Environment Protection Authority

# The South Australian monitoring, evaluation and reporting program (MERP) for aquatic ecosystems

## Context and overview

EPA South Australia

**The South Australian monitoring, evaluation and reporting program (MERP) for aquatic ecosystems: context and overview**

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# Abbreviations

| | |
|---|---|
| **AUSRIVAS** | Australian River Assessment System |
| **EP Act** | Environment Protection Act 1993 |
| **DEWNR** | Department of Environment, Water and Natural Resources |
| **EPA** | South Australian Environment Protection Authority |
| **MERP** | monitoring, evaluation and reporting program |
| **NRM** | natural resources management |
| **SARDI** | South Australian Research and Development Institute |
| **SoE** | state of the environment |
| **WDF** | European Water Directive Framework (2000/60/EC) |

# Summary

This report outlines changes to the previous, traditional water quality monitoring approaches used in South Australia. This information had been provided to support decision making by the EPA, natural resources management (NRM) regional bodies and organisations with an interest in water quality management. Monitoring was carried out to measure and evaluate the consequences of human activities (eg disturbance) on the biological/ecological condition of our waters while accounting for the noise[1] introduced by natural spatial and temporal variability (eg largely climate effects).

The new and current approach expands beyond water quality to encompass aquatic ecosystems and uses multiple lines of evidence to assess the condition and the pressures that impact on ecosystems. The program also provides, where possible, assessments at different scales using a tiered approach.

At the broadest scale, a landuse risk characterisation identifies the major human disturbances likely to be impacting on different waters, and provides a coarse, desk-top assessment of the likely condition of specific waterways in a region. More detailed assessments will describe the biological condition and environmental risks at the local scale, which could represent a stream reach, marine embayment, estuary, and lake or groundwater body.

An even more detailed assessment of the source of specific problems at the site scale may also be applied as a third layer of investigation, either for unexpectedly impacted sites or for issue-based studies.

The new program is referred to as the aquatic ecosystem monitoring, evaluation and reporting program or MERP.

The main driver for developing the aquatic ecosystem MERP is the recognition that much of the data collected in the past, analysed using a suite of physical and chemical (ie water quality) parameters, cannot be meaningfully assessed for either ecosystem condition or temporal trend. In the absence of statistically significant trending, most monitoring programs provide lots of data that are not routinely analysed and used for clear management outcomes. Even the monitoring conducted by the EPA since 1994 that included some measure of biological condition (eg macroinvertebrates for inland waters, seagrass and reef health for coastal environments), have also threatened to go down the 'data-rich but information-poor' syndrome that plagues most physico-chemical water monitoring programs around the world (eg Ward *et al* 1986).

The changes in aquatic ecosystem MERP are expected to provide a better return on investment and staff resources in terms of maximising the use of water quality information, with the aim of achieving water quality goals and protecting associated environmental values for different waters in the state.

The new strategy will provide information that can be used for multiple purposes and by a range of different users. It will also encourage collaboration with other water agencies and provide obvious benefits in terms of sharing funding costs, consistency in data collection and analysis, and maintaining a critical mass of experienced staff with appropriate knowledge and expertise in applied aquatic sciences in the state.

The communication tool at the forefront of the EPA aquatic ecosystem MERP is the online 'Aquatic Ecosystem Condition Reports' which describe the condition of waters in South Australia. The reported results will be scaled using one of six possible condition ratings, ranging from 'Excellent' (effectively unimpacted) to 'Very Poor' (highly disturbed) for each major type of aquatic ecosystem (eg streams and coastal waters are currently available while wetlands, estuaries and groundwaters will be developed in future years).

[1] Spread in environmental data caused by natural variation.

# 1 Aquatic ecosystem condition monitoring, evaluation and reporting

## 1.1 Purpose of this report

This report outlines the main drivers for the EPA to conduct water monitoring and assessment programs, reviews the equivalent approaches adopted elsewhere, clarifies the purpose of the program, and proposes a way forward which covers all natural waters in South Australia using the aquatic ecosystem monitoring, evaluation and reporting program (MERP).

The document contains relatively sophisticated concepts and content. It is aimed at a scientific audience in fields such as natural resources management, water quality/ecosystem monitoring and assessment, and/or environmental reporting.

## 1.2 Scope of the aquatic ecosystem MERP

Only natural waterbodies are assessed as part of the aquatic ecosystem MERP.

The term ‘natural’ in this context means waterbodies that enable natural aquatic ecosystem functions to occur by providing habitat for plants and animals, and allowing the movement of living organisms and water between different waters. Natural waterbodies can include coastal and marine waters, creeks, rivers, lakes, wetlands, groundwaters (aquifers) and estuaries, as well as locations such as West Lakes, Torrens Lake, constructed wetlands for stormwater control and South East drains.

In contrast, unnatural waterbodies are those waters that have been constructed in a way that does not support natural aquatic ecosystem functions, due to their isolated nature, construction materials or design. They include swimming pools, concrete-lined stormwater drains and lakes, and water supply reservoirs; none of these will be assessed as part of the aquatic ecosystem MERP.

# 2 The South Australian context

## 2.1 Legislative requirements

In refocusing the EPA aquatic ecosystems MERP, it is important to consider the legal drivers that require state's waters to be monitored in the first place, to ensure that the redesigned program will deliver the necessary information to meet the legislated requirements outlined in the *Environment Protection Act 1993* (EPAct).

The EP Act provides clear direction in terms of monitoring the environment in South Australia in several different sections, including in the objects of the Act (clause 10), environmental authorisations requiring tests, monitoring or audits (clause 52) and in the preparation and publication of state of environment reports (clause 112).

Clause 10(1)(b) states that the objects of the Act are 'to ensure that all reasonable and practicable measures are taken to protect, restore and enhance the quality of the environment having regard to the principles of ecologically sustainable development'. In clause 10(1)(b)(vii) this is expanded to include the following: 'to provide for monitoring and reporting on environmental quality on a regular basis to ensure compliance with statutory requirements and the maintenance of a record of trends in environmental quality'. The follow-on clause 10(1)(b)(viii) is 'to provide for reporting on the state of the environment on a periodic basis'.

The requirement for testing, monitoring and auditing in clause 52 relates to point (single) source licence conditions and providing data to the EPA to demonstrate the performance of specific licensees in relation to any discharges or emissions to the environment. Monitoring carried out under this section of the Act relates to compliance monitoring and is performed by third parties, not the EPA, and is not the focus of this report.

