

The Framework for Marine and Estuarine Water Quality Protection:

A Reference Document

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2. Background and Purpose

Land-based impacts on the marine and estuarine environment

It is estimated that some 80 percent of coastal and marine water quality impairment world-wide is caused by broad scale land use activities (UNEP 1995; Zann 1995). Land-based activities such as urban and industrial and agricultural development can have significant detrimental effects on marine and estuarine environments by contributing suspended sediment, nutrients, pathogens, heavy metals and other pollutants (UNEP 1995; Zann 1995). Some of the adverse effects of land use on the marine environment in Australia can be seen in the Great Barrier Reef World Heritage Area where excessive nutrients, sediments and chemical pollutants are impacting on coral communities and seagrass beds (GBRMPA 2001). Declining water quality in the reef has the potential to affect the reef ecosystems, tourism, recreation and commercial fishing (GBRMPA 2001).

International Programs

The Global Program of Action for the Protection of the Marine Environment from Land-based Activities (GPA) was initiated under the United Nations Environment Programme and is aimed at preventing the degradation of the marine environment from land-based activities at the national and regional levels with coordination at the global level (UNEP 1995). The GPA targets sewage, persistent organic pollutants (POPs), radioactive substances, heavy metals, oils (hydrocarbons), nutrients, sediment, litter and physical alteration of habitats (UNEP 1995). The GPA was adopted in 1995 by 108 governments, including Australia.

Water quality management in Australia

The Commonwealth is committed to protecting Australia's fresh and marine waters through development and implementation the National Water Quality Management Strategy (NWQMS). The key objective of the strategy is:

To achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.

The NWQMS was jointly developed by two Ministerial Councils - the Australian and New Zealand Environment and Conservation Council (ANZECC, now the Environment Protection and Heritage Council, EPHC) and the Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ, now the Natural Resource Management Council, NRMC). The Strategy provides a nationally consistent approach to water quality management, and the information and tools to help water resource managers, planning and management agencies, regulatory agencies and community groups manage and protect their water resources.

The NWQMS consists of some 21 guideline documents which broadly cover – ambient and drinking water quality, monitoring, groundwater, rural land uses and water quality, stormwater, sewerage systems and effluent management for specific industries. Two new publications were released in 2001:

- ◆ *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)* – referred to here as the *Water Quality Guidelines*; and
- ◆ *Australian Guidelines for Water Quality Monitoring and Reporting (2000)*- referred to here as the *Monitoring Guidelines*.

These publications provide a new approach for deriving water quality guidelines, objectives and targets. They provide highly detailed and comprehensive information for water quality monitoring and management in Australia and New Zealand.

To protect the nation's marine environment from the adverse effects of land-based activities, the *Framework for Marine and Estuarine Water Quality Protection* (the Framework) has been developed. The Framework which implements key elements of the National Strategy and provide a nationally consistent approach to coastal water quality protection. In particular, this framework guides development of *Water Quality Improvement Plans* (WQIP) for key coastal waterways ('hotspots'), threatened by pollution.

The Framework focus is environmental protection through the reduction of land-based pollution. The key components of the Framework include identification of:

- the environmental values of those coastal waters (section 4);
- the water quality issues and pollutants of concern (section 5);
- water quality objectives for the coastal waters (section 5);
- the total maximum pollutant loads required to meet the water quality objectives (section 6);
- the allocation of pollutant loads to diffuse and point sources (section 6);
- river flow objectives (section 7)
- management measures and control actions, their time lines and costs (section 8) to protect the designated environmental values and objectives; and
- a monitoring, evaluation and reporting program (section 13).

A stepwise or phased approach can be used to guide setting of interim targets and implementation of management measures and control actions to ensure attainment and maintenance of water quality and river flow objectives over the longer term.

The Commonwealth will give effect to the Framework through Commonwealth-State arrangements for specific coastal waters. It is anticipated that preparation of WQIPs may take up to 18 months.

Purpose

The purpose of this document is to explain the key elements of the Framework and to guide the preparation of WQIPs. Suggested reporting requirements are included to give examples of the information that should be included in a WQIP.

3. Consultation

The respective state environmental protection agency will be responsible for preparing a WQIP. To ensure the plan is consistent with the needs and desires of the community, the plan should be developed in consultation with the community and other relevant stakeholders. A steering committee comprised on agency, industry and conservation interests and may be formed to oversee development and implementation of the plan.

A Stakeholder Consultation Strategy will be required in development of the plan to ensure all stakeholders (including the community) are involved in the planning process. Stakeholders are people and organisations that have an interest in, are affected by or are involved in the development of a WQIP. Stakeholders may have different ideas about the environmental values requiring protection and the consultation processes adopted should aim to obtain input from as many stakeholders as possible. Consultation allows stakeholders to provide information and ideas that may assist in the preparation of the plan

and enhances opportunities for community involvement in plan development and implementation. Stakeholders may include:

- Water managers (councils and water corporations);
- Industry;
- Community (residents, local industry, operators of commercial premises, conservation groups);
- Coordination groups (catchment management committees and trusts);
- Research bodies;
- Land owners;
- Industry representatives;
- Educational institutions, such as schools and universities;
- Local, State/Territory, Commonwealth Government departments and agencies;
- Environmental groups;
- Primary industry, such as Landcare groups, farmers' organisations, irrigation corporations, fishing organisations;
- Tourism industry; and
- Coordination groups, such as catchment management committees and trusts.

Raise awareness of the issues

To maximise input from the consultation process, all stakeholders should understand what they are being asked to do, why it is important, how the process is going to work and how they can provide input to the plan.

Information sessions, meetings, brochures, advertisements and displays can be used to raise awareness of the issues and provide information about the consultative process. Next, input can be sought from the community and other stakeholders on determining environmental values and water quality objectives for the area.

Consultative processes

Stakeholders can be involved through meetings, discussion forums, field trips and surveys. Discussion forums can be held, outlining the purpose and background of the consultation followed by group or open floor discussions led by facilitators and including providing technical input. The views and discussions raised should be recorded. It may be useful to establish a stakeholder advisory committee to bring together all major interests in one forum to discuss ideas, issues and proposals and provide a sounding board.

Where there are a large number of interest groups, mechanisms should be established to canvass all views and provide feedback as the process evolves. The strategy employed should ensure:

- meetings are widely advertised, registration is easy and there is a system in place for delivering background information and agendas to all participants prior to meetings;
- conflict resolution measures such as facilitators are available as required;
- outcomes of meetings such as draft environmental values and water quality targets are accessible to all stakeholders;
- mechanisms are in place for obtaining comment on plans;
- recommendations are put forward from the consultation process (these may include scientific and economic assessments); and
- contact is made and maintained with all stakeholders, including those with strongly opposing views.

Further information can be found in Section 17 on Public Involvement.

4. Waters and catchments of concern

A catchment is the area of land from which a river, lake or estuary gathers its water, including all tributaries and groundwater flows.

All activities, human and natural, occurring within a catchment have the potential to affect the water quality and flow regimes of the receiving waters. Effective catchment management requires adequate information about the catchment and the receiving aquatic ecosystem being protected. Delineating the marine/estuarine waters to which the plan applies and the boundaries of the catchment that contributes to those waters ensures that the key polluting processes and the extent of those processes can be identified.

Reporting Requirements

The WQIP should describe the contributing catchment and water body under the proposed management plan. A map of the receiving waters, contributing catchment, sub catchments and other relevant information (cadastral information, towns, rivers, etc) should be included. These shall be overlain with cadastral information. A Geographic Information System (GIS) generated map should be used to delineate catchment boundaries of the coastal waters. While the WQIP should determine the entire contributing catchment, management actions and projects within a WQIP may be more effective when focussed on individual sub-catchments, therefore relevant sub-catchments should also be detailed in the plan.

5. Environmental Values

Protection of the environmental values of coastal water bodies is fundamental to their protection and management. Environmental values are particular values or beneficial uses of the environment that are important for a healthy ecosystem or for public benefit, welfare safety or health and which require protection from the effects of pollution, waste discharges and deposits (ANZECC & ARMCANZ 2000a). They include those values, which the local community and other stakeholders want to protect and enjoy now and in the future. The *National Water Quality Management Strategy* sets out the following environmental values that may require protection:

- Aquatic ecosystems;
- Primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods);
- Recreation and aesthetics;
- Drinking water;
- Industrial; and
- Cultural and Spiritual values.

No specific water quality guidelines are provided for *industrial water* and *cultural and spiritual values*. These values cover a range of specific uses and should be considered by the community in the planning and management of their water resources.

Environmental values should be determined for all coastal waters and associated segments with a particular water body/segment often holding more than one value. Determination of environmental values should be based on social and economic considerations as well as science, hence a requirement for broad public consultation for their determination. When determining environmental values, the following may require consideration:

1. the types of water uses and activities occurring (e.g. drinking water, agricultural, industrial, ecosystem protection and recreation);
2. the number and location of these uses and activities;

3. any default values, uses or activities (e.g. water bodies in a World Heritage Area or marine park will have the environmental value of *aquatic ecosystem protection* as a minimum and may also have others);
4. the duration of these uses (e.g. *recreation* may apply only at certain times of the year);
5. proposed future uses or activities; and
6. any other environmental, social and economic considerations that may influence the selected environmental values.

Many water bodies will have default environmental values that should not be compromised (Appendix 3). For example, water bodies in National Parks, conservation reserves, World Heritage Areas or those classified as Ramsar wetlands will have the default environmental value of *aquatic ecosystem protection* and in many cases will have others such as *recreation and aesthetics*. In these water bodies, the default environmental value does not exclude the assignment of other environmental values (e.g. *primary industries* - production of aquatic foods for human consumption) but the default value will generally take precedence.

Additionally, any environmental values that are specifically prescribed in state environmental protection policies or other statutory processes should be provided for.

Sources of information

Information about current uses and values can be obtained from local knowledge, surveys, monitoring programs, land tenure maps, scientific reports, environmental protection policies and planning documents. Stakeholder knowledge of recreation patterns and perceptions of the relative naturalness of different sections of waterway can help identify the environmental values of segments of water bodies. Surveys of residential, business and tourism communities will provide information on uses and values of importance to the broader community.

All of the uses proposed as environmental values by the community and other stakeholders should be listed and evaluated to make sure they are uses that require protection from the effects of pollution. Specific uses can then be aligned with the broad environmental values (Table 1).

- Information for setting Environmental Values:**
- Maps
 - Surveys
 - Local knowledge
 - Discussions
 - Reports
 - Planning documents
 - Scientific information
 - Monitoring data

Table 1. Environmental values and some attendant uses. The existing uses of water often provide a strong indication as to the environmental values to be protected.

Environmental values of water	Examples of use
Aquatic ecosystems	Maintenance of aquatic ecosystems Fish breeding and spawning Biodiversity conservation Eco-tourism Aquaculture
Primary industry	Irrigated agriculture Aquaculture Human consumption of aquatic foods Stock drinking water Commercial fishing
Recreation and aesthetics (primary and secondary contact)	Swimming Recreational fishing Boating Visual amenity
Industrial Water	Washing Cooling Processing requirements
Cultural and spiritual	Sacred sites Spiritual use Presence of certain plant and animal communities Traditional use

Stakeholders should be aware that the water quality they desire for a water body may not be immediately achievable. Water quality monitoring (physical, chemical and biological) data can be used to determine the environmental values currently supported by a water body. Monitoring can indicate how much change is acceptable to maintain those values or is needed to support new or additional values.

Level of protection

Where *aquatic ecosystem protection* is determined as an environmental value, a decision is required as to what level of protection is needed. This will, in turn, directly influence the water quality objectives, management measures or control actions to be set for that water body. There are three levels of protection:

- *High conservation/ecological value systems.* These are systems that are largely unmodified or have undergone little change. They are often found within national parks, conservation reserves or inaccessible locations. Targets for these systems aim to maintain no discernable change from this natural condition (i.e. no physical, chemical and biological change).
- *Slightly to moderately disturbed systems.* These systems have undergone some changes but are not considered so degraded as to be highly disturbed. Aquatic biological diversity may have been affected to some degree but the natural communities are still largely intact and functioning. An increased level of change in physical, chemical and biological elements of these ecosystems is to be expected.
- *Highly disturbed systems.* These are degraded systems likely to have lower levels of naturalness. These systems may still retain some ecological or conservation values that require protecting. Targets for these systems are likely to be less stringent and may be aimed at retaining a functional but highly modified ecosystem that supports other environmental values also assigned to it (e.g. primary industries).

The planning group should decide the appropriate level of protection based on the community's long-term desires for the ecosystem and other environmental, social and

economic considerations. They should choose whether to maintain the existing condition or improve a modified ecosystem by targeting the most appropriate condition level. More information on the level of protection can be found in the *Water Quality Guidelines*.

The *Water Quality Guidelines* (ANZECC & ARMCANZ 2000a) sets out water quality guidelines for the protection of *aquatic ecosystems*, for the "second" and "third" levels of protection: *slightly to moderately disturbed ecosystems* and *highly disturbed ecosystems*.

