plastic or glass	200		acidify with nitric acid to pH 1 to 2	1 month	

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
Inorganic (non-metallic)						
ammonia	plastic or glass	500		refrigerate	6 hours	strict protocol required to reduce effects of contamination store in area free of contamination (ammonia vapour may permeate the walls of even high density polyethylene containers) pressure filtering is preferred
				field filter through 0.45 µm cellulose acetate membrane and refrigerate	24 hours	
				field filter and freeze	1 month	
chlorine	plastic or glass	500		keep out of direct sunlight, analyse immediately	5 minutes	this analysis should be carried out in the field within 5 minutes of sample collection
cyanide, total	plastic or glass	500		if no interfering compounds are present, then add sodium hydroxide to pH >12, refrigerate and store in the dark	24 hours	the preservation technique will depend on the interfering compounds present sulfides and oxidising agents potentially cause large errors in the determination of different cyanide forms refer to the analytical method for suitable preservation techniques
iodide	plastic or glass	500		refrigerate	1 month	
fluoride	plastic	200		none required	1 month	PTFE containers are not suitable

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
nitrate	plastic or glass	250		field filter through 0.45 µm cellulose acetate membrane and freeze	1 month	
				refrigerate	24 hours	unfiltered sample
nitrite	plastic or glass	200		immediate analysis		analyse as soon as possible after collection
				freeze	2 days	
				field filter through 0.45-µm cellulose acetate membrane and freeze	1 month	
phosphorus, total	plastic or glass	500		refrigerate	24 hours	acidification not recommended for persulfate oxidation method
				freeze	1 month	
				acidify with sulfuric acid or hydrochloric acid to pH 1 to 2, refrigerate and store in dark	1 month	
phosphorus, dissolved	plastic or glass	50		field filter through cellulose acetate membrane and refrigerate or field filter and freeze	24 hours – 1 month	
sulfate	plastic or glass	200		refrigerate	1 week	
sulfide, total	plastic or glass	500	fill container completely to exclude air	None required for field measurement, preserve with zinc acetate for laboratory analysis	1 week (preserved)	

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
nitrogen, total	plastic or glass	500		refrigerate or freeze	24 hours – 1 month	
total Kjeldahl nitrogen (TKN)	plastic or glass	500		acidify with sulfuric acid or hydrochloric acid to pH 1 to 2, refrigerate	24 hours	
				refrigerate	24 hours	
				freeze	1 month	
Organics						
biochemical oxygen demand (BOD)	plastic or glass	1,000	do not pre-rinse container with sample fill container completely to exclude air	refrigerate and store in the dark	1 day	glass containers are preferable for samples with low BOD (<5 mg/L)
chemical oxygen demand (COD)	plastic or glass	100	fill container completely to exclude air	acidify with sulfuric acid to pH 1 to 2, refrigerate and store in dark	1 week	glass containers are preferable for samples with low COD (<5 mg/L)
	plastic	100		freeze	1 month	
hydrocarbons, oil and grease	glass, solvent washed	1,000	do not pre-rinse container with sample do not completely fill container ^a	refrigerate	1 day	extract on site where practical extract sample container as part of the sample extraction procedure
				acidify with sulfuric acid or hydrochloric acid to pH 1 to 2 and refrigerate	1 month	

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
monocyclic aromatic hydrocarbons (MAH)	glass, vials with PTFE lined septum	500	fill container completely to exclude air.	Acidify with hydrochloric acid to pH 1 to 2 and refrigerate. If residual chlorine is present, for each 40ml of sample add: <ul style="list-style-type: none"> • 25 mg of ascorbic acid • 3 mg of sodium thiosulfate or • 3 mg of sodium sulfite. 	1 week	2 x 40-mL vials are recommended for purge and trap analysis
polycyclic aromatic hydrocarbons (PAH)	glass, solvent washed	500	do not completely fill container do not pre-rinse	refrigerate and store in the dark if sample is chlorinated, add 80 mg of sodium thiosulfate for every 1,000 mL of sample to container prior to sampling	1 week	extract on site where practical extract sample container as part of the sample extraction procedure
polychlorinated biphenyls (PCBs)	glass, solvent washed with PTFE cap liner	1,000–3,000	do not completely fill container do not pre-rinse	if sample is chlorinated, add 80 mg of sodium thiosulfate for every 1,000 mL of sample to container prior to sampling	1 week	extract on site where practical extract sample container as part of the sample extraction procedure a 40-mL vial with PTFE-lined septum is recommended for micro-extraction
pesticides (organochlorine, organophosphorus and nitrogen-containing)	glass, solvent washed with PTFE cap liner	1,000–3,000	do not pre-rinse container with sample do not completely fill sample container with air	refrigerate if sample is chlorinated, add 80 mg of sodium thiosulfate for every 1,000 mL of sample to container prior to sampling	7 days	extract on site where practical extract sample container as part of the sample extraction procedure