Clause 112 relates to the preparation and publishing of a report on the state of the environment (SoE) at least every five years and this provides the most detail in relation to MERP activities by the EPA. The SoE report must:

1 Include an assessment of the condition of the major environmental resources of South Australia;

– Include a specific assessment of the state of the River Murray, especially taking into account the Objectives for a Healthy River Murray under the *River Murray Act 2003*;

2 Identify significant trends in environmental quality based on an analysis of indicators of environmental quality;

3 Review significant programs, activities and achievements of public authorities relating to the protection, restoration and enhancement of the environment;

4 Review any progress made towards achieving the objects of the EP Act; and

5 Identify any significant issues and make any recommendations that, in the opinion of the Authority, should be drawn to the attention of the Minister.

## 2.2 Historical approach

Since it was established in 1994, the major focus of the EPA is licensing point source polluting industries and activities listed in Schedule 1 of the EP Act. Many of these licensees have required some sort of compliance monitoring to provide a means of documenting the scale of environmental impact from their activities (clause 52), which in many cases has contributed towards further industry upgrades and improvements through environment improvement programs.

The EPA also initiated a water quality MERP for streams, groundwater and nearshore marine environments in 1994. This was usually referred to as the 'water quality monitoring program' rather than a monitoring, evaluation and reporting program, although it was implicit that the program did evaluate and report on the data being collected.

The aim was to characterise the ambient or general background water quality (ie water chemistry) of these habitats (Cugley 1995), often for the first time, and assist in setting benchmarks for licensed industries to head towards in terms of minimising the impact from their discharges to the environment. The results from the ambient monitoring program also formed the basis for the trigger values listed in south-central Australia in the national water quality guidelines (ANZECC & ARMCANZ 2000).

The scope of the previous water quality monitoring program was largely based around monthly or quarterly sampling of surface waters and 1–2 samples per year for groundwater sub-programs, with a suite of water chemistry parameters analysed and compared against national guideline values to infer the condition of waters. Biological indicators were also incorporated into the stream and coastal sub-programs to provide a complementary assessment of condition for these waters.

Aquatic macroinvertebrates were used to assess stream conditions using predictive models developed as part of the national river health program (Australian River Assessment System or AUSRIVAS[2]). This involved sampling the two major stream habitats (flowing riffles and still-water edges) in autumn and spring of at least one year. The coastal sub-programs involved separate seagrass and reef health assessments, typically carried out over longer time periods (decadal for seagrasses, five-yearly for some reefs) on more of an opportunistic basis depending on available funds and volunteers to collect some of the data.

The selection of priority waterbodies from across the state was largely designed to include sites that were expected to be minimally disturbed throughout South Australia, based on existing knowledge about the water quality and biological condition of different waters at the time. This included inland surface water sites from national parks and well-vegetated catchments that were dominated by different types of agricultural activities carried out in each region of the state. Marine sub-programs were designed to include a gradient of sites ranging from unimpacted reference sites through to highly impacted sites (eg industry discharges).

The EPA's monitoring sub-programs proceeded in this manner from 1994 until 2007, with significant increases in site coverage introduced in 2003 during an expansion phase as additional funds were made available. There were also some modifications to the program introduced over time as a result of method changes and in response to data reviews that necessitated changes to the suite of analytes being assessed for some waters.

The results from the water quality monitoring program were generally simplified into a traffic light summary to convey the inferred condition of sites based on each water quality variable that was measured.

**Good** water quality was coded **green** for variables that were either below toxicant concentrations or within values listed in the national guidelines that were expected to represent minimally disturbed, unimpacted waters. **Moderate** results were coded **orange** for sites that occasionally fell outside the numerical values listed in the national guidelines, and **poor** results were coded **red** for sites that were regularly different from the expected background concentrations.

This approach has been used in a range of information brochures, technical reports and community documents published by the EPA since about 1997[3]. Much of this information has also been summarised in state of environment (SoE Reports in 1998, 2003 and 2008).

The raw data and information derived during data analyses also contributed to regulatory actions in managing point source pollution (eg identification of suitable background reference sites to compare against impacted sites and provide baselines that can be used to assess the effects and recovery from discharges and spills) and the generation of guidance documents and policies aimed at reducing the broader effects from diffuse (multiple, non-point, typically from broad landuses) sources of pollution to South Australian waters. In addition to these uses, requests for data and its interpretation were also regularly made by the public, media, politicians, NRM boards and researchers for a wide range of purposes and uses.

2 Further details available at <http://ausrivas.canberra.edu.au>.

3 See water quality publications <www.epa.sa.gov.au/pub_water.html>.

The strategy used in the collection of data was expected to show major trends in water quality over time. The expectation was that 5–10 years of monthly data was needed to be able to start to show meaningful changes in various measures, while being able to account for seasonal and yearly differences from variable climatic patterns (eg wet and dry years).

The overall design of the water quality monitoring program developed by the EPA followed a similar approach that has been widely used elsewhere in the world since the 1970s. However, it was only since the 1990–2000s that greater attention has been made by many of the more developed countries, to include assessments of non-point diffuse sources of pollution and measures of biological condition and habitat degradation, into a wider monitoring framework that attempts to address all sources of human disturbance to water resources.

## 2.3 Some problems with the traditional water quality design

There have been many critiques of the design and relevance of water quality based MERPs carried out by government agencies and research organisations around the world over the past two to three decades (see references cited in Dixon & Chiswell 1996, Ongley & Ordonez 1997).

Despite numerous improvements in terms of design criteria and indicator selection, it appears that most programs continue to collect considerable datasets with little clear information being generated, much less used for management outcomes. There are of course many instances where the collection of baseline data on water chemistry, microbial levels or some other physical or biological measure from a specific area or ecosystem has been an important input for the success of other projects and studies. However, this opportunistic use of data does not justify the collection of data that populate databases and are occasionally made available to the public via web portals.

Interestingly, the US EPA and US Geological Survey websites report on several reviews of water monitoring during the 1990–2000s[4] that concluded the following:

- The US EPA and states cannot make statistically valid inferences about water quality and lack the basic data to support management decisions.
- Improved water quality monitoring information is necessary to help the states make more effective use of limited resources.
- There is inadequate data for national reporting on freshwater, coastal and ocean water quality indicators.
- There is no way to develop a national picture of water quality.

Many of these critical comments about traditional water quality monitoring could also apply to the data that have been collected in South Australia. However, most of the data collected so far has in fact helped form our understanding of the condition of different waters, its variability and the likely risks to the environmental values associated with them. But the program needed to be broadened out from its focus on essentially providing baseline data on a range of water quality (chemistry) measurements and redirected to provide an objective source of information to answer specific, clearly defined questions that will support the management and eventual wise use of our waterways.