Reporting Requirements

The designated environmental values and where they apply should be outlined in the plan (Appendix 2, Table 1). Social and economic trade-off's underpinning the water quality objectives should be documented

6. Water quality issues, pollutants of concern, water quality objectives and maximum loads.

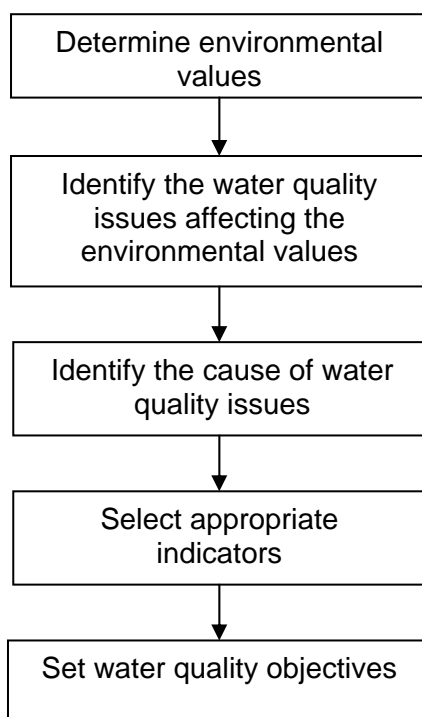


Figure 1 The key steps in identifying water quality objectives

Water quality issues

To develop an effective water quality management plan, a clear understanding of the water quality issues of concern and their causes is required (DEQ 1997). Water quality issues are the evidence of impairment of environmental values. Such issues may include beach closures from contaminated urban runoff, biodiversity decline from frequent algal blooms, fish kills from toxicants and reduced dissolved oxygen following algal bloom collapse and loss of seagrasses from excessive nutrients and sediments (Table 2).

Table 2 Examples of water quality issues that commonly affect the environmental values of water and their associated pollutants and stressors

Environmental Value	Common water quality issues	Common pollutants and stressors
Aquatic Ecosystems	Death/stress of aquatic organisms Loss of seagrasses Smothering of benthic fauna Loss of spawning trigger for fish Loss of aquatic plants	Low dissolved oxygen, toxicity (algal blooms or chemical contamination), habitat modification, chemical contamination, altered habitat conditions (sediment, algal blooms), acidic waters, increased salinity, heavy metals, hydro-modification Nutrients and turbidity Suspended sediment Hydro-modification, altered temperature Acidic waters
Drinking Water	Taste and odour problems from algal blooms and suspended sediment Human health problems and scares Reduced treatment and disinfection capability	Nutrients, sediment and salinity Toxins from algal blooms, chemical contamination, pathogens Nutrients and suspended sediment
Primary industries (irrigation, stock, aquaculture, human consumption of aquatic foods)	Water unsuitable for consumption by stock Contaminated foods (mussels) Fouled pumps and corroded pipes Water unsuitable for irrigation	Toxins, suspended sediment and salinity Heavy metals, chemical contamination, microbial hazards Suspended sediment, salinity Salinity
Recreation & aesthetics	Smell and odour problems Beach closures (health risks) Nuisance growth of aquatic plants scums, toxic blue greens	Nutrients and sediment Microbial hazards Nutrients, turbidity, light and temperature
Industrial	Blockage of intake screens from algal or plant growth Equipment fouling, corroding pipes	Nutrients and light Suspended sediment and salinity
Cultural & spiritual	Dependant on the particular cultural and spiritual use	Dependant on the particular cultural and spiritual use

Identifying water quality issues highlights key facts and background information for that water body and the nature of impairment (US EPA 1999c). These issues should be documented and should include information about the likely pollutant causing these issues and describe the impact these issues have on the environmental values assigned to the water body. Environmental flows may also influence certain water quality issues (e.g. algal blooms and loss of biodiversity) and should be considered in determination of the causes of the water quality issues. Monitoring data, previous studies and reports, best professional judgement, community input and observation may be used to identify relevant water quality issues.

Pollutants of concern

For the purpose of this document, pollutants include all natural and man-made contaminants that can affect water quality, for example, nutrients, sediments, organochlorines, heavy metals, oil and hydrocarbons, chemical constituents and pathogens.

When developing a WQIP it is important that the types, causes and sources of the pollutants are clearly identified (US EPA 1999a). This assists in determining appropriate management strategies and identification of areas in need of specific action.

The water quality issues provide a starting point for determining the pollutants of concern. In some cases the relationship between the issues and the pollutants are reasonably well known. For example, a combination of increases in nutrients and light and reductions in flow may trigger algal blooms. In other cases, such as fish mortality, the links may be less clear and investigative studies may be required to determine the cause of the problem. Examples of some of the common water quality issues and the pollutant often associated with them are provided (Table 2). Problem identification monitoring, existing monitoring and technical reports may help to identify the pollutants of concern and their sources and impacts.

Water quality objectives

Water quality objectives are measurable outcomes (numerical or narrative values) that should ensure protection and or maintenance of the environmental values. They should address water quality issues. Water quality objectives are the measures of environmental and management performance and should form the basis of WQIPs. It may not always be obvious if objectives will be immediately achievable or attainable in some areas without disproportionate costs, and so a set of interim targets may be required to guide management to achieving the water quality objectives over time.

To determine the effectiveness of management actions and achievement of water quality objectives a set of performance indicators are required. Only those indicators considered relevant to the impairment and protection of environmental values and achievement of management goals are selected for deriving water quality objectives. The water quality issues and associated pollutants may assist in determining appropriate indicators. A range of indicators are described in the *Water Quality Guidelines*.

Water quality objectives may be defined for a range of physical (e.g. turbidity, suspended sediment and temperature), chemical (e.g. phosphorus, nitrogen, biochemical oxygen demand and toxicants) and biological parameters (e.g. algae, diatoms, macroinvertebrates and fish). Other aspects of catchment condition such as erosion levels, riparian vegetation and channel morphology are sometimes used as surrogates or short-term indicators of water quality (DEQ 1997).

Detailed procedures for applying the national guidelines and determining water quality objectives are described in the *Water Quality Guidelines* (ANZECC & ARMCANZ 2000a). The major steps involved in determining water quality objectives include determining water quality required to protect the desired environmental values, assessing the difference from current water quality, considering the cost of management actions and resolving any cost trade offs relating to the protection of the environmental values (ANZECC & ARMCANZ 1998).

Ideally, the water quality objectives should be based on locally derived data so as to accommodate natural spatial and temporal variations in aquatic ecosystems. Derivation of

objectives based on local data may not always be possible. In these situations national water quality guidelines can be used as interim or default water quality objectives while additional information can be gathered to tailor them to local conditions.

In addition to the guidelines a range of other information may need to be considered in determining water quality objectives for an area. For example, baseline data, reference data, monitoring results, scientific findings, literature (reports, papers etc), best professional judgement, technical feasibility of the water quality objectives and economic, cultural and social constraints and trade offs.

Where more than one environmental value applies to the same receiving waters, the environmental values need to be prioritised and the most stringent guideline should be used (ANZECC & ARMCANZ 2000a). The most stringent guideline will in many cases also protect the other environmental values. In most cases, the water quality requirements for protection of *aquatic ecosystems* are the most stringent of all the environmental values. However, the order or stringency may vary between different indicators. There are no explicit guidelines to protect *industrial* or *cultural and spiritual* values, so the water quality requirements for these environmental values should be considered relative to the specific use.

Where a water body already has environmental quality better than described by the water quality objectives, the plan should ensure that the water body undergoes no decline in water quality.

Reporting Requirements

For each water body (or portion thereof), the plan should outline the environmental values assigned to that water body, water quality issues, and the water quality objectives set to protect or maintain the designated environmental values (e.g. Appendix 2, Table 1). Social and economic trade-off's made in identifying these values, issues and objectives should be documented.

7. Total Maximum Pollutant Loads

The total maximum pollutant load is the maximum load of a pollutant that a water body can receive and still meet it's water quality objectives and maintain or protect the designated environmental values.

The total load of pollutants that can be assimilated by the receiving waters is determined by the condition and characteristics of those waters (Cullen 1999; ANZECC & ARMCANZ 2000a). Loads take into account the total amount of pollutants entering the system from one or multiple sources and are often used to analyse pollutants that are delivered in pulses during rainfall/run-off events. This episodic delivery of pollutants is characteristic of diffuse pollution and thus diffuse pollutants should be measured in terms of loads. In many instances loads may give a better indication of the total amount of pollutants entering a water body than concentrations. For example, while nutrient concentrations are responsible (with other factors) for stimulating algal growth, it is the total load of key nutrients in the ecosystem that controls the final biomass of aquatic plants (ANZECC & ARMCANZ 2000a). Load based objectives are usually described in terms of reducing constituent loads by a certain percentage or quantity (e.g. reducing total phosphorus by 30 % over 3 years or reducing 100 000kg of total phosphorus per year).

The key steps in determining the total maximum pollutant load to the receiving water body and the associated allocations to the pollutant sources are outlined in Figure 2

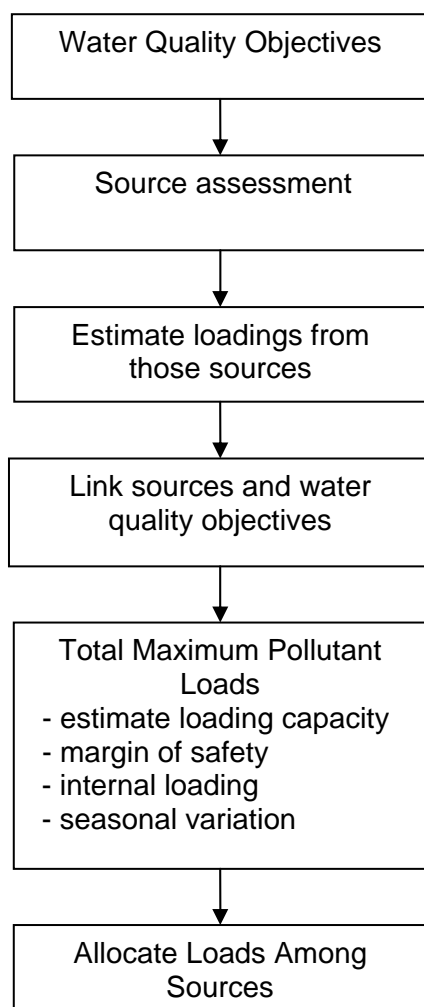


Figure 2 Determining Total Maximum Pollutant Loads and Load Allocations to different sources

Pollutant Source Inventory

To manage pollutants effectively, the sources of the pollutants in the catchment (Table 3) need to be identified. Often the types and sources of pollutants may be inferred from the nature of the problem, land use patterns and management practices (DEQ 1997).

Ecosystem complexities, the diffuse nature of some pollutants and the limited availability of data in some areas can make the sources of pollutants sometimes difficult to identify and quantify.

The sources of pollutants are categorised into two categories, point source and diffuse (non point source) pollutants.

Point source pollution

Point sources are discharged from a discrete point such as a sewage treatment plant, feedlot, mine, abattoir or an industrial operation (Cullen 1991). Point source pollution tends to be easier to manage than diffuse pollution.

Diffuse pollution

Diffuse source pollutants are widespread in origin and from a management viewpoint, cannot be attributed to a single point. Examples include stormwater and agricultural runoff, forestry and construction activities and septic systems. Diffuse pollution enters waterways through runoff, infiltration, drainage, seepage, atmospheric deposition and leaching processes. As water runs off land it mobilises and transports natural pollutants and those from human activities, which then deposit into rivers, lakes, wetlands, coastal waters and ground waters. The greatest loads of diffuse pollution are associated with rainfall/runoff events (Cullen 1991; DEQ 1997; Cullen 1999). A study of phosphorus exports from Monkey Creek, NSW found that 61% of the phosphorus and 41% of the water moved down the creek in 1% of the time (Cullen 1991). It is often harder to identify and quantify the often sporadic discharges of diffuse pollution making it more difficult to regulate or control than point source pollution.

Table 3 Major pollutants and stressors and their common sources and causes

	Microbial hazards (pathogens, viruses, bacteria, protozoa)	Toxicants (chemicals, metals, pesticides, herbicides)	Sediment	Nutrients	Salinity	Temperature changes	Dissolved oxygen changes
Point sources							
Industry		✓	✓	✓	✓	✓	✓
Wastewater treatment plants	✓	✓		✓			✓
Animal feedlots	✓	✓	✓	✓			
Dams						✓	✓
Mines	✓	✓	✓			✓	
Diffuse sources							
Stormwater	✓	✓	✓	✓			
Agriculture	✓	✓	✓	✓	✓		✓
Forestry		✓	✓	✓	✓	✓	
Construction		✓	✓				
Septic	✓	✓		✓			✓
Landfills	✓	✓	✓				
Atmosphere		✓		✓			
Other							
Shipping/Marinas	✓	✓		✓			
Dredging		✓	✓	✓			

The more information about the sources and characteristics of the pollutant the easier it is to design cost effective and equitable management measures. Where possible, a source assessment should be undertaken, which involves listing, characterising and quantifying individual pollutant sources or categories of sources contributing to impairment of a water body, and includes information such as the:

- type of source (point, diffuse, background, atmospheric);
- location of each source;
- magnitude or relative contribution of loads from each source;
- delivery/transport mechanisms (runoff, erosion, groundwater, leaching and atmospheric deposition); and

- time scale of loading to the water body (duration and frequency of pollutant loading to the receiving waters; USEPA, 1999c).