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
phenolic compounds (including chlorinated phenols)	amber glass, solvent washed with PTFE cap liner	1,000	do not pre-rinse container sample	refrigerate and store in the dark	24 hours	
			do not completely fill container	acidify to pH 1 to 2 refrigerate and store in dark if sample is chlorinated, add sodium thiosulfate to container prior to sample collection	3 weeks	
total organic carbon (TOC)	amber glass with PTFE cap liner	100		acidify with sulfuric acid to pH 1–2, refrigerate and store in the dark	1 week	analyse as soon as possible phosphoric acid can be used instead of sulfuric if necessary
	plastic			freeze	1 month	inorganic carbon needs to be purged before analysis so volatile organic compounds will be lost
Microbiological/biological						
faecal coliforms or <i>E coli</i> , etc	Glass or plastic, sterilised.	Confirm with laboratory	do not completely fill container	for chlorinated/ chlorinated water add sodium thiosulfate to concentration 100 mg/L for samples with high heavy metals add EDTA refrigerate	24 hrs (preferably <6 hrs)	from AS/NZS 2031:2001
chlorophylls	plastic or glass	1,000		refrigerate filter and freeze residue	24 hours 1 month	refrigerate in dark

Analyte	Container type	Typical volume (mL)	Filling technique	Filtration and preservation	Holding time	Notes
Radiochemical analysis						
alpha and beta activity (gross)	plastic or glass	1,000	no air gap	acidify with nitric acid to pH 1–2	1 month	
alpha and beta activity except radio-iodine	plastic	as required	no air gap	filter for soluble analysis immediately add 20 ±1 ml of 50% (v/v) nitric acid per litre of sample the pH should be <1 refrigerate and store in the dark	analyse as soon as possible	safety precautions and shielding are dependent on the activity of this sample it is imperative that radioactive dust is not inhaled or left on clothing
gamma activity	plastic	consult laboratory		see b	depends on the half-life of the radionuclide	safety precautions and shielding are dependent on the activity of this sample it is imperative that radioactive dust is not inhaled or left on clothing

- ^a Samples for oil and grease analysis should be collected in glass containers with Teflon®-coated equipment as these analytes will stick to the rubber tubing of automated sampling equipment resulting in an unrepresentative sample.
- ^b If there is suspended matter and a separate measurement is required, or the solids are not readily dissolved, filter the sample and treat as two separate samples. Add quantitatively to the sample a known amount of solution containing non-radioactive isotopes of interest. For samples containing metals, the solution is usually acidified to a pH of less than 2; the acid used should not precipitate or volatilise the elements of interest. Refrigerate and store in the dark.

Notes from AS/NZS 5667.1:1998:

- Plastic = plastic containers, eg polyethylene, PTFE, polypropylene, PET and similar. Glass = borosilicate glass container. Vials are flat-bottomed borosilicate glass vials, typically 30–50 mL capacity with screw caps. The caps should have PTFE faced septa, or liner.
- The preservation technique will depend on the method of analysis to be used. Other methods of preservation may be suitable and prior liaison with the analytical laboratory is required.
- Refrigerate = cool to between 1°C and 4°C (see clause 11.2.2 of AS). Freeze = freeze to –20°C (see clause 11.2.3 of AS)

