Guidelines for Protecting Australian Waterways

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Acknowledgments

This project had its beginning in late 1998 when the Queensland Environmental Protection Agency (EPA) initiated a project aimed at developing conservation strategies for waterways to complement proposed water resource and associated development strategies. In December 1998, and May and September 1999, workshops were held with representatives from key government agencies, experts from academic institutions and key EPA officers. These workshops assisted in forming the conceptual framework and the early versions of two of the guidelines. The valuable contributions from the participants at and after the workshops are acknowledged.

That work is now being developed further by this project team with the financial support of Land & Water Australia, whose support is gratefully acknowledged.

The process for developing the guidelines involved firstly workshops in all State capital cities and Darwin to discuss the scope of the package and secondly the review of the draft guidelines. This was designed to capture inputs to the guidelines from interested parties in these jurisdictions, and the worth of the resulting guidelines is greatly enhanced by these contributions. Thanks are therefore due to the workshop attendees and all reviewers of the guidelines. Special thanks also go to the individuals from each jurisdiction who organised their local workshop.

Lastly, the contributions from Queensland EPA officers in the development and review of the guidelines are gratefully acknowledged.

Executive summary

1. INTRODUCTION

Objectives of the project

Land & Water Australia (LWA) identified a gap in the tools and techniques available to water managers for conserving waterways and planning for ecologically sustainable development. Hence, it funded this project, which has been led by the Queensland Environmental Protection Agency and Montgomery Watson Harza, with key support from James Cook University and Adelaide University.

The objectives of the project are to provide:

- a systematic and adaptable approach to protecting waterways and floodplains;
- implementation tools to support application of the approach;
- assistance with setting priorities for protection and repair; and
- assistance with identifying data gaps and priorities for research and monitoring.

The targeted users are government planners/managers, developers, consultants and the community. Possible applications include conservation plans, waterway management strategies, rehabilitation plans, water-resource development studies, environmental impact assessments and statutory planning schemes.

Why protect waterways?

> The first rule of rehabilitation is to avoid the damage in the first place! It is easy, quick and cheap to damage natural streams. It is hard, slow and expensive to return them to their original state. Usually we are not capable of returning anything approaching the subtlety and complexity of the natural system. For this reason, the highest priority for stream rehabilitators is to avoid further damage to streams, especially streams that remain in good condition.
>
> (Rutherfurd et al. 1999).

The Council of Australian Governments gives similar recognition to protecting natural values of waterways in its water reform agenda (COAG 1994), now being implemented. A powerful force for protection has been the recognition by communities, government and industry that continuing degradation does not make environmental, social or economic sense.

Professor Peter Cullen (2001) has called for a system of river reserves, which he advocates

> … will do four things. It will protect some internationally unique river systems for the enjoyment and education of Australians. It will help meet Australia's international obligations on protecting biodiversity. It will allow the development of benchmarks of river health so that we can assess how developed rivers change over time. It will allow rivers to act as biological 'seeding' sources for rivers downstream that are degraded, helping to restore downstream rivers to a healthy state.

Limitations of existing waterway protection tools

Protection of waterways has not always received the degree of attention suggested by Rutherfurd et al. (1999). There is a host of social and political reasons for this, often reflected in the negative connotation that protection somehow equals 'locking up' resources. The result has been that, despite complex webs of legislation applicable to rivers, the protection afforded is usually patchy.

Another major difficulty has been deciding just what to protect. Conspicuous examples of waterway neglect – such as urban creeks – tend to receive a disproportionate share of the resources. Rehabilitation projects are valuable ways of educating people and attracting political support, but are the benefits as great as those from protecting waterways that are already in good condition? Various methods for comparing waterways and establishing priorities have been tried, but none appears to be widely used.

There is no nationally agreed method for defining significant waterways as a basis for protection; nor are there consistent principles for waterway protection. Dunn's (2000) LWA-supported survey of river managers in Australia identified the need for

> an overarching framework for river management goals which acknowledges both community expectations for protection of a range of river values, and the government's own commitments to protection of biodiversity.

There is also limited information on sustainability thresholds – with a shortfall in research on Australian aquatic ecosystems, particularly in relation to stress (Bailey and James 2000). The complexity of riverine processes and the limited availability of long-term monitoring data mean that it is often difficult to tell when disturbances are outside natural ranges.

2. THE WATERWAY PROTECTION GUIDELINES

Products

The outputs/products from this project are:

- *Conceptual framework* – the concepts behind the guidelines;
- *Ecological value guideline* – a method for defining the natural (flora and fauna, geomorphology, hydrology and water quality) values of waterways;

- *Ecological sustainability guideline* – comparison of methods for determining the ecological sustainability of waterways;
- *Planning guideline* – an outline of planning instruments and processes, including guidance on setting priorities; and
- *Evaluation guideline* – a systematic method for evaluating impacts of planning and development on waterways.

The package is complementary to the *Rehabilitation Manual for Australian Streams* (Rutherfurd et al. 1999). The guidelines focus on protection, through planning and development control, of natural, modified and degraded waterways.

The guidelines also support one aspect of the National Water Quality Management Strategy (NWQMS) by providing a detailed approach to identifying and protecting aquatic ecological values. They do not attempt to deal with the social or economic components of waterway protection, although these are clearly important factors in decision making. However, the guidelines support the wider scope of the NWQMS in one respect: they deal with the intrinsic values of riparian zones and floodplains.

Consultation and adoption

The guidelines have emerged over the past few years, with an early step being a workshop of ecologists, geomorphologists and other practitioners from Victoria, New South Wales and Queensland held in December 1998. This was followed by workshops in May and September 1999.

For this project, a series of scoping papers was prepared and public comment sought through the LWA website in November 2000. Workshops were held during this period in all State capital cities and in Darwin, with a general invitation for participation through water-related email and news networks. Comments were used to develop the draft guidelines which were again posted on the LWA website for comment. The comments have been incorporated and the final guidelines are now released. Four conferences, at which aspects of the guidelines have been presented, provided further informal input.

The consultation helped to collect information about the various methods used to assess natural significance and sustainability. Australia has several documented methods, some of which have been applied nationally and some state wide. These have been reviewed as part of guideline development. Case studies from several States have also been documented.

LWA and the project team have deliberately avoided advocating a single national method. Apart from the challenge of negotiating an agreement, there may be technical or political constraints. Instead, the team has developed a framework that draws on overseas and Australian experience and can be adapted to a variety of contexts. The evolution of the national water quality guidelines from 1974 to 2001 illustrates how a national approach can be useful in different contexts over a long period, by limiting the level of prescription and by leaving adoption up to each jurisdiction. The waterway protection guidelines are meant to evolve through experience, as well as through the development of new approaches.

3. FITTING THE CONCEPTS TOGETHER

Linking analysis to management

The guidelines are based on the premise that the key to protecting waterways is understanding their ecological values (significance) and sustainability (in response to threats). This information is then used to support planning and/or development evaluation. The main outcome is that waterways are healthy and their natural values are protected. Figure ES1 shows the relationship of these components (the conceptual framework) and the corresponding guidelines.

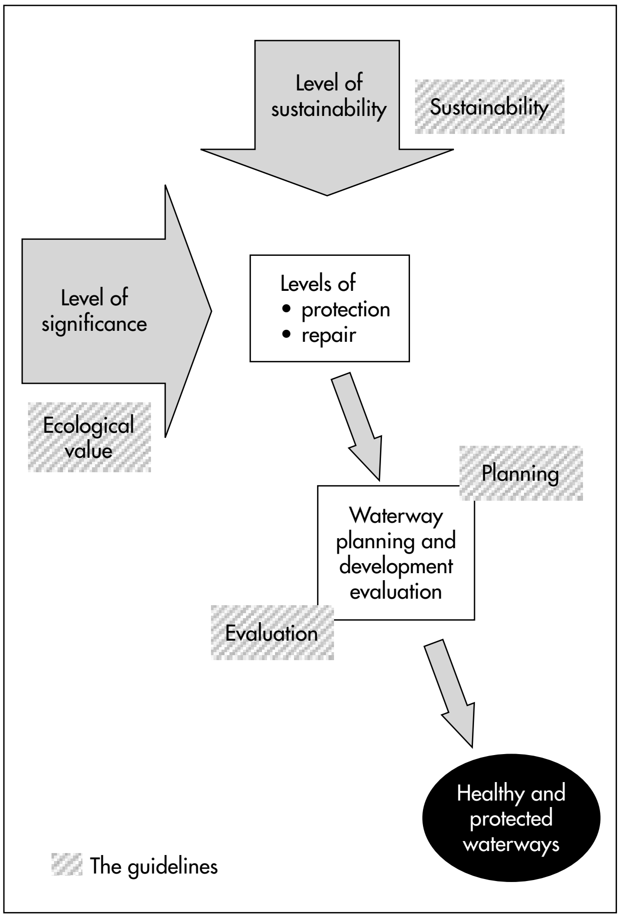

Figure ES1. Overview of the conceptual framework, showing where the guidelines fit.

Guiding principles for waterway protection

Dunn (2000) recommended that a set of principles be developed for the protection of *biodiversity, ecosystems and processes.* It is difficult to provide guidance to practitioners about what to measure and assess (let alone protect) without such a foundation. To help with the drafting of the guidelines, the team derived a set of principles from State and federal laws, policies and strategies.

The goal of the guidelines is *maintenance of ecological values*, where 'values' encompasses both waterway health and integrity. The principles are divided into those applying to all waterways and those applying to waterways of high conservation priority – reflecting many of the assessment methodologies and approaches to conservation in the various Australian jurisdictions (Dunn 2000). The premise is that all waterways should be healthy (as a minimum), but that some waterways warrant a greater level of conservation.

GOAL:

To maintain the ecological values of waterways and floodplains

ECOLOGICAL PRINCIPLES:

For all waterways and floodplains:

1. Maintain natural structures and functions[a] that are essential to waterway health.
2. Prevent serious and irreversible loss of natural[b] diversity.
3. Mimic natural streamflow characteristics to support the health of target species/communities.
4. Protect rare or threatened structures and functions.
5. Conserve representative examples of waterways and their natural features.

Greater protection for waterways and floodplains of high conservation priority:

6. Maintain the integrity of natural structures and functions[a] that contribute to ecological value.
7. Maintain natural[b] diversity.
8. Maintain natural streamflow characteristics.

[a] Includes species, taxa, communities, habitats, geomorphic features and natural processes

[b] Includes flora, fauna, geomorphology, water quality and hydrology

The consultation process has proven these principles to be reasonably well accepted – which is hardly surprising considering their genesis. They will be subject to further scrutiny and comment as the guidelines are used.

However, some aspects go beyond the current level of protection in most jurisdictions, because:

- the overall goal relates to ecological values, rather than narrower concepts such as health or biodiversity;
- maintaining health is the minimum target for all waterways, but maintaining the integrity of all values is the target for waterways of high conservation priority; and
- the inclusion of representative waterways recognises that common systems are also worthy of protection.

Each guideline has been developed with these principles in mind.

4. ECOLOGICAL VALUE GUIDELINE

Defining the ecological value of waterways should be an early step in the waterway protection process, as it establishes the structures and functions that need to be maintained. The guideline defines ecological value as:

> the natural significance of ecosystem structures and functions, expressed in terms of their quality, rarity and diversity. Significance can arise from individual biological, physical or chemical features or a combination of features.

The ecological value guideline has drawn on two recent related reviews undertaken for LWA (Dunn 2000; Phillips et al. 2001) and includes a summary of existing methods for determining aspects of ecological value. These methods include State of the Rivers (Western Australia, Queensland), Index of Stream Condition (Victoria), Stressed Rivers (New South Wales) and the National River Health Program's AusRivAS (national), along with some international examples (Canada's Heritage Rivers, the United States' Wild and Scenic Rivers, the United Kingdom's SERCON).

Criteria for identifying ecological value are drawn from a practitioner survey undertaken by Dunn (2000), namely:

- *naturalness* – to what extent are the waterway's structures and functions similar to natural?
- *representativeness* – how typical are the waterway's structures and functions of its particular waterway type?
- *diversity or richness* – how biodiverse and geodiverse is the waterway?
- *rarity* – how unusual (and/or threatened) are the structures and functions of the waterway?
- *special features* – does the waterway system contain (or support) significant physical, chemical or biological features?

The criteria are further defined through *indicators* at two scales (regional/catchment scale and local scale). Different indicators are applicable to differing spatial and temporal scales – depending on the context. Most of the readily adopted indicators and measures are structural (patterns) rather than functional (processes). Both types are required, but very little functional information is currently obtainable. For each indicator, the guideline identifies *measures* (eg. total annual diversions, percentage of exotics, species richness) that can be enumerated using field or other data.

A generic method for deriving ecological values is set out in Figure ES2. Classifying waterways according to 'type' (step 4) is important for defining reference condition against which *naturalness* can be compared, and for assessing the *rarity* and *representativeness* of particular river types.

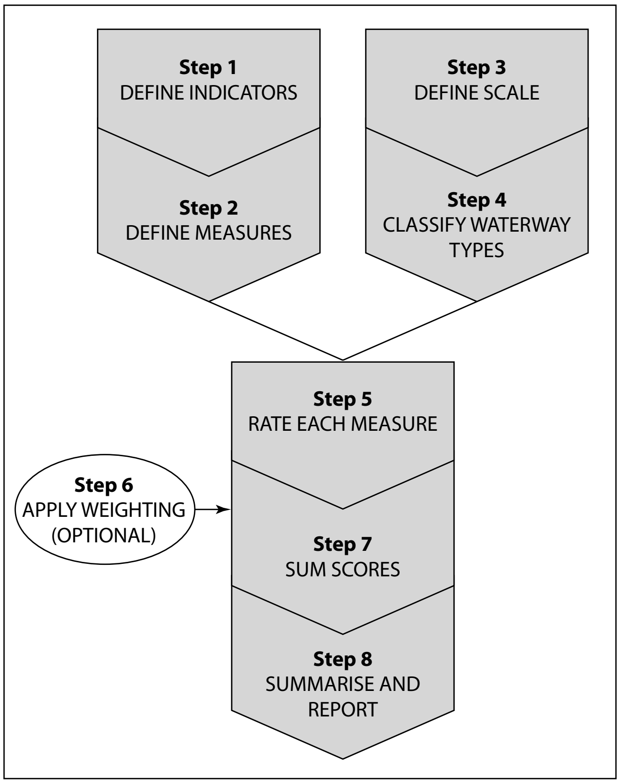

Figure ES2. Summary of method for ecological value assessment

This method is sufficiently flexible to accommodate a range of applications (from simple qualitative assessments to scientifically robust assessments) depending on the project requirements, resources, and skills available. The guideline provides examples of complex and simple applications. Outputs from the method can be produced in a variety of ways (eg. tabular, graphical). The information from such assessments can then be used as an input to prioritisation of waterway protection actions and evaluations of proposals (eg. dams, residential estates).

5. SUSTAINABILITY GUIDELINE

The sustainability guideline provides:

- a working definition of ecological sustainability;
- a discussion of approaches to determining sustainability;
- criteria and indicators for sustainability;
- a discussion on temporal and spatial issues (eg. relating to cumulative impacts); and
- a method for describing the sustainability (or non-sustainability) of projects (see figure ES3).

The guideline defines ecological sustainability as

> the ability of environmental systems (including biota and surrounds) to maintain their essential life functions in a healthy way (where 'healthy' implies the ability of the system to persist with minimal unnatural stress or inhibition of natural functions).

The guideline then outlines particular considerations in determining sustainability, including stability (the ability of a system to maintain structure/patterns in the face of disturbance), vulnerability (susceptibility to change) and thresholds (the conceptual points or ranges which represent change in waterway health in response to human induced changes).

The guideline nominates a pressure–state–response (PSR) model as a basis for sustainability assessments. The PSR model is based on causality, where human activities exert pressures on the surrounding environment and thus change its state. Knowledge about the state of the environment may then elicit a response from society (eg. new policy, changes in attitude), which may influence those activities that exert pressure on the environment.

There are five main steps involved in the sustainability assessment. These are discussed in detail in the guideline and are summarised in Figure ES3. Examples of sustainability indicators are provided for both a rigorous sustainability assessment as well as a less rigorous qualitative appraisal. The guideline provides a range of discussion points and suggested approaches to identifying sustainability.

It is recognised that approaches for assessing sustainability are less well developed than those for defining ecological value. This is due in part to a lack of data on waterways and lack of knowledge on how to define waterway sustainability. Until such knowledge is acquired, our ability to define waterway/floodplain sustainability will be limited. As our knowledge of waterway structures, functions and pressures improves, the methods for determining waterway sustainability will also need to be reviewed and, if necessary, adapted to incorporate new knowledge.

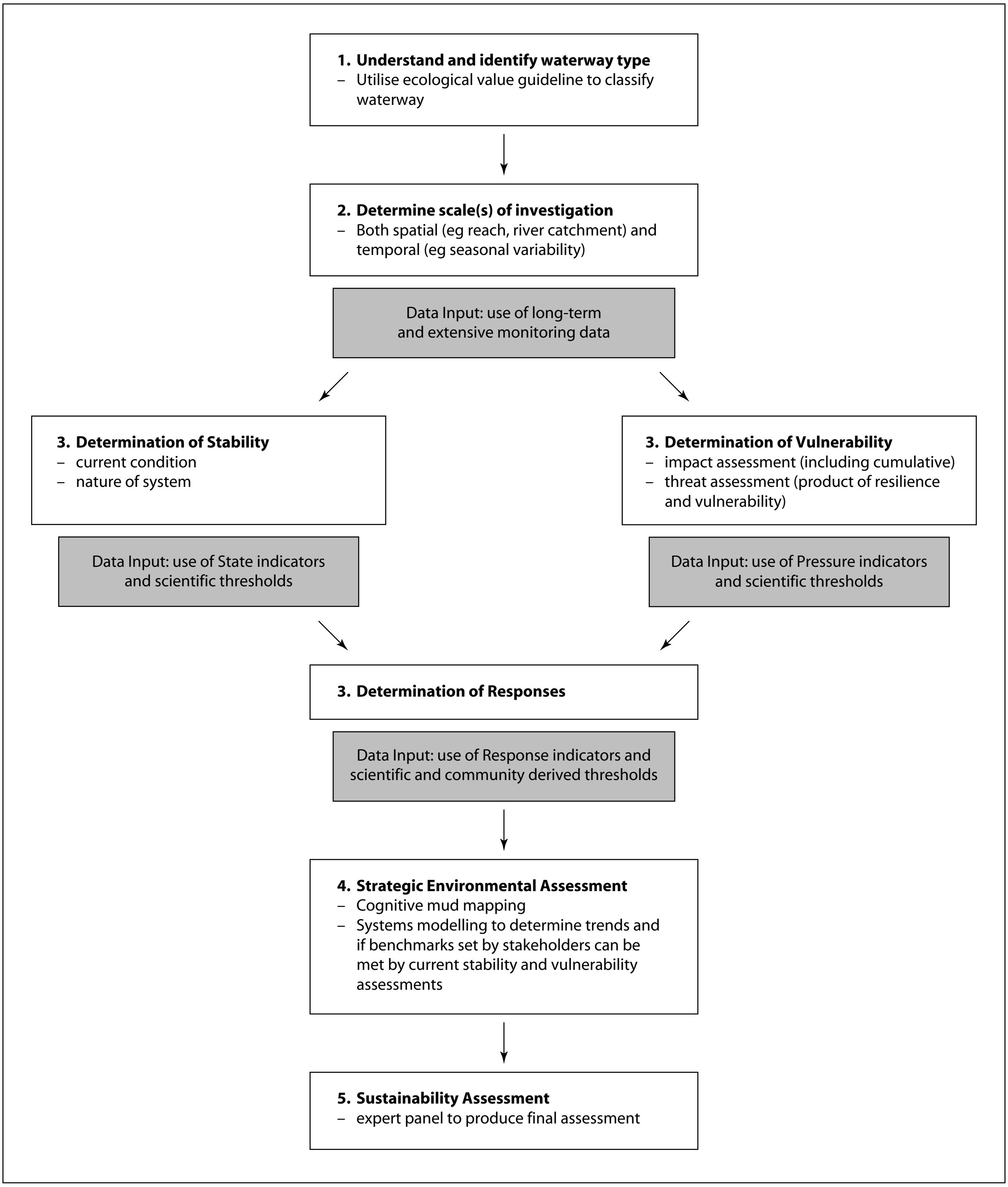

Figure ES3. An ecological sustainability assessment method.