Existing and specific monitoring, reports, aerial photography, empirical models, computer models (USEPA 1999c), literature, conceptual models and best professional judgement can be used in determining the sources and quantity of pollutants.

The ease of determining the sources of pollutants to a receiving water body will depend on the type of pollutant, the range of different land uses and activities within the catchment, the nature of the catchment ecosystem (Gale *et al.* 1993) and the type and availability of data and information. Some areas of the catchment may contribute proportionately larger amounts of point or diffuse sources of pollutants than others and these may be identified and treated as critical source areas for management (Gale *et al.* 1993).

The current estimated pollutant loads

The ability to determine or estimate the loadings will depend on the type and source of pollutant (diffuse or point source), location, transport mechanisms (runoff, infiltration or direct discharge) and attenuation during transport (in-stream assimilation), timing of loading and the data available (EPA 1999a,c).

Diffuse pollution

Measuring the contribution of pollutants from diffuse sources is often difficult and pollutant loads are often underestimated (Cullen 1991; 1999). Direct measurement can be difficult and requires numerous measurements over a range of stream flows for a number of years (Cullen 1991). Load estimates will vary depending on the frequency and timing of samples especially if samples are not collected during high flows when larger quantities of diffuse pollutants are generally transported. Increasingly, export coefficients and models are being used to determine the loads of pollutants arising from diffuse sources. Pollutant assimilation through physical and biological riverine and estuarine processes may need to be addressed in some instances. Determination of diffuse pollution may require interpolation of monitoring information with modelled information based on land use pattern, practices and catchment characteristics (e.g. soil type and topography). In many cases only estimates of pollutant loads from diffuse sources will be available. There may be errors (e.g. sampling, chemical analysis, calculation, simplified models, inappropriate coefficients) associated with estimates of diffuse pollutant loads generated from a range of techniques and these need to be taken into consideration (e.g. included in the margin of safety) in determining total maximum pollutant loads.

Internal Loading

Contributions of pollutants from internal loading and groundwater accession can be quite substantial, especially in stratified lakes and wetlands and can make it difficult to quantify the contribution of pollutants from all sources (Boulton and Brock 1999). Internal loading is the storage or entry of nutrients or pollutants into a water body from the sediments (Boulton and Brock 1999). Nutrient loading (commonly phosphorus) can be responsible for continued eutrophication and occurrence of algal blooms in the water body for years after the input of nutrients from external sources has ceased (Boulton and Brock 1999). The plan should identify if internal loading is likely to be a significant contributor of pollutants to the water bodies of concern and if so identify strategies for quantifying or making allowances for these loads.

Load Calculations

The calculation of pollutant loads may not be straightforward. The techniques used in calculating or estimating each load component should be outlined in the plan. Where models and equations are used, the associated errors should be outlined. A range of data

types and techniques can be used for estimating the magnitude of pollutant source loads including:

- existing monitoring data (community, agency, regulatory);
- licensing information;
- export coefficients;
- empirical models and relationships;
- computer models; and
- best professional judgement.

Volume 2 of the *Water Quality Guidelines* (ANZECC & ARMCANZ 2000a) contains a number of case studies that show the types of approaches that can be used to determine the loads of substances (e.g. Section 8.2.3 case study 4). Examples of additional information and resources that can be used to determine loads of certain pollutants are described below:

- The load Calculation Protocol (NSW EPA; <http://www.epa.nsw.gov.au/licensing/lblprotocol/index.htm>) is used by licensees to calculate assessable pollutant loads and lists the acceptable load calculation methods for each assessable pollutant in the scheme under each classification of licensed activity (NSW EPA 1999). This protocol is useful in determining loads from point sources. Source monitoring (direct measurement), emission factors (formulae and known characteristics of certain required variables) and mass balance calculations (calculation of pollutant load by quantifying materials going in and out of a process; NSW EPA 1999) are used to calculate actual loads.
- National Pollutant Inventory (www.environment.gov.au/epg/npi) is an emission reporting and public information system that provides information on the types and estimates the quantities of certain emissions to air, land and water. The NPI provides estimated aggregated loads for diffuse sources and emissions from specific facilities. Care should be taken in using these values in load calculations that require reasonably accurate estimates of emissions.
- Total Maximum Daily Load Protocols (TMDL) (<http://www.epa.gov/owow/tmdl/index.html>) are used in the United States to determine the maximum amount of pollutant that a water body can receive and still meet water quality standards and to allocate pollutant loadings among point and nonpoint pollutant sources (EPA 1999a, c). The calculation must also account for seasonal variation in water quality. It can be expressed in terms of mass per time, toxicity, or other appropriate measures.

The total maximum pollutant load

The total maximum pollutant load is the total load of a pollutant that can be discharged and still maintain the water quality objective for that water body. The difference between the current pollutant load and the total maximum pollutant load provides a broad management goal and an indication of the reduction in pollutant loadings required to meet the acceptable level.

Determination of the total maximum pollutant load can be complex requiring cause and effect relationships to be established between the water quality objectives of the receiving environment and the pollutants and their sources. The analysis needs to estimate the degree to which historical and existing loads exceed the total maximum pollutant load or the assimilative capacity of the water body and therefore the pollutant reduction needed to attain the water quality objectives (US EPA 1999a). A range of techniques such as long-term monitoring data, qualitative assumptions, best professional judgement, previously

documented relationships and mathematical, process, empirical and inference modelling may be used to assist in determining cause and effect relationships, historical loadings and the total maximum pollutant load (US EPA 1999b, c).

Once the total maximum pollutant load has been determined it guides the setting of allocations to all sources. These allocations must take pollutants generated or cycled through internal loading and a margin of safety to account for errors in estimation. These concepts are outlined in more detail below.

$$\text{Total Maximum Pollutant Load} = \Sigma\text{PSA} + \Sigma\text{DA} + \text{IL} + \text{MOS}$$

PSA = point source allocations, the portion of the total load allocated to existing or future point sources;

DA = diffuse source allocations, the portion of the total load allocated to existing or future nonpoint sources;

IL = internal loading, the portion of the total load allocated to internal loading

MOS = margin of safety, a measure or estimate that accounts for the uncertainty in the relationship between pollutant loads and receiving water quality.

Margin of safety (MOS)

The MOS used in establishing the total maximum pollutant load accounts for uncertainty in estimating pollutant loads, water quality monitoring, ecosystem processes and modelling. The errors associated with determining internal loadings and loads from atmospheric deposition and many diffuse sources may be significant and need to be incorporated into the MOS. The MOS may be calculated explicitly by setting conservative targets, adding a safety factor to estimates of loads or reserving a portion of the available loading capacity as a margin of safety (EPA 1999b). Alternatively, the MOS may be calculated implicitly by using conservative assumptions in deriving numeric targets, numeric model applications or analysing feasibility of prospective restoration activities (EPA 1999b).

Allocations to each source (point and diffuse)

Once the total maximum pollutant load has been established, the allocations to each point and diffuse source and internal loading need to be made. Allocations for future sources may need to be included where there is likely growth that may result in increases in pollutant loads. A portion of the total maximum pollutant load may be referred and allocated to future sources. These allocations should be made in addition to allocations for the margin of safety.

Allocations of pollutant loads must ensure that water quality objectives will be met and maintained and that the load reductions are technically feasible (US EPA 1999a). All segments and sources requiring allocations to achieve water quality objectives should be determined. Allocations to each source should be undertaken in an equitable and cost-effective manner amongst the sources. Decisions about whether to spread the reductions across all sources or target a number of sources may depend on the magnitude of impact, management controls in place, feasibility, probability of success and costs (US EPA 1999b). Social and economic factors and constraints should be taken into consideration in determining pollutant load allocations.

Allocations should be expressed as numeric allowable pollutant loads, required numeric reductions in pollutant loads, narrative statements of desired conditions, effluent

requirements or performance based actions or practices (US EPA 1999a,d). The margin of safety and the effects of seasonal variation (e.g. changes in rainfall/runoff) should be addressed when determining allocations.

For diffuse sources, allocations are the best estimates of the loading and can range from reasonably accurate estimates to gross allotments depending on the nature and availability of data and the techniques used (US EPA 1999a). Where allocations are made for diffuse sources, reasonable assurances must be made to ensure that the reductions will occur.

In some areas, atmospheric deposition may be a significant cause of water quality problems. Atmospheric deposition is the deposition of airborne particles, gases and pollutants onto the surface of the earth by settling, impaction and adsorption or during precipitation events (US EPA 2001a). Where atmospheric deposition has been identified as a significant source of pollutants, the sources of the atmospheric pollution will need to be identified before attempts can be made to achieve required load reductions.

Seasonal Variation in Pollutant Loads

Seasonal variation and high and low flow conditions influence the loads of pollutants to water bodies, therefore the variations in loading needs to be considered in determining allocations to all sources to ensure that the water quality objectives will be met year round. To account for seasonal variation there may be the need for different allocations in different seasons. Allocations need to ensure that environmental values will be protected at all times.

Allocation Example

Total Maximum Pollutant Load

Nutrient models were used to determine the total maximum pollutant load of phosphorus to a large, shallow estuary. It was found that to maintain the ecosystem processes of the estuary, phosphorus loads discharge to the estuary must be 300 000 kg/yr or less.

Existing Load

The total existing phosphorus load is 350 000 kg/yr where:
150 000 kg/yr is derived from rural diffuse sources
95 000 kg/yr is derived from urban stormwater
85 000 kg/yr from a wastewater treatment plant and
20 000 kg/yr from internal loading in the estuary.

Therefore a reduction of phosphorus loads of 50 000 kg/yr is required.

Allocations and load reductions to diffuse sources

To account for uncertainties in the analysis, the state applies a margin of safety of 25% (equalling 75 000 kg/yr).

The total reduction in phosphorus loads required is $50\,000 + 75\,000 = 125\,000$ kg/yr.

It was found that through the implementation of Best Management Practices (BMPs) the following estimated phosphorus load reductions can be obtained:

35 % reduction from rural diffuse sources = 52 500 kg/yr
25% reduction from improved stormwater management = 23 750 kg/yr

Using these reductions, the phosphorus load allocated to:
rural diffuse sources is 97 500 kg/yr (current load 150 000 - estimated reduction 52 500);
urban stormwater is 71 250kg/yr (current load 95 000 - estimated reduction 23 750).

Therefore, total load allocation to diffuse sources is 168 750 kg/yr.

Allocations and load reductions to point sources

Given the above reductions to diffuse sources the load allocations to the point sources required to meet the total maximum load of phosphorus to the lake can be calculated as follows:

Allocations to point sources
= total Maximum Pollutant Load – Allocations to diffuse sources – Internal Loading - MOS
= $300\,000 - 168\,750 - 20\,000 - 75\,000$
= 36 250 kg/yr

The allocation to point sources is 36 250 kg/yr, therefore, load reductions are required by the wastewater treatment plant. The plant needs to reduce its phosphorus loads by 48 750 kg/yr (around a 57% reduction) to meet the requirements of the estuary. While this is a large reduction, it is technically feasible but at a reasonably high cost. However, in this particular case further reductions to diffuse sources are currently unavailable.

Summary

Therefore, to meet the Total Maximum Pollutant Load of phosphorus to the estuary:

- agricultural BMPs can be used to achieve phosphorus loads of 97 000 kg/yr,
- stormwater BMPs can be used to achieve phosphorus loads of 71 250 kg/yr; and
- the wastewater treatment plant needs to improve treatment to achieve phosphorus loads of 36 250kg/yr.

Decision support systems (DSS)

Decision support systems (DSS) are integrated approaches to help people make decisions and can include a range of tools and processes such as computer models, expert systems, geographic information systems, simulation models, databases, discussion groups and structured thought processes (Stuth and Stafford Smith 1993). DSS need to be able to integrate a range of information into a common framework, provided for individual decisions and decision makers and require an understanding that different decisions will be important to different people (Stuth and Stafford Smith 1993). To develop a DSS information about the decision makers and potential users, and likely issues or problems the DSS will need to deal with is required.

DSS fall into two categories, soft or hard DSS. Soft DSS are non-computer based systems and are generally centred around systems thinking and conceptualising (Stuth and Stafford Smith 1993). Hard DSS are generally computer-based systems such as spreadsheets, databases and GIS or predictive models (Stuth and Stafford Smith 1993). The system required will depend on the complexity of the problems and required decisions and the available resources. It is important to note that whatever the system, they are tools for *assisting in* making decisions not making decisions (Stuth and Stafford Smith 1993).

The lead group may wish to develop a DSS that can provide information on the likelihood of success of the plan, and the degree and timeliness of reductions in pollutant loads, including provision for future growth which accounts for reasonably foreseeable increases in pollutant loads.