In response to these reviews the US EPA has pursued a more rigorous environmental monitoring and assessment program (EMAP) that promotes a consistent approach to the ecological assessment of waters in the US[5]. There is also supporting documentation to assist states develop water and biological monitoring programs, including statistical and design support tools, and a format for assessing and reporting on the ecological health of the nation's waters on a revolving four-year cycle. Considerable resources are being devoted to the application of random probability designs to sample wadable streams, lakes, estuaries and coastal habitats, and scaling the results across the entire population of

4 Intergovernmental Task Force on Monitoring Water Quality 1995; General Accounting Office 2000; National Research Council 2001; National Academy of Public Administration 2002; Heinz Centre Report 2002; State of Environment Report 2003.

5 See <www.epa.gov/emap>.

these water types to report on the percentage of waters assessed in different condition grades with confidence limits included as a measure of the statistical strength of each assessment.

This is important if there is a requirement to be able to show if the combined effort of water quality policies and improvements to discharges is having a broad, beneficial effect on water quality in a catchment, region or state. This design is also the only way to demonstrate if the effects from diffuse pollution are lessening over time but it will take decades of consistent and comparable data collection to be able to show that widespread changes (ie improvements hopefully) have actually occurred to any ecosystem.

Recent reports from the USA on wadable streams, coastal environments, lakes and wetlands[6] incorporate probability designs and appear to provide large datasets and summaries (eg percentages of monitoring sites in different grades) that will hopefully be useful for management outcomes. However, the link from data collection and reporting and turning this into information for 'wise' management appears to be elusive in this context, despite all the effort placed on sound statistical study designs, sampling multiple indicators and working up multimetric condition indices. While local authorities may use the data to identify the better sites for conservation management and protection and the poorer ones for rehabilitation efforts, the reports do not provide a clear indication of the major issues and solutions to either maintain or improve the condition of sites.

The more traditional water quality data (ie concentrations of stressor substances or toxicants) definitely provide useful measures that should contribute towards describing and characterising different waters. However, the reliance on water quality indicators for the purpose of assessing ecosystem condition is fraught with potential error, over-interpretation and misinformation. It is only one line of evidence that should be considered along with other assessment approaches in describing aquatic ecosystems.

This concern was made clear in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). The guidelines include statements that they 'are not sufficient in themselves to protect ecosystem integrity; they must be used in the context of local environmental conditions and other important environmental factors, for example, habitat, flow and recruitment' (pg 3, 1–1) and 'the guidelines for water quality management …are therefore a necessary but only partially sufficient tool for aquatic ecosystem management or rehabilitation' (pg 3, 1–2).

Consequently, the revised program by the EPA needed to be capable of describing the likely causes driving any ecosystem condition assessment for different waters, identify risks to specific waters as a result of human disturbance and uses, and help in setting targets for various rehabilitation and restoration projects. There were, however, significant challenges in redesigning/refocusing the previous water quality MERP into an aquatic ecosystem MERP that could deliver these capabilities.

There were no approaches in the published literature that are capable of adequately assessing aquatic ecosystem condition and showing meaningful and timely trends in a way that is directly useful for managing different waters. In part, this has to do with trying to unravel the meaning behind what are often poorly articulated questions and objectives that water monitoring programs are expected to be capable of addressing. It is usually the case that these programs are expected to provide information that is useful in a management context for the benefit of society but invariably they fail due to a number of reasons, such as:

- There is typically a strong reliance on numerical outputs without a clear recognition of the uncertainty associated with any interpretation using such an approach.
- Much of the numerical concentration limits in national guidelines are often misused and treated as standards and thresholds that should not to be exceeded. In fact they are supposed to be trigger values that if exceeded should indicate a potential environmental problem exists and promote or 'trigger' a management response (eg further investigations to determine whether the local environmental values are being impacted or not). The values

6 See <www.epa.gov/owow/monitoring/reporting.html>.

themselves simply provide a level of certainty that there should be no significant impact on environmental values for a waterbody if the guidelines are achieved.

Another problem lies in attempting to show environmentally significant ‘trends’ that can be informative and useful for management purposes, using the currently available statistical packages for trend detection in water quality data. For example, a detailed analysis of the ambient monitoring data collected from South Australia from 1994 to 2007 showed no clear trend because there is too much noise introduced by seasonal and yearly climatic variation to indicate whether any particular water quality parameter is clearly increasing or decreasing over time (T Corbin & C Jenkins, EPA unpublished data 2012). Analyses of trends using 3, 5 or 10 years or more of data, yielded conflicting patterns, largely because the sample size increased over time, making any interpretation of the data suspect and of limited value for actually managing waters in the state.

Furthermore, there is also an obvious problem with the underlying scientific hypothesis that trending software is typically based on, namely that there is no trend. This argument may be reasonable for largely stable, predictable environments when a linear trend is expected but is clearly problematical wherever environmental conditions are naturally highly variable and so different from one another that trends are unlikely to occur (McBride 2002); the latter generally applies to most South Australian inland waters.

There are also issues with the sources and magnitude of errors eg sampling, analytical (laboratory generated), associated with each individual water quality parameter that present additional problems when trying to interpret the outputs from the statistical trending of water quality data.

Finally, it is also important to note that the results from previous water quality assessments should be continually revised and updated as new information becomes available. This includes reviewing the assumptions behind previous assessments to ensure any information generated in the past remains relevant over time. For example, the current national water quality guidelines for south central Australia (ANZECC & ARMCANZ 2000) used data from 15 streams across South Australia to generate trigger values for physical and chemical stressors in relation to slightly disturbed ecosystems. However, on reflection the majority of sites were impacted by agriculture and the statistical distribution method used to define trigger values was unduly influenced by two large, turbid streams, meaning that the values listed in the national guidelines are too high to be representative of, or protective of, most unmodified or slightly modified streams.

Similarly, work undertaken by the EPA (Gaylard 2005 and 2009) and Primary Industries and Resources SA (Bryars *et al* 2003) have shown that even when nutrient concentrations are well below the south central Australian estuarine and marine trigger values, significant harm to seagrass systems can occur. The means that the nutrient criteria are likely to be far higher than appropriate for the majority of the State’s coastal waters.