6. PLANNING GUIDELINE

The planning guideline provides information and guidance on the planning instruments and associated processes for protecting the ecological values of waterways, irrespective of where they occur on the continuum from undisturbed to highly modified.

The guideline includes:

- a discussion on how waterway protection can be included in relevant planning processes;
- a review of different planning instruments, based on work by Dunn (2000) and Phillips et al. (2001) (eg. legislation, agreements, policies, codes of practice);
- a generic four-step planning process (establishing a vision, developing the plan, implementing the plan and monitoring/reviewing the plan);
- a detailed seven-step process for developing the plan;
- guidance on the level/degree of protection to be applied to a waterway; and
- guidance on prioritisation of protection activities (ie. how to determine which waterway should be given priority for protection, depending on the ecological values of the waterways and threats to them).

The appendixes provide detailed commentary on the various protection instruments, and some examples of other planning processes relevant to waterway protection planning. Two particular components of the planning guideline are considered below.

Levels of protection

The guideline recognises that different levels of protection can apply to waterways, depending on the current and desired ecological values of the waterways. These levels are:

- *Conservation* (the highest level of protection), to protect representative sections of waterways identified as having high ecological value. This could be applied through a State river-protection policy, with support from other specific instruments (eg. plans to protect natural flows).
- *Sustainable use*, which allows for activities that do not compromise the ecological sustainability of the waterway concerned. Holistic instruments such as catchment planning are relevant examples.
- *Protection of remaining values*, a more specific approach addressing particular remnant values or specific threats (eg. a threatened-species management plan, which maintains habitat values for a species that is now rare).

Prioritising protection

The conceptual framework can be used as the basis for prioritising protection. The resulting 'matrix' (Figure ES4) combines ecological value with threats (ie. risks to sustainability). This requires an understanding of a waterway's ecological value and its relative level of sustainability (see other guidelines).

The matrix can assist in:

- deriving protection priorities (using relative positions of waterways on the matrix), and categorising appropriate management responses;
- demonstrating the consequences of threatening processes and/or repair actions for ecological values by plotting the expected resultant trajectory; and
- highlighting data/knowledge deficiencies (eg. if the ecological values are known but inadequate information is available on threats).

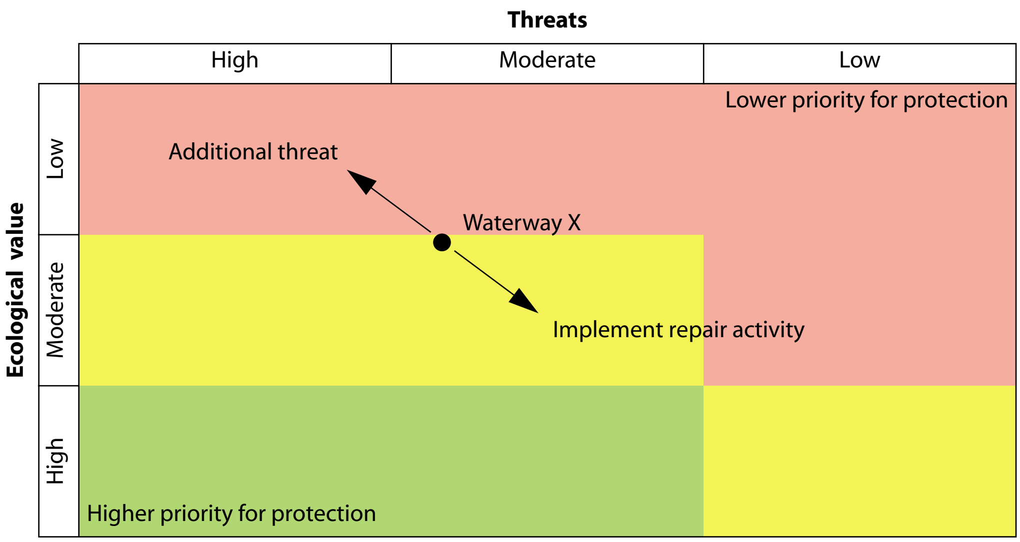

Figure ES4. Example of a conservation priority-setting process

7. EVALUATION GUIDELINE

The evaluation guideline is intended to assist environmental impact assessment associated with catchment planning and projects. It provides a comprehensive technical framework for advising proponents on the ecological information needed in environmental assessment reports, as well as providing some benchmarks against which to judge sustainability. The guideline does not address economic, social or amenity issues.

An overview of the process is set out in Figure ES5.

The guideline attempts to break down the waterway protection principles into more measurable components. These can be used for scoping (defining terms of reference) as well as for setting performance criteria for acceptable levels of impact. The guideline also provides an outline method, which is applicable to both temporal and spatial effects, for considering cumulative impacts.

It is inevitable that information will be lacking in some cases – whether about ecological values or threatening processes. The result may be that ecological value and long-term sustainability are underestimated because our understanding of a given area or waterway is incomplete. The guideline discusses approaches to applying the precautionary principle in different environmental and developmental contexts.

Once all the available information is assembled, usually within an EIS, the question facing the agencies responsible for project evaluation is *"How are we to ensure that the overall impacts of a project are evaluated?"* The guideline provides the following three approaches to evaluate the information, and analyses their use both alone and in combination:

- *Threshold analysis* (application of a series of thresholds for each criterion, above which impacts are deemed to be unsustainable);
- *Scoring system* (summated numerical product of rating and weighting for each criterion); and
- *Expert panel* (based on a subjective assessment by a multidisciplinary expert panel, assembled specifically for individual catchments).

A combination of the threshold and expert panel options is probably the most justifiable approach. It provides the highest validity, at the expense of some transparency. It also offers greater effectiveness in that those involved with the expert panel will be in a strong position to justify their conclusions about sustainability. It can also accommodate data gaps because panel members may be in a position to make a reasoned judgment, based on their experience of similar systems, about particular impacts.

8. APPLICATION OF THE GUIDELINES

The guidelines can potentially assist a wide array of applications, including:

- *Conservation/protection strategies/plans.* Conservation priorities should be the basis for establishing levels of protection. For example, knowing that a stream has high ecological value and is susceptible to threats will help to demonstrate its priority for protection in relevant policies, strategies and plans.
- *Environmental/water quality objectives for individual waterways.* The national water quality guidelines apply concentration targets (trigger levels) differently according to the type of waterway (estuary, lowland river etc.) and its 'level of protection' (eg. high ecological value, slightly to moderately disturbed or highly disturbed). These guidelines support measuring level of protection and developing trigger levels, to assist with establishing appropriate water quality objectives.
- *Waterway management and rehabilitation plans.* Degradation in many waterways results in some values and ecological function being affected, for example through the creation of discontinuities in riparian vegetation. The ecological value of these systems may be increased through selective rehabilitation (such as rehabilitation of riparian vegetation).
- *Water resource studies and environmental impact assessments.* When applied to a particular catchment, the guidelines help to determine values, sustainability of environmental impacts and the types of mitigation factors that are critical for maintaining sustainability. Ecological criteria can be used alongside economic and social criteria to compare development options. Impact assessment of individual developments can be supported by a more systematic approach to defining sustainability.
- *Catchment and stormwater management plans.* Assessment of values and threats is now an accepted part of catchment and stormwater planning. The guidelines can help to fine tune remedial actions by accurately depicting natural values and associated threats. One result is a wider focus on the waterway as a system, rather than as a problem to be solved. For example, gross pollutant traps and water-sensitive urban design can both have unintended adverse impacts if all stream values are not taken into account.
- *Statutory planning schemes.* Planning schemes and planning policies provide mechanisms for helping to achieve defined environmental, social and economic objectives. This is primarily through geographical planning for future land use and through development control within the land use designations. The guidelines can assist in setting environmental objectives and identifying waterways that are in need

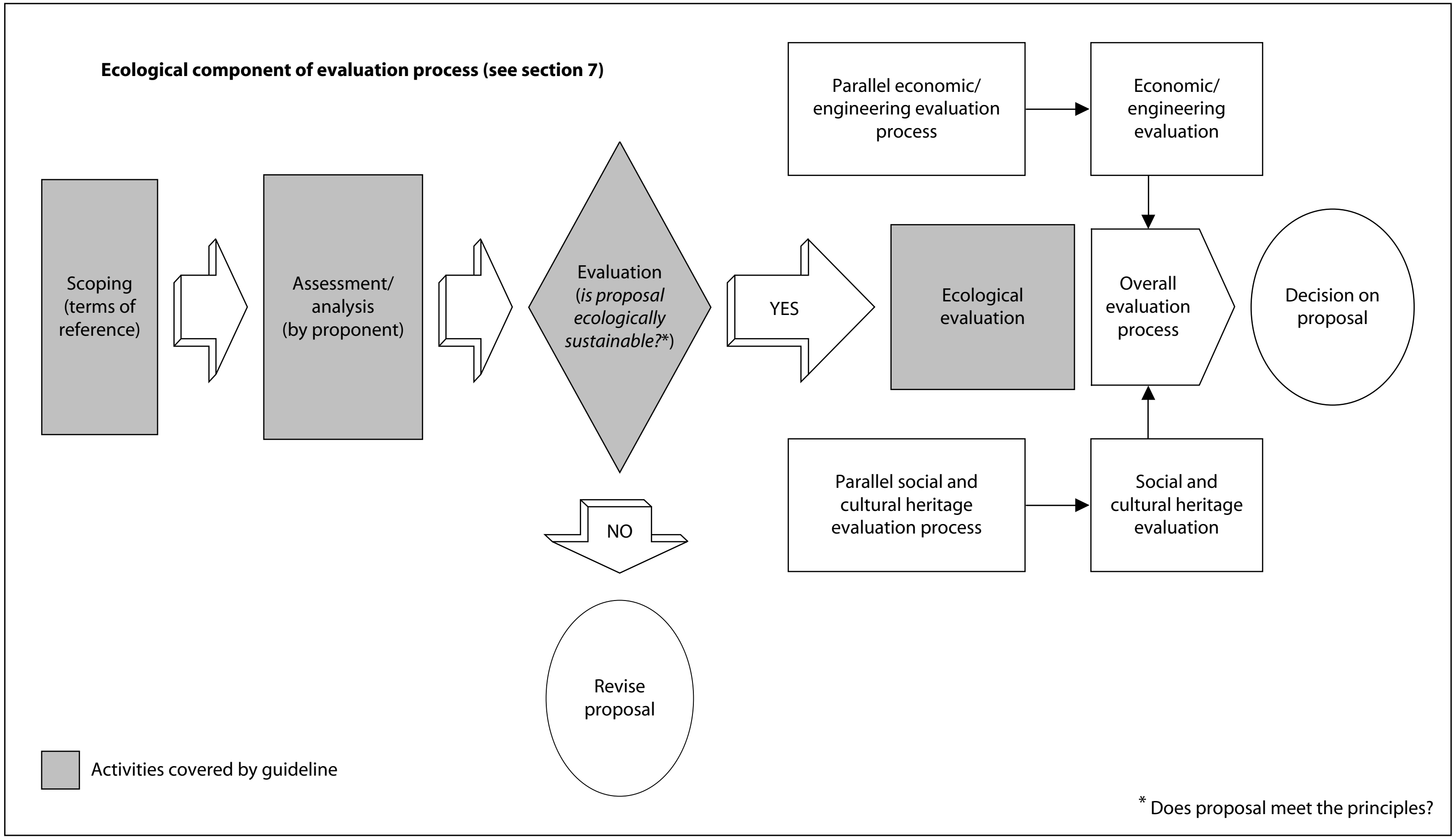

Figure ES5. Context of, and process for, ecological component of evaluations.

of greater protection. In turn, the effects of different land uses and development controls, and relative threats to values, can be evaluated.

9. IMPLEMENTATION AND REVIEW

The guidelines are the immediate **output** of this project. The intended **outcome** is an improved rigour and effectiveness of research, planning and decision-making processes for waterway protection planning and management. The guidelines should be seen as an initial version, which will be reviewed following feedback from users and researchers.

Comments on the draft guidelines tended to focus on their application. A number of commentators noted that creating a set of guidelines applicable to all types of rivers in Australia is difficult, and that the guidelines may be hard for community groups to use. LWA and the project team acknowledge both issues. However, early indications from two case studies – one a large rural area subject to cyclonic conditions, the other a diverse urban area in the midst of national parks – are that the methods can be successful. In both cases, the classification system and the ecological values assessments were carefully modified to suit the study context.

In regard to the use of the document by a community readership, while its volume, detail and complexity do not lend themselves to easy reading, the underlying logic is simple and provides a clear link from concepts to detail. There are many precedents for community groups supplementing their core expertise by using their networks to draw on the skills of scientists.

Quality control (ie. credible results) is one of the difficulties facing anyone who adapts and applies the guidelines. This is a valid issue and implies that, without a consistent approach, results will not be comparable. At this early stage, the guidelines need a great deal of testing and refinement before we attempt to standardise national benchmarks.

The guidelines are a compendium of approaches for assessment, planning and evaluation, based on a combination of ecological values and sustainability. Early experience is positive and many commentators have strongly supported the provision of this type of information. Many of the individual techniques are already in use in Australia, but the guidelines represent the nation’s first systematic approach to waterway protection.

Glossary

Allochthonous: organic material that is developed or derived externally from a particular waterbody.

Autochthonous: organic material that is developed or produced within a particular waterbody.

BAS (bioregional aquatic system): a derived unit for waterway classification, based on biological, physical and chemical characteristics. Applies to channel, banks and floodplains of ephemeral and permanent waterways.

Benchmarking: an approach used in developing waterway management regimes in the face of uncertainties about cause and effect. Comparative data from modified or natural systems are used to define changes in condition.

Biodiversity: the variety of all life forms – the different plants, animals and microorganisms, the genes they contain and the ecosystems that they form at local and regional level.

Biogeographic region (bioregion): an extensive region distinguished from adjacent regions by its broad physical and biological characteristics.

C.A.R.: Comprehensive, Adequate, Representative – as applied to reservations of natural areas or features.

Carrying capacity: the maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a defined impact area without progressively impairing bioproductivity and ecological integrity.

Catchment: the area within which rainfall contributes to the run-off flowing to a particular point on a waterway.

Conceptual framework (for waterway protection): a systematic and comprehensive approach to protecting waterway ecology and geomorphology, which can be used to guide decisions on development and management (being developed as part of this project).

Condition: the quality or state of a waterway, floodplain or catchment, expressed in terms of the integrity of natural features.

Conservation: all the processes and actions of looking after a place to retain its natural significance and always includes protection, maintenance and monitoring (AHC 1996).

Conservation priority: a measure of the relative importance of protecting the biological, physical and other conservation values of an area (cultural heritage values can be included, but methodologies are outside the scope of these guidelines).

Criterion: a standard or rule by which a judgment can be tested or made.

Cumulative impact assessment: the assessment of the impact on the environment resulting from the incremental impact of an action when added to other past, present or reasonably foreseeable actions, regardless of what agency or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place simultaneously or over time.

Ecological integrity: the ecological values, including biodiversity, geodiversity, essential ecological processes and life support systems (of a waterway and floodplain).

Ecological sustainability: the ability of ecosystems to maintain their structural and functional integrity in response to perturbations.

Ecological value: the natural significance of ecosystem structures and functions, expressed in terms of their quality, rarity and diversity. Significance can arise from individual biological, physical or chemical features or a combination of features (see appendix D4 for more information on ecological value and environmental value).

ESD (ecologically sustainable development): using, conserving and enhancing resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be improved.

Ecosystem: a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit.

Ecosystem structures: the site-specific characteristics of an ecosystem (eg. species composition, soil, hydrology); synonymous with 'features' or 'patterns'.

Ecosystem functions: the biological, chemical and physical processes that take place within an ecosystem (eg. carbon cycling, nutrient assimilation).

Ecosystem services: the beneficial outcomes that result from ecosystem functions (eg. cleaner water); the outcomes may accrue to other ecosystems or to humans.

Environmental assessment: generic term for the process of assessing the environmental effects of projects, plans, programs and policies. Generally involves scoping, analysis/assessment and evaluation.

EIA (environmental impact assessment): a process for the orderly and systematic evaluation of a proposal, including its alternatives and objectives, and its effect on the environment, including the mitigation and management of those effects. The major output of the analysis/assessment phase of EIA is a report (eg. environmental impact statements) produced by the proponent.

Equilibrium: a state of balance of the structures and processes that affect the ecological and physical integrity of a waterway.

Evaluation: the review of a proponent's environmental assessment reports (such as an EIS). Usually coordinated by a government agency, with input from stakeholders.

Floodplain: land that is adjacent to a waterway (and includes the riparian zone), is subject to flooding (typically at an average recurrence interval of 100 years) and is intricately linked to the waterway.

Geodiversity: the physical (geomorphological) diversity of waterway systems at a range of scales from channel to landscape.

Geomorphology (fluvial): the physical structures, processes and patterns associated with waterway systems – including landforms, soils, geology and the factors that influence them.

Habitat: the biophysical medium or media occupied, or once occupied and potentially able to be reoccupied, by an organism or group of organisms.

Hydrology: properties, distribution, and circulation of water on and below the earth's surface and in the atmosphere.

Indicator: physical, chemical, biological or socio-economic measures that best represent the key elements of a complex ecosystem or environmental issue.

Measure: a specific determinant for an indicator.

Mitigation: an action taken or planned to reduce the adverse impact of a development. Actions can be associated with policy, planning, design, construction, operation or management.

Principle: a fundamental tenet that provides the basis for waterway planning and management.

Regional ecosystem: a vegetation community in a bioregion that is consistently associated with a particular combination of geology, landform and soil.

Representativeness: serving as a typical or characteristic example.

Rehabilitation: repair of the fundamental elements to an approximation of natural condition.

Remediation: repair to an improved or equilibrium condition (which may not resemble natural condition).

Restoration: repair to a known past state or an approximation of the natural condition.

Riparian zone: the channel margin under the immediate influence of median flows.

Scoping: a process for determining the scope of issues to be addressed in the environmental impact assessment process and for identifying the significant issues related to a proposal.

SEA (strategic environmental assessment): the systematic and comprehensive process of evaluating the environmental effects of a policy, plan or program and its alternatives.

ToR (terms of reference): a document prescribing the matters to be considered in an environmental assessment, as specified by the relevant government agency as an outcome of scoping.

Threatening processes: current or future events that might have an adverse impact on ecological integrity. Events may be constant, variable or episodic. Events may arise through a current or future action (eg. catchment land-use changes) or through inaction (eg. allowing active stream bank erosion to continue).

Waterway: a river, creek or stream in which water flows permanently or intermittently; includes bed and banks and any other element of a river, creek or stream that confines or contains water.