A few examples of DSS systems developed for managing aspects of catchment management are outlined below:

- **WATERSHEDSS (WATER, Soil, and Hydro-Environmental Decision Support System;** <http://h2osparc.wq.ncsu.edu>; Osmond *et al.*, 1995) is a DSS that was designed to help watershed managers identify water quality problems and select appropriate best management practices for their watershed. This system consists of an assessment and evaluation system, an education component; a bibliography of non point source literature; a database of agricultural best management practices; a water quality modelling tool; and a pollutant budget spreadsheet (Osmond *et al.* 1995).
- **BASINS (Better Assessment Science Integrating Point and Nonpoint Sources;** <http://www.epa.gov/OST/basins/>) is a software system that has been released to assist in the examination of environmental information, support analysis of environmental systems and provide a framework for examining management alternatives (EPA 2001b). The system comprises of national databases, assessment tools and models (eg. an in-stream water quality model, loading transport models and a nonpoint source annual loading model) in and GIS environment (ArcView).
- The Catchment Modelling Toolkit is a system of software currently under development by the Cooperative Research Centre for Catchment Hydrology (<http://www.catchment.crc.org.au/toolkit/>). The system will consist of a range of catchment modelling tools that will allow predictions to be made about the movement of water, particulates and solutes from land to receiving waters enabling managers to evaluate catchment management actions at regional scales.

Reporting Requirements

The plan should detail the:

- existing loads from each source (point source and diffuse);
- total maximum pollutant load to achieve water quality objectives;
- margin of safety used in determination of the TMDL;
- allocations to each source to ensure the total maximum pollutant load will be met; and
- percentage change between the allocation and existing load for each pollutant to be addressed by the plan (e.g. Appendix 2, Table 2).

A graph of the current and allocated pollutant loads to each source category, land use or enterprise should be included. The plan should describe the basis to the total maximum pollutant load estimates, how seasonal variation is accounted for in determining the total maximum loads, and the margin of safety used in their estimation.

8. River Flow Objectives

The seasonal and annual variability of flow is essential for maintaining healthy aquatic ecosystems (ARMCANZ & ANZECC 1996; Boulton and Brock 1999; Gordon *et al.* 1999). Flow controls and influences many physical, chemical and biological processes occurring in aquatic ecosystems and provides habitat, linkages to wetlands and floodplains, flushing of pollutants, organic matter or sediment, and spawning cues or triggers fish breeding and many other essential processes. Changes to the quantity, timing and duration of flows can adversely affect many of these processes.

River regulation, abstraction and land use change have altered the natural pattern of stream flow (timing, quantity and quality of flow), sediment regimes (rates of deposition and erosion and channel morphology) and the integrity of the channel (channel form; this affects available habitat and the ability for fish and invertebrates to migrate upstream; Walker 1985; Boulton and Brock 1999). For example, in many river systems these changes have resulted in reductions in the quantity of water in the channel and the occurrence of small and medium floods as well as extreme changes in the seasonal availability of water (water is often held over winter and released in summer). These modifications can change the quality and quantity of in stream habitat, affect water quality and alter cues for fish spawning.

It has been widely recognised that water is specifically required for the environment to '...sustain and where necessary restore ecological processes, habitats and biodiversity of water-dependent ecosystems' (ARMCANZ & ANZECC 1996). Much work is being undertaken to determine what these water requirements are.

River flow objectives, also referred to as environmental water requirements or environmental flows, are the flow regime required to protect or attain the designated environmental values of the waterbody. In many cases, river flow objectives, will be equivalent to the environmental flows set for the system to maintain or restore ecological processes and biodiversity of water dependent ecosystems (ARMCANZ & ANZECC 1996).

To address the increasing demand on our water resources, the Council of Australian Governments (COAG) agreed to implement a "strategic framework to achieve an efficient and sustainable water industry.". The Water Reform Framework includes provisions for water entitlements and trading, environmental requirements and institutional reform.

The State and Territory governments are currently determining and implementing flow allocations for the environment as part of their implementation of the CoAG Water Reform Framework. Each State and Territory government has specific approaches for determining environmental flow allocations. Where these approaches and rules are available and where allocations to the environment have already been determined for the water bodies of concern, these should be considered in determining river flow objectives for those waters.

The *National Principles for the Provision of Water for Ecosystems* (ARMCANZ & ANZECC 1996) were developed to provide policy direction on providing water for the environment in the context of water allocation for other needs. These principles are undergoing revision to provide further ongoing direction in the area of providing water for ecosystems. These principles should be given adequate consideration when determining environmental water provisions, providing water for the environment, managing environmental water allocations, providing for other uses and in determining research needs and community involvement (ARMCANZ & ANZECC 1996).

In setting river flow objectives the quantity, timing, duration of flow need to be carefully considered because they are critical for maintaining physical and chemical processing, aquatic and riparian biodiversity and protecting nationally listed threatened species and ecological communities. To protect aquatic ecosystems, river flow objectives may need to protect important high and low flows; maintain habitat inundation (wetland and floodplain); maintaining natural wetting and drying regimes, maintaining important seasonal changes in flow and minimising the effects of dams and weirs.

In allocating water to the environment, there is limited information on the minimum flow requirements of different organisms and how flow modification will affect these organisms (Gordon *et al.* 1999). A number of numerical techniques have been developed to assist in the determination of flow requirements, although many of these techniques have been focussed on the preservation of trout or salmon habitat in cold water (Gordon *et al.* 1999). These techniques fall into three categories: historical discharges; threshold calculations; and in-stream habitat simulation (Gordon *et al.* 1999). A description of these techniques can be found in Gordon *et al.* (1999).

The Environmental Flows Initiative, a component of the National River Health Program (<http://www.ea.gov.au/water/rivers/nrhp/flows.html>) has been developed to assist in determining how to best identify the environmental flow needs of our rivers, estuaries and groundwater resources, implement environmental water allocations and reduce future environmental risks. The national reports published under the Environmental Flows Initiative provide an overview of the environmental water requirements of three major ecosystem types, an analysis of threats to these systems and methods for determining adequate water allocations.

The hydrological regimes of many rivers across Australia were assessed as part of the Ecosystem Health component of the National Land and Water Resources Audit. The assessment took into account changes in total flow (diversions, abstractions and inter-basin transfers), changes in variability of flow, changes in seasonal patterns of flow (timing) and changes in the magnitude of seasonal flow to produce an overall assessment of hydrological condition (Norris *et al.* 2001). The hydrological disturbance index and the modelled natural data generated during the assessment provide information on current condition or natural condition that may be of use in the development of river flow objectives. See http://audit.ea.gov.au/ANRA/atlas_home.cfm for further information.

The allocation and over-allocation of water in many cases to agriculture, industry and the environment means that it is unlikely that the natural flow patterns will be restored completely where the economy significantly benefits from altered flow patterns. However, there are often areas where we can make adjustments to maintain or improve river health while continuing to benefit from water use.

Summary

In setting river flow objectives, consideration should be given to:

- the CoAG Water Reform Framework;
- the National Principles for the Provision of Water for Ecosystems;
- any existing State and Territory processes and environmental allocations;
- existing numerical techniques (e.g. historical discharges, thresholds, habitat simulation techniques);
- the Environmental Flows Initiative;
- the National Land and Water Resources Audit;
- scientific information; and
- scientific and local knowledge.

Given the linkages between the range of water uses (domestic, agricultural, industrial, tourism, recreation and the environment) significant community involvement may also be required to determine river flow objectives.

Interim River Flow Objectives identified in NSW

Interim water quality and river flow objectives have been identified, in 31 catchments in New South Wales (NSW). The objectives are to act as guidelines to water resource management committees preparing river, water and groundwater management plans. Eleven river flow objectives were identified that deal with critical elements of natural river flows to:

- Protect pools in dry times
- Protect natural low flows
- Protect important rises in water levels
- Maintain wetland and floodplain inundation
- Mimic natural drying in temporary waterways
- Maintain natural flow variability
- Maintain natural rates of change in water levels
- Manage groundwater for ecosystems
- Minimise effects of weirs and other structures
- Minimise effects of dams on water quality
- Make water available for unforeseen events

The flow regimes required to meet these objectives will vary between environments and regions and will in most cases require determination based on the individual environmental, social and economic characteristics of the area.

NSW EPA (2001) <http://www.epa.nsw.gov.au/ieo/index.htm>

Reporting Requirements

The plan should outline the flow objectives relevant to different water bodies (or segments of water bodies) within the catchment and propose the flow regimes that will help to ensure those river flow objectives are met (e.g. Appendix 2, Table 3).

9. Time required to attain and maintain water quality and river flow objectives

The time required to attain and maintain water quality and river flow objectives will depend to a large extent on the characteristics of the catchment ecosystem, the types and sources of pollutants and the management measures and control actions that have been implemented. In some cases management measures such as increasing the level of treatment of wastewater may lead to water quality objectives being met relatively soon. However, in other cases such as reducing phosphorus loads from agricultural land there may be significant lag times between improving land management practices and subsequent attainment of water quality objectives. Synergistic effects, the presence of other pollutants, and seasonal and climatic variability, can override detection of improvements in water quality over the short to medium term.

Reporting Requirements

The plan should incorporate an estimate of the length of time required to attain and maintain water quality and river flow objectives and how these estimates were derived. This information will assist development and implementation of the plan and appropriate risk management measures.

10. Management measures and control actions

Management Measures

Management measures and control actions are measures, tools or actions that are implemented to control the addition of pollutants to our waters. They generally fall into one or more of the following categories- pollution prevention and minimisation, modification of contaminants, amelioration of degradation, and incentives to induce compliance (UNEP 1995; Table 4).

Table 4 Examples of the types of measures used to manage land-based pollution to the marine environment (UNEP 1995)

Prevention or minimisation	Modification	Reduction or amelioration	Requirements and incentives to induce action to comply with measures
Best available techniques	Waste recovery	Environmental quality criteria for measuring progress (biological, physical and/or chemical)	Economic instruments and incentives (e.g. "polluter pays", whole cycle costing, trading)
Best management practice	Recycling including effluent reuse	Land-use planning requirements	Regulatory measures
Cleaner production	Waste treatment	Rehabilitation of degraded habitats	Institutional changes
Application of environmentally sound technologies			Technical assistance and training
Product substitution			Education and public awareness

An integrated approach to water quality protection requires an appropriate mix of management measures and control actions to achieve the desired water quality and river flow objectives (ANZECC & ARMCANZ 1998). In determining a suite of management measures there are a number of factors and issues that should be considered, such as, the effectiveness, acceptability, sustainability and administrative and technical feasibility of

the measure and any public health, equity and distributional or fiscal issues as a result of implementing the measure or action. Additionally, each management measure should be evaluated on the basis of their environmental, social and economic benefits and impacts (ANZECC & ARMCANZ 1998).

Tailored to local conditions

Specific management measures should be selected to suit the local conditions and environment (DEQ 1997). A single management practice or set of management practices is rarely completely transferable from one location to another. The types of management measures and actions that can be implemented in an area are influenced by a range of issues such as the type, sources and causes of the pollutant, environmental conditions or characteristics of the area, pollutant reduction goals, maintenance required and their cost (NCSU 2000).

Specific management measures may include minor and major capital works, regulatory, institutional, infrastructure, educational, technological, best practice, operating and economic tools and activities. Examples of regulatory, market based and educational tools for managing water pollution from specific sources are provided in Table 5.

Point sources such as effluent from wastewater treatment plants, industrial waste and some intensive agricultural waste are often managed using control actions (licensing discharges) but can also be managed using market based (per unit charges for pollutants) and education (pollutant sources and minimisation campaigns).

Control actions (i.e. regulatory measures) are generally not suitable for managing diffuse sources of pollution, which often require changes in attitude and behaviour. Diffuse sources are generally managed using best management practices (excluding stock from riparian vegetation, efficient irrigation practices, fertiliser minimisation and constructed wetlands), education programs (diffuse pollutant and water minimisation campaigns) and market-based approaches (tradeable pollutant credits, subsidies for revegetation and charges for using substances that affect water quality).

A range of management approaches may be used to achieve river flow objectives such as regulatory (licensing and monitoring extractions), best management practice (releasing water to best mimic natural variability, no extraction from streams in no flow periods), capital works (removing weirs, installing variable level off-takes and fish ladders on dams) and market based instruments (water pricing, trading, banking mechanisms; Siebert *et al.* 2000).

Table 5 A reference list of tools to achieve objectives (after ANZECC/ARMCANZ 1998)

SOURCE	INSTRUMENT FOR MANAGEMENT		
	REGULATORY	MARKET BASED	EDUCATIONAL
POINT SOURCES (Licensable)			
Sewage treatment works	Licence limits, Regulations	Per unit charges for significant pollutant concentrations	Public information about sources of Phosphorous and Nitrogen. Minimise wastewater and contaminants at source
Industrial works	Licence limits, Regulations, Specific regulations for toxics	Per unit charges for significant pollutant concentrations	Public information about pollutants released. Minimise wastewater and contaminants at source
Food processing works (abattoirs, milk processing, etc)	Licence limits, Regulations, Specific regulations for toxics	Per unit charges for significant pollutant concentrations	Public information about pollutants released. Minimise wastewater and contaminants at source
Irrigation	Licence limits, Regulations, Specific regulations for toxics	Water pricing and tradeable water titles	Public disclosure of agricultural chemicals used
Forestry	Operational limitations on licences	Financial penalties for increases in erosion	Public disclosure of erosion caused and runoff changes
Stormwater	Monitoring requirements on licences; best practice conditions	Per unit charges for significant pollutant concentrations	Education campaign on litter and garden pollution
DIFFUSE (NON-POINT) SOURCES (Non-licensable)			
Rural runoff	Enforcement by Soil Conservation Agencies of soil erosion measures; Local and Regional Plans	Subsidies to reduce the price of revegetation. Use of product charges. Financial incentives for soil erosion measures.	Extension training. Property management planning campaign.
Urban runoff	Approvals of land use to include runoff controls. Local and Regional Plans	Fines for polluting activities, eg not cleaning up dog faeces.	Litter reduction, garden management and minimise water use campaigns.
Sewer overflows	Guidelines		

Treatment Trains

A treatment train, also known as a management practice system, is a suite of management practices designed to function together to achieve water quality goals and objectives effectively and efficiently (NCSU 2000). They are often effective because they treat the pollutant at a number of points along the pollutant delivery process (Figure 3). To ensure the system functions effectively, the management measures should be selected, designed, implemented and maintained in accordance with site-specific considerations (NCSU 2000).