Appendix 3 Example of a field sampling planning checklist

Parameter	Reference	Preparation check	Execution check
Permissions to access land and wells for sampling or drilling			
Coordination with laboratories <ul style="list-style-type: none"> • sample containers • laboratories are prepared for samples • all paperwork required • QA/QC 			
Equipment <ul style="list-style-type: none"> • see equipment checklist • ensure all sampling equipment is available and in working order • calibration of meters 			
Site work <ul style="list-style-type: none"> • monitoring plan • safety plan • site plan, maps, diagrams • hydrological assessment • details of wells: <ul style="list-style-type: none"> – construction details – SWL information • sampling • sample frequency • sample location • analytes 			
Sample transportation <ul style="list-style-type: none"> • sample preservation • holding times • chain of custody • transport of samples (eg couriers, bus) 			

Appendix 4 Example of a field equipment checklist

Equipment list	Check	Equipment list	Check
Documentation		Field filtration	
Monitoring plan including site plan		Filtration apparatus, syringe etc.	
Appropriate area maps		Filters	
Well records		Kit bag/tool box	
Field notebook/record sheets/Purge sheets		Tools – spanner/shifter/Stillson wrench/screw drivers	
Chain of custody sheets		Spare pump motors	
Purging/sampling equipment		Paper towel	
Water level probe and batteries		Disinfectant wipes	
Water quality meter		Ziploc bags for samples	
Standards to calibrate water quality meters		Safety equipment	
Flow-through cell		First-aid kit	
Bailers and cord		Mobile phone/communication equipment	
Sample containers (including containers for duplicates and blanks)		PPE – wide brimmed hat, wet weather gear, disposable overalls, etc	
Pump and tubing		Sunscreen/sunglasses	
Labels for samples		Sample storage and transport	
Disposable gloves		Eskies and ice	
Quality control samples		Packing tape	
Field blanks		Address labels (eskies)	
Transport/equipment blanks		Courier information	
Decontamination		Other	
Clean work area, eg plastic groundsheet		Other equipment for site specific or remote area requirements	
Buckets		Keys for gates/wells	
Demineralised/deionised water		GPS and batteries	
Detergent solution		Tools—spanner/shifter, etc.	
Sponges, scrubbing brush		Digital camera and batteries/ charger	

Appendix 6 Example of a groundwater sampling record sheet

Site details

Date:

Location:

Well ID:

Unit number:

Well details

SWL (Start): (m)

Casing material:

Drill depth: (m)

Screen length: (m)

Casing diameter: (m)

Purging

Purge method:

Well volume: (L)

Time started:

Min purge vol: (L)

Time stopped:

Pump depth set at: (m)

Flow rate: (L/min)

Flow cell used: Y/N

Sampling

Sampling method:

Date Sampled:

Time sampled:

Sampled By:

Field analysis

Observations (colour, odour, etc)	Time (mins)	SWL (m)	Volume (L)	Cond (mS)	pH	Temp °C	DO (ppm)	Redox (mV)	Turbidity (NTU)

Appendix 7 Example of a chain of custody form

Customer	SA EPA	Laboratory	ABC Labs
Project Name	Clean lake	Contact Name	S Linard
Reference Number	05112/36	Address	524 Magill Road, Tranmere
Contact	P Bond	Phone	8234 5678
Phone	8123 4567		

Sample ID	Sample	Matrix	Sampling		Container			Analysis required						Notes			
								0.05	5	0.02							
	Location	Water, soil	Date	Time	Type	Size (mL)	Preserve	Ammonia	BOD 5	Phos							
W1-1	W1	Water	1/11/05	2 pm	G	1,000	4°C	x	x							Ammonia – total as N	
W1-2	W1	Water	1/11/05	2 pm	G	250	4°C			x						Phosphorus – total as P	
W1-3	W1	Filter	1/11/05	2:30 pm	Filter paper												2 litres filtrate

Sample relinquished by				Sample received by					Agreed condition (temp, intact, etc)
Name/organisation	Initials	Date	Time	Name/organisation	Signature	Date	Time	Sample	
Sampler				Courier					
Courier				Laboratory					