Abbreviations and acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
APFD	annual proportional flow deviation
ARI	average recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AusRivAS	Australian river assessment system
BACI	before/after and control/impact
BAS	bioregional aquatic systems
CAMBA	China Australia Migratory Birds Agreement (bilateral agreement between Australia and China for the protection of migratory birds)
CIA	cumulative impact assessment
COAG	Council of Australian Governments
CWMB	catchment water management board
EIA	environmental impact assessment
ERAPSM	environmental risk assessment and priority-setting model
ESD	ecologically sustainable development
FLOWRESM	flow restoration method
GIS	geographic information system
HCV	high conservation value
IA	impact assessment
ICM	integrated catchment management
IFR	in-stream flow requirement
IGAE	Intergovernmental Agreement on the Environment
IQQM	integrated quantity and quality model
JAMBA	Japan Australia Migratory Birds Agreement (bilateral agreement between Australia and Japan for the protection of migratory birds)
LUF	land use factor
MARA	multi-attribute rapid assessment
MODSS	multi-objective decision support system
NPWS	National Parks and Wildlife Service
NSESD	National Strategy for Ecologically Sustainable Development
NWQMS	National Water Quality Management Strategy
O/E ratio	ratio between observed and expected levels
PBH	pressure–biota–habitat
PPT	potential problem threshold
Ramsar Convention	Convention on Wetlands of International Importance
RFA	regional forest agreement
SAT	special asset threshold
SEA	strategic environmental assessment
SERCON	system for evaluating rivers for conservation (United Kingdom)
SoE	state of the environment
ToR	terms of reference
WRP	water resource planning (formerly water allocation and management planning) in Queensland
WCED	World Commission on Environment and Development

Part A – Conceptual Framework

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1 Introduction

Land and water resources developments, individually and collectively, have resulted in major and irreversible environmental damage to rivers and wetlands. The cumulative impacts of small developments have also had a substantial effect on some waterways. Waterways have been modified as a result of human occupation, land clearing, water regulation, impacts on water quality, river engineering, urbanisation and introduced species (DEST 1996).

Protection of waterways is often hampered by insufficient data and knowledge of their capacity to adapt to change. Consequently, many decisions about resource use have been carried out without an adequate understanding of the consequences. A major constraint to waterway protection has been the lack of an objective and comprehensive definition of waterway sustainability.

Water resource management takes place amid increasing community awareness of environmental issues, economic efficiency and equity. Government programs seek better outcomes for all stakeholders and the natural environment. The National Water Reform Framework, introduced under the auspices of the Council of Australian Governments (COAG), has been a major driver of this process.

Water availability in Australia has profoundly influenced economic development. Harnessing water has been driven largely by the urban, industrial and agricultural sectors, to which water brings direct and measurable financial benefits.

Although monetary benefits of water resource developments can be quantified with some precision, adverse environmental impacts cannot. The limited way in which the impacts on the conservation/ecological values of waterways have been assessed causes particular concern. Many impacts (such as the ecological effects of changes in downstream flows) are difficult to predict technically, let alone to evaluate in dollar terms. There are often secondary social, ecological or economic effects (such as changes in offshore fisheries production) that may be ignored or considered only peripherally.

A series of laws and policies introduced in Australia since the early 1970s has resulted in gradual progress towards a more balanced approach to decision making. The National Strategy for Ecologically Sustainable Development (Commonwealth of Australia 1992) remains a seminal document for legitimising and directing changes in government planning and assessment processes. Negotiations at Commonwealth and State levels resulted in a water reform agenda (COAG 1994; ARMCANZ and ANZECC 1994) that placed ecologically sustainable development (ESD) at the centre of water resources planning.

Protection of waterways has received less attention in Australia than water resource development. Our current inability to accurately assess impacts and to define 'sustainable development' reflects the relatively low level of support for research and long-term monitoring, which are necessary to achieve the ecological sustainability of waterways.

This part of the guidelines describes a conceptual framework for dealing with waterway protection. It suggests a set of working principles to guide protection and introduces a suite of four complementary guidelines covering ecological values, sustainability, planning and evaluation (impact assessment).

The guidelines are relevant to all waterways, including intact and modified systems. Practical tools for rehabilitation, such as environmental flow assessment and channel management techniques, are outside the scope of the guidelines. They are available and are referenced where relevant.

2 Why a conceptual framework?

The guidelines project addresses a gap in the tools and techniques available to water managers for conserving waterways and planning for ecologically sustainable development. Its framework allows maximum use of existing data and it identifies additional data requirements.

The purpose of the project is to provide:

- a systematic and adaptable approach to protecting waterways and floodplains;
- implementation tools to support application of the approach;
- assistance with setting priorities for protection and repair (restoration, rehabilitation); and
- assistance with identifying data gaps and priorities for research and monitoring.

The guidelines are intended for all stakeholders – government (conservation, environmental, planning and resource management agencies), developers/consultants, landholders and the community.

Traditionally, governments tended to operate as the main stakeholder responsible for waterways protection. Increasingly, industry and the community have become involved (Boully 2000). Dunn (2000) argued that ecological value assessment is "essentially a political process" and that "if pursued independently, it is unlikely that conservation measures will be implemented."

The resources available to each group will vary widely and the guidelines have been drafted to maximise adaptability. Application of the guidelines may require competent scientists to undertake some of the primary data collection and analysis on behalf of users, but the guidelines are sufficiently flexible for use by groups with fewer skills and resources.

3 Scope

The guidelines are intended to be applicable to all waterways and can support planning, policy, regulation and development control (see Part A, section 4.2) for in-stream, wetland, riparian and floodplain, and estuarine systems. They are also adaptable to terrestrial systems. Catchments and waterways are functionally related and catchment factors are treated as integral.

The guidelines deal only with biophysical components and do not attempt to deal with the social or economic components of waterway protection. In that sense, they are consistent with the draft National Principles for the Provision of Water for Ecosystems (ARMCANZ and ANZECC 2000). Water allocation decisions require consideration of economic, social and ecological values. However, both the draft National Principles (as shown in Figure 1) and these guidelines focus only on the ecological component of relevant processes.

The conceptual framework addresses waterway significance, sustainability and protection (see Figure 2). These underpin both broad-scale conservation planning and strategic and project-specific impact assessment. Applied at both catchment and project scale, the framework offers the possibility of dealing with cumulative impacts and achieving long-term sustainability.

The framework includes the following elements:

- a method for describing ecological significance (value);
- a method for defining ecological sustainability; and
- approaches to conservation/protection planning and evaluation that draw on the two methods.

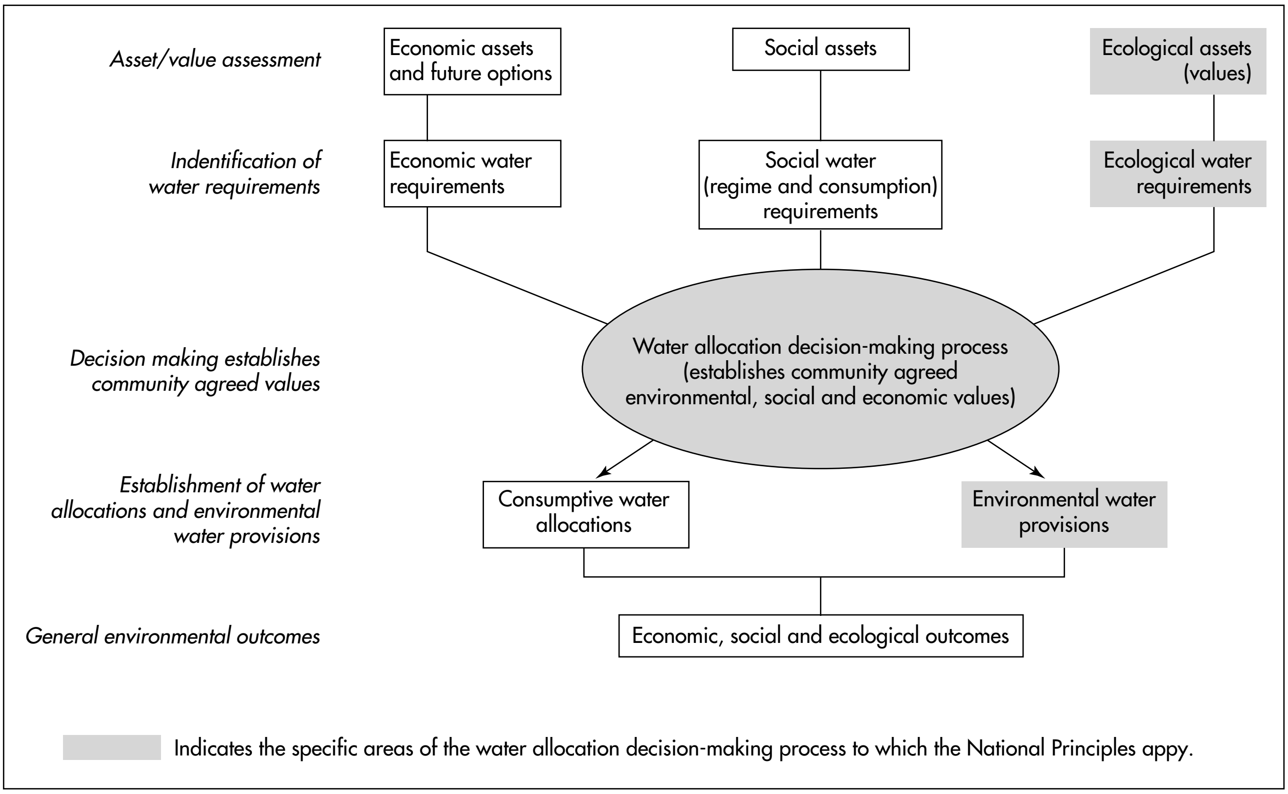

Figure 1. Generalised decision-making process for water allocation. (Source: Draft National Principles for the Provision of Water for Ecosystems [ARMCANZ and ANZECC 2000].)

The framework also provides a way to incorporate ecological value and sustainability methods into planning for waterway repair – particularly when setting priorities.

Priorities for Waterway Protection

"Although it is important to classify areas on overall ecological value irrespective of the major management intervention proposed, it is also important to identify subsets of those where particular management interventions are a priority, particularly for assessments at regional or State-level scale. At these scales, targeting priorities areas is usually necessary and … the first priorities should be high-value areas under threat/risk. Management priorities should be recognised up front in designing the assessment scope."

Commentary on the project's scoping papers (January 2001)

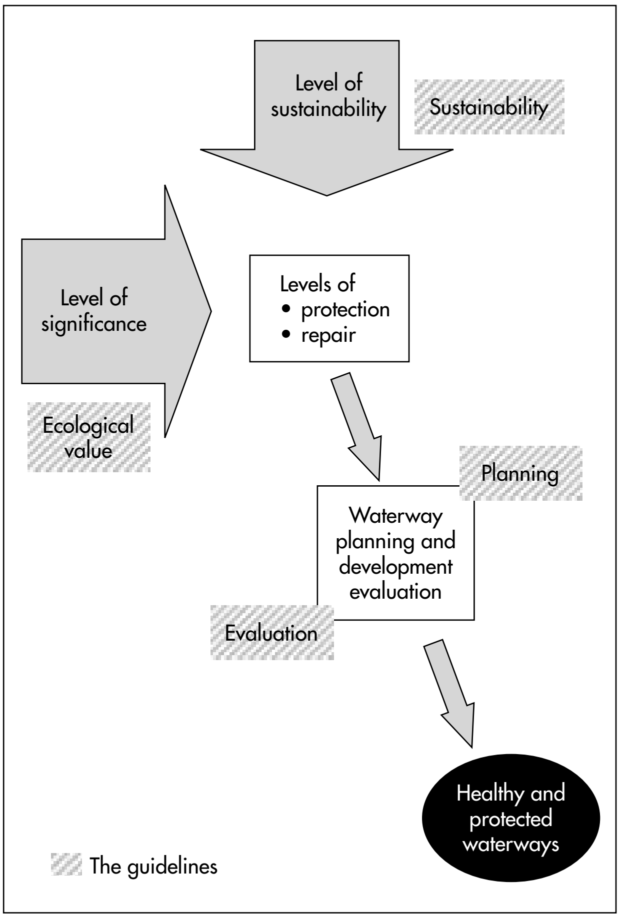

Figure 2. Overview of the conceptual framework, showing where the guidelines fit.

4 Approaches to waterway protection

4.1 What is waterway management?

'Management' is the spectrum of activities associated with conservation, development and operation of waterways, including:

- planning;
- policy and regulation;
- development control (catchment and in-stream);
- land/catchment management;
- storage operation, water diversion and flow regulation;
- flood control;
- in-stream management (eg. recreation, navigation);
- waterways creation, including channel and drainage construction;
- rehabilitation and restoration (channel, floodplain, catchment); and
- monitoring and applied research.

These categories can be considered as protection (see Part A, section 4.2) or repair (restoration and rehabilitation). Figure 3 illustrates the importance of getting the right 'mix' of protection and repair measures in different contexts, for example by emphasising protection of those waterways with higher values.

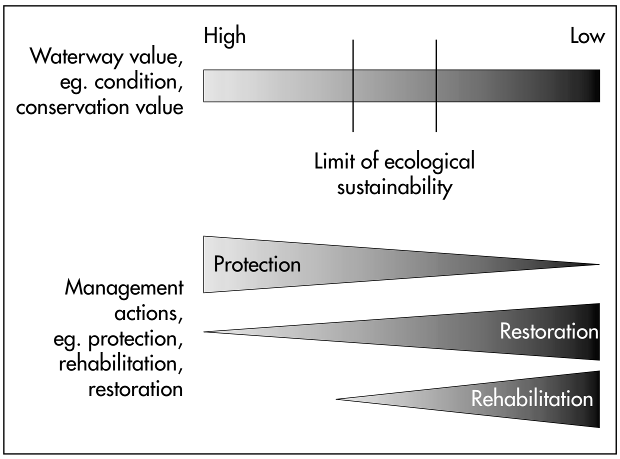

Figure 3. Relationship between waterway value, sustainability and management.

In Australia, the body of knowledge about land and waterway resource management is perhaps strongest in restoration and management (eg. Rutherfurd et al. 1999; Koehn et al. 1999). Methods for protecting waterways are less well articulated, particularly in scientifically defining the limits of acceptable change. Some recent attempts in Queensland to apply rational techniques to flow management offer some promise (eg. Arthington and Zalucki 1998; QDNR 1998a,b,c) but environmental outcomes have yet to be measured.

4.2 What is waterway protection?

Definitions

Waterway protection is one component of conservation, is an active process of management, and is not simply a 'locking away' of natural systems. The following definitions are used (AHC 1996):

Conservation: all the processes and actions in looking after a place in order to retain its natural significance – always includes protection, maintenance and monitoring.

Protection: taking care of a place by maintenance and by managing impacts to ensure that natural significance is retained.

Maintenance: the continuous protective care of the biological diversity and geodiversity of a place – distinguished from repair.

Repair: involves restoration and reinstatement.

Monitoring: ongoing review, evaluation and assessment to detect changes in the natural integrity of a place, with reference to a baseline condition.

Protection in these guidelines concentrates on the first three categories of management (Part A, section 4.1), namely:

- *planning:*
  - conservation planning (eg. national parks plans, aquatic reserve plans, community nature conservation, species recovery plans)
  - catchment planning (eg. integrated catchment management strategies/plans)
  - water resources (eg. water resources development planning)
  - statutory land use plans (eg. local government planning schemes)
  - regional plans (eg. regional environmental plans, natural resource management plans)
- *policy and regulation:*
  - legislation (eg. planning, water resources, threatened species/ecosystems, environmental protection)
  - strategies/agreements (eg. biodiversity, wetlands conservation strategies, Ramsar Convention on Wetlands (1971), bilateral agreements with China and Japan to protect migratory birds)
  - policy (eg. State planning policies)
  - designation of protected areas (eg. national parks, reserves)
  - compensatory and incentive-based schemes (eg. covenants, agreements, grants, charges and levies, tax policy)
  - voluntary mechanisms (eg. Land for Wildlife, private sanctuaries)
- *development control:*
  - development approvals (eg. construction, drainage, channelisation, fishways)
  - operational licensing (eg. pollution control, water diversion, chemical use)
  - codes of practice (eg. industry codes and best-management practices)

Other management categories noted in Part A, section 4.1 focus on the operation or repair of degraded systems. Although some of these can be categorised as protection, the emphasis in this project is on *retention of existing ecological values*. The guidelines are intended to complement Rutherfurd et al.'s (1999) *Rehabilitation Manual for Australian Streams*.

Effective waterway protection and repair are impeded by the absence of an agreed and systematic set of principles on which to base river conservation (Dunn 2000), and by the difficulty of defining the limits of sustainability. These issues are discussed further in Part A, section 5.

4.3 Current status of waterway protection measures in Australia

Practitioners in each Australian jurisdiction have differing ranges of protection measures available to them. No comprehensive review has been undertaken, but based on several recent reviews – notably Maher et al. (1999) and Dunn (2000) – a number of common issues emerge:

- **Complexity of legislative, policy and administrative frameworks:**

  Land tenure over Australian waterways varies, with two States having Crown ownership of bed and banks and the remainder restricting Crown ownership to below the high tide mark (Maher et al. 1999). Ownership of the water itself also varies, with some States owning all water, and others only that within watercourses.

In most jurisdictions, numerous Acts significantly affect waterway protection and many have conflicting provisions (Dunn 2000). In several cases, overallocation of available water for consumptive use threatens species listed under nature conservation legislation.

Government policies, strategies and agreements (such as those for biodiversity, conservation, wetlands, Ramsar, World Heritage and catchment management) overlie the legislative framework.

These complexities have been highlighted in various catchment management strategies. Institutional and legal arrangements are often a major impediment to concerted action by stakeholders. Catchment-level waterway protection is beginning to be incorporated into legislation and institutional arrangements in some jurisdictions.

- **Conservation legislation does not have a primary focus on waterways:**

  Legislation specific to waterways has tended to focus on development control over barriers (eg. dams, weirs), regulation of water diversion or abstraction, and restriction of water pollution. Other conservation issues – notably environmental flow provision and riparian vegetation management – have only recently begun to achieve statutory recognition (for example in the *NSW Water Management Act 2000*).

  Formal protection of ecological values of waterways is generally limited at State level to areas within national parks, fisheries and threatened species. The Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* has the potential to protect biodiversity in waterways. With the exception of the *Victorian Heritage Rivers Act 1992* and the *NSW Water Management Act 2000* (which can codify high conservation value waterways), waterway conservation tends to be managed through legislation which is land use oriented – such as that governing land use planning and development control.

  Wetlands and estuarine/marine systems have statutory protection in some jurisdictions, while only Victoria and the ACT have an equivalent for freshwater waterways. Most States and Territories have committed to the development of representative systems of freshwater reserves, but implementation has not yet been achieved (Nevill 2001). Although wildlife conservation includes aquatic species, many of the mechanisms to protect wildlife (such as vegetation clearing controls) are more applicable to land.

  Specific waterway corridors are less commonly protected by statute, although many planning schemes designate conservation zones along some urban waterway corridors. This contrasts with the United States and Canada, where specific (individual river) and generic (applicable to all eligible rivers) legislation exists (see Part D).

  Catchment and streamflow protection is similarly uncommon in Australian jurisdictions, with the notable exception of many domestic water supply catchments – although the emphasis is on protection of a single (consumptive) value, rather than ecology *per se*. Legislation which attempts to limit or otherwise manage water diversions to protect downstream waterway ecological values is gradually being introduced.

- **Interjurisdictional inconsistencies in legislation and culture:**

  States and Territories have differing perspectives on allocating and managing water. Water moves across jurisdictions and is subject to varying ownership. Beds, banks and floodplains also have varying tenures.

  Some jurisdictions have a greater proportion of unallocated water and there are cyclical pressures for water harvesting. Decision-making processes reflect different histories of development and current attitudes to further development. Where catchments cross borders, this may lead to conflicts about the balance between further development and conservation.

  The COAG water reforms have sought to address such issues. States and Territories are actively revising their regulatory frameworks to accommodate the reform principles and achieve a more consistent approach.

- **Lack of consistent principles for waterway protection:**

  A recent survey (Dunn 2000) of river managers across Australia identified the need for "an overarching framework for river management goals which acknowledges both community expectations for protection of a range of river values, and the governments' own commitments to protection of biodiversity."