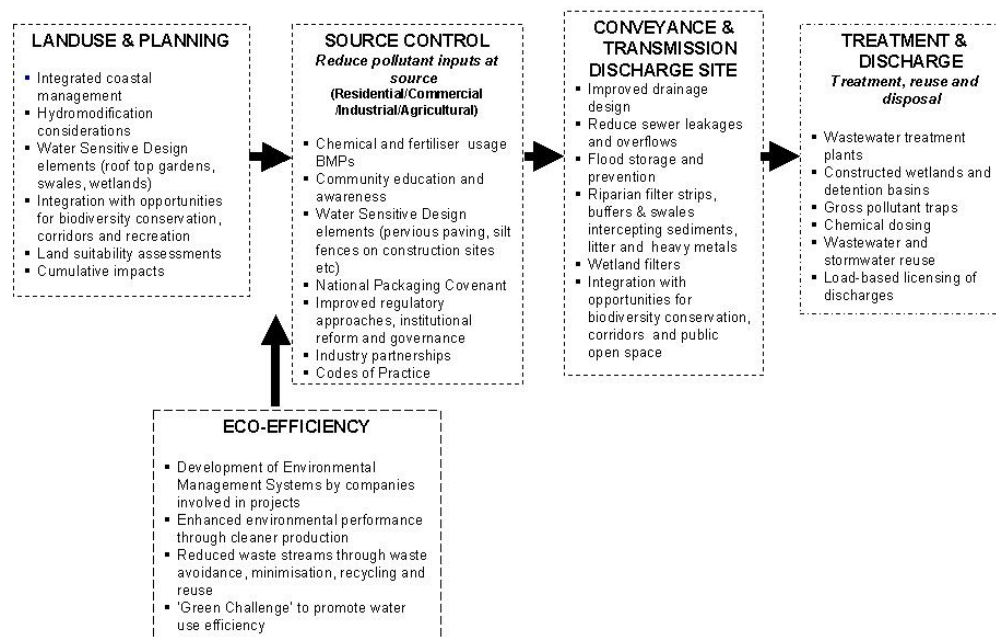


Figure 3 Components of a treatment train

Cost-Effective Management Measures

Those measures that prevent, minimise and control pollution at or near the source should be prioritised for implementation initially because avoiding or minimising the damage in the first place is easier and less costly than attempting to return systems to their natural state after being polluted.

Each of the relevant management measures will accord different water quality benefits, therefore a cost-benefit analysis should be undertaken to identify the most efficient (economic and environmental) means of achieving the required water quality improvements. Once determined, plan should describe the selected management measures used to achieve each of the water quality and river flow objectives, when and how the options will be used and how they will achieve the stated objectives should be described in the plan (DEQ 1997) together with their cost and likely effectiveness.

Stepwise approach

The issues addressed by the plan may be quite large and complex and the water quality and river flow objectives set may not be achievable immediately. Interim targets may be used to work towards the overall objectives of the plan. A stepwise or phased approach to implementation of management actions can be used to attain the water quality and river flow objectives in an efficient and cost-effective manner. This approach involves reaching the overall objectives of the project through a series of smaller, often locally implemented and environmentally beneficial management steps (Figure 4; UNEP 2001; GPA document). For example, a stepwise approach to water quality improvements (and associated investments) may be to reduce catchment nutrient discharges:

- by 30% within the first five years, by a combination of reducing discharges from licensed premises and excluding stock from rural waterways; and
- by a further 20% over a subsequent five year period, through the revegetation of riparian areas, implementation of rural land use best management practices and replacing traditionally engineered urban stormwater drainage systems with constructed wetlands.

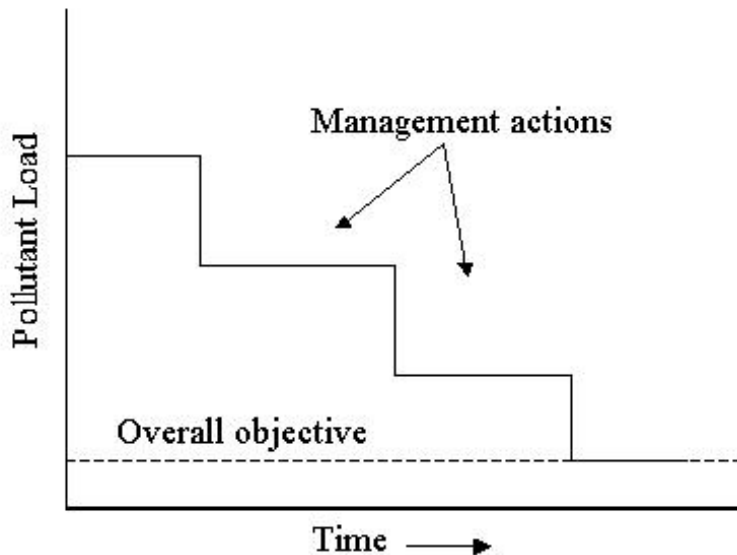


Figure 4 Stepwise approach to achieving water quality objectives (after UNEP 2001 draft).

A stepwise approach should guide the setting of interim targets (e.g. 30% reduction over 5 years). The management actions should be aligned with these interim targets and prioritised for implementation over short (1-3 years) medium (3-6 years) and long term (6-10 years) time scales. Proposed control actions and management measures should, where possible, be linked to anticipated improvements in the quality and quantity of flows to receiving waters and may need to be evaluated in terms of their social and economic costs, to ensure that they are acceptable to the community and government.

Reporting Requirements

The plan should outline the management actions that have been proposed, together with information about their likely effectiveness/pollutant reduction capability (e.g. Appendix 2, Table 4).

11. Timeline for Action

The timeline sets out the time required for implementation of the management measures and the achievement of water quality objectives. A detailed and realistic time line is essential for effective and timely completion of the management measures identified in the WQIP. The timeline establishes the logical sequence of planned projects, linking all components of the plan together.

Some tasks and management measures may be dependent on others and may contribute to a timeline being extended. Identification of such dependencies of tasks on the timeline can be used to manage projects effectively and assist in assessing risks where the timing of tasks is crucial.

Some tasks, management actions or water quality objectives may form milestones (significant achievements) of the project. Milestones are significant outputs or achievements to be undertaken within the plan within a certain timeframe. These milestones should be highlighted in the timeline and can be used to assess the project progress in meeting targets and for scheduling progress payments.

In some instances, the achievement of some water quality or river flow objectives may take years or decades. In these cases, the timeline for implementation of management measures may need to be broken into phases (DEQ 1997).

Reporting Requirements

The timeline should include the schedules (dates for starting and completing tasks or duration of tasks) for:

- collecting baseline data;
- addressing and overcoming institutional impediments;
- undertaking monitoring;
- implementing management measures;
- changes to or implementation of regulatory arrangements and monitoring activities;
- achieving water quality and river flow objectives;
- revising targets, management actions, monitoring; and
- reviewing and reporting and publishing.

12. Accountabilities

Identification of accountabilities ensures that all relevant parties are aware of and understand their roles and responsibilities in implementation of the plan. The authority, organisation or individual responsible for implementing various management measures should be clearly identified and accountable to the government and community. The legal or contractual authority that can be employed to assure implementation of the plan should be identified (DEQ 1997). Accountabilities for all aspects of the plan including achieving objectives, monitoring, evaluating and reporting should be clearly outlined. The roles and responsibilities for each Stakeholder should be clearly outlined and should match their capacities.

To ensure that the plan will be implemented and the water quality improvements are maintained over time the plan needs to demonstrate commitment over the long term. The ongoing commitment and implementation of the plan should be reflected in its objectives, timeline, monitoring plan, funding strategy and accountabilities of various stakeholders (DEQ 1997).

Reporting Requirements

Accountabilities for all aspects of the plan including achieving objectives, monitoring, evaluating and reporting should be clearly outlined in the plan. Accountabilities for undertaking management actions can be reported as in Appendix 2, Table 3.

13. Adaptive Environmental Management

Often planning and management decisions are based upon estimates or the best available information, however, once implemented changes to these decisions may be required. Adaptive environmental management is a strategy in which the causes of problems are identified, management solutions are determined, tried and monitored to determine their effectiveness (Horsfield 1998; Boulton and Brock 1999). It is a continual improvement process that involves refining management activities in response to their effects on the system (Boulton and Brock 1999). In this way the strategy can be flexible and react to

changes over time (depending on the time scale). This approach is often used to test the predicted effects of particular management strategies.

The adaptive environmental management process might be implemented through a range of activities (Horsfield 1998) including:

- active involvement of a wide group of interested parties and stakeholders through the planning process;
- inclusion of environmental, ecological, economic, political, social and cultural conditions in the management process;
- workshops to involve stakeholders in a cooperative process;
- recognition and acceptance of uncertainty in management and the willingness and resources to adapt management strategies accordingly. Development of a range of management options and a strategy for managing adaptively;
- implementation of monitoring programs designed to report on the effectiveness of management actions; and
- feedback mechanisms for long term evaluation and adaptation of management policy and strategy.

It is important that the plan, projects implemented under the plan and specific management activities can be modified in response to monitoring results.

Reporting Requirements

The process and timing for revising the plan and any strategies for adaptive environmental management should be described in the plan.

14. Monitoring and Reporting

Monitoring is fundamental to the successful implementation of a WQIP, as it is the primary mechanism for evaluating the effectiveness of the plan and implementation of management measures (Gale *et al.* 1993). Without an adequately designed monitoring program it will be impossible to determine the effectiveness of the management measures in improving water quality. Water quality may improve markedly as a result of some management measures (e.g. upgrading treatment levels of wastewater discharge), but may take many years to show measurable responses to other management measures (stock exclusion from riparian vegetation). Therefore it is important that the monitoring program is designed to ensure adequate data is collected and analysed to measure and assess the response to these changes over time.

Monitoring is undertaken for a number of reasons, for example:

- to determine baseline conditions and gather data;
- to identify water quality issues;
- to ensure compliance with regulations;
- to quantify water quality improvements;
- to track the effectiveness of management measures;
- to provide a feedback process to guide adaptive management, and
- to determine progress towards water quality and river flow objectives and maintenance or attainment of environmental values (ANZECC & ARMCANZ 2000b).

One of the key reasons to undertake monitoring under a WQIP is to track the effectiveness of management measures. This type of monitoring may be used to determine the extent to which management measures are implemented, determine if there are changes to the extent to which management measures are being implemented, measure the extent of voluntary implementation efforts, determine relative adoption rates of management measures and determine the extent to which management measures are properly

maintained. An example of an overview of a land treatment monitoring program is provided in Figure 5.

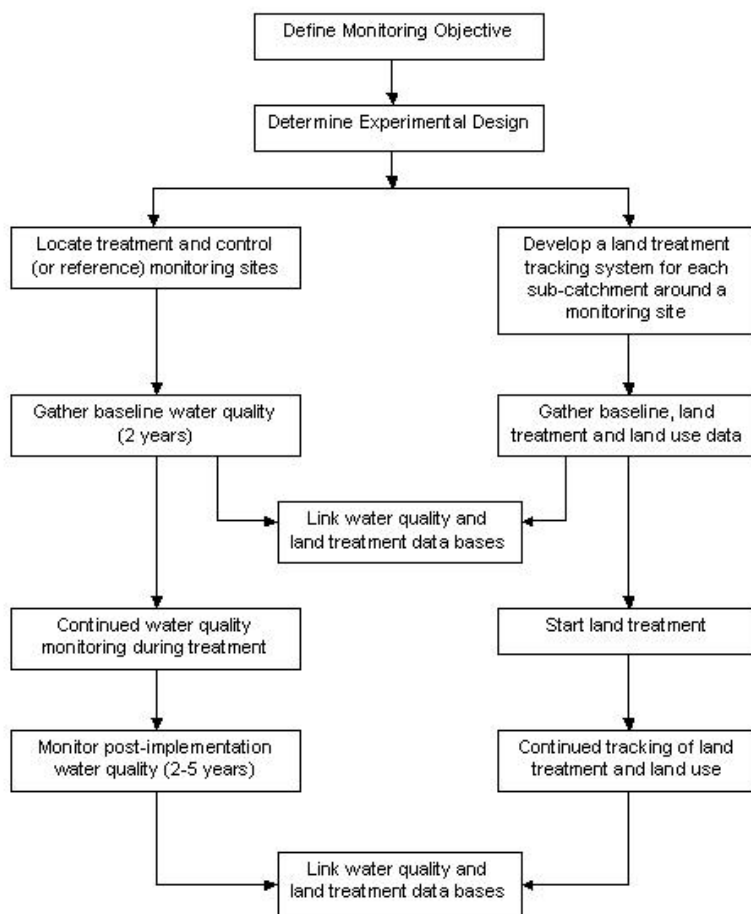


Figure 5 Overview of a monitoring program design for land treatment monitoring (after Coffey *et al.*, 1995).