## 2.4 What outcomes are expected from aquatic ecosystem MERPs

A review of the vast literature on aquatic ecosystem MERPs has shown that their key purpose can generally be summarised into at least one of the following:

1. To assess ecosystem state (or condition) – a spatially explicit concept.
2. To assess any (statistically) significant trends in condition (can be defined spatially and/or temporally)
3. To characterise and rank existing and emerging problems (can be pollutants and/or other environmental stressors)
4. To design and implement projects (ie largely specific studies aimed at filling knowledge gaps and research studies that use hypothesis testing or pattern analyses).
5. To respond to emergencies (largely to collect evidence and assist with clean-ups using spatially and temporally based sampling).

All of these reasons are typically elements that are incorporated into state-based water quality monitoring programs carried out by EPAs, environment departments and/or water authorities around the world. Not surprisingly, these reasons align fairly well with the expectations of the EPA, as outlined in section 2.1 but there are differences in wording that can lead to different interpretations and ultimately affect the final design of monitoring programs. For example, clause 112 of the EP Act requires an assessment of the condition of ‘major’ resources, which could be interpreted to mean human-use drinking water catchments, the largest waterbodies in each region, or take on a broader meaning to include the major types of waterbodies in the state (eg inland, groundwater, estuarine, and coastal waters). The latter interpretation has been used in the revised monitoring program because it recognises the water categories already used in the *Environment Protection (Water Quality) Policy 2003* and the national water quality guidelines (ANZECC & ARMCANZ 2000). This approach also recognises the dual importance of protecting aquatic ecosystems in addition to protecting human values and uses of waters, and ensures a statewide focus for monitoring programs in the future.

The South Australian legislation requires the identification of significant trends in environmental quality. There is no specification in terms of the meaning behind the word ‘significant’ and this can mean either ‘statistically significant’ or ‘environmentally significant’. The EPA considers the latter to be of greater relevance, provided that there is some measure of confidence in the assessment. The generality in the wording of the legislation allows a broad interpretation of environmental quality that can encompass weight of evidence, multi-indicator condition assessments as the preferred way of demonstrating environmental quality. Repeated measurements of these condition assessments will show whether there are any obvious trends (changes) occurring to the overall condition of sites and regions over time.

This approach is in contrast to traditional statistical trending that attempts to show a certain prescribed level of change in a single variable over time, and using similar trending results from other variables to infer changes in overall condition over time. As already discussed, the high variability among existing data from a range of waters in SA requires a new way of considering and reporting on trends that does not rely on currently available statistical analyses.

The other key purposes of monitoring such as responding to spills and the identification of emerging problems and issues are important elements of the monitoring and evaluation, regulation and enforcement roles carried out by the EPA. For example, the Water Quality Branch conduct a range of studies aimed at providing baselines for different waters, filling knowledge gaps, assessing risks from potential contaminants, and also investigates the environmental effects from discharges and spills to receiving waters.

# 3 International and interstate advances with water monitoring programs

## 3.1 Useful directions by other aquatic ecosystem MERPs

### United States

The US EPA has focused recent attention on designing new monitoring programs that will provide statistically valid assessments of the conditions in both monitored and unmonitored waters, and document the confidence limits for each assessment. This is expected to provide decision-makers in the US EPA, and others with an interest in water quality, with the following information:

- reliable assessments of water quality for all water types assessed throughout the country
- lists of impaired waters based on accurate study designs
- appropriate data to be used for establishing ambient water quality guidelines in national and state reporting and regulation actions by the US EPA.

The US EPA recommend that a regular review of the data being generated by the new programs is carried out every 2–5 years, to ensure that relevant data is being collected and that information that contributes to management understanding and action (where needed) is being made available to the relevant decision-makers.

The principal driver behind this work is to provide the underlying data needed to support the objective of the US Federal *Water Pollution Control Act* or *Clean Water Act, 1972* (CWA)[7] to 'restore and maintain the chemical, physical and biological integrity of the Nation's waters'. This legislation established an interim goal for the protection and propagation of fish, shellfish, and wildlife, and this has been traditionally interpreted by the US EPA to include the protection of the entire aquatic community (Davies & Jackson 2006).

This approach has been used by different states in the US in setting water quality goals to protect designated 'aquatic-life uses' (ALU) that have been assigned for each waterbody. For example, ALUs may include protecting the spawning habitat of salmon or recreational fishing habits and uses, or account for highly modified systems by designating a concrete channelised stream as a water conveyance. However, there is no consistent approach used across the country to determine biological condition and set ALUs, and this has limited the ability to report on the condition of the nation's waters (Davies & Jackson 2006).

Two studies from the USA, identified during the review of the world literature on water monitoring, provide logical approaches that could be modified and used as part of the design for the aquatic ecosystem MERPs in South Australia. Davies & Jackson (2006) introduced the biological condition gradient as a way of describing how 10 important ecological attributes change with increasing levels of stressors and/or disturbance. This descriptive model represents aspects of biological condition that are common to probably all current assessment methods, and can provide a consistent way of reporting the results to the public. The gradient can be calibrated and customised to specific regions and divided into ratings or tiers (usually from 4–6) of differing biological condition. This model is being tested and applied to various states in the USA and has been adopted as an assessment and reporting tool for the water monitoring program in South Australia (eg streams and coastal waters, with future work to be applied to wetlands and estuaries).

Bryce *et al* (1999) describes the application of a relative risk assessment to place sample sites along a human disturbance gradient using existing maps and databases of selected stressors at the riparian and catchment scale. This approach has been modified to include stressors relevant to the South Australian setting, and used for the inland waters

[7] US Code title 33, sections 1251–387.

program as a coarse first-tier risk characterisation of the likely site or subcatchment condition based on a range of landuse, geographical and other existing measurements and data.

### European Union

The other major change in water monitoring is occurring in Europe following the establishment of the European Water Framework Directive (WFD 2000/60/EC) in 2000 that provides a legal framework for the protection and restoration of clean water across Europe, ensuring its long-term, sustainable use[8]. Member countries have to ensure that a co-ordinated approach adopted to achieve the WFD objectives and implement programs of measures for that purpose. The scope of the directive is very broad and relates to water quality in rivers, lakes, canals, groundwater, transitional (estuarine) waters and coastal waters out to at least one nautical mile from the shoreline.

The fundamental objective of the WFD is to maintain the ‘high status’ of waters where it exists, preventing any deterioration in the existing status of waters, and achieving at least ‘good status’ in relation to the ecological status of all waters by 2015. Significantly, the importance of protecting and enhancing the status of aquatic ecosystems (and terrestrial ecosystems and associated wetlands) has been recognised by its inclusion in the first objective of the WFD. The actual assessment of the ecological status of waterbodies is to be based on their classification into one of five categories using data from a prioritised (and comprehensive) list of biological, chemical, physical and hydro-morphological elements[9].