  The purpose of the policy framework would be to guide decision making and to establish priorities for protection and rehabilitation. Dunn (2000) recommended that a set of national principles for protection of waterways should be developed, based on existing principles (such as the National Reserve

System for Marine Protected Areas) but catering for the unique features of waterway systems, such as linearity.

- **Inconsistent approaches to identifying waterways for protection:**

  Many methods exist for assessing and classifying Australian waterways. Examples are the Australian Heritage Commission's Wild Rivers program (Environment Australia 1999; Stein et al. n.d.), the National River Health Program (AusRivAS), NSW Stressed Rivers Assessment (DLWC 1998) and Victorian Heritage Rivers. Each has been developed for a different purpose. For example, the National River Health Program (NRHP 1994) was designed to measure condition using a method, which could be practically applied across the country, with a narrow range of indicators. The differences between State approaches are substantial and the only national approach (Wild Rivers) that focused on high ecological value was forced to adopt generic indicators to achieve sufficient geographic coverage.

  The lack of a nationally agreed method for defining significant waterways limits the validity of cooperative arrangements to support protection programs.

- **Budgetary pressures:**

  Governments are increasingly reluctant to acquire land through purchase. Protection is being pursued through voluntary agreements, trusts and other mechanisms, including regulations.

  The reservation of waterway corridors is now a common part of urban planning and development approval (eg. open space contributions). This support for protection reflects community pressure as well as constraints such as flooding.

  In rural areas there are different tenures/landholdings and development pressures, and most activities are not controlled through planning schemes. Adequate protection of waterways generally involves curtailing of economic uses; for example, riparian and floodplain areas are often very well suited to agriculture. Compensation and long-term management issues make waterway corridors more difficult to secure. Controlling changes in upstream water quantity and quality is a complex issue and involves similar economic considerations.

- **Unresolved pressures on water allocation:**

  Environmental flow management is in its infancy and technical methods are still under development. Gaining stakeholder endorsement of management plans is often protracted and controversial (Maher et al. 1999), and the preservation of entitlements is a vexed issue.

  Many rivers have flow regimes that sustainably support downstream ecology and geomorphology, but are under pressure from demands to harvest more water for consumptive use. Only a handful of Australian rivers have statutory protection against further diversion.

- **Limited knowledge of sustainable thresholds:**

  There is a fundamental shortfall in research on Australian aquatic ecosystems, particularly in relation to the impacts of stress factors (Bailey and James 2000). Our knowledge is geographically patchy and is not comprehensive across the biota and processes in individual rivers. Waterways involve complex lateral, vertical, longitudinal and temporal interactions. Long-term monitoring in particular has been chronically underfunded, meaning that we cannot usually tell when perturbations are within natural ranges. We know little about the condition of many modified river systems before European settlement. Another shortcoming is the lack of river system monitoring after developments have occurred, which is necessary to measure the shift in ecosystem structure and function following an 'unnatural' perturbation.

All these issues have been recognised in developing these guidelines. In some cases, the issue is addressed directly, such as in the definition of ecological value. Where the issue is not addressed directly – notably legislation, administration and budgets – the guidelines have been drafted to provide flexibility across different jurisdictions and levels of scientific certainty.

4.4 Concepts in waterway protection

4.4.1 Conservation and ecological value

A 'conservation value' is a value which people place on natural (biological, chemical and physical) and cultural heritage assets. Other values, which are influenced by the level of conservation, are implicitly included because they are supported by ecosystem services (see Part A, section 4.4.4). Examples are human health, scientific interest, recreation and visual amenity.

Dunn (2000) defines natural components as 'ecological' values. If assessed in a systematic way, they provide a credible basis for comparing ecosystems and assigning priorities to their protection.

Various systems have been applied to the definition of high conservation value waterways. Examples are Australia's Wild Rivers (Environment Australia 1999; Stein et al. n.d.), Victoria's Heritage Rivers, NSW High Conservation Value rivers (part of NSW Stressed Rivers

Assessment, DLWC 1998), the United States Wild and Scenic Rivers, and Conservation Value of Waterways in the Wet Tropics World Heritage Area (Pusey et al. 1999).

These classifications protect only some waterways, because most waterways do not meet threshold biological attributes. Some of the techniques rely on biological criteria, or are aimed at only the most valuable waterways. The NSW Stressed Rivers approach tends to focus on those systems that are unhealthy or are becoming so.

A broader based system would provide a better basis for managing all waterway systems, rather than just those few that are of very high ecological value or are in need of rehabilitation.

Although the ecological value guideline (Part B) offers technical criteria for describing ecological value, the most important determinant of waterway protection is community and government commitment. For example, those rivers in North America that support salmon fisheries tend to be favoured for protection because of the ecosystem services that they provide to humans and wildlife. While most methods use objective data to measure different criteria, the relative importance of each criterion is a value judgment for stakeholders. In turn, a person's willingness to support the protection of particular waterways is likely to be influenced by the technical information available to inform his or her judgment.

4.4.2 Ecological sustainability

Sustainability has social and economic dimensions, which are briefly explored in Part C (the sustainability guideline). In an ecological sense, sustainability is defined as:

> the ability of environmental systems (including biota and surrounds) to maintain their essential life functions in a healthy way. The term healthy implies the ability of the system to persist with minimal unnatural stress or inhibition of natural functions.

Concepts describing sustainability include:

- ecological integrity – the protection of native biodiversity, essential ecological processes, and life support systems (Commonwealth of Australia 1992);
- the maintenance of life support systems and the achievement of a 'natural' extinction rate (Sutton 1999);
- maintaining and enhancing natural capital, avoiding overexploitation of renewable resources, and minimising waste (ANZECC 1991);
- maintaining the composition, structure and processes of an ecological system (Committee of Scientists 1999); and
- 'intergenerational equity' – maintaining natural ecosystems and resources that have no known substitutes, the loss of which would be detrimental for future generations (Young 1993).

The critical features of this set of descriptions are the reference to stress, inclusion of both biotic and abiotic factors, and emphasis on functions (processes).

4.4.3 Waterway health

Young (1999) noted that "river health is not a scientific concept, but rather, is a means of communicating to a non-technical audience an understanding of the condition of riverine systems." Health is contextually defined, and has also been called 'biological quality' in the United Kingdom.

A healthy waterway is described as being free from distress, more resilient and less at risk from disturbances (Norris and Thoms 1999). There appears to be no universally accepted definition of health although the term itself is in wide use. The appeal of the word is that it has a generic meaning to which most people can relate. However, it is generally applied as a narrower concept than sustainability because some ecosystem components that are essential to sustainability are not necessarily essential to health (eg. the presence of rare species).

Health may also be a measure of sustainability where time-series data are compared and trends in waterway health can be related to external pressures or stresses.

4.4.4 Ecosystem structures, functions and services

Environmental impact assessments and some planning processes have tended to rely on inventory data, focusing on ecosystem structures. Recent assessment techniques have attempted to give insights into ecological functions fundamental to waterway health. Without this information, sustainability is difficult to assess. Consequently, assessing ecological value and sustainability requires the measurement of the following (King 1997):

- *ecosystem structures* – the site-specific characteristics of an ecosystem – encompasses other terms such as 'state', 'features' or 'pattern' (eg. species composition, soil, hydrology);
- *ecosystem functions* – the biophysical processes that actually take place within an ecosystem (eg. carbon cycling, nutrient assimilation); and
- *ecosystem services* – the beneficial outcomes that result from ecosystem functions (eg. cleaner water), which may accrue to other ecosystems or to humans.

Functions and services are processes, with the distinction being that functions are internal and services are external

(King 1997). Both need to be addressed by ecological value and sustainability measures.

In developing tools to support the protection of a particular waterway, the following questions need to be addressed:

- What is the ecological significance of the waterway?
- How have past changes affected its current state or condition?
- To what extent is that significance threatened by existing or likely future changes?
- How can management techniques be used to protect or enhance that significance?

Maintaining ecological sustainability depends on understanding how changes to natural function will affect future structural integrity and vice versa. If those dynamic factors are sufficiently altered, the system may be irreversibly changed (ie. the impact is unsustainable).

Structural indicators are typically inventories and/or enumerations of attributes such as species richness, habitat quality and linkages. These are often 'snapshots' and tend to dominate environmental impact studies.

Process indicators are usually more complex and take longer to measure. They may require targeted research and long-term monitoring of structural indicators. Some can be measured more routinely, but a comprehensive assessment would be a major undertaking.

4.4.5 Biodiversity

Biodiversity assessment requires both an understanding of structural diversity and the processes that maintain diversity. When evaluating ecological value, a lack of diversity does not necessarily imply lesser value, because some waterways have naturally low diversity (see Part B, Ecological Value Guideline).

Biodiversity comprises a number of categories:

- genetic diversity;
- species diversity;
- ecological function diversity;
- community diversity; and
- regional (or landscape) diversity.

Ward et al. (1999) identified indicators, which vary with the biodiversity category under consideration, for the composition and structural and functional (process) components of biodiversity (see Table 1).

The 'hierarchy' of scales in the first column can aid indicator selection to deal with spatial variability (see Part A, section 4.4.11).

4.4.6 Geomorphology and hydrology

Streamflow is a primary determinant of waterway health and integrity, and is given some prominence in the principles. Poff et al. (1997) suggest that maintenance of natural flow characteristics is perhaps the most critical single factor for maintaining stream ecology and geomorphology.

A recent survey of river managers reported in Dunn (2000) supported the use of geomorphological and hydrological values in assessing conservation significance. For instance, certain channel types and hydrological regimes may be relatively rare and this may give them high value, regardless of the associated biota.

In turn, the use of physical, chemical and hydrological parameters provides a linkage to catchment and biogeographic regions, which can form one spatial

Table 1. Indicators of biodiversity (Source: Ward et al. 1999).

Hierarchical level of biodiversity	Composition	Structure	Function
• Genetic	• Allelic diversity	• Heterozygosity • Polymorphism	• Gene flow • Genetic drift • Mutation rate
• Population/species	• Frequency of occurrence • Relative abundance	• Microhabitat structure	• Life history • Metapopulation dynamics • Adaptation
• Community/ecosystem	• Alpha diversity (number of species per habitat) and beta diversity (species turnover between habitats)	• Habitat heterogeneity • Ecotones	• Energy flow • Patch dynamics • Succession • Connectivity
• Landscape	• Gamma diversity (number of species in region)	• Geomorphic patterns • Large-scale environmental gradients • Ecotones	• Disturbance regimes • Hydrological processes • Connectivity

dimension for considering rarity and representativeness. For example, certain ecosystems or channel morphologies may be common in some bioregions but rare in others. Comparing waterways in a bioregional, rather than a State or national, context carries less risk of undervaluing those waterways.

4.4.7 Waterway classification

Waterways and floodplains vary in longitudinal, lateral and vertical dimensions, and the variation can be analysed as characteristic patterns that form distinctive waterway types. Part B includes several criteria for ecological value – namely naturalness, representativeness and rarity – that reflect, to some degree, these patterns and types. For example, headwater and lowland parts of rivers vary naturally in a range of features including the extent of riparian vegetation, channel form and bed composition. Because of these natural differences, direct comparison of the naturalness of sites within these two waterway types is not valid. It is necessary to first develop a classification of waterways, so that ecological value criteria can be applied to particular waterway types.

Classification not only provides a basis for defining a reference condition against which naturalness can be compared, but also for assessing the relative rarity and representativeness of particular waterway types. Other criteria, such as biodiversity, are less influenced by specific waterway features and can be derived independently of waterway type. The ecological value guideline presents an example of a waterway classification for this purpose.

4.4.8 Waterway homogeneity

Aquatic systems can be dealt with as entities at different scales – catchment, subcatchment, individual waterway or waterway reach. In most cases, catchment and subcatchment analyses will be too coarse to provide useful levels of differentiation. Individual small streams may have sufficient linear homogeneity to form essentially single reaches, but in most cases waterways will need to be divided into ‘representative’ stream reaches (Anderson 1998), where ‘representative’ means that the characteristics of the reach are similar throughout its length. Defining the characteristics of major waterway systems is conceptually simple, although data requirements can be high and survey requirements extensive.

Classification of waterways should also accommodate the relatively sedentary parts of the system (such as riparian vegetation and stable beds and banks) and the dynamics of other parts (such as flowing water, sediment transport and animal movement). The contrast between the static and dynamic elements is far more pronounced than in terrestrial systems, where most features are essentially sedentary (notably vegetation, soils, landforms and many of the fauna species). In contrast, certain key elements of aquatic systems may be mobile for short periods. Fluctuations in flow, water quality, sediment deposition and mobilisation, bank slumping, fish populations and other factors occur relatively quickly – particularly in association with flood events.

Consequently, we must also consider the sum of the parts when breaking down a waterway into discrete linear segments for classification purposes. At some point in the analysis, the segments must be reassembled to ensure that the classification achieves its purpose.

4.4.9 Catchment/waterway interactions

Linkages between waterways and their catchments are well understood by waterway managers. The impacts of changes to flow regimes, water quality, habitat connectivity and sediment transport can have profound effects on waterway integrity. Catchment activities and developments produce cumulative impacts on most Australian waterways.

Waterway protection aims to maintain or enhance waterway ecological values, and requires a high level of understanding of the structures and functions within waterways and their floodplains.

Dealing with catchments at a similar level of understanding requires a huge resource effort that may be beyond the means available. The challenge is to ensure that the protection framework takes account of processes that influence waterway ecological values. The framework should establish techniques for determining which of the catchment processes most influence sustainability.

4.4.10 Cumulative impacts

The connections within and between ecosystems mean that any event cannot be considered in isolation. The effect of any episode is incremental to impacts that have already occurred. Cumulative impacts are a perennial problem for planning and impact assessment, because the tools and techniques to evaluate them are usually inadequate. Impacts can be one or both of two types:

- individual changes over time, such as the installation of a series of weirs on a single river over the course of a century;
- several changes within a relatively short period, such as an irrigation scheme involving impoundments, interbasin transfers and agricultural land use changes.

The combined impacts of many changes can be *greater* than the sum of the impacts of the individual changes. Examples are:

- fragmentation of habitat at regional scale;
- disruptions to corridors;
- encroachment of exotic species;

- reduction in geomorphic diversity; and
- reduction in organic and sediment loads to estuaries.

The challenge is to choose criteria that relate to an *appropriate reference condition* – natural, modified or a 'desired future state'.

For multiple actions, the challenge is to combine the individual impacts to assess overall impacts. Techniques such as simulation modelling and quantitative risk assessment may be required, but their validity depends on an understanding of the effects of change on the receiving environment.

Technical approaches to cumulative assessments are developed in both the sustainability guideline (Part C) and the evaluation guideline (Part E).

4.4.11 Spatial and temporal dimensions

Sustainability needs to be considered at all relevant scales for efficient functioning of ecosystems. As stated by the Commonwealth of Australia (1992), the global dimension of environmental impacts should be recognised and considered.

The difficulty in defining adequate spatial and temporal scales for ecological assessments is well recognised (Committee of Scientists 1999; Boughton et al. 1999). Concepts such as 'river continuum' (Vannote et al. 1980), 'flood pulse' (Junk et al. 1989) and 'integrated catchment management' require an understanding of the flow-on processes between neighbouring or related habitats that bring about interdependence of environmental elements. Streams and catchments should be considered as complex systems (Campbell 1986; ARMCANZ and ANZECC 1994; QDPI 1993). Connections within and between waterways mean that an impact at one location is not going to be isolated or static.

4.4.11.1 Spatial variability

Spatial scale typically varies from landscape to microhabitat. Landscape-level data are critical for obtaining evidence of cumulative impacts in interrelated and interdependent systems (Boulton 1999), and for consideration of ecological sustainability over multiple human generations (Committee of Scientists 1999).

Liston and Maher (1997) recommend catchment-scale assessment of aquatic ecosystems. However, more data at smaller scales, such as subcatchments, may be needed in some areas. For example, Macmillan (1986) recommends 'order-3' catchments as incorporating sufficient diversity to be a suitable scale for limnological assessment. However, the author notes that some in-stream biota may require whole-of-river health assessments.

The importance of habitat-level classification is well recognised (Kershner and Snider 1992; Committee of Scientists 1999; Maddock 1999). Some species have specific habitats that can be used as a primary measurement of sustainability, because without a suitable living space they may disappear from an area. For example, waterway habitats have geomorphic and flow characteristics that provide a natural link between the physical environment and its inhabitants. This makes them fundamental indicators of river health (Maddock 1999).

The Committee of Scientists (1999) suggests selecting and monitoring appropriate focal species, from which projections about waterway health at a larger scale can be made. The area to be managed is compared with the habitat needed by a number of focal species to assess risk to native species and ecological processes.

Townsend and Riley (1999) recommend multiscale, multitemporal studies of river function to evaluate river health. The relevance of the scale depends on the way in which perturbations move through the physical space of the catchment, and through the ecological space of the river food webs.

Ecological management plans give prominence to hierarchical approaches to spatial scale. For example, the Committee of Scientists (1999) provides a table of sustainability attributes (grouped under composition, process and structure) by scale (site, catchment and region). Smith and McDonald (1998) recommend identification of threats to the sustainability of activities and resources at various hierarchical scales, using indicators specific to those scales. As Boughton et al. (1999) argue, hierarchy theory relies on a different set of questions for each level in the hierarchy.

These guidelines adopt the hierarchical approach by requiring the spatial scale to be identified before assessment and matched with the sustainability considerations. For adequate understanding, we may need to assess at several scales. For example, to assess the sustainability of a waterway in the face of further development, we might have to undertake the assessment at reach, subcatchment and catchment levels. If the expected impact is likely to be localised (eg. a small point-source discharge), the assessment would be restricted to a reach level. However, if the impact is likely to be more widespread (eg. flow alterations), then a catchment-wide study may be required.

Spatial variability is of two types:

- *Between sampling locations within a waterway/ catchment system*. This is a question of representativeness of samples. How can there be confidence that a monitoring program is representative of other locations?

- *Between catchments/regions*. This is most critical when certain indicators (such as ecological processes) are not available for all catchments and a comparative approach is needed. For instance, assessment of the importance of littoral rainforest to in-stream productivity may need to be based on research on similar waterways in other regions.

Both types of spatial variability can be addressed by sampling design and the use of sufficient resources to carry out a comprehensive and representative collection of data.

The first type of spatial variability can be managed, to some extent, by selecting indicators and associated measures applicable at the study scale – reach, subcatchment or catchment. For example, catchment clearing may be assembled at broad scale, whereas fish flow preferences may need to be assembled initially at local scale. Through sampling design and results analysis, the locally based information may be applicable at larger scales.

The second type of spatial variability is of most concern when indicators are complex and/or resource intensive. The result can be geographically patchy and insufficient for intercatchment comparisons. One approach may be to determine primary and secondary indicators, where the former are suitable for such comparisons.

For example, regional corridor function is a useful primary catchment scale indicator that could be measured for several catchments using distribution records for a few key fauna species, combined with assessment of habitat connectivity for those species (eg. in-stream barriers and contiguous riparian vegetation). An example of a secondary indicator is the structure and composition of riparian vegetation, which may be important both to the habitat quality for certain species and to aquatic productivity. However, this information is less likely to be consistently available.

The Realities of Data Gathering

Most information requirements for State/regional-level planning require spatially extensive data that can generally only be afforded through rapid assessment methods. These tend to be 'snap shot' approaches, particularly for biotic condition. Further, most interest groups want information on ecology in shorter time scales than is scientifically ideal.

For example, it has been estimated that it will take three years of annual fish surveys before there is a 90% probability of sampling a fully representative population of fish for a site. However, there is usually pressure to draw conclusions from initial surveys.

A report is being prepared on Pressure–Biota–Habitat (PBH) results which examines some of the spatial issues in relation to how dense a sampling within a subcatchment is required before there is a relatively high probability of sampling rare species. This monitoring program is focusing on subcatchment planning baseline / performance auditing information. However at this stage PBH has not been tested for temporal variation.