Key components of a monitoring program

The key components of a monitoring program generally include setting monitoring objectives, designing the study (scale, measurement parameters, methods, number, timing and frequency of sampling), field sampling, laboratory analyses, data analysis and interpretation and reporting and dissemination of information (Figure 6; ANZECC & ARMICANZ 2000b). The *Monitoring Guidelines* (ANZECC & ARMICANZZ 2000b) contain detailed information on both general and specific aspects of designing a monitoring program.

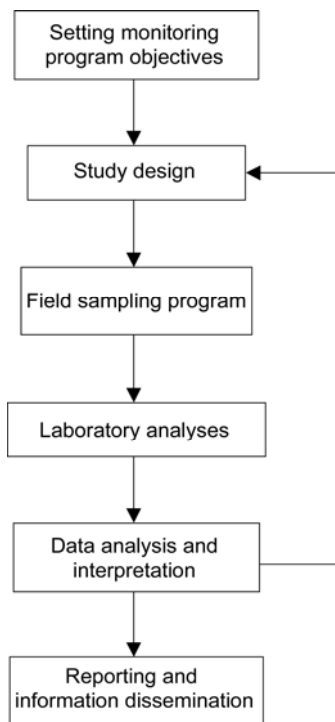


Figure 6 Framework for a water quality monitoring program (ANZECC & ARMCANZ 2000b).

Objectives

Objectives are specific statements that are used to complete the design of the monitoring program. The objectives help determine what data will be gathered, how and what it will be used for. Monitoring objectives should be specific and measurable, realistic and attainable (ANZECC & ARMCANZ 2000b). To define monitoring objectives, the issues to be addressed (e.g., excess nutrients leading to algal blooms, contaminants having chronic effects on biota; ANZECC & ARMCANZ 2000b) should be identified and the available information about the issues obtained. This information can be used to obtain an initial understanding of the system (ANZECC & ARMCANZ 2000b) and develop monitoring objectives. An example of a monitoring objective relating to nutrient dynamics might be:

To determine annual phosphorus loads to a lake from surface inflows, groundwater and sediment releases (ANZECC & ARMCANZ 2000b).

Study design

The study design of the monitoring program needs to be designed carefully to ensure that it will meet the objectives of the program. The type (descriptive, measuring change, improve understanding), scope (spatial and temporal boundaries), sampling design (sites, sampling variability, precision and accuracy) and specific data requirements of the study all need to be considered in the study design (ANZECC & ARMCANZZ 2000b). Each of these components is described more fully in chapter 3 of the *Monitoring Guidelines* (ANZECC & ARMCANZZ 2000b).

A few of the main types of monitoring that should be considered in developing a monitoring program are outlined as follows:

- **Baseline monitoring** is used to gather information on the existing conditions of the waters of concern and provides a basis for future comparisons. To give a good indication of the condition of the system and its variability, this type of monitoring should be undertaken for a couple of years. In many instances this is not possible and

in these cases existing baseline data from other monitoring programs can sometimes be used.

- **Control or reference sites** are often used to compare to test or disturbed sites where no pre-disturbance data exists for those sites. Control sites are generally undisturbed sites that have the same characteristics as the disturbed site (ANZECC & ARMCANZ 2000b). Control sites can be difficult to find in many situations. Reference sites are those sites that are representative of the conditions that should occur at the test or disturbed site in the absence of disturbance. The reference condition is generally one of best available condition as there are few areas in that remain undisturbed (Reynoldson *et al.* 1997). In some situations paired catchments are used, where one catchment is the test catchment, which will undergo some disturbance, while the other which has nearly identical characteristics (slope, aspects, length, geology, soils etc) to the test catchment undergoes no change and is used as a comparison.
- **Trend monitoring** is used to assess the effectiveness of management actions and to document changes in conditions over time. These conditions are compared to baseline and target values to identify if there are any trends in water quality as a result of management actions. Pre- and post monitoring data collection is required in the evaluation of trends. Monitoring needs to be related to management measures to be able to detect changes in water quality as a result of management actions. The effects of some management actions may take a long period of time to be reflected in water quality, therefore monitoring may need to be undertaken over a long period of time for trends to be identified.

Whatever the type of monitoring program, it needs to produce data of sufficient quality and quantity to assess whether objectives have been met. Therefore, statistical requirements and procedures need to be considered in designing a monitoring program to ensure that any changes can be detected with a reasonable degree of confidence.

Field Sampling

The field sampling component needs to consider specific data requirements such as measurement parameters, scale and frequency of sampling and the accuracy and precision of the data required (ANZECC & ARMCANZ 2000b). There may be a trade off between the statistical power (the ability to say that a change is statistically significant) and the cost of the sampling. Detailed information on elements of the field sampling can be found in chapter 4 of the *Monitoring Guidelines* (ANZECC & ARMCANZ 2000b).

Laboratory Analysis

Laboratory analysis should produce accurate and precise data that can meet the requirements of the monitoring program (ANZECC & ARMCANZ 2000b). Selection of analytical methods often depends on the information required by the investigation and the substances to be analysed. There are standard or accepted methods for most analytic techniques (chemistry, sediments and biota), many of these have been referenced in the *Monitoring Guidelines* (ANZECC & ARMCANZ 2000b). Adequate QA/QC procedures should also be developed or used to ensure the data generated from the analyses are precise, accurate and reliable.

Data Analysis and Interpretation

Data analysis is a fundamental component of the monitoring program. There are a suite of statistical analysis techniques and packages available for undertaking data analysis that ranges from descriptive statistics (mean and median etc), analysis of variance through to regression and multivariate type analyses (ANZECC & ARMCANZ 2000b). The type of

analysis required will be determined by the objectives of the monitoring program and may be limited by the data collected. While not an exhaustive reference, the *Monitoring Guidelines* provide guidance on the use of common statistical methods to assist in the identification of suitable methods of analysis (ANZECC & ARMCANZ 2000b). Complex studies may require advice from a professional statistician.

Quality Assurance/Quality Control (QA/QC)

Quality Assurance (QA) and Quality Control (QC) procedures are essential components of all phases of the monitoring program. They help to anticipate and avoid likely errors and problems and ensure the data collected are of a known quality. QA is the implementation of checks on the success of the quality control and includes managerial activities, staff training, data validation, and audits of laboratory and data analysis and management (Table 6; ANZECC & ARMCANZ 2000b; NCSU 2000). QC is the implementation of procedures to maximise the integrity of monitoring data and includes procedures for proper collection, handling and storage of samples, replicate samples, inspection and calibration of equipment, analysis of blank or spiked samples and use of standards or reference materials (ANZECC & ARMCANZ 2000b; NCSU 2000). To control or minimise sampling and processing errors a QA/QC protocols should be developed or used for each component of the monitoring program. Common QA and QC activities are outlined below.

Table 6 Common Quality Assurance and Quality Control Activities.

Quality Assurance Activities	Quality Control Activities
<ul style="list-style-type: none"> • Assignment of roles and responsibilities • Determination of the number of samples required to obtain data at a certain confidence level • Tracking sample custody from field to analysis • Development of data quality objectives • Auditing field and laboratory operations • Maintenance of accurate records • Training of personnel in sampling techniques and equipment use 	<ul style="list-style-type: none"> • Duplicate samples • Analysis of blank and spike samples • Using replicate samples • Regular calibration of equipment • Inspection of reagents

Costs

A high level of commitment is required for a successful monitoring program and to ensure that monitoring activities are carried out for the life of the project. The plan needs to allocate sufficient financial (in the order of 10% of the project funds), and technical and human resources to design and implement an adequate monitoring program. Monitoring programs range from expensive formal scientific programs to less expensive community-based monitoring programs, such as Waterwatch, or a combination of the two depending on the objectives and the resources available (ANZECC & ARMCANZ 1994).

Community and landholder involvement in catchment monitoring can offer great benefits, yielding information of both scientific and practical relevance, helping to develop shared ownership of catchment knowledge and commitment to action, and modifying previous approaches to land and water management (ANZECC & ARMCANZ 1994). Community based monitoring can be an invaluable component of the monitoring program providing that adequate training and QA/QC procedures are in place.

Reporting

Reporting allows dissemination of information about results and project progress to whoever commissioned the study, stakeholders or the public depending on the purpose and requirements of the plan. A reporting schedule should be determined to ensure ongoing dissemination of information and findings to the relevant groups. Interim results may be reported frequently for example on a monthly, quarterly or six-monthly basis and depending on the WQIP may provide results with limited interpretation. These reports allow progress and findings to be reviewed ensuring that the project or plan stays on track and meets its objectives.

Final reports are generally quite detailed and should contain information about all aspects of the WQIP or project. These reports generally contain at a minimum: an executive summary, an introduction, methods and study description, results, discussion of the results, conclusions, recommendations for future work, references and appendices containing information that is too detailed to be included in the body of the report. Projects undertaken as part of a WQIP need to include information that demonstrates whether or not the water quality objectives or targets of the project were met.

More information on reporting can be found in chapter 7 of the *Monitoring Guidelines* (ANZECC & ARMCANZ 2000b). Specific reporting requirements of projects from WQIPs will be outlined in the guidelines for developing and implementing a water quality protection project.

Reporting Requirements

The plan should outline the processes for monitoring and/or modelling the effectiveness of the management actions to determine if the allocated pollutant loads and water quality and river flow objectives will be met.

15. Budget

A budget allows the tracking of resources and determination of what can be achieved by the plan. The approximate costs of all aspects of implementation of the plan should be outlined in a budget and should include all aspects (labour, materials etc) of the following costs:

- administration and operating;
- consultation processes (brochures, advertisements for stakeholder involvement, meetings and discussion forums);
- planning (identification and quantification of major pollutants and their sources, determining project objectives and goals, evaluation of management options);
- all management actions (capital works, education, regulatory, technological);
- monitoring (pre-, during- and post-project) up to 10 percent of the budget;
- evaluation of monitoring results;
- reporting and review; and
- publishing and communication costs.

For each of the costs, the proponent and stakeholder contributions, in-kind contributions, grants, donations, cost-share funds and Commonwealth funds should be outlined. The budget should document the committed funding for the next three years and list potential sources of funding after that including the mechanisms by which the funds will be tapped (DEQ 1997).

Reporting Requirements

A budget for implementation of the plan is required and should include as much detail as possible on each of the above components.

16. Market based approaches

Market based approaches, more commonly known as economic instruments, use market signals (prices) to provide incentives for decision makers to consider environmental issues and take on some or all of the environmental and societal costs that result from their decisions (Scott *et al.* 1998). These approaches try to align private costs with social costs to reduce negative environmental impacts. Market based approaches attempt to ensure that resource use decisions take into account all the costs and benefits (social, environmental, economic) of the decisions (ANZECC & ARMCANZ 1994; Scott *et al.* 1998). These approaches can in many cases lead to more cost-effective environmental outcomes and provide incentives to use new solutions and technologies to address a problem (National Action Plan for Salinity and Water Quality 2002).

Increasingly market based approaches are being used in pilot programs to help address biodiversity, salinity, water allocation, water quality and other natural resource management issues (National Action Plan for Salinity and Water Quality 2002). There are a large number of potential mechanisms that can be used for solving water quality problems that are not solely focussed on regulatory controls. The instruments should aim to achieve waste minimisation, cleaner production, best management practices and reuse and recycling (ANZECC & ARMCANZ 1998). A review of current pilot programs and schemes using market based approaches to address NRM issues has been undertaken as part of the National Market-based Instruments Pilots Program. Further information can be found at <http://www.napswq.gov.au/about/mbi.html>.

Some examples of the market based approaches that can be used as management measures in a WQIP to achieve water quality and river flow objectives include:

- **Product charges:** charges, tariffs or levies are applied to products or materials that may affect water quality (e.g. soluble fertilisers and pesticides) as an incentive to reduce their use or develop alternatives (ANZECC & ARMCANZ 1998; Scott *et al.* 1998).
- **Subsidies and tax concessions:** are used to promote desirable activities (revegetation subsidies to help combat salinity and sedimentation; ANZECC & ARMCANZ 1998; Scott *et al.* 1998).
- **Emission taxes:** producers of pollution buy or sell the right to pollute. Taxes are levied against polluters encouraging polluters to avoid paying taxes by reducing their pollution emissions (Scott *et al.* 1998).
- **Environmental liability:** polluters are legally liable for any environmental damage (Scott *et al.* 1998).
- **Water pricing:** bulk water prices reflect the full costs of water supply and management (costs of managing surface and groundwater, storage and supply) to achieve full cost-recovery (Scott *et al.* 1998).
- **Tradeable permits:** a limit is established for the pollutant or resource (water, nutrients, salinity etc), then allocated and traded amongst participants (ANZECC & ARMCANZ 1998; Scott *et al.* 1998). As part of the Salinity and Drainage Strategy, a salt credits trading scheme is operating between the irrigation districts of New South Wales, Victoria and South Australia (Scott *et al.* 1998). As part of the Bubble

Licensing Scheme operating in NSW, limits are set on the total pollutant load generated instead of specifying limits on each individual source (National Action Plan for Salinity and Water Quality 2002).