The protection of unique and valuable habitats, drinking water resources and bathing waters are to be recognised as important water quality objectives within the framework but they will only be applied to specific bodies of water. They will not apply to all waters as for the aquatic ecosystem objective. The WFD also includes a number of important concepts such as basing assessments against a comparison with reference (ie least disturbed, best possible) conditions, allowing only a slight departure from reference as a result of minimal anthropogenic impacts and applying the precautionary principle to environmental protection assessments and actions.

The WFD states that existing monitoring programs must be adapted to meet the needs and goals of the directive by December 2006[10] and measures for achieving environmental objectives by 2009. Three types of monitoring were specified in the directive including long-term surveillance monitoring for broad trend assessments, operational monitoring to track the effectiveness of interventions designed to improve condition, and investigative monitoring to provide more detailed information about specific waterbodies. However, no methods have been specified and it is up to all member states to decide on the approaches to be used in assessing the health of their surface waters and groundwater.

According to its website, as of March 2008[10], 26 of the 27 member states had provided an overview of their monitoring programs and more than 54,000 surface water stations (comprising 24,000 for surveillance monitoring, 40,000 for operational monitoring, and 12,000 common to both) and more than 51,000 groundwater stations were being monitored and assessed. The same website also stated that some problems remain unresolved in terms of monitoring all of the essential biological parameters (phytoplankton, other aquatic flora including diatoms, benthic invertebrates, fish) and adequately describing the decisions used in designing their new monitoring programs.

### Interstate

There are many similarities between the American CWA, European WDF and Australian National Water Quality Management Strategy developed in Australia and New Zealand (ANZECC & ARMCANZ 2000) in terms of raising the importance of biological measures in condition assessments, setting water quality objectives for different waters, and assessing condition (eg health or status) against agreed environmental values for each waterbody. The language varies

8 See <http://ec.europa.eu/environment/water/water-framework/objectives/index_en.htm>.

9 See text and references in <http://ec.europa.eu/environment/water/water-framework/objectives/index_en.htm>.

10 <http://ec.europa.eu/environment/water/water-framework/pdf/water_note6_monitoring_programmes.pdf>.

across these countries and among their legislative tools but the essential interpretation appears to be comparable between the agencies that have taken responsibility for implementing each respective approach.

In Australia, most states and territories are currently in the process of designating environmental values to specific waters or are planning strategies to roll-out this approach in the near future. This will provide a logical framework for defining the boundaries of each relevant waterbody, setting water quality objectives, identifying natural and human-induced factors affecting each ecosystem, and establishing monitoring and assessment programs to report against the success or otherwise in meeting the designated environmental values for different waters.

The national guidelines also promote the use of decision trees and trigger values to assess the risks to waters, which leads to condition assessments based on measures of actual or likely potential harm. Previously, measures of potential environmental hazard based on numerical values from national guidelines had been used in Australia (ANZECC & ARMCANZ 2000).

Currently, there are a range of different water monitoring approaches to assess the water quality and ecological condition of waters. Most water quality monitoring programs use a similar formula of monthly or quarterly sampling or carry out a short-term opportunistic campaign, collecting data from a suite of parameters and comparing values against those included in the national water quality guidelines for either ambient waters (eg nutrients, physical and chemical modifiers) or chemical toxicants that are based on laboratory eco-toxicology effects data.

The ecosystem condition program typically uses multiple indicators as condition measures and include: different variations of the index of stream condition (Victoria, Tasmania); pressure–vector–response stream and estuary program (Queensland); sustainable rivers audit (Murray–Darling Basin Commission and partner states in Queensland, New South Wales, Victoria and South Australia); freshwater, estuarine and marine ecosystem health monitoring program (EHMP in South East Queensland); and a myriad of other methods trialled in catchments and regions for a range of different outcomes and reasons.

The Australian River Assessment System (AUSRIVAS) provides a national bio-assessment of stream health that was initiated throughout Australia in 1994 and new models continue to be worked on to try to improve the outputs using this method (eg Victoria, NSW and Queensland). In marine waters, the Reef Life Survey (RLS) aims to assess biological and habitat condition of rocky reef environments throughout temperate Australia using scientifically trained volunteer divers. This program is relatively new but has received good participation throughout the southern states.

The Federal Government is also promoting different monitoring and evaluation indicators and protocols to assist with natural resource management across the country and the National Water Initiative has promoted complementary tools such as the Framework for Assessment of River and Wetland Health (FARWH). It is important to note that the intent of this summary is not to include all methods currently in use nor to critically analyse existing approaches, only to state that a range of methods are in use in Australia (and elsewhere) and that no one approach has been adopted widely in terms of water monitoring designs.

Most ecosystem condition work incorporates some measure of catchment landuse, geomorphic, hydrological, riparian, water chemistry, sediment and biotic elements into an assessment framework, that are expected to provide meaningful and interpretable information that can assist in the ‘wise’ management of our waters. They also rely on an understanding of the linkages between scales whereby some broad catchment processes interact and influence what happens at the local scale. Similarly, there are also interactions between the plants and animals, water, sediments and the surrounding landscape that contribute to the condition or state of any waterbody.

The key relationships between the living and non-living parts of the environment are usually summarised in picture form as conceptual models that show the linkages and interactions, and help ensure the major parts of the environment are considered in designing a condition assessment program. Some programs describe these conceptual models in detail whereas others invariably use the same logic but may not prepare finished models for use as communication tools. The revised aquatic ecosystem MERP provides a description of the major processes and components of each water-type in conceptual diagrams, and outlines the reasons why specific indicators have been included in the design of each program.

It is important to note that there are only five major ways of turning environmental data into information from condition assessments:

- comparison against national guidelines
- comparison against reference sites
- testing against a model of the ecosystem
- testing against a disturbance gradient
- use expert rules to rank or rate sampled sites.

Most current methods tend to use several of these elements in the design of water monitoring and assessment programs, particularly incorporating the use of local reference sites (ie least disturbed, best condition examples from an area) and comparisons against national water quality guidelines in determining the condition rating of site data. The Sustainable Rivers Audit and SE Queensland EHMP also use independent panels of scientists and apply expert rules to weight what are considered to be the most important measures, to decide on the final condition ratings for monitored data. An important design component of the SE Queensland program also involves selecting only the most sensitive indicators that respond to a land clearance disturbance gradient. These approaches all attempt to use a science-based logic path to turn measured data into a condition score that can be readily understood by others.