Hydrologic modelling where there are extended (100 years) flow records allows better resolution of temporal variation than some other indicators. However, there are few gauges in unregulated rivers and these are the streams most likely to have relatively high ecological values.

The NSW fish survey (Harris and Gehrke 1997) looked at four seasons' worth of data and made some recommendations on timing (summer)/frequency of sampling for fish.

A randomised stratified approach to choosing sites was used to get an unbiased overall picture of fish stocks in rivers – this approach is likely to be unsuccessful for assessing the presence of rare fish species. Integrated Monitoring of Environmental Flows (IMEF) algal monitoring took a different approach – targeting areas (weir pools) most susceptible to bloom formation and therefore likely to be most sensitive to flow interventions.

Biotic indicators are important but the most difficult to measure. The limits of measuring just one or two biotic indicators (eg. riparian vegetation and macroinvertebrates) should be recognised. While process indicators are important they are impractical for large scale studies at this stage. However they may be the most sensitive indicators for some ecological evaluations at smaller scales such as the monitoring of ecological changes with environmental flow releases.

The nested hierarchy approach to site selection and integration of indicator results is practical. The challenge is choosing an ecologically significant minimum spatial scale for representative site selection and also defining the scale at which meaningfulness is lost through integration of information. This site selection will vary depending on whether the aim is to get a generalised picture of river health, identify rare features/biota, assess risk/threat, identify an early warning system for degradation, etc.

Commentary on the project's scoping papers, January 2001

4.4.11.2 Temporal variability

The choice of temporal scale in assessment is vital for realistic interpretation of the sustainability of a waterway. What is 'normal' will be a factor of the inherent natural variability of the waterway system. Understanding of longer-term trends often requires long-term or specifically designed sampling, particularly if there are highly variable flows. Seasonal and other natural temporal trends make it difficult to make causative associations of change and to assign them to anthropogenic activities (Boughton et al. 1999).

Short-term monitoring may produce misleading information if it fails to account for short, medium and long-term variations. There is also a need to target functions that are suitable for long-term monitoring (Cairns 1990) and to select indicators that reflect medium to longer-term temporal and spatial changes (Walker and Reuter 1996).

Temporal variability is generally managed in one or more of the following ways:

- selecting indicators that integrate information over time (eg. macroinvertebrates);
- monitoring over time (eg. seasonal and long-term water quality programs); and
- modelling using numerical or physical simulations (eg. hydrology).

The guidelines include indicators that integrate temporal variability, either statistically (such as median annual flow) or biologically (such as macroinvertebrates). Information can then be presented as representative of a central tendency (eg. a mean or a median value) over a nominated period.

Monitoring and modelling are usually needed to supply the requisite information. They can also provide information about temporal variability, such as statistical measures of variation and time-series analysis.

4.4.11.3 Spatial and temporal indicators

Spatial and temporal variation cannot be described with a universal set of indicators. Some controlling factors, such as climate and geology, are relevant over long periods and large areas (ultimate controls). Factors such as organic debris and predation are relevant over short periods in a local context (proximate controls). Figure 4 illustrates this and suggests a continuum of indicators, combining structural and functional concepts.

Typically, catchment planning needs to focus mostly on ultimate controls, whereas proximate controls are more relevant to individual projects, for example building a small weir. Some indicators are relevant at more than one scale.

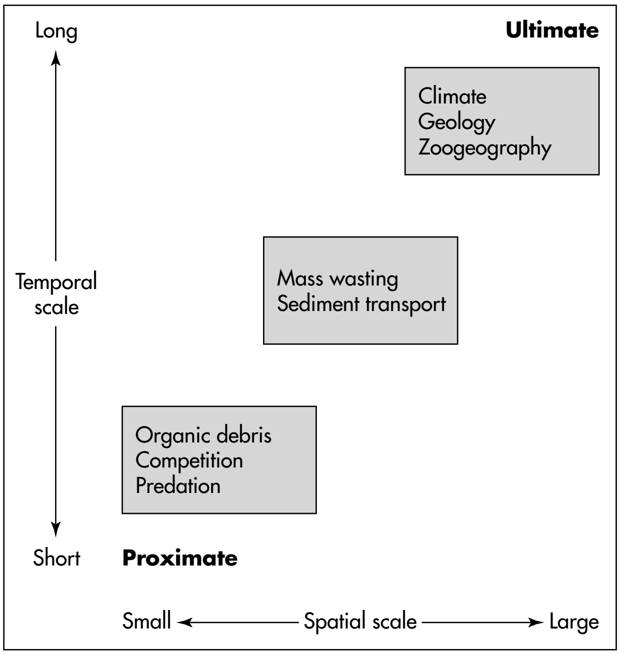

Figure 4. Proximate and ultimate controlling factors (Source: Naiman et al. 1992).

5 Principles for waterway protection

Dunn (2000) recommended that a set of principles be developed for protection of "biodiversity, ecosystems and processes". The conceptual framework is difficult to translate into a series of guidelines without such principles. In effect, they are the basis by which we should rank conservation priorities and judge the acceptability of proposed changes.

Such principles should be articulated in a manner that reflects our understanding of waterway health and ecological value. Dunn (2000) cites the following examples:

> "It is vital to anticipate, prevent and attack at source the causes of significant reduction or loss of biological diversity" (ANZECC 1996b);
>
> "Wild rivers should be given long-term protection to enable future generations to benefit from their special values" (Environment Australia 1999);
>
> "The biological diversity and ecological processes associated with wild rivers should be maintained, particularly by maintaining indigenous plant and animal populations in their natural communities" (Environment Australia 1999); and

"Central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas" (ANZECC 1996b).

Definitions

The following terms are used repeatedly in this document and are defined here. Other terms are defined in the glossary.

- *Ecological value:* the natural significance of ecosystem structures and functions, expressed in terms of their quality, rarity and diversity (significance can arise from individual biological, physical or chemical features or a combination of features);
- *Ecological sustainability:* the ability of ecosystems to maintain their natural structural and functional integrity in response to perturbations;
- *Ecological integrity:* the ecological values, including biodiversity and geodiversity, essential to ecological processes and life support systems (of a waterway and floodplain); and
- *Ecological health:* the ability to maintain ecological structure and function over time, and the degree of similarity to unimpacted waterways of the same type (River Murray CWMB 1999).

A singular problem in applying ecological health and integrity outcomes to waterways is that the terms are difficult to define precisely. Waterway health in particular is now a familiar term, but neither the literature nor the practitioners have settled on a universal definition (see River Murray CWMB [1999], for a similar conclusion).

Integrity encompasses not only waterway health, but also its intrinsic worth or value. A useful analogy, provided by James Karr of the University of Washington, is that "a person can lose a limb and thereby lose bodily integrity, but still be considered healthy". Though not acknowledged in the definition, catchment process and the physical integrity of waterway systems are critical to the maintenance of ecological integrity.

A working set of principles is needed to support both planning and environmental assessment. Appendix A1 summarises relevant goals, objectives and principles from a selection of sources. Although the list is not exhaustive, it suggests that there are two common features, namely:

- similar terminology, particularly in relation to actions such as 'protect', 'maintain' and 'conserve', and to desirable outcomes such as 'biodiversity', 'ecological processes' and 'sustainability'; and
- a lack of specificity (in most cases, achievement of the goals/objectives/principles would be difficult to measure, and there is a need to present outcomes in ways that can be measured over time).

A set of working ecological principles has been selected from existing documentation and input by a number of practitioners. These principles explain the assumptions of the guidelines and are set out to encourage debate.

The goal of the guidelines is 'maintenance of ecological values', where 'values' encompasses both waterway health and integrity. The principles are divided into those applying to all waterways and those applying to waterways of high conservation priority – reflecting many of the assessment methodologies and approaches to conservation in the various Australian jurisdictions (Dunn 2000). The premise is that all waterways should be healthy (as a minimum), but that some waterways warrant a greater level of conservation.

GOAL:

To maintain the ecological values of waterways and floodplains

ECOLOGICAL PRINCIPLES:

For all waterways and floodplains:

1. Maintain natural structures and functions[a] that are essential to waterway health.
2. Prevent serious and irreversible loss of natural[b] diversity.
3. Mimic natural streamflow characteristics to support the health of target species/communities.
4. Protect rare or threatened structures and functions.
5. Conserve representative examples of waterways and their natural features.

Greater protection for waterways and floodplains of high conservation priority:

6. Maintain the integrity of natural structures and functions[a] that contribute to ecological value.
7. Maintain natural[b] diversity.
8. Maintain natural streamflow characteristics.

[a] Includes species, taxa, communities, habitats, geomorphic features and natural processes

[b] Includes flora, fauna, geomorphology, water quality and hydrology

Ecologically sustainable development may be possible in most contexts, even for high conservation priority waterways. However, finding compatible development may be difficult because so many factors contribute to ecological values and small perturbations could alter the structures and functions that give rise to these values.

With one exception, all principles focus on unusual or important characteristics, such as rarity and diversity. The principle dealing with representativeness recognises that commonly encountered systems have value in their own right and may deserve protection as a good example of type. This point is explored further in the ecological value guideline (Part B).

The guidelines draw on the ecological principles to develop methods, criteria and indicators. Details of these linkages are provided in the guidelines and examples of strategies to achieve the principles are given below.

Strategies to achieve the ecological principles are:

- Establish conservation priorities based on ecological value and sustainability (or threats to the values).
- Designate and communicate the special significance of high conservation priority waterways.
- Prepare waterways/catchment management strategies in accordance with priorities.
- Reflect relevant State, national and international legislation/agreements/policies in waterway management strategies.
- Involve stakeholders in establishing priorities and developing strategies.
- Consider the longitudinal, lateral and vertical dimensions and connectivity of waterways in developing strategies and evaluating development proposals.
- Use best available information in decision making and use precaution where knowledge is lacking.
- Repair degraded systems to at least an equilibrium state.
- Recognise that natural functions and features of waterways are complex and often unique, and may not be replaceable.

6 Guidelines

6.1 Guidelines and their role

The conceptual framework requires several implementation tools to support environmental management, planning and impact assessment. The following areas represent significant gaps and thus impediments to achieving sound environmental outcomes. Hence, these are the focus of the project:

- evaluating ecological significance (ecological value guideline);
- analysing biophysical sustainability (ecological sustainability guideline);
- undertaking environmental planning (planning guideline); and
- assessing development proposals (evaluation guideline).

As noted earlier, Australia already has tools available for some aspects of waterway management – notably restoration and rehabilitation. Figure 2 shows where the guidelines fit in the conceptual framework. Figure 5 illustrates how the guidelines are envisaged to support a generic environmental planning process, and Figure 6 is a similar representation of a generic assessment process for development plans and projects.

6.2 How and where the guidelines can be applied

The guidelines can potentially assist a wide array of applications, including:

- *Conservation/protection strategies/plans:* Conservation priorities should be the basis for establishing levels of protection. For example, knowing that a stream has high ecological value and is susceptible to threats will help to demonstrate its priority for protection in relevent policies, strategies and plans.

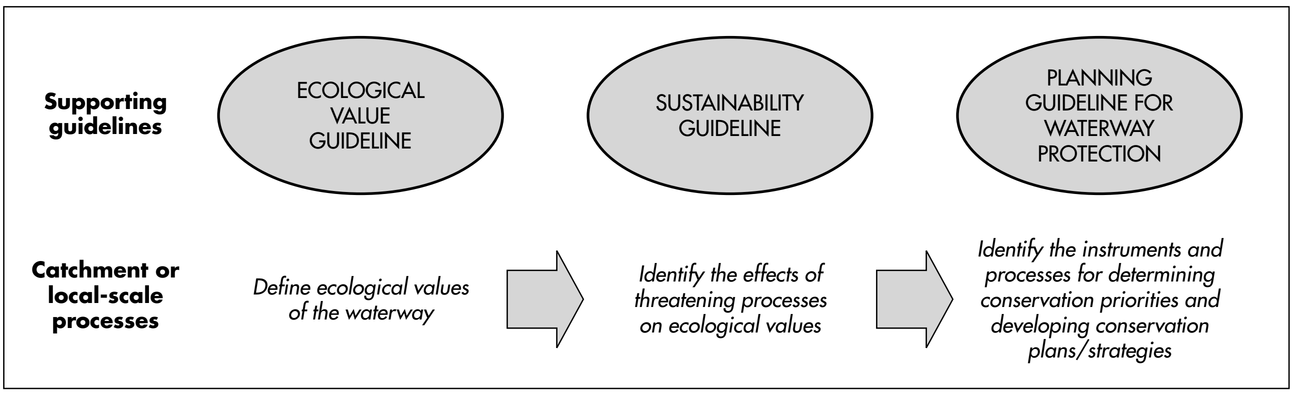

Figure 5. Waterway protection planning and management model—role of guidelines.

- *Environmental/water quality objectives for individual waterways:* The Australian Water Quality Guidelines (ANZECC and ARMCANZ 2001) apply concentration targets (trigger levels) differently according to the type of waterway (estuary, lowland river, etc.) and its 'level of protection' (eg. high ecological value, slightly–moderately disturbed or highly disturbed). These guidelines support measuring 'level of protection' and developing trigger levels to assist with establishing appropriate water quality objectives.
- *Waterway management and rehabilitation plans:* Degradation in many waterways results in some values and ecological functions being affected, for example through the creation of discontinuities in riparian vegetation. The ecological value of these systems may be increased through selective rehabilitation (such as rehabilitation of riparian vegetation).
- *Water resource studies and environmental impact assessments:* When applied to a particular catchment, the guidelines help to determine values, sustainability of environmental impacts and the types of mitigation factors that are critical for maintaining sustainability. Ecological criteria can be used alongside economic and social criteria to compare development options. Impact assessment of individual developments can be supported by a more systematic approach to defining sustainability.
- *Catchment and stormwater management plans:* Assessment of values and threats is now an accepted part of catchment and stormwater planning. The guidelines can help to fine tune remedial actions by accurately depicting natural values and associated threats. One result is a wider focus on the waterway as a system, rather than as a problem to be solved. For example, gross pollutant traps and water-sensitive urban design can both have unintended adverse impacts if all stream values are not taken into account.
- *Statutory planning schemes:* Planning schemes and planning policies provide mechanisms for helping to achieve defined environmental, social and economic objectives. This is primarily through geographical planning for future land use and through development control within the land use designations. The guidelines can assist in setting environmental objectives and identifying waterways that are in need of greater protection. In turn, the effects of different land uses and development controls, and relative threats to values, can be evaluated.

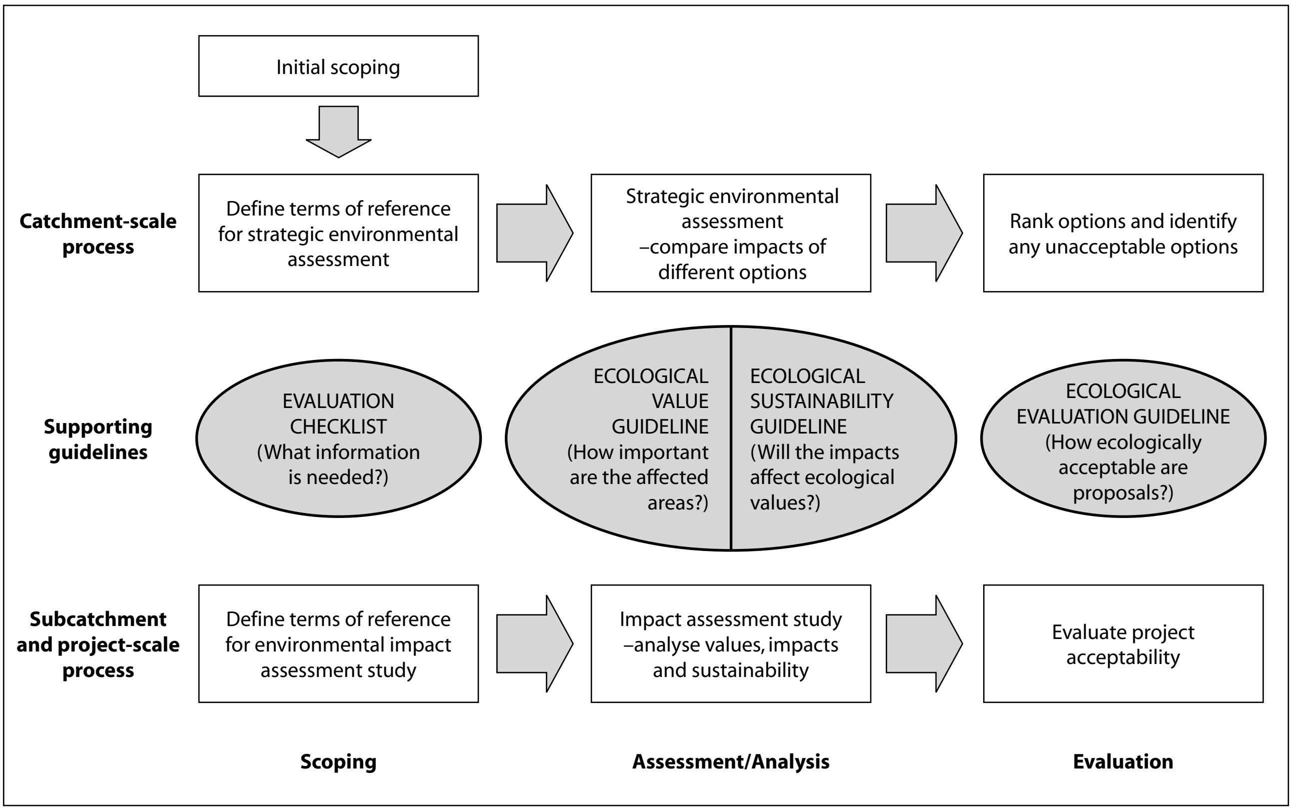

Figure 6. Environmental assessments of developments affecting waterway—role of guidelines.

Future directions

It is certain that the guidelines will require revision to incorporate new information and concepts. The test of their worth and flexibility will come through application.

Future enhancement might include:

- other conservation values, notably cultural heritage, recreation and landscape (although methods for assessing these values are different, the framework of significance, sustainability, planning, and evaluation has already been adapted in trials);
- improved data to produce information relevant to the guidelines;
- contributions by users, particularly as new information and methods come to hand; and
- further development of the concepts of spatial and temporal variation and cumulative impacts to refine indicators and methods.

Appendix A1

Principles for waterway protection

This is a sample of principles from Australian sources relevant to waterway protection (and restoration/rehabilitation). The list is by no means exhaustive, and is provided to put into context the principles established in the waterway protection guidelines. Although principles are grouped according to themes (general, biodiversity, special features, etc.), many principles relate to more than one theme. Hence there is substantial overlap between the groupings.