- **Financial incentives:** penalties for non-compliance with standards or regulations (Scott *et al.* 1998). Financial incentives are provided to licensees to reduce emissions in the most cost-effective way under Load Based Licensing processes in NSW <http://www.epa.nsw.gov.au/licensing/lblprotocol/index.htm>.
- **Performance bonds:** where a payment is made to authorities for potential environmental damage. These may be suitable in situations where there is one source of damage that can be reasonably estimated (cost of rehabilitating mine sites) (Scott *et al.* 1998).
- **Codes of practice:** voluntary standards and codes of practice guide natural resource owners and managers on how to comply with the law and to encourage sustainable use of resources (Scott *et al.* 1998; Murray-Darling Basin Ministerial Council 2001).
- **Rebates/discounts:** in the licensees' annual fee are given for reducing the load of pollutants emitted. Where a licensee fails to meet agreed load targets, a retrospective pollutant load fee with interest must be paid (NSW EPA 1999).

Reporting Requirements

Any market-based approaches that could be used to realise pollutant reductions should be described in the plan and where appropriate included in the suite of management actions.

17. Review

Review is an important component of water resource management planning and projects as it identifies opportunities and information gaps, evaluates progress towards water quality and river flow objectives, and provides information to ensure continual improvement of the WQIP. Review ensures that the plan is still on track towards meeting the overall goals of the WQIP. Aspects of the WQIP that should be reviewed include the water quality and river flow objectives, the management measures used, monitoring program, and the overarching commitments (including legislative frameworks).

Reporting Requirements

The plan should outline the process and timing for reviewing the plan.

18. Public involvement

Public involvement

Public involvement can provide a valuable source of ideas, information and data to assist in plan and project identification, development and implementation. Public involvement can help foster a feeling of ownership, which can be very important to the success of the WQIP or specific project especially when related to diffuse pollution. The community should be involved in development, implementation and evaluation of the plan to ensure that:

- community needs are accurately reflected;
- impacts on the community are well understood and incorporated into relevant decision-making (e.g. cultural, social, economic and political) processes;
- the associated costs (financial, amenity, etc.) will be acceptable to the community;

- management strategies are appropriately targeted; and
- a shared ownership of catchment knowledge and commitment to action are being developed.

The public may be involved at a number of different levels, depending on their interest and expertise, and the mechanisms available for their involvement.

Public Reporting

Public reporting allows communication of information about the plan and its implementation to stakeholders, community, contractors and other groups. In addition to providing information, public reporting ensures that there is some degree of transparency of processes and decisions, accountability for actions and decisions and continual stakeholder dialogue. Information about development and implementation of the plan can be disseminated through a range of options including publications (technical reports, papers, journals, newsletters, brochures), Internet web pages, media releases and articles, videos and presentations (slides, PowerPoint). The choice of media will depend on the audience (type and number), purpose of the information, distribution mechanisms and cost.

More detailed information on reporting can be found in chapter 7 of the *Water Quality Guidelines* (ANZECC & ARMCANZ 2000b).

Reporting Requirements

A consultation strategy should be outlined in the plan. The strategy should set out the means for public consultation to ensure that structured community input will be obtained during the:

- identification of environmental values, water quality issues and water quality objectives;
- identification of river flow objectives;
- identification of management actions to reduce nutrient discharges and attain objectives;
- determination of monitoring activities (including community based monitoring); and
- development and revision of the plan.

19. Revision

Revising the plan enables deficiencies, gaps, problems and improvements to be identified. The plan may need to be modified to account for any changes to objectives and barriers that might have become evident. Revision may occur on a number of levels such as providing documents for community comment on the whole plan or revising management actions on the examination of monitoring results.

Revising allows the effectiveness of strategies and measures to be determined and may need to address environmental effectiveness, economic costs and benefits, equity, adaptive management and timing of the plan.

Reporting Requirements

The timelines and processes for revising the plan should be described.

20. Glossary

Term	Definition
Acidic	Having a high hydrogen ion concentration (low pH)
Aesthetic	Aspects of, say, a water body, that can be considered beautiful or pleasant to the senses
Algae	Comparatively simple chlorophyll-bearing plants, most of which are aquatic and microscopic in size
Alkalinity	The quantitative capacity of aqueous media to react with hydroxyl ions. The equivalent sum of the bases that are titratable with strong acid. Alkalinity is a capacity factor that represents the acid-neutralising capacity of an aqueous system.
Anaerobic	Conditions where oxygen is lacking; organisms not requiring oxygen for respiration
Aquaculture	Commonly termed fish farming, but it broadly refers to the commercial growing of marine (mariculture) or freshwater animals and aquatic plants
Aquatic ecosystem	Any watery environment from small to large, from pond to ocean, in which plants and animals interact with the chemical and physical features of the environment
Aquifer	An underground layer of permeable rock, sand or gravel that absorbs water and allows it free passage through pore spaces
Assimilative capacity	The maximum loading rate of a particular pollutant that can be tolerated or processed by the receiving environment without causing significant degradation to the quality of the ecosystem and hence the environmental values it supports
Baseline data (studies)	Also called pre-operational data (studies); collected (undertaken) before a development begins
Biochemical (or biological) oxygen demand	<p>The decrease in oxygen content in mg/L of a sample of water in the dark at a certain temperature over a certain period of time which is brought about by the bacterial breakdown of organic matter</p> <p>Usually the decomposition has proceeded so far after 20 days that no further change occurs. The oxygen demand is measured after 5 days (BOD₅), at which time 70% of the final value has usually been reached.</p>
Biota	The sum total of the living organisms of any designated area
Bloom	An unusually large number of organisms per unit of water, usually algae, made up of one or a few species
Catchment	The total area draining into a river, reservoir, or other body of water
Concentration	The quantifiable amount of chemical in, say, water, food or sediment
Contaminant	Biological (e.g. bacterial and viral pathogens) and chemical (see Toxicants) introductions capable of producing an adverse response (effect) in a biological system, seriously injuring structure or function or producing death
Control	That part of an experimental procedure, which is like the treated part in every respect except that it is not, subjected to the test conditions. The control is used as a standard of comparison, to check that the outcome of the experiment is a reflection of the test conditions and not of some unknown factor.

Control Action	Regulatory prescriptions or requirements set as a result of resource management processes and requirements
Effluent	A complex waste material (e.g. liquid industrial discharge or sewage) that may be discharged into the environment
Environmental water provisions	Those water regimes that are provided as a result of the water allocation decision-making process taking into account ecological, social and economic impacts or implications. They may meet in part or in full the ecological water requirements.
Environmental water requirements	Are descriptions of the water regimes needed to sustain the ecological values of water-dependent ecosystems at low level of risk.
Environmental values	Particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and that require protection from the effects of pollution, waste discharges and deposits. Several environmental values may be designated for a specific water body.
Eutrophication	Enrichment of waters with nutrients, primarily phosphorus, causing abundant aquatic plant growth and often leading to seasonal deficiencies in dissolved oxygen
Groundwater	Water stored underground in rock crevices and in the pores of geologic materials that make up the earth's crust; water that supplies springs and wells
Guideline (water quality)	Numerical concentration limit or narrative statement recommended to support and maintain a designated water use
Habitat	The place where a population (e.g. human, animal, plant, microorganism) lives and its surroundings, both living and non-living
Indicator	A parameter that can be used to provide a measure of the quality of water or the condition of an ecosystem
Leachate	Water that has passed through a soil and that contains soluble material removed from that soil
Level of protection	A level of quality desired by stakeholders and implied by the selected management goals and water quality objectives for the water resource
Management goals	<p>Long-term management objectives that can be used to assess whether the corresponding environmental value is being maintained. They should reflect the desired levels of protection for the aquatic system and any relevant environmental problems.</p> <p>Management goals will mostly be narrative statements focusing management on the relevant water quality objectives.</p>
Management measures	Management actions such as best management practices for respective land uses or enterprises
Pathogen	An organism capable of eliciting disease symptoms in another organism
Pesticide	A substance or mixture of substances used to kill unwanted species of plants or animals
pH	Value that represents the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution.
Pollution	The introduction of unwanted components into waters, air or soil, usually as result of human activity; e.g. hot water in rivers, sewage in the sea, oil on land
Potable water	Water suitable, on the basis of both health and aesthetic considerations, for drinking or culinary purposes

Quality assurance (QA)	The implementation of checks on the success of quality control (e.g. replicate samples, analysis of samples of known concentration)
Quality control (QC)	The implementation of procedures to maximise the integrity of monitoring data (e.g. cleaning procedures, contamination avoidance, sample preservation methods)
Reference condition	An environmental quality or condition that is defined from as many similar systems as possible and used as a benchmark for determining the environmental quality or condition to be achieved and/or maintained in a particular system of equivalent type
River flow objective	Also referred to as environmental water requirements or environmental flows, are the flow regime required to maintain or restore ecological processes and biodiversity of water dependent ecosystems
Salinity	The presence of soluble salts in or on soils or in water
Sediment	Unconsolidated mineral and organic particulate material that settles to the bottom of aquatic environment
Stakeholder	A person or group (e.g. an industry, a government jurisdiction, a community group, the public, etc.) who have an interest or concern in something
Stressors	The physical, chemical or biological factors that can cause an adverse effect in an aquatic ecosystem as measured by the condition indicators (see Section 3.3.2)
Toxicant	A chemical capable of producing an adverse response (effect) in a biological system at concentrations that might be encountered in the environment, seriously injuring structure or function or producing death. Examples include pesticides, heavy metals and biotoxins (i.e. domoic acid, ciguatoxin and saxitoxins).
Water quality guideline	See 'Guideline (water quality)'
Water-dependent ecosystems	Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of flowing or standing water above or below ground. The instream areas of rivers, riparian vegetation, springs, wetlands, floodplains, groundwater and estuaries are all water-dependent ecosystems.
Water quality objective	A numerical concentration limit or narrative statement that has been established to support and protect the designated uses of water at a specified site. It is based on scientific criteria or water quality guidelines but may be modified by other inputs such as social or political constraints.

21. References

ANZECC (1992). *Australian Water Quality Guidelines for Fresh and Marine Waters*. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC & ARMCANZ (1994). *Policies and Principles: A Reference Document*. National Water Quality Management Strategy Paper No 2, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ARMCAZ & ANZECC (1996). *National Principles for Provision of Water for Ecosystems*. Sustainable Land and Water Resources management Committee Subcommittee on Water Resources Occasional Paper SWR No 3. Agriculture and Resource Management Council of Australia and New Zealand & Australian and New Zealand Environment and Conservation Council.

NHMRC & ARMCANZ (1996). *Australian Drinking Water Guidelines*. National Water Quality Management Strategy Paper No 6, National Health and Medical Research Council & Agricultural and Resource Management Council of Australia and New Zealand, Australian Government Publishing Service, Canberra.

ANZECC & ARMCANZ (1998). *Implementation Guidelines*. National Water Quality Management Strategy Paper No 3, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ANZECC & ARMCANZ (2000)a. *The Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ANZECC & ARMCANZ (2000)b. *Australian Guidelines for Water Quality Monitoring and Reporting*. National Water Quality Management Strategy Paper No 7, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ANZECC & ARMCANZ (2000)c *The Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. National Water Quality Management Strategy Paper No 4, Volume 2, Aquatic ecosystems – rationale and background information. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

Boulton, A.J. and Brock, M.A. (1999). *Australian Freshwater Ecology Processes and Management*. Cooperative Research Centre for Freshwater Ecology. Gleneagles Publishing, Glen Osmond, South Australia.

Coffey, S.W., Spooner, J., and Smolen, M.D. (1995). *The Nonpoint Source Manager's Guide to Water Quality and Land Treatment Monitoring*. North Carolina Agricultural Extension Service, Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, NC.

Cullen, P. W. (1999). *The Challenges of Managing Diffuse Pollution*. Proceedings of the International Conference of Diffuse Pollution “Solutions and Innovations”, Sheraton Perth Hotel, Western Australia 16-20 May 1999. CSIRO Land and Water, Wembley, WA.

DEQ (1997). *Guidance For Developing Water Quality Management Plans That Will Function as TMDLs for Nonpoint Sources*. Oregon Department of Environmental Quality Water Quality Division, Watershed/Basin Section 811 Sixth Avenue, Portland Oregon 97204 (<http://waterquality.deq.state.or.us/wq/nonpoint/NPCover.htm>)

EPA (2001)a. *Water Quality Objectives for Rivers and Streams – Ecosystem Protection*, Policy Background Paper. Draft State Environment Protection Policy (Waters of Victoria), November 2001. Environment Protection Authority Victoria, Southbank, Victoria.