The EPA aquatic ecosystem MERP, wherever possible, incorporates all five elements as part of its design.

## 3.2 What are the important questions we need to ask

A recurring message from the numerous publications that describe how to set up water monitoring programs is the need to have well defined questions and objectives clearly articulated and agreed prior to starting any data collection program. The questions need to provide sufficient detail to assist in scoping out the design of the monitoring program (eg what and where to measure, how often, how data will be assessed and reported, how frequently data should be processed and analysed) otherwise there may be surprises when attempting to use poorly targeted data to answer vague questions.

For example, the following questions have often been raised in the course of setting up an aquatic ecosystem MERP, irrespective of the purpose (eg describing ambient conditions, investigative or compliance monitoring):

1. What is the condition of surface, ground, estuarine, and near coastal waters?
2. Where, how and why are water quality conditions changing over time?
3. Where are the problems related to water quality and what is causing or responsible for these problems?
4. Are water quality goals, objectives and environmental values being met in all waters?
5. Are intervention and remediation programs aimed at addressing water quality problems working effectively and improving the condition/state?
6. What is the spatial and temporal impact (ie environmental harm) from spills and discharges to the environment that may result in prosecution or some other form of enforcement action?

All of these questions require further clarification because they do not provide:

- Any indication of the scale of assessments both spatially and temporally (eg are all waters of a predetermined size to be included in the study design, what is the sample unit to be assessed and reported, and should data be assessed annually, or every 5 years, 10 years or more?).
- A clear description of what is meant by the term ‘condition’ (eg does it refer to the water quality, habitat and ecosystem health or all of these elements?).

- A framework to define the essential choices that will be involved in making the condition assessments such as:

    1. What measures should be used.
    2. How many samples will be required.
    3. What criteria to use in assigning environmental significance to data obtained during sampling.
    4. Should assessments use classical null-hypothesis based significance testing with associated power calculations to make scientific inferences about the data or should assessments avoid significance tests and simply report condition and document the confidence intervals as an alternative indication of effect size, precision and statistical significance (Newman 2008).
    5. Should comparisons be compared to national guidelines or based on comparison against local reference sites.
    6. How should the condition of sites be assessed against what is likely to be some form of human disturbance gradient, while accounting for natural disturbance.

Questions 1 and 2 are related to ambient monitoring programs that aim to describe and define the condition of environments and attempt to show any important changes that occur over time. Any monitoring design attempting to achieve these objectives would need to be able to distinguish patterns relating to human disturbance from the effects of natural variability.

Question 3 relates to identifying the source of water quality impacts and whether environmental harm is occurring or likely to occur in the future. This work would typically be pursued as a follow-up source identification study arising from the ambient monitoring program. It could include further biological assessments to confirm the spatial extent of any impact and direct toxicity assessments or in-situ experiments with sensitive organisms to provide a measure of risk to aquatic ecosystems.

The last three questions (4, 5 and 6) all relate to assessing management outcomes at different scales. At a broad scale the environmental values provide a whole ecosystem focus for assessment, whereas the intervention, remediation and investigation studies provide finer scale site-based assessments. The management needs from these questions largely relate to policy and planning, regulatory controls, strategic investment planning for natural resource management and priority setting, public relations, and may also contribute in some cases towards national obligations (eg implementing the national water quality management strategy).

# 4 The new aquatic ecosystems MERP for South Australia

## 4.1 Concepts

After reviewing the scope and expected outcomes from many of the water monitoring programs currently in place around the world, elsewhere in Australia, and the program conducted in South Australia from 1994–2007, it was clear that major changes needed to be made to ensure that future data and assessments actually provides useful information on the condition and trends of waters in South Australia.

The focus of the new program is the direct measurement of important biological groups and related indicators of condition and risk rather than the use of chemical surrogates as in most monitoring programs (Cullen 1990). This is consistent with the risk-based approach of the national water quality management strategy (ANZECC & ARMCANZ 2000) and the recent revision of the sediment quality guidelines (Simpson & Batley 2007).

Data from chemical and physical measurements are still collected but is only expected to provide supporting information to help identify and assess the risks of potential impacts from human actions in the landscape. Where additional chemical risks have been defined or emerging issues identified, targeted studies will be undertaken to better understand the issues and risks.

In the past chemical and physical data were used to infer condition by comparison against the numerical values listed in the national guidelines for toxicants and nutrient and other physical data for waters in south-central Australia (ANZECC & ARMCANZ 2000). Complementary biological programs have already been incorporated into most traditional water quality monitoring programs in SA (eg benthic macroinvertebrates for streams, seagrasses and reef health assessments for coastal waters) but this work has generally been viewed as supporting information rather than the most critical work to demonstrate whether adverse effects are actually occurring to our waters—addressing concerns about adverse effects actually occurring rather than just recording whether a particular water quality parameter is high and may pose a risk of causing an adverse effect.

This shift in thinking is not new since Karr (1996, 2006) has promoted the importance of maintaining the biological integrity of waters for many years, largely as an attempt to interpret the wording of the CWA legislation in the USA. Biological integrity was defined by Karr (1996) as the ability to support and maintain a balanced, integrated, adaptive biological system having the full suite of genes, species and assemblages and processes (eg mutation, demography, biotic interactions, and nutrient and energy dynamics) expected in the natural habitat of a region. This point is important because Karr considered that biological integrity implied an unimpaired condition, or the quality or state of being complete or unaffected by human activities. These issues have been and continue to be widely discussed and debated in the scientific literature but most authors invariably accept Karr's definition and its scope because it captures all the essential information related to the ecological condition, state or health of an ecosystem.

While the intention in the European Union's WDF involves monitoring and assessing phytoplankton, diatoms, macrophytes, fish and invertebrates, this approach would be unrealistic for SA to pursue as it would dilute limited resources, take many years to work out methods and expertise for all groups, and divert attention away from the condition assessments that we believe are possible to develop using existing capabilities. Instead, we will continue to expand and improve the use of existing bio-monitoring approaches that are sensitive to the landuse changes and impacts from human development in the South Australian landscape.