General principles

Principle	Source	Ecological outcome
States and territories work cooperatively and coordinate activities within catchments, including where rivers cross borders.	Wild Rivers	Catchment focused management of rivers
Establish landcare practices to protect areas of waterways with high environmental value or sensitivity.	COAG Water Resource Policy	Ecologically sustainable rivers
Manage wetlands in accordance with ESD principles.	Queensland Wetlands Strategy (1998)	Ecologically sustainable rivers
Promote ESD through conservation and ecologically sustainable use of natural resources.	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	Ecologically sustainable rivers
Protect natural heritage in an ecologically sustainable way to enhance our economic and social wellbeing.	QPWS mission (1999)	Ecologically sustainable rivers
Allow only nature-based and ecologically sustainable uses.	*Nature Conservation Act 1992* (Qld)	Ecologically sustainable rivers
Ensure the health, diversity and productivity of waterways is maintained or enhanced for the benefit of future generations.	Australian Natural Heritage Charter (ANC 1996) and Intergovernmental Agreement on the Environment (1992)	Maintenance of ecological values for future generations
Base decisions on the precautionary principle where environmental impacts cannot be accurately predicted.	SEQ 2001 Regional Framework for Growth Management (Queensland 1994)	Maintenance of ecological values
Ensure public and private decisions are guided by careful evaluation to avoid serious or irreversible damage to the environment.	Intergovernmental Agreement on the Environment (1992)	Maintenance of ecological values
Acknowledge that knowledge of natural heritage and the processes affecting it are incomplete.	Australian Natural Heritage Charter (ANC 1996)	Maintenance of ecological values
Where there are real or potential threats of serious or irreversible environmental harm, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.	Australian Natural Heritage Charter (ANC 1996)	Maintenance of ecological values
Acknowledge that living organisms, earth processes and ecosystems may have values beyond social, economic or cultural values held by humans.	Australian Natural Heritage Charter (ANC 1996)	Principle of existence value

General principles (cont'd)

Principle	Source	Ecological outcome
Achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.	National Water Quality Management Strategy	Protection of ecological values
Protect, conserve, rehabilitate and manage the coast, including its resources, processes and biological diversity.	*Coastal Protection and Management Act 1995* (Qld)	Protection of ecological values
Provide for the protection of the environment.	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	Protection of ecological values
Recognise that the health of water-dependent ecosystems is influenced by the protection and/or rehabilitation of many interrelated biophysical elements (eg. environmental water provisions, pollution control, habitat and biodiversity rehabilitation, and good catchment management).	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Healthy, protected water-dependent ecosystems
In accordance with the precautionary principle, limited knowledge of water-dependent ecosystems should not be used as a reason for degrading them or postponing measures to prevent their degradation.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Healthy, protected water-dependent ecosystems
Manage on a multidisciplinary basis. Address causes, not symptoms, wherever possible.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Whole-of-ecosystem protection
Ensure that actions aimed at restoration, rehabilitation or remediation of water-dependent ecosystems redress the most limiting factor as a first priority. (The most limiting factor is that resource essential for the ecosystem structure and functioning but most lacking.)	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Rehabilitation of key ecological structures and functions
Adopt an adaptive management approach to management of water-dependent ecosystems.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Ecologically sustainable development
Ensure planning processes allow for environmental water provisions to be adapted on the basis of monitoring and improved knowledge.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Environmental water provisions, based on best available knowledge
Promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources.	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	Ecologically sustainable development
Provide stable and productive soil, high-quality water and protective and productive vegetation cover within each of the State's water catchments.	*Catchment Management Act 1989* (NSW)	Integrated management of water resources
Protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity, and their water quality.	*Water Management Act 2000* (NSW)	Healthy protected water-dependent ecosystems
Ensure strategies are adaptive and able to respond to technological, economic, environmental and social change and to differences between catchments and aquifers.	NSW Water Conservation Strategy 2000	Protection of water resources
Ensure water is not used for a purpose where water of a lower quality could be used more efficiently and economically (water quality is matched to its purpose).	NSW Water Conservation Strategy 2000	Healthy, protected water-dependent ecosystems
Recognise best practice in water conservation by instituting awards which celebrate and promote achievements in water conservation.	NSW Water Conservation Strategy 2000	Healthy, protected water-dependent ecosystems

General principles (cont'd)

Principle	Source	Ecological outcome
Ensure that all groundwater systems are managed so that the most sensitive identified beneficial use or environmental value is maintained.	NSW Groundwater Quality Protection Policy (n.d.)	Healthy, protected water-dependent ecosystems (groundwater)
Ensure, for new developments, the amount of work required to demonstrate adequate groundwater protection is proportional to the risk posed by the development and the values of the resource.	NSW Groundwater Quality Protection Policy (n.d.)	Healthy, protected water-dependent ecosystems (groundwater)
Formally recognise water regimes needed to maintain or restore physical, chemical and biological processes of wetlands, in water allocation and management plans.	NSW Wetlands Management Policy 1996	Healthy, protected water-dependent ecosystems (wetlands)
Ensure that wetland requirements and monitoring are incorporated into the environmental objectives set by the NSW Government for river flows and water quality.	NSW Wetland Action Plan 2000–2003	Healthy, protected water-dependent ecosystems (wetlands)
Adapt environmental objectives and river management to provide for adjustments based on expanding knowledge, river health monitoring, and changing community and economic values.	A Draft Five Year Strategy for Water Management in New South Wales 1999–2003	Improvements to river values over time
Recognise the important links between river flows and water quality.	A Draft Five Year Strategy for Water Management in New South Wales 1999–2003	Improved water quality
Substantially rehabilitate highly stressed rivers.	A Draft Five Year Strategy for Water Management in New South Wales 1999–2003	Rehabilitation of water-dependent ecosystems
Recognise and consider the global dimension of environmental impacts of actions and policies.	National Strategy for Ecologically Sustainable Development 1992	Holistic management of environmental impacts
Integrate economic and environmental goals in policies and activities.	National Strategy for Ecologically Sustainable Development 1992	Promote better environmental management
Link policy development to state-of-environment and state-of-rivers reporting for continuous improvement of sustainability.	Water Development Plan for Tasmania Scoping Document, December 2000	Comprehensive identification of environmental issues that require effective management
Promote the adoption of aquatic biodiversity information and conservation management into Regional Forest Agreements, Regional Catchment Management Strategies, and Heritage River, Streamflow, Nutrient and Salinity management plans.	Victoria's Biodiversity – Directions in Management (n.d.)	Healthy, protected water-dependent ecosystems
In conjunction with other agencies, including the Murray–Darling Basin Commission and adjacent State governments, continue strategic and coordinated investigations into the ecology and management of freshwater environments.	Victoria's Biodiversity – Directions in Management (n.d.)	Improved management of freshwater ecosystems
Recognise the need for improved valuation, pricing and incentive mechanisms in environment protection.	A Summary of the Western Port and its Catchment Schedule (F8) to State Environment Protection Policy (Waters Of Victoria) 2000	Holistic management of the environment and natural resources
Integrate water quality management decision-making processes with long and short-term economic, environmental, social and equity considerations.	Western Australia's State Water Quality Management Strategy 2000	Improved short-term and long-term holistic management of water quality and aquatic ecosystems
Develop technical guidelines and manuals for river restoration and rehabilitation based on information needs.	Waterways Western Australia – A statewide waterways management program (n.d.)	Healthy, protected water-dependent ecosystems

General principles (cont'd)

Principle	Source	Ecological outcome
Develop a framework for determining environmental values and solutions to eutrophication in Western Australia, based on the National Water Quality Management Strategy.	State of the Environment Reporting in Western Australia 1998	Healthy, protected water-dependent ecosystems
Prevent environmental degradation and adverse risks to human health and the health of ecosystems by promoting pollution prevention, clean production technology, reuse and recycling of materials and waste minimisation programs.	*Environment Protection Act 1997* (ACT)	Healthy, protected water-dependent ecosystems
Ensure that the use and management of the water resources of the Territory sustain the physical, economic and social wellbeing of the people of the Territory while protecting the ecosystems that depend on those resources.	*Water Resources Act 1998* (ACT)	Holistic management of water resources and protection of aquatic ecosystems
Protect waterways and aquifers from damage and, where practicable, reverse damage that has already occurred.	*Water Resources Act 1998* (ACT)	Maintain waterway health and water quality
Ensure water resources are able to meet the reasonably foreseeable needs of future generations.	*Water Resources Act 1998* (ACT)	Promote ecologically sustainable development
Achieve healthy streams and sound water management by undertaking many small improvements across the project catchment.	ACT Sustainable Water Action Management Project 2000	Rehabilitation of water-dependent ecosystems
Maintain and where appropriate enhance the ACT's water quality (as measured by appropriate standards) by minimising water pollution.	ACT Water Pollution Environment Protection Policy 1999	Rehabilitation of water-dependent ecosystems
Promote the adoption of sound environmental practices and procedures as a basis for ecologically sustainable development, through the integrated consideration of environmental and economic values in planning and decision-making processes.	A Summary of the Western Port and its Catchment Schedule (F8) to State Environment Protection Policy (Waters Of Victoria) 2000	Ecologically sustainable development
Ensure that diffuse source and point source pollution does not prejudice the achievement of water quality objectives and that pollutants discharged to waterways are reduced as far as is reasonable and practical by the use of best-practice environmental management.	Tasmania's State Policy on Water Quality Management 1997	Healthy, protected water-dependent ecosystems
Ensure efficient and effective water quality monitoring programs are carried out and the responsibility for monitoring is shared by those who use and benefit from the resource, including polluters, who should bear an appropriate share of the costs arising from their activities, water resource managers and the community.	Tasmania's State Policy on Water Quality Management 1997	Healthy, protected water-dependent ecosystems
Identify and protect environmental assets, such as wet-lands, native vegetation and habitats at risk from salinity.	South Australia's draft State Dryland Salinity Strategy 2000	Healthy, protected water-dependent ecosystems
Develop technologies, including sampling, monitoring and modelling tools, for characterisation, assessment and remediation of groundwater and soils contaminated with organic compounds, especially petroleum hydrocarbons, chlorinated solvents, munition compounds and pesticides.	Centre for Groundwater Studies Biennial Report 1996–1997	Healthy, protected water-dependent ecosystems (groundwater)
Recognise the role of indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity.	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	Ecologically sustainable development
Integrate groundwater quality protection with the management of groundwater quantity.	NSW Groundwater Quality Protection Policy	Improved water quality

Principles aimed at maintaining rare features

Principle	Source	Ecological outcome
Manage habitats for optimum conditions for survival of rare or threatened wildlife.	Queensland Wetlands Strategy (1998)	Maintain habitats
Promote the use of fishways over selected barriers with priority given to threatened species and sites that maximise the available upstream habitat.	Victoria's Biodiversity – Directions in Management (n.d.)	Maintain in-stream biodiversity
Protect rare ecological, geomorphological and hydrological features.	Dunn (2000)	Protection of rare features

Principles aimed at maintaining naturalness

Principle	Source	Ecological outcome
Protect the environment in a way that maintains the ecological processes on which life depends.	*Environmental Protection Act 1994* (Qld)	Maintain ecological processes
Maintain essential ecological processes and life support systems.	National Strategy for ESD (1992)	Maintain ecological processes
Mimic natural streamflow characteristics to maintain ecological function.	Draft Fitzroy Basin Water Allocation and Management Plan (1998)	Mimic natural streamflow characteristics
Prevent environmental degradation where there are threats of serious or irreversible damage.	National Strategy for ESD (1992)	Prevent serious or irreversible damage
Provide water to maintain the health and viability of river systems and groundwater basins.	National Principles for Provision of Water for Ecosystems	Provision of water for the environment
Provide (as far as possible) the water regime necessary to sustain the ecological values.	National Principles for Provision of Water for Ecosystems	Provision of water for the environment
Manage water allocation to maintain natural values and functions.	Queensland Wetlands Strategy (1998)	Provision of water for the environment
Treat river systems as an integral entity, wherein the condition of the river column is linked to the health of the catchment.	Wild Rivers	Integrated catchment planning
Protect or enhance the water quality of receiving waters.	Brisbane City Council Draft Waterway Code (1999)	Protect, enhance water quality
Recognise the interconnectedness between upstream and downstream activities.	Dunn (2000)	Recognise unique features of rivers
Acknowledge the non-uniformity of rivers.	Dunn (2000)	Recognise unique features of rivers
Water allocation and management decisions must take a precautionary approach by first ensuring that natural ecological processes and biodiversity of water-dependent ecosystems are maintained.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Protect natural values of water-dependent ecosystems
Protect water quality, river flow regimes and riverine ecosystems not seriously affected by human activities.	A Draft Five Year Strategy for Water Management in New South Wales 1999– 2003	Protect natural values of water-dependent ecosystems
Provide water for the environment based on mimicking natural flow regimes as much as possible.	A Draft Five Year Strategy for Water Management in New South Wales 1999– 2003	More water available to maintain environmental flows and improve ecosystem health
Prevention of degradation of water-dependent ecosystems in good condition should, in general, be considered as a higher priority than the rehabilitation of degraded water-dependent ecosystems.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Protect natural values of water-dependent ecosystems

Principles aimed at maintaining naturalness (cont'd)

Principle	Source	Ecological outcome
Protect or enhance areas of good quality riparian habitat or remnant vegetation.	Watercourse Survey and Management Recommendations for the Upper Marne River Catchment (South Australia) (n.d.)	Protect natural values of water-dependent ecosystems
Prioritise protection of refuge areas and maintenance of water connections up and down the watercourse in areas with highly variable flow patterns.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Maintain key ecological linkages
Target the nursery industry with information on alternatives to weeds and pest plants.	ACT Weeds Strategy – A 10-year Strategy for Implementing a Coordinated Program for Controlling Weeds 1997	Protect natural values of water-dependent ecosystems
Acknowledge the non-substitutable nature of rivers.	Dunn (2000)	Recognise unique features of rivers

Principles aimed at maintaining representative river types

Principle	Source	Ecological outcome
Manage some rivers with conservation as a priority.	QEPA, 2000	Protection of ecological values
Provide for the permanent preservation of natural condition and protection of the area's cultural resources and values.	*Nature Conservation Act Amendment 1994* (Qld)	Protection of ecological values
Restore additional inland water systems consistent with community-driven priorities.	State of the Environment Reporting in Western Australia 1998	Restoration of a diverse range of river types
Establish a comprehensive, adequate and representative reserve system specifically for rivers.	ANZECC (1996)	Protection of significant features

Principles aimed at maintaining biodiversity

Principle	Source	Ecological outcome
Protect biodiversity by dedicating protected areas, protecting and managing wildlife.	*Nature Conservation Act 1992* (Qld)	Protect biodiversity and ecological processes
Promote conservation of biodiversity.	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	Protect biodiversity and ecological processes
Protect biological diversity and maintain ecological processes and systems.	National Strategy for the Conservation of Australia's Biological Diversity (1996)	Protect biodiversity and ecological processes
Protect biological diversity.	National Strategy for ESD (1992)	Protect biodiversity and ecological processes
Conserve biological diversity and ecological integrity.	Intergovernmental Agreement on the Environment (1992)	Protect biodiversity and ecological processes
Promote water conservation measures that do not compromise public health or have detrimental impacts on the ecological health of a catchment.	NSW Water Conservation Strategy 2000	Promote the conservation of biodiversity
Management of water bodies should aim for healthy water-dependent ecosystems that generally contain a diversity of interconnected habitats and a diverse biota, often with a significant proportion of biota being intolerant of degraded conditions.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Promote and maintain biodiversity of water-dependent ecosystems

Principles aimed at maintaining biodiversity (cont'd)

Principle	Source	Ecological outcome
Ensure that the use and management of resources protects ecosystems (including their biological diversity) and minimises the detrimental effects of use.	*Water Resources Act 1997* (SA)	Protect the biological diversity of water-dependent ecosystems
Where possible and practical, rehabilitate environmentally degraded areas and restore their ecosystem support functions.	NSW Groundwater Quality Protection Policy	Restore and maintain ecosystem functions necessary for biodiversity
Anticipate, prevent and attack at source the causes of significant reduction or loss of biological diversity.	National Strategy for the Conservation of Australia's Biological Diversity 1996	Prevent biodiversity decline in water-dependent ecosystems
The conservation of Australia's biological diversity is affected by international activities and requires actions extending beyond Australia's national jurisdiction.	National Strategy for the Conservation of Australia's Biological Diversity 1996	Broad and holistic management to protect biodiversity
Central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas integrated with the sympathetic management of all other areas, including agricultural and other resource production systems.	National Strategy for the Conservation of Australia's Biological Diversity 1996	Holistic and integrated management to protect biodiversity of water-dependent ecosystems
Recognise the close, traditional association of Australia's indigenous peoples with components of biological diversity, and share equitably benefits arising from the innovative use of traditional knowledge of biological diversity.	National Strategy for the Conservation of Australia's Biological Diversity 1996	Integrate indigenous knowledge into management frameworks to maintain and improve biodiversity
Protect and restore high-value wetlands and maintain natural (biological and physical) diversity within the agricultural areas of Western Australia.	State of the Environment Reporting in Western Australia 1998	Protect and maintain biodiversity of water-dependent ecosystems (significant wetlands)
Lack of full knowledge should not be an excuse for postponing action to conserve biological diversity.	National Strategy for the Conservation of Australia's Biological Diversity 1996	Protect and maintain biodiversity of water-dependent ecosystems
Ensure that land use activities or proposals that involve the clearing of naturally occurring native vegetation in conservation networks, habitat corridors or other sites of ecological significance are subject to an assessment and decision process directed at protecting nature conservation values.	ACT Nature Conservation Strategy 1998	Prevent encroaching development from impacting on areas of ecological significance
Ensure that 'best practice' in restoration of riparian vegetation is continually developed and communicated to natural resource managers and landholders and is included in relevant codes of practice.	Victoria's Biodiversity – Directions in Management	Restore and maintain biodiversity of water-dependent ecosystems (riparian zone)
Identify processes and categories of activities that have or are likely to have significant adverse impacts on the conservation and ecologically sustainable use of biological diversity.	National Strategy for the Conservation of Australia's Biological Diversity 1996	Protect and maintain biological diversity of water-dependent ecosystems

Principles aimed at maintaining special features

Principle	Source	Ecological outcome
Provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance.	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	Protection of significant environmental aspects
Assist in the cooperative implementation of Australia's international environmental responsibilities.	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	Environmental protection in accordance with relevant international obligations
Conserve wetlands of regional or national significance.	NSW Wetland Action Plan 2000–2003	Protection of significant wetlands
Identify WA wetlands of national importance and progressively develop an inventory of the State's wetlands that will contribute to the national inventory.	Wetlands Conservation Policy for Western Australia 1997	Protection of significant wetlands
Wetlands of recognised conservation significance should be given special protection and management to maintain their ecological values.	South Australia's State Water Plan 2000, Volume 1 – Policies for a Sustainable Future	Protection of the ecological values of wetlands
Protect values of internationally recognised waterways and wetlands	*Nature Conservation Act 1992* (Qld)	Protection of internationally significant species/taxa/ecosystems

Part B – Ecological Value Guideline

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1 Purpose

> The purpose of the ecological value guideline is to:
>
> - provide a systematic, comprehensive and flexible method to describe the ecological values of waterways and floodplains; and
> - support both environmental planning and development assessment.

The ecological value guideline aims to be technically credible as well as adaptable to a wide range of applications, users and data availability. It presents and evaluates methods and criteria for assessing ecological value and, where appropriate, discusses indicators and measures to illustrate the means of measuring the criteria. Case studies show the application of ecological value information to planning and management.

2 Scope

The guideline is designed for tidal and non-tidal waterways, wetlands, riparian zones and floodplains, and is also applicable to terrestrial systems. It covers biophysical aspects – biology, hydrology and geomorphology.

This focus is consistent with the values set down in, and complementary to, the National Water Quality Management Strategy (ARMCANZ and ANZECC 1994), which includes not only aquatic ecology but also recreation, aquaculture, agriculture and drinking water (see Appendix D4). The guideline provides a method for defining the aquatic ecology value, as well as subaquatic and floodplain values.

The guideline supports planning, as well as strategic and project-level impact assessments. It is intended to assist at all scales from reach, through subcatchment, to catchment.

Application of the guideline produces outputs in a variety of forms (such as maps, databases, spreadsheets and narratives) that describe and communicate the ecological values of waterways.

3 Concepts and limitations

3.1 What is ecological value?

Dunn (2000) defined the scope of waterway ecological value to include "not only the aquatic biota (fish, invertebrates, macrophytes) but also the biota of the riparian or foreshore zone, the river habitats and geomorphology. It is also taken to include the river processes, both physical and biological, and the roles a river may play in sustaining other systems such as karst, estuary, floodplains and wetlands."