EPA (2001)b. *Nutrient Objectives for Rivers and Streams – Ecosystem Protection*, Policy Background Paper. Draft State Environment Protection Policy (Waters of Victoria), November 2001. Environment Protection Authority Victoria, Southbank, Victoria.

Gale, J.A., Line, D.E., Osmond, D.L., Coffey, S.W., Spooner, J., Arnold, J.A., Hoban, T.J. and Wimberley, R.C. (1993). *Evaluation of the Experimental Rural Clean Water Program*. United States Environment Protection Authority (EPA-841-R-93-005) (<http://h2osparc.wq.ncsu.edu/info/rcwp/>).

GBRMPA (2001). *Great Barrier Reef Catchment Water Quality Action Plan, A Report to Ministerial Council on Targets for Pollutant Loads, September 2001*. Great Barrier Reef Marine Park Authority, Townsville.

Gordon, N.D., McMahon, T.A., and Finlayson, B.L. (1999). *Stream Hydrology An Introduction for Ecologists*. John Wiley & Sons Ltd, Chichester. 526pp.

Murray-Darling Basin Ministerial Council (2001). *Integrated Catchment Management in the Murray-Darling Basin 2001-2010. Delivering a sustainable future*. Murray-Darling Basin Ministerial Council, Canberra.

National Action Plan for Salinity and Water Quality (2002). *Investigating New Approaches. A Review of Natural Resource Management Pilots and Programs in Australia that Use Market-based Instruments*. A joint initiative of all States and Territories and the Commonwealth under the National Action Plan for Salinity and Water Quality.

Norris, R.H., Prosser, I., Young, B., Liston, P, Bauer, N., Davies, N., Dyer, F., Linke, S. and Thoms, M. (2001). *The Assessment of River Condition (ARC) an Audit of the Ecological Condition of Australian Rivers*. Final Report submitted to the National Land and Water Resources Audit Office. Cooperative Research Centre for Freshwater Ecology and CSIRO Land and Water, Canberra.

NSW EPA (1999). *Load Calculation Protocol for use by holders of NSW Environment Protection Licenses when calculating assessable pollutant loads*. Gazetted on 10 May 2002. NSW Environment Protection Agency. (<http://www.epa.nsw.gov.au/licensing/lblprotocol/index.htm>)

Osmond, D.L., Line, D.E., Gale, J.A., Gannon, R.W., Knott, C.B., Bartenhagen, K.A., Turner, M.H., Coffey, S.W., Spooner, J., Wells, J., Walker, J.C., Hargrove, L.L., Foster, M.A., Robilliard, P.D., and Lehning, D.W. (1995). *WATERSHEDSS: Water, Soil and Hydro-Environmental Decision Support System*, <http://h2osparc.wq.ncsu.edu>. 2002.

Reynoldson, T.B., Norris, R.H., Resh, V.H., Day, K.E. and Rosenberg, D.M. (1997). The reference condition: a comparison of multimetric and multivariate approaches to assess water-quality impairment using benthic macroinvertebrates. *Journal of the North American Benthological Society*, **16**(4): 833-852.

Scott, F., Kaine, G., Stringer, R. and Anderson, K (1998). *Sustainability in a Commercial Context: Potential for Innovative Market-based Approaches*. Occasional Paper No. 19/98. Land and Water Resources Research and Development Corporation, Canberra.

Siebert, E., Young, D. and Young, M. (2000). Market-based Opportunities to Improve Environmental Flows: A Scoping Paper. Report to Environment Australia. Policy and Research Unit CSIRO Land and Water, PIRSA Rural Solutions, Adelaide.
(<http://www.ea.gov.au/water/policy/envflows.html>); accessed 16-12-02)

Stuth, J.W. and Stafford Smith, M. (1993). Decision support for grazing lands: an overview. In Stuth, J.W. and Lyons, B.C. (Eds). *Decision Support Systems for the Management of Grazing Lands, Emerging Issues* (Man and the Biosphere Series, Volume 11. United Nations Educational, Scientific and Cultural Organization, Paris, France.

UNEP (1995). *Global Programme of Action for the Protection of the Marine Environment from Land-based Activities*. Intergovernmental conference to adopt a global programme of action for the protection of the marine environment from land-based activities, Washington, D.C., 23 October – 3 November 1995. United Nations Environment Programme.

UNEP (2001 draft). *Guidance of municipal Wastewater. Practical Guidance for Implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) on Sewage*. United Nations Environment Programme in collaboration with the World Health Organisation, United Nations Centre for Human Settlements and the Water Supply and Sanitation Collaborative Council. United Nations Environment Programme, The Hague, The Netherlands

US EPA (1999)b *Draft Guidance for Water Quality-based Decisions: The TMDL process (Second Edition)*. EPA 841-B-99-001, August 1999. United State Environmental Protection Agency, Office of Water, Washington DC.

US EPA (1999)a. *Protocol for Developing Sediment TMDLs (First Edition)*. EPA 841-B-99-004, October 1999. United State Environmental Protection Agency, Office of Water, Washington DC.

US EPA (1999)c. *Protocol for Developing Nutrient TMDLs (First Edition)*. EPA 841-B-99-007, November 1999. United State Environmental Protection Agency, Office of Water, Washington DC.

NCSU (2000). *National Management Measures to Control Nonpoint Source Pollution from Agriculture DRAFT*. North Carolina State University, Raleigh, NC.

US EPA (2001)a. *Frequently Asked Questions About Atmospheric Deposition, A Handbook for Watershed Managers*. United States Environment Protection Agency, EPA-4453/R-01-009 September 2001. Office of Wetlands, Oceans and Watersheds, Washington DC, and Office of Air Quality, Planning and Standards, Research Triangle Park NC.

US EPA (2001)b. *Better Assessment Science Integrating point and Nonpoint Source, Version 3 (BASINS 3.0)*. Fact Sheet, EPA 823-F-01-021, June 2001. United States Environmental Protection Agency, Office of Water. <http://www.epa.gov/ost/basins/>

Zann, L.P. (compiler) (1995). *Major findings of the State of the Marine Environment Report for Australia*. Great Barrier Reef Marine Park Authority Townsville Queensland and Department of the Environment, Sport and Territories, Canberra.

Appendix 1: The Framework for Marine and Estuarine Water Quality Protection

. A water quality improvement plan will as a minimum:

- a. delineate the marine and estuarine waters to which the plan applies and the catchment which contributes pollutants to those waters;
- b. identify the environmental values of those marine and estuarine waters;
- c. set out the water quality issues, pollutants of concern, and water quality objectives for those waters, and:
 - the estimated total maximum pollutant loads to achieve and maintain the water quality objectives, and how this differs from the current estimated pollutant loads (assumptions used for the basis of these estimates shall be detailed);
 - the estimated constituent point and diffuse source allocations of the total maximum pollutant loads (including from marine activities eg. aquaculture);
 - the estimated point source allocations to each licensed point source, and the allocations to non-point sources of contaminants, including atmospheric deposition or natural background sources;
 - the margin of safety used in establishing the total maximum pollutant load which accounts for uncertainty, including that associated with estimating pollutant loads, water quality monitoring, ecosystem processes and modelling;
 - how decision support systems will be developed and applied to appraise the likelihood of success of the plan, and the degree and timeliness of reductions in pollutant loads, including provision for future growth which accounts for reasonably foreseeable increases in pollutant loads (eg. approved industrial point sources, urban expansion); and
 - seasonal variation in pollutant load inputs, such that the water quality objectives will be met all year round.
- d. set out the river flow objectives for those waters, having regard for ecological and geomorphic processes relating to, but not limited to:
 - protecting natural low flows;
 - protecting important rises in water levels;
 - maintaining wetland and floodplain inundation;
 - maintaining natural flow variability; and
 - maintaining or rehabilitating estuarine processes and habitats.
- e. estimate the time required to attain and maintain water quality and river flow objectives, and the basis to those estimates;
- f. describe the control actions and/or management measures which will be implemented to ensure:
 - discharges of pollutants to coastal waters are less than the total maximum pollutant loads, for all sources irrespective of category or land use activity; and
 - environmental flow provisions will achieve the identified river flow objectives.

- g. set out a timeline, including interim targets and milestones, for implementing the control actions and/or management measures and attainment of water quality and river flow objectives, including a schedule for revising the regulatory and management arrangements, as appropriate;
 - h. identify accountabilities for implementing the various source control measures, as well as strategies for the maintenance of effort over time;
 - i. identify strategies for adaptive environmental management, recognising the implications to environmental monitoring programs of management interventions over time;
 - j. set out the processes for monitoring and/or modelling and reporting on the effectiveness of the control actions and/or management measures, and whether pollutant loads and environmental water provisions are being met;
 - k. provide time lines and costs for plan implementation;
 - l. identify opportunities for market based approaches to implement the plan;
 - m. provide for the periodic review of water quality objectives, total maximum pollutant loads, river flow objectives and environmental water provisions;
 - n. set out the means for public involvement and public reporting; and
 - o. identify the process and timing for revising the plan.
2. As an Appendix to the water quality improvement plan, the plan will also contain:
- a. legal advice stating and describing the jurisdiction's statutory capacity to implement the plan and commitments for legislative reform, as appropriate;
 - b. the programs and funding committed by the jurisdiction to implementing the plan; and
 - c. a "reasonable assurance" ie. a high degree of confidence that projected reductions in the total pollutant load and attainment of environmental water provisions will be achieved. The grounds to the "reasonable assurance" should be substantiated.

Appendix 2: Reporting Specifications

Table 1 Environmental Values and Water Quality Objectives - MEWQ ref 1 (b) & 1 (c)

(Note: Guidance is available at www.ea.gov.au/water/quality/targets/handbook/)

Segment of water body	Environmental Values (EV) for segment	Water Quality Issues	Water Quality Objectives (prioritise and identify the most stringent objective)
E.g. Harvey River Estuary	Aquatic Ecosystem Protection	(a) Algal blooms (b) Stress/death of fish	<ul style="list-style-type: none"> ▪ Total phosphorus of μgL^{-1} ▪ Total nitrogen of μgL^{-1}

Table 2 Total pollutant load allocations (kg/yr) - MEWQ ref 1(c)

Pollutant Source	Existing Load (kg/yr)	Load Allocation (kg/yr)	Percentage Change (+/-)
Point Sources (list all according to catchment waterway, waterway sub-catchment, source category and enterprise)			
Diffuse Sources (list all by catchment waterway, waterway sub-catchment and land use category)			
Marine-based sources (by source category and enterprise)			
Internal loading			
Margin of safety			NA
Future (committed and anticipated future growth) - total point sources (list all according to catchment waterway, waterway sub-catchment, source category and enterprise) - total diffuse sources (list all by catchment waterway, waterway sub-catchment and land use category)		NA	NA
Total Maximum Load (add allocations to all sources)*			

Table 3 River flow objectives - MEWQ ref 1(d)

River Flow Objective <i>May include but not limited to the following:</i>	Segment of River	Proposed Flow Regime
Protect pools in dry times		
Protect natural low flows		
Protect important rises in water levels		
Maintain wetland and flood plain inundation		
Mimic natural drying in temporary waterways		
Maintain natural flow variability		
Maintain natural rates of change in water levels		
Manage groundwater for ecosystems		
Minimize effects of weirs and other structures		
Minimize effects of dams on water quality		
Make water available for unforeseen events		

Table 4 Management measures and control actions to achieve total maximum pollutant load - MEWQ ref 1 (e), (f), (g), (h) and (k)

Management categories and land uses	Management Actions	Projected reductions from point sources	Projected reductions from diffuse sources	Timelines	Costs	Responsible Authority	Effectiveness Ranking
Land use & planning e.g. <ul style="list-style-type: none"> ▪ Integrated coastal management ▪ Water Sensitive Urban Design elements ▪ Water balance ▪ Other (<i>specify</i>) 							
Eco-efficiency e.g. <ul style="list-style-type: none"> ▪ EMS by industries ▪ Cleaner production ▪ Water use efficiency ▪ Other (<i>specify</i>) 							
Source Control e.g. <ul style="list-style-type: none"> ▪ Community education and awareness ▪ Improved regulatory mechanisms ▪ Institutional reform ▪ Other (<i>specify</i>) 							
Conveyance e.g. <ul style="list-style-type: none"> ▪ Improved drainage design ▪ Flood storage and prevention ▪ Riparian filter strips ▪ Wetland filters ▪ Other (<i>specify</i>) 							
Treatment and Discharges e.g. <ul style="list-style-type: none"> ▪ Wastewater treatment plants ▪ Load based licensing of discharges ▪ Industrial discharges ▪ Other (<i>specify</i>) 							

Appendix 3: Default Environmental Values

Examples of land uses or conventions that may attract default environmental values

Environmental value	Designated land use/convention
Aquatic ecosystems	World Heritage Areas Ramsar Wetlands National Parks Treaty/convention Conservation Reserves Areas of National Environmental Significance Sanctuaries (e.g. Whale) Threatened or protected species
Primary industry	Gazetted fishing zone
Recreation and aesthetics (primary and secondary contact)	Designated recreation areas (swimming holes, beaches, pools etc) Designated scenic lookouts and trails
Drinking water	Designated drinking water source (aquifer or surface)