## 4.2 Landuse modifications and problems with applying the unimpacted reference state concept

It is important to recognise that for South Australian streams, lakes and wetlands, estuaries and some coastal environments and groundwater systems, the effects of European settlement (eg widespread vegetation clearance, grazing and cropping practices; urban settlements and associated industry developments; impoundments and dams; aquaculture) since 1836 have produced such profound changes that possibly no truly pristine (ie unimpacted) environments remain anywhere in the state. Even our national parks have been invaded by pest plants and animals which alters community composition and can lower any resulting condition assessment (eg introduced snails, trout and marron in Deep Creek National Park on the Fleurieu Peninsula; marron and feral pigs in Flinders Chase National Park on Kangaroo Island; and feral goats, stock and introduced mosquitofish in the Flinders Ranges and Far North).

The nearshore marine environments are not immune to widespread degradation either. The old adage that ‘dilution is the solution to pollution’ has often been used historically to allow the disposal of vast quantities of pollution into our coastal ecosystems. Nitrogen discharges from sewage treatment plants, industry and runoff from largely changed landscapes has resulted in the loss of over 9,000 ha of seagrass in Gulf St Vincent (Bryars *et al* 2008). While there are possibly some truly unimpacted marine areas remaining, it is likely that where coastal development has altered the landscape, the marine environment is likely to have also been affected.

Extensive land clearance and agricultural activity have also impacted on the quality and quantity of groundwater that is available for use. In the South East for example, agricultural practices have lead to extensive nitrate contamination throughout the unconfined aquifer (eg Schmidt *et al* 1996, Lawson & Stadter 2004). This diffuse contamination poses a threat to the long-term use of the groundwater as a water resource, as well as likely effects on groundwater (dependent) ecosystems. Development has the potential to impact on groundwater, with point source pollution limiting possible future uses by changing the chemical and biological composition of an aquifer.

Nutrient enrichment from human activities is a problem affecting inland and coastal waters throughout the world, so it is hardly surprising that most waters in South Australia show evidence of excessive levels of nitrogen, phosphorus, and in some cases carbon. This includes large growths of green and brown filamentous algae, phytoplankton blooms or dense growths of other types of aquatic plants, and aquatic communities dominated by pollution-tolerant plants and animals that thrive in nutrient enriched waters. Consequently, all programs will focus on assessing nutrient status and risks because that is the most obvious threat to the condition of waters in South Australia, and has already been highlighted as a widespread issue from the monitoring and studies carried out by the EPA in the past.

Other issues such as metal, hydrocarbon, pesticide, other organic contamination tend to be localised and confined near point source discharges, and will continue to be assessed as part of ongoing audits and snapshots to ensure the area impacted by such chemicals is documented and does not increase over time. Recent work by the EPA on metals and organic contaminants in mussels and fish has not shown widespread contamination and does not support their inclusion in future monitoring programs, other than as part of local and special interest studies (Gaylard *et al* 2011 and P Goonan, EPA unpublished data 2012).

## 4.3 Principles for a revised MERP

The following broad principles are used, wherever possible, as part of the underlying logic that underpins the design of the monitoring, evaluation and reporting program for aquatic ecosystems in South Australia.

1. An expectation that no further degradation of the condition of the state’s waters should occur, apart from the effects from natural events such as drought, flood, ocean upwelling and fire.
2. All waters that are assessed below ‘Good’ condition (eg sites assigned to any of the three worst of six possible ratings) will be identified and issues that need addressing to improve their condition will be documented. This will promote future interventions that should aim to either improve the condition of affected waters or, if not, meet agreed environmental values that have been endorsed by the wider community.
3. All assessments of condition should include, where possible, comparisons against nearby least impacted or best condition reference conditions and an assessment of major risk factors that have the potential to degrade biological communities.
4. All assessments should focus on biological features and indicators because they provide a direct assessment of ecosystem health and condition. The focus of assessment is a relatively new science, with methods and indicators still to be developed. Indirect measures of condition such as chemical and physical monitoring should still be included because this provides another line of evidence in support of each condition

assessment. While ecosystem protection will form the cornerstone for the monitoring design, human health, irrigation and recreational enjoyment should also be recognised as important environmental values for some waters (eg potable water catchments and groundwater supplies, coastal recreation).

5 The accurate identification of adversely impacted waters is a critical part of the design of any monitoring and assessment program. The design should attempt to limit assigning sites as unimpacted when in fact they are adversely impacted (called Type 2 errors relating to false negatives) by some level of human disturbance. This compares to most programs that attempt to minimise false positive assessments of no effect when there is one (called Type 1 errors). This issue relates to basic study design features and the underlying philosophy used to statistically analyse and interpret data. Since the EPA is concerned with adopting a precautionary approach to environment protection actions, it is important to accurately identify all impacted waters and will rely on a multiple lines of evidence approach and tiered assessments to describe the condition and risks relating to sites and different waterbodies.

6 Levels of statistical precision and confidence should be appropriate to the MERP objectives and type of data collected, and all confidence intervals for relevant measures will be reported, wherever possible, with any write-up of data collected as part of the future monitoring program.

7 Data will generally be reported against a human disturbance gradient to allow a clear interpretation of impact and likely sources. Impacts as a result of climate changes and natural events will also be described by using local reference sites as a comparative basis for separating effects as a result of natural versus human disturbances to the environment.

8 Rolling regional sampling programs will be incorporated to ensure that each region of the state is comprehensively sampled at least once in every five years as part of the state of environment reporting cycle. The design of all water monitoring programs will include different levels or tiers of assessments and will generally include some sort of broad risk characterisation at a large spatial scale and finer site-based statistical and targeted surveys. This approach should also include additional relevant and comparable data collected by other organisations (eg NRM boards, DEWNR, SA Water Corporation and SARDI) wherever possible.

9 There should be a regular review of the aquatic ecosystem MERP to ensure appropriate data and information is being generated using the funds that are invested in the program. This review will be carried out after the completion of the first series of regional assessments in 2013–14, and the findings will subsequently be published on the EPA website.

## 4.4 Design elements

### 4.4.1 Tiered assessment approach

The new monitoring program follows a tiered, decision-tree approach that incorporates multiple lines of evidence (ie weight of evidence) to support the assessment as to whether sites are or are not affected, or at risk of being adversely impacted, by some sort of human disturbance that affects water quality and aquatic ecosystem health.

The following levels of assessment will be generally be considered and assessed for each water-type to be monitored:

**Tier 1:** A broad, desk-based, hazard and risk assessment of human disturbances, taking into account likelihood and consequence of impacts for all waters in a region based on landuse, climatic and topographic data, locations of point sources of pollution, and historical data. This will identify any major issues of concern and provide an indication of the likely biological condition of different waters. The results will be used to validate and test that the conceptual model for each water-type captures the major processes and components of the ecosystem, and ensure all relevant indicators of condition and risk are included in any site-based assessment conducted as part of more detailed investigations.