Although ecological value implies an ecosystems-centred view, this description recognises the intrinsic values of hydrology, water quality and geomorphology, not simply their support for ecosystems. The concept includes the integration of all these elements within an ecosystem, as well as relationships between ecosystems.

> **Ecological value is:**
>
> the natural significance of ecosystem structures and functions, expressed in terms of their quality, rarity and diversity. Significance can arise from individual biological, physical or chemical features or a combination of features.

The guideline adopts several assumptions that influence its scope and direction, namely:

- Ecological value is fundamental to assigning protection and rehabilitation/restoration priorities for waterways.
- Ecological value necessarily includes both objective and subjective elements.
- Objective data are fundamental to any evaluation, but comprehensive data are usually lacking. To be useful, the method must be applicable even when information is missing.
- Information about values has important implications for waterway management. Therefore, the method must be as accurate and precise as practicable.
- Numerical methods may assist with synthesising data, provided that they produce credible conclusions.
- Ecological value can be determined at multiple scales (eg. local, regional or national).
- A hierarchy of criteria, indicators and measures is desirable to describe ecological value.

3.2 Methods for describing ecological value

Ecological assessments of terrestrial environments have been undertaken in most States and Territories (eg. Sattler and Williams 1999). Criteria-based approaches include the Register of the National Estate, World Heritage, Regional Forest Assessments and the National Reserve System.

However, such methods are not directly transferable to aquatic environments because of inherent differences between terrestrial and aquatic ecosystems. For example, water quality at any point in a waterway will be affected by upstream activities and potentially by downstream barriers. Any section of waterway depends on its catchment to maintain ecological values. Consequently, the analysis of values requires consideration of a broader geographic scope than a particular waterway section.

Many methods have been developed in Australia and overseas for describing the values of waterways and wetlands. Dunn (2000) reviewed techniques for identifying and protecting rivers of high ecological value, including the United States Wild and Scenic Rivers, Australian Wild Rivers, Victorian Index of Stream Condition, Western Australian State of the Rivers, Queensland Conservation Value and New South Wales Stressed Rivers approaches. Table 2 is a summary of methods, techniques and key criteria, adapted from Dunn (2000) and Phillips et al. (2001).

Table 2. Summary of methods for waterway assessment (adapted from Dunn 2000 and Phillips et al. 2001).

Name of method	Category of method	Technique	Focus/criteria
National River Health Program – AusRivAS (Australia)	Condition assessment	Collects macroinvertebrate data from river systems throughout Australia. Individual site data is grouped to characterise reference condition, then formalised via AusRivAS model software. Models are calibrated to allow comparison of macroinvertebrate assemblages between reference and impacted sites.	Macroinvertebrates used to: • assess river health • infer environmental impact
Wild Rivers (Australia)	Condition assessment and naturalness value	Uses a 'river wildness' index comprising State data of various disturbance indicators. Data is combined using specific decision rules to give all river sections across the country a score, giving a level of river system disturbance. Indices of catchment and in-stream disturbance form the basis of the overall score.	Assess naturalness using: • catchment disturbance • waterway disturbance
Index of Stream Condition (Victoria)	Condition assessment and naturalness value	An assessment of individual indicators. Data for each indicator are scored, indexed and given arbitrary numerical values. The indicator scores are then combined to give an overall value. More applicable to disturbed systems, but useful for naturalness value.	Hydrology Physical form Streamside zone Aquatic life Water quality
Stressed Rivers (NSW)	Condition assessment and conservation value	A subcatchment-level approach in which categories are derived through measurement of environmental and hydrological stresses, resulting in a matrix of stress classifications and management categories. Also identifies rivers of high conservation value, using a criteria-based analysis.	Water usage Species of significance Remnant habitats Geomorphology
State of the Rivers (WA)	Condition assessment and naturalness value	A method for mapping major forms of degradation within the State. Rivers are assigned one of five categories defining river condition to determine the feasibility for rehabilitation (if required), and to assist the Water and Rivers Commission management objectives.	Pressures on rivers Waterway disturbance
Water Resource Environmental Planning (Qld) – conservation value guideline	Conservation value	Conservation value derived using a numerical approach for ecological criteria. A weighting system is used for combining indicators. Values include ecology, geomorphology, hydrology, recreation, landscape and cultural heritage. This work led to the development of this guideline. (Although developed independently of SERCON, the system has a number of similar features.)	Naturalness Condition Bio- and geodiversity Rare and threatened Uniqueness/rarity Cultural heritage

Table 2. (cont'd) Summary of methods for waterway assessment (adapted from Dunn 2000 and Phillips et al. 2001).

Name of method	Category of method	Technique	Focus/criteria
SERCON (UK) (System for Evaluating Rivers for Conservation) Boon et al. (1997)	Ecological value	A broadly based technique for assessing conservation value. Uses six criteria which are relevant to nature conservation assessment. River Habitat Survey forms part of method, followed by a scoring system with weightings.	Naturalness Representativeness Physical diversity Species richness Rarity Special features
River Habitat Survey (UK)	Condition assessment	Assesses habitat quality of rivers and streams based on their physical structure. Uses a data base of habitat requirements, site/reach classifications and association of flora/fauna with different habitats. (Currently being integrated with SERCON.)	Bank and channel physical attributes Land use Understorey vegetation Riparian trees Channel Dimensions Additional Features
RIVPACS (UK)	Condition assessment	The RIVPACS software package predicts the macroinvertebrate fauna to be expected at a river site in the absence of environmental stress. The model compares the observed with the expected fauna to assess the biological quality of a site. (RIVPACS was the basis for AusRivAS.)	Macroinvertebrates used to: • assess biological quality • infer environmental impact
Wild and Scenic Rivers (US)	Conservation and recreation value	Applies to rivers in a free-flowing condition, evaluated on the basis of one or more outstanding scenic, recreation, geologic, fish and wildlife, historic, or cultural values.	Wild (naturalness) Scenic Recreational
Heritage Rivers (Canada)	Conservation value	A cooperative program developed by the Canadian provincial and territorial governments to identify and preserve rivers of importance. The criteria for preservation range from natural heritage (physical attributes, geography, flora, fauna, etc.) to indicators of Canadian history and recreational appeal.	Physical attributes Significant flora and fauna Historical Recreational Naturalness
Pusey et al. (1999)	Ecological value	Developed for rivers in the wet tropics of Queensland, the method uses 10 criteria, seven of which relate to nominated flora and fauna groups. Uses an unweighted rating system and reports the overall conservation value as green, red or amber, based on rules of combination.	Ecosystem function Flora and fauna of conservation interest Invertebrate diversity Flow regime
State of the Rivers (Qld)	Condition assessment	Describes the condition of rivers using a range of physical criteria, including riparian and in-stream measures. Uses a site-based proforma, with sites chosen as representative of homogenous reaches.	Physical Scenic and recreational
'Expert System' approach to the assessment of the conservation status of rivers (South Africa) O'Keefe et al. (1987)	Conservation value	A method for assessing the major conservation attributes of rivers and communicating these in a conceptually simple manner.	Naturalness/condition Diversity or richness Rarity/uniqueness Special features
A protocol for assessing natural values of New Zealand rivers (New Zealand) Collier (1993)	Ecological value	Provides a description of ecological values using a numerical, expert panel assessment method.	Naturalness/condition Diversity or richness Representativeness Rarity/uniqueness Special features

The above methods fall into two types of assessment: condition and ecological/conservation value. These categories are not always clearly differentiated and need some explanation.

Condition assessments provide an index of change against a nominated benchmark, usually selected on the basis of one or more key indicators measured against a reference condition. The measured change provides a picture of condition. Typically, condition assessments have a limited number of indicators, which reflect the methodology (eg. field inspections) or are a surrogate for broader concepts (eg. the use of time-series data to examine sustainability). They tend to focus on indicators of structure, rather than function; and they measure the level of disturbance or stress.

Ecological/conservation value assessments are generally more comprehensive, using a broader range of criteria and indicators. The assessments result in estimates of value based on comparison with benchmarks of different types. They often include processes that are critical to maintaining the long-term ecological value, or ecosystem services that influence ecological value. Condition assessments are often useful in contributing structural data to ecological value assessments.

The ecological/conservation value methods in Table 2 show reasonable consistency in the criteria they use. Typically, criteria include condition/naturalness, representativeness, diversity and rarity, measured in biophysical terms. Some systems include cultural heritage and/or geodiversity.

Most methods focus on biotic factors. Physical and chemical components tend to be considered in so far as they affect habitat and ecosystem health. However, they are increasingly being recognised for their intrinsic value, particularly in regard to the scarcity of certain geomorphic features, to water quality or to hydrologic regimes (eg. Dunn 2000; Qld EPA 1999a).

A common problem with all the techniques lies in getting adequate data for valid results. There is no shortage of broad criteria, but specific measures require much effort to assemble data at the range of scales required. Data limitations have meant that either the range of measures has been narrow (eg. Australian Wild Rivers) or the data gathering has focused on snapshots of condition, which in turn have been used to establish priorities for intervention.

Some techniques have been developed on the basis that there will be a subsequent data-gathering exercise. For example, a Queensland EPA approach (QEPA 1999a) grew out of a need to define data requirements for a comprehensive assessment program to accompany a State-wide strategy for water resources development. As such, initial planning was not limited to existing data, and priorities for protection and management were planned to address both ecological value and sustainability.

The methods in Table 2 use a variety of approaches in different jurisdictions, with no system having widespread acceptance. The only conservation-value system applied nationally (Australian Wild Rivers) does not appear to have received ongoing support from the States, Territories or Commonwealth, although it is being integrated with the AusRivAS data set. The method used was adapted to the available data in order to produce outputs across the country, but the limited set of indicators was an acknowledged constraint on usability of outputs.

The challenge in developing a guideline on ecological values is to make the technique rigorous enough to be reproducible and applicable across Australia, while having the flexibility to accommodate gaps in the data. The technique also has to be applicable to local and regional scales, which means that the indicators chosen and the methods of aggregation must allow for comparison at all scales.

3.3 Dealing with spatial and temporal variability

Much of the information relevant to ecological value will vary depending on where and when the information is gathered. This is particularly true of waterway systems where factors like water quality, flow and in-stream ecology change in response to environmental factors, such as rainfall and life cycles. The issue for ecological value assessment is to ensure that assessments are reliable and reflect natural variability. Fortunately, recent heightened activity on ‘state of the environment’ indicators has helped provide a reasonable range of measures that go some of the way to overcoming the problems of variability.

A brief discussion of both types of variability appears in the conceptual framework (Part A). The approach used for ecological value indicators is set out in Part B, section 5.

Case Study: The NSW Stressed Rivers Assessment

In 1998 the New South Wales Government published a 'stressed rivers' approach to the management of water use in unregulated streams. The method allowed for different priorities and policies, depending on the individual circumstances of each subcatchment, within a consistent framework. Rivers are classified according to their assessed level of environmental and hydrologic stress (see Appendix D6) and conservation value. High priority subcatchments include:

- those where demand for water already equals or exceeds supply (hydrologic stress);
- those where the water environment is significantly degraded (environmental stress);
- areas of particular natural environmental value (High Conservation Value, or HCV).

Indicators of environmental value included overall physical disturbance level of rivers (Australian Heritage Group database), presence of wetlands, national park (or similar), riparian vegetation, water birds, threatened species, fish species diversity, and absence of alien fish species. Using these data the agencies assigned an environmental value, high conservation value or no identified conservation value to each subcatchment. Differences in data across the State meant that indicators and measures were adapted to suit the data available in each subcatchment.

The assessment used the following methods:

- selection of subcatchment and mapping boundaries;
- estimation of hydrologic stress as the proportion of daily flow extracted within subcatchments, based on 80th or 50th percentile stream flow;
- compilation of environmental stress indicators, including extent of riparian vegetation, bank condition, terrestrial vegetation cover, the presence of structures, water quality data, and for tidal zone areas, the extent of acid sulphate soils and their risk to aquatic systems;
- statistical (principal component) analysis to rank indicators according to thresholds into overall stress levels of high, medium or low; expert panels also assessed the environmental stress for each subcatchment;
- consultation with regional stakeholders to provide subjective assessment input;
- assessment and rating of overall future risk to stream health and water usage;
- identification of conservation value; and
- overall stress classification – hydrologic and environmental stress rankings combined to create a final category of stress for a subcatchment.

Some rivers justified a greater level of protection and management on the basis of high stress or HCV ratings. These are given special consideration during the development of water management plans and they may also warrant priority for planning.

Management implications

Water Management Committees have been established to assist government in the development of water management plans to address future water access rules and trading arrangements, as well as water quality and river rehabilitation strategies, for each subcatchment.

The aim is to develop water management plans for stressed and HCV rivers as a priority. Plans for the remaining rivers will then be developed progressively. For HCV subcatchments, water transfers may be within or out of such subcatchments, and an environmental assessment of impacts (*Environmental Planning and Assessment Act*) on the identified conservation values must be undertaken.

One lesson from the Stressed Rivers Assessment Program is that clear enunciation of the management purpose and implications is important, so that those doing the assessment can choose an appropriate spatial scale and indicator criteria. For instance, the National Parks and Wildlife Service (NPWS) and NSW Fisheries assessed the unregulated subcatchments of New South Wales for classification into two classes – with and without identified conservation values.

The initial assessment resulted in 81% of the subcatchments having identified conservation values. Although scientifically credible, this was considered too great a proportion to inform priority setting. Further refinement of the classification was required to identify HCV subcatchments (15% of the total).

The criteria for this refinement were understood to include the known presence of threatened fish species or the threat/risk of impacts from water extraction. However, the HCV description of High Conservation Value might have been more accurately applied to 'priority' conservation value subcatchments for flow management planning.

The stressed rivers approach demonstrated that combining environmental values with threats to those values can be a basis for river planning and management at a local, regional or statewide scale. The system successfully dealt with the variability in data across different subcatchments. Although there were difficulties with communicating program objectives to some of the local stakeholders, the approach demonstrated the practicality of the method.

Source: Department of Land and Water Conservation, 1998

4 Criteria for defining ecological value

Naiman et al. (1992) asserted that there was an emerging consensus about the following 'fundamental attributes' of criteria needed for classifying ecological values of natural systems:

- they should encompass broad spatial and temporal scales;
- they should integrate structural (eg. community composition) and functional (eg. community productivity) characteristics under various disturbance regimes; and
- they should convey information about underlying mechanisms controlling in-stream features.

The authors suggested that relevant information needed to be assembled at 'low cost' and with a 'high level of uniform understanding among resource managers'.

Meeting these criteria should be seen as a long term goal, but there appears to be no existing system which encompasses all of them (Naiman et al. 1992). For the purposes of the guideline it is important to offer a practical approach, while recognising that the geographic coverage of data and our ability to measure more complex indicators are likely to improve over time.

Dunn (2000) suggested the following five criteria for identifying ecological value:

- *naturalness* – to what extent are the waterway's structures and functions similar to natural?
- *representativeness* – how typical are the waterway's structures and functions of its particular waterway type?
- *diversity* or *richness* – how biodiverse and geodiverse is the waterway?
- *rarity* – how unusual (and/or threatened) are the structures and functions of the waterway?
- *special features* – does the waterway system contain (or support) significant physical, chemical or biological features?

Each criterion is discussed briefly below.

4.1 Naturalness

> "Naturalness is a widely accepted term in conservation assessment and broadly understood to mean lack of human-induced disturbance … The concept embodies ecological integrity, which is the capacity of an ecosystem to sustain itself and remain robust to natural forms of disturbance … Naturalness of river processes is generally inferred from the biota or from the capacity of the river to maintain its natural chemical properties and balance." (Dunn 2000).

While acknowledging the impacts of indigenous peoples on the landscape, 'natural' denotes the condition at the time of first European settlement. It is often difficult to quantify even such a recent benchmark because of the lack of historical data and the extensive modifications that have occurred since.

When data are unavailable, we need to make comparisons with undisturbed waterways of similar type. If no reference site is in natural condition, then the comparison is to a least-disturbed reference condition. For example, when assessing the condition of riparian vegetation, it is reasonable to assume that introduced species were not naturally present. However, the native species present may be naturally occurring, or their presence may be an artefact of subtle modifications. In the absence of species lists from the time of European settlement, the only benchmark available will be a reference site.

Comparison with reference site condition also permits a relative scaling of indicator measures, allowing a more conservative approach. For example, we might judge a waterway to have poor water quality in relation to a particular guideline, but moderate water quality in relation to the reference condition – the approach adopted in ANZECC and ARMCANZ (2001). From an ecological viewpoint, it is therefore important to understand the reference condition when valuing the indicator.

4.2 Representativeness

Waterways which have features typical of a type or class of waterways are said to be representative. Waterway types are derived from a classification and may be generic (such as alpine mountain streams) or specific (see Appendix B3) depending on the purpose of the classification and the resources available. Representativeness generally arises from a combination of geomorphic, ecological and hydrological features, but occasionally representative individual features may be of high value (such as particular fish communities).

Dunn (2000) argued that representativeness is a valid criterion of ecological value, albeit one that "was considered by respondents to be somewhat less significant as a criterion than the other four criteria." The criterion may not itself be a value, but rather a management aim arising out of the values assessment.

Representative examples may or may not be common, so some examples may also have rarity value. A good representative example is likely to be in natural condition. A difficulty arises when a waterway type is common and modified, in which case the major value may come from its representativeness.

Case Study: Pressure–Biota–Habitat (NSW)

A project known as PBH (Pressure–Biota–Habitat) developed and tested a framework for the simultaneous assessment of the conservation value and health of New South Wales river reaches. The framework considers various attributes of a river's anthropogenic pressures (eg. altered water quality and alien species invasion), native biota (eg. riparian vegetation and aquatic macroinvertebrates) and habitats (eg. diversity of flow and substratum types). Attributes are organised by the following six criteria, which are used to judge conservation value, health or both:

- physical diversity
- biological diversity
- vigour
- resilience
- rarity
- risk factors

For example, data on the abundance and composition of fish assemblages can be used to calculate attributes related to biodiversity (number of species), vigour (abundance or biomass of native species) and rarity (number of rare species).

The PBH framework evaluates conservation assets (biophysical features of special significance) and potential problems (evidence of ill health or its likely causes) by comparing attribute levels with appropriate thresholds. However, attribute levels are first standardised to take account of natural variation. For example, the number of native fish species in New South Wales rivers declines naturally at higher elevations, so a total of three native fish species is unexpectedly high (and therefore significant for conservation) at a site of 500 metres altitude, but unexpectedly low (and therefore possibly symptomatic of ill-health) at sea level. Standardisation is achieved by developing numerical models that predict the attribute values expected for an average site in a given geographical setting (eg. region of the State, elevation, river size etc.). Attribute levels can be expressed as ratios between observed levels and expected levels (O/E ratios). A high O/E ratio indicates that an attribute level is greater than expected given the location of the site, and a low O/E ratio indicates that the attribute level is below expectation.

The thresholds are value judgments, informed by scientific information, about what constitutes good health, conservation value and potential problems. A special asset threshold (SAT) is a point above which the level of an attribute is considered particularly significant for conservation. A potential problem threshold (PPT) is the point that separates attribute levels signifying good health from those signifying ill health, a potential threat to conservation or an impediment to natural recovery. Several forms of input can be used in order to set thresholds, including data from reference sites, historical data, palaeoecological data, experimental laboratory data, quantitative models and best professional judgment. Various forms of output can be generated from the comparison of attribute levels with thresholds. For example, the number or proportion of relevant attributes above and below SATs and PPTs can be reported. Various types of scoring system are also possible.

The framework was tested by means of a Multi-Attribute Rapid Assessment (MARA) at 122 sites on unregulated streams in central and eastern New South Wales. MARA comprised visual assessments, measurements and sampling of water quality, flow, physical structure, diatoms, riparian and aquatic vegetation, macroinvertebrates and fish over a 200-metre reach at each site. The survey data were used to generate 32 attributes, and predictive relationships were established between 21 of these and site catchment area, elevation and slope, allowing adjustment for natural variation associated with these physical factors. The analysis generally showed that different components of pressure, biota and habitat provided different information, so that the capacity to extrapolate from one component to another was very limited.

Source: Chessman, in prep.

Representativeness is considered in government decisions about protection or use of areas. In effect, this recognises that protection of commonly occurring natural systems is important, particularly in the context of intergenerational equity.

4.3 Diversity/richness

Waterway diversity reflects "the behaviour of the river and interaction between the hydrology, landscape, processes and biota" (Dunn 2000). Dunn noted that "geological and geomorphological features are included because of their importance in shaping the river processes and ecosystems. Geoheritage also has intrinsic values which are as yet poorly acknowledged."

Diversity is a hierarchical indicator, in the sense that the components of diversity operate from a micro to a macro scale, and applies at genetic, species, community and regional levels. Diversity is commonly measured for species or communities, but less commonly at other levels. Genetic diversity in particular is complex and time-consuming to measure.

Some comments on this guideline suggested that biodiversity conservation should be the primary aim.

Others argued that biodiversity was secondary to the other criteria and that some streams have naturally low diversity – which should not detract from their overall ecological value.

4.4 Rarity

> Anything that is uncommon, whether biota, river form or process, is of value in the global bio- or geo-diversity context … Rivers with unusual natural water chemistry or hydrology are in many cases distinctive of inland Australia and contribute understanding of the continent's history as well as being of significance for their present day characteristics.
>
> (Dunn 2000)

A waterway may be unusual because of one feature (eg. a gorge) or because of a combination of features (eg. mineral water associated with mound springs). Rarity applies when the natural features either:

- have intrinsic natural value (eg. rare/threatened species), regardless of whether they support other values; or
- support unusual landscape or recreational values – for example, a permanent waterhole in an arid area may provide unique swimming, boating and fishing opportunities, as well as scenic amenity.

Rarity also applies to areas where humans have intervened for conservation purposes (eg. riparian rehabilitation) and the resulting features are unusual. However, rarity resulting inadvertently from human intervention, for instance of ecosystems associated with an untapped bore or with a weir pool, does not usually meet this criterion, though the ecosystems may have value under other criteria.

4.5 Other special features

> This criterion includes features which are uncommon within the landscape generally, or sustain other important or interesting ecosystems, such as karst, estuary or floodplain wetlands. It also includes other important functions rivers may provide in maintaining the wider context, such as drought refuge or avenue for dispersal. Other special features also capture those species which are not uncommon but are otherwise of importance, such as keystone or indicator species. It also includes species which might be termed flagship species, that is, those species which are especially important to the community often in a symbolic sense or by association. These include species such as platypus, river red gum and Murray cod which are also important indicators of the state of Australia's rivers generally.
>
> A river may have special value not so much for its in-stream characteristics, but for the role it plays in sustaining terrestrial species. Where there has been extensive alteration to the wider landscape, the river environs may be important as a refuge and corridor for terrestrial species and communities.
>
> (Dunn 2000)

The United Kingdom's System for Evaluating Rivers for Conservation (SERCON) identifies special features as those which "contribute greatly to the overall conservation value … but which are not commonly encountered or are not appropriately assessed" using the other criteria (Boon et al. 1997). SERCON also uses an additional category to cover 'additional features of importance' that are unable to be assessed with the scoring system (eg. the most northerly point of a population distribution).

Case Study: River Management Plan for the Wakefield Catchment (South Australia)

The Wakefield River is an ephemeral waterway located approximately 100 kilometres north of Adelaide. Impacts from vegetation clearing and agriculture have contributed to the alteration of riverine habitats and the modification of the flow regime.

A habitat assessment method was developed to determine environmental water requirements necessary to maintain essential ecological processes and biodiversity for the river system.

A survey was conducted to assess biophysical condition using aerial photography and geographic information systems (GIS). Ecological studies included macroinvertebrates (species richness, composition and abundance) and fish populations. The results were used to develop an index of 'biotic integrity' for each survey site.

From the assessment, important riparian habitat (i.e. areas with a good diversity of native riparian vegetation, a range of in-stream physical habitats and good water quality) was given highest protection priority.

A scientific panel determined the critical flow parameters for each zone, using data on representative habitats, fauna sampling and hydrology. The river system was divided into river process or geomorphic zones, each of which had 'unique assemblages of river morphologies or physical habitats'. Geological and topographic maps, longitudinal stream profiles, field site visits and aerial video observations (different from those for the stream condition assessment) were used to delineate the geomorphic zones based on bed slope, channel pattern and morphology, and sediment character.

One geomorphic zone (the mobile zone) was considered to be relatively intact and of high ecological value due to a wide range of habitats in relatively good condition, and was recognised as worthy of special protection in the river management plan.

5 Indicators

5.1 Indicators for assessing ecological value

The criteria described in Part B, section 4 require the measurement of indicators which are relevant to structures and functions that contribute to ecological value. Table 3 lists the indicators used in each of the *ecological/conservation value methods* previously summarised in Table 2.

The indicators used most often are:

- level of disturbance, compared to natural or some other reference condition, of hydrology, water quality, flora, fauna, geomorphology and ecological processes;
- rarity of flora/fauna or geomorphological features;
- habitat diversity and flora/fauna diversity; and
- services to surrounding geomorphic or ecological systems – such as flooding, refuge, key habitat, migration or karst landscapes.

Dunn (2000) used a survey of practitioners to develop a set of 'attributes' for each of the five criteria, as set out in Appendix B1.

Given the genesis and relevance of Dunn's work, the attributes in Appendix B1 have been used as a basis for this guideline. However, during the consultation and review process, some participants felt that the attribute/indicator set may be difficult to apply, partly because of overlaps and complexity. To assist with applying Dunn's work, we have made the following modifications:

- Dunn's *attributes* of high ecological value have been rephrased as *indicators* of a range of ecological values from low to high;
- overlaps and redundancies between indicators have been reduced; and
- indicators have been arranged in generic categories (hydrology, flora/fauna, etc.).

We have included measures and examples to provide a more objective way to assign ratings to each indicator. Not surprisingly, the functional indicators are the most difficult to measure and are less specific than desirable. However, it is likely that assessments with the resources to undertake functional analysis will develop the most

Table 3. Indicator types used in different ecological value methods.

Method	Indicator types																	
	Rarity			Naturalness/ condition					Diversity			Representative-ness				Other		
	Flora/fauna	*Geomorphic features*	*Other (eg. hydrology/ water quality)*	*Flora/fauna*	*Hydrology*	*Geomorphology*	*Water quality*	*Ecological processes*	*Habitat*	*Flora/fauna*	*Physical*	*Habitat*	*Hydrology*	*Flora/fauna*	*Geomorphology*	*Floodplain habitat*	*Special habitat or ecology*	*Karst landscape*
Wild Rivers (Australia)				✓	✓	✓	✓		✓	✓	✓							
Index of Stream Condition (Vic)				✓	✓	✓	✓		✓	✓	✓							
Stressed Rivers and HCV (NSW)	✓			✓	✓	✓	✓			✓								
Conservation Value guideline (Qld)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓	
Wild and Scenic Rivers (US)[a]	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓					✓	✓	✓
River Habitat Survey (UK)				✓	✓	✓	✓		✓	✓	✓						✓	
SERCON (UK)	✓			✓		✓			✓	✓	✓	✓		✓		✓	✓	
Heritage Rivers (Canada)	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓						✓	
Pusey et al. (1999)	✓		✓	✓	✓		✓	✓	✓	✓							✓	
Natural Values (NZ)	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓				
River Conservation System (SA)	✓			✓	✓	✓	✓		✓	✓								

[a]The wild and scenic rivers method does not identify particular indicators

appropriate functional measures. Functional measures can be added to the guidelines in future editions.

The completed tables (one for each criterion) of indicators and measures are set out in Appendix B2. These tables are central to the method, regardless of the scale of the assessment, and include two types of information that assist their application:

- identification of the *indicators* as essential or desirable – this is a guide to those indicators that are most critical to defining ecological value; and
- the scales at which *measures* are applicable:
  – *local* measures are intended to support reach and subcatchment assessments; and
  – *catchment* measures are intended to support regional and catchment assessments.

The scales have both a spatial and a temporal dimension in that catchment indicators tend to reflect longer time scales. Local measures monitored over long periods may also be relevant at different temporal scales.

5.2 Weightings

Weightings developed by expert surveys or similar techniques were also used for systems developed in the United Kingdom (Boon et al. 1997), New Zealand (Collier 1993) and South Africa (O'Keefe et al. 1987).

In each case, the authors acknowledged the limitations of this type of weighting process, but implied that weightings need to reflect a scientific understanding. Boon (2000) discussed the alternative of surveying the general public, noting that two studies have indicated that public opinion may be broadly in line with the views of specialists or conservationists. A valuable outcome of the process for collectively developing and weighting criteria/indicators is that the participants found it "an extremely valuable exercise in its own right, forcing [participants] to examine their own intuitive judgements" (O'Keefe et al. 1987).

It will probably take some time to achieve a consensus about how to set weightings at a State or national scale, let alone about the weightings themselves. The evidence from recent waterway valuation exercises in Australia shows that the outcomes are politically sensitive, and the weightings are important to those outcomes.

When this guideline is first applied, weightings should be considered case by case, to reflect the purpose of the assessment and the views of the stakeholders. The numerical calculations are simple to use in a spreadsheet and, by running sensitivity analyses with varying weightings, different outcomes can be compared for the different weightings.

6 Waterway classification and reference condition

6.1 Classification

Waterways and floodplains vary in longitudinal, lateral and vertical dimensions and the variation can be analysed as characteristic patterns which form distinctive waterway types. The ecological value criteria of naturalness, representativeness and rarity reflect, to some degree, these patterns and types. For example, headwater and lowland parts of waterways vary naturally in a range of features (eg. extent of riparian vegetation, in-stream substrate type). These natural differences invalidate direct comparisons of the naturalness of sites within these two waterway types. It is necessary to first develop a classification of waterways, so that ecological value criteria can be applied in the context of different waterway types.

Classification of waterway types is critical for defining a reference condition against which existing naturalness can be compared. Classification also provides a basis for assessing the relative rarity and representativeness of particular waterway types. Other criteria, such as biodiversity, are less influenced by specific waterway features and can be derived independently of waterway type.

Appendix B3 presents an example of a classification used for the Burnett River system in Queensland (Phillips et al., in prep.). The waterway types that resulted from the classification were called 'bioregional aquatic systems' (BAS).

6.2 Reference condition

Reference sites describe the range of conditions that naturally occur within a given type of waterway. They are used to define "attainable quality" (Omernik 1995) or "best available condition" (Reynoldson et al. 1997), which is considered more realistic than pristine quality or condition. In many parts of Australia, such as the eastern coastal lowlands, few waterways provide good benchmarks for determining what a 'natural' waterway is. However, the selection of modified sites as benchmarks carries a risk of incremental degradation if applied without discrimination.

The reference condition concept is a critical part of many existing and developing monitoring and assessment methods for aquatic resources. For example, projects such as biocriteria development by the United States Environmental Protection Agency (Davis and Simon 1995), river classification and water quality assessment in the United Kingdom (Wright et al. 1989) and the National River Health Program in Australia (NRHP 1994; Parsons and Norris 1996) all use the reference site concept as a central component of the assessment process.

Reference condition should be based on pre-established criteria that exist at a wide range of reference sites, rather than relying on information from one or a few control sites (Reynoldson et al. 1997). These reference conditions (structure and function) then serve as the standard against which to compare test-site conditions.

There have been many approaches used to describe reference conditions (Hughes 1995; Johnson et al. 1993). These include reference conditions based on:

- *regional reference sites* (applicable to whole aquatic communities; acceptable levels of disturbance must be established; difficult to apply to wetlands; habitat classification still required);
- *historic data* (useful if sites have been sampled; inconsistencies possible in databases);
- *palaeoecological data* (essentially limited to lakes, diatoms and chironomids; poorly suited to streams);
- *biotic indices* (compare to a predetermined hierarchy of values; conditions represented by indices may not be attainable because of habitat differences);
- *experimental laboratory data* (establishes relationships between test species and stressors; not applicable to wider community and not tested on many stressors);
- *quantitative methods* (establish reference conditions through curve fitting; data reliability can affect models);
- *best professional judgment* (usually undertaken by panel of experts and/or peer review; value of judgment is a function of the scientists' expertise and the quality of the data supplied to them); and
- *disturbance methods* (reference sites are those with no or minimal disturbance, for example the monitoring river health program critera in Table 4).

In the many cases where pristine sites are unavailable, the reference condition 'best attainable quality' is used. Phillips et al. (2001) used the 'best' value for each indicator within each waterway unit or BAS (see Appendix B3). This approach is similar to that used by others (eg. Harris and Silveira 1999). Reference condition must be defined within each BAS, to account for natural differences in waterway type when comparing condition values derived from different BASs. The 'best' is defined as that score representing best condition or the greatest value for a particular attribute/indicator. Therefore, the site used to define the reference condition may vary depending on the particular indicator being used.

Table 4. Example of criteria used to define reference condition (Source: Conrick and Cockayne 2000).

No.	Reference condition selection criteria
1	No intensive agriculture upstream
2	No major extractive industry (current or historic) within 20 km
3	No major urban area (>5000 population) within 20 km
4	No significant point-source waste water discharge within 20 km upstream
5	No dam or major weir within 20 km upstream
6	Seasonal flow regime not greatly altered
7	Riparian zone of natural appearance
8	Riparian zone and banks not excessively eroded beyond natural levels or significantly damaged by stock
9	Stream channel not affected by major geomorphological change

7 Method for ecological value assessment

The above discussion shows that a valid method for ecological value assessment of Australian waterways will:

- incorporate biological, hydrological and geomorphological values;
- assign relative values for any waterway or reach, not just those of high value;
- be based on a set of criteria and indicators derived from consultation with waterway managers across Australia (Dunn 2000);
- use a numerical system which can be modified to suit different circumstances;
- incorporate weightings to reflect the relative contributions of criteria and indicators of ecological value;

- accommodate data or resource constraints, through a combination of redundant measures and qualitative appraisal;
- employ information technology (GIS, databases, etc.) to improve analysis and outputs; and
- provide a variety of possible reporting styles, which can be designed to suit the context of the application.

We outline a suggested method in Figure 7 and provide more detail on the following pages. Once criteria, indicators and measures have been determined (Part B, sections 4 and 5), the critical steps are to define scale, classify the waterways, select reference condition (Part B, section 6) and determine the ratings.

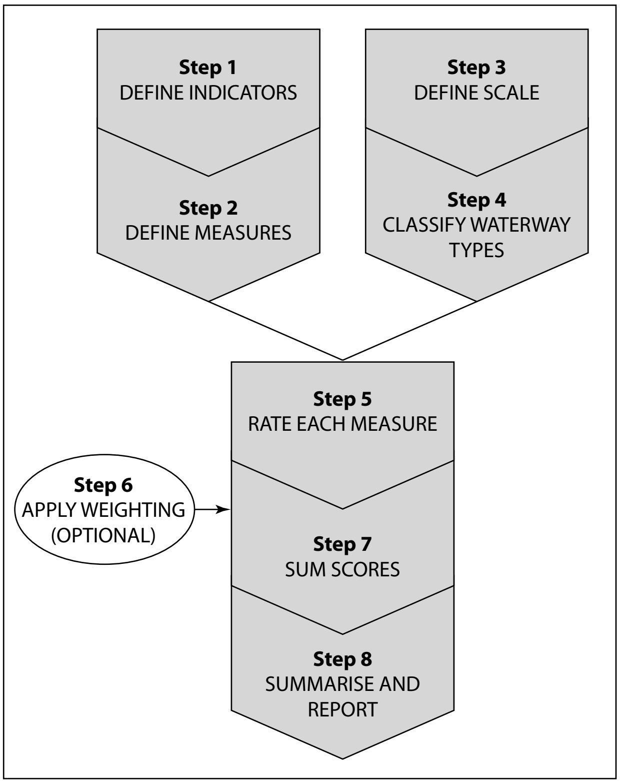


Figure 7. Summary of method for ecological value assessment.

STEP 1: Define appropriate indicators

1.1 From Appendix B2, select indicators from tables B2.1–B2.5 appropriate to the purpose of the evaluation. For instance:

- in preparing a plan to protect regional biodiversity, emphasis may be placed on indicators of flora/fauna diversity and habitat diversity;
- for the development of a local conservation plan for rare and threatened taxa, communities and habitats, indicators should at least consider rarity and related special features; or
- for a plan aimed at identifying areas for protection from proposed catchment development, all the key indicators should be included – as a minimum – for each of the criteria.

STEP 2: Define measures

2.1 From the same tables, select measures for each of the indicators chosen in step 1, based on:

- available data plus new data that can be assembled during the evaluation; and
- the scale of the project (measures are defined according to scale).

In some cases, it may be appropriate to aggregate local scale measures to catchment scale. For example, water quality data is collected at individual (i.e. local) sites, but may be sufficiently consistent across a subcatchment or even a catchment to provide meaningful statistics.

2.2 Transfer the selected indicators and measures to a proforma (for numerical evaluations, it is desirable to use a spreadsheet or input to a database).

STEP 3: Define waterway scale (in parallel with step 1)

3.1 Define the waterways appropriate to the application (catchment planning, project assessment, etc.):

- *For catchment evaluations*, identify all the waterways potentially affected by development. This will generally be all waterways in the catchment, but the study boundaries may specifically exclude some areas (such as upper reaches or individual subcatchments). Also identify any other waterways known (or likely) to have significant ecological value.
- *For subcatchment and individual waterway (project) evaluations*, generally the relevant waterways are the main stream from the upstream inundation point (in the case of a water infrastructure proposal) to the downstream limit of waterway impact (which in major water infrastructure projects will be the marine end of the estuary). This includes tributaries affected by the inundation or by changes in main channel flow.

STEP 4: Classify waterways within the defined scale/area (see Part B, section 6)

4.1 Break the affected length of the waterway into components appropriate to the application, to provide manageable units for analysis of ecological value and to assist with measuring *rarity, representativeness* and *naturalness*:

- *For catchment evaluations,* it will usually be sufficient to identify the main river channel and tributaries. Use professional judgment in dealing with very large catchments, where lower-order waterways may also need inclusion.
- *For subcatchment and reach evaluations,* define reaches that have broadly similar physical, chemical and biological attributes (see Appendix B3).

The minimum scale defined in this step (reach, third-order stream, etc.) will be the scale at which ecological value is defined (for convenience called a 'waterway unit'). For example, in a local assessment, a unique ecological value description would be developed for each of the defined reaches within the study area.

4.2 Define waterway types and reference condition by determining the method to be used for selecting them (see Part B, sections 6.1 and 6.2 respectively). Based on the chosen methods, identify appropriate waterway types and reference sites/values.

STEP 5: Rate each measure

5.1 Rate each waterway unit on a scale of 1 to 5 for all relevant indicator measures and enter the rating in the spreadsheet. Wherever possible, determine ratings using measured data and agreed benchmarks. Some of the rating scales will be difficult to interpolate and ratings will tend to be either 1 or 5. 'Yes/No' responses may be used for simple applications (see Appendices B4 and B5 for a comparison).

Note that, at this stage of the guideline's development, the ranges adopted will be a matter for the user to define. However, in many cases setting upper and lower limits will be fairly clear cut. For example, the upper and lower limits for catchment modification are '100% uncleared' and '100% cleared'; no barriers and the presence of a major dam would be the upper and lower limits for in-stream connectivity.

5.2 Document the information used to determine the rating for each measure. For example, for water chemistry (naturalness), a typical entry might be:

> Four parameters (dissolved oxygen, conductivity, total phosphorus and total nitrogen) had low variation with respect to the reference site, based on comparison of annual ranges, means and standard deviations, as well as diurnal variation