**Tier 2:** A field-based assessment of a subset of Tier 1 sites in a region that may incorporate a random probability design component to characterise the status of a water-type, and sampling a subset of previously identified highest and poorest quality sites to be able to show if changes coincide with major climatic changes in the landscape, or if other regional patterns are evident in the data collected. This work will assess the biological condition of both sites and a water-type in a region, and identify risks and likely causes that require either further evaluation or intervention actions.

**Tier 3:** A more detailed source identification component may follow on from any unexpected Tier 2 results to confirm impacts are real, document the spatial area affected and identify the source of any disturbance to the condition of sites in a region. This may involve field and/or laboratory studies (eg ‘mesocosm’ experiments or ecotoxicological analyses) in addition to further detailed chemical analyses of water, sediment or biotic samples to confirm whether contaminants are accumulating and/or causing effects in the environment. The results would help to inform whether there was any need for management intervention, particularly if the impact threatened the environmental values of specific waters in the State.

### 4.4.2 Aquatic ecosystem condition reporting

Aquatic ecosystem condition will generally be reported on a 6-level rating scale:

1 Excellent

2 Very Good

3 Good

4 Fair

5 Poor

6 Very Poor

This rating system will be applied to different waterbody categories:.

**Creeks, lakes, wetlands and estuaries:** Condition grades will be derived and reported using the biological condition gradient approach (Davies & Jackson 2006) for the streams, lakes and wetlands, and estuaries components of the sub-program. The results for these waters will be reported as one of possibly six condition ratings, depending on the variability of results in a region, with ‘Excellent’ representing natural (or undisturbed) conditions and ’Very Poor‘ representing severely altered conditions.

**Nearshore marine waters**: The nearshore marine waters sub-program will use a different approach to convert measured data into a similar scoring system to infer site condition. This difference is largely because of the limited understanding of the variability, sensitivity and important thresholds of many of the new measurements that are being included in the coastal program. Despite this, the program will focus on being able to show the major effects from nutrient enrichment on seagrasses and related light[11] climate of our nearshore coastal waters.

Discrete categories for each indicator have been defined by assessing the variability and statistical distribution of historical data and using expert opinion to evaluate the differences between sites from low and high risk waters. The measured data will be converted into an index of condition, using upper and lower thresholds for specific indicators that have been set using data taken from known impacted and pristine locations. Six condition ratings are expected to be reported, with ’Excellent‘ representing an unimpacted state and ’Very Poor‘ a heavily impacted state.

**Groundwaters**: The groundwater sub-program will involve a landuse risk characterisation component and an assessment of chemical concentrations (eg nutrients, pesticides) followed by a comparison against the trigger values in the national guidelines (ANZECC & ARMCANZ 2000). The results will be reported as probable condition grades using arbitrary statistical distributions of the data but will also require additional follow-up work for any unexpected results and poor results, to ensure the assessments represent the expected ‘real’ condition of monitored bores and wells.

[11] The amount of light penetration into the water.

This additional work will probably include some comparison of biological processes occurring in selected groundwaters against similar measurements in nearby unimpacted groundwaters to provide a measure of the magnitude of any disturbance on the major biological community that exists in underground waters. Further work using traditional ecotoxicological methods may also be used to confirm whether the presence of chemicals causes adverse effects based on a laboratory risk-assessment approach.

### Design details for the different water-types in South Australia

The logic and methods used to assess the condition of and risks to nearshore marine waters, creeks, lakes and wetlands, estuaries and groundwater will be outlined in separate reports (in preparation) associated with each of these water categories. They will provide additional information about the indicators to be measured and assessed, sites and regions, frequency of assessment, and data analysis methods for each water-type.

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# 6 Glossary

**Ambient:** an adjective that means surrounding, completely enveloping, encompassing. In terms of ambient water quality it generally refers to the environment not immediately impacted by a point source discharge. This mean it is possible to describe the ambient water quality in a national park, broad-scale agricultural setting or even some urban catchments, but not immediately downstream from an industry discharge point or pipe.

**Condition**: refers to the state in which things exist and can be quantified as a quality or rank. The term relies on defining the criteria to rate different states or levels of assessment in the case of water quality indicators.

**Diffuse pollution**: typically refers to non-point source pollutants that run off or seep into waterways from broad areas of land such as agriculture or urban settings, as well as dispersal from airborne pollutant sources. Non-point sources are generally the largest contributors to water pollution at the catchment scale.

**Macroinvertebrate**: an animal without a backbone (ie an invertebrate) that is large enough to be seen by the naked eye (eg snails, yabbies, worms, and insects such as waterbugs, midges and mayflies).

**Rating:** refers to the condition classification or grade. This is intended as a simple communication tool, to summarise the relative condition in a single, simple to understand phrase.

**Point source pollution**: refers to the entry of pollutants from well-defined locations, such as a pipe or sewer outflow. Industrial factories, sewage treatment plants, and stormwater outflow pipes are common point sources of water pollution.

**Reference**: a benchmark that is typically used as a comparison of a state or condition against a natural, unaffected, preferred or desired state or range of states.

**Spatial**: an adjective that refers to the nature of space, size, area or position.

**State:** another term for condition, stage, rank or circumstances at any time.

**Sub-program:** refers to the monitoring and assessment activities relating to different South Australian water types—coastal, creeks, lakes and wetlands, groundwaters and estuaries.

**Temporal**: an adjective that refers to the timeframe(s) over which monitoring and reporting occurs.

**Trend**: refers to change with respect to time. This has typically been interpreted and assessed using standard statistical analyses which rely on showing a linear relationship between an indicator and time. There are a number of assumptions that need to be considered when using different statistical approaches, and in many cases it is arguable whether they are appropriate for highly variable water quality data. An increasing or decreasing linear trend in individual water quality parameters is of limited value in the context of assessing ecosystem status. With regard to the South Australian aquatic ecosystems MERP, changes in condition over time will be used to show trends in environmental quality for different waters in the State.

**Water**: refers to all waters including inland, groundwater, estuaries and marine waters.

**Water quality**: In view of the complexity of factors and the large choice of variables used to describe the status of water bodies in quantitative terms, it is difficult to provide a simple definition of water quality. For the purposes of the EPA, water quality is a technical term that refers to the suitability of water to sustain various uses and processes. It is typically thought of and described in terms of the biological, physical and chemical properties of an aquatic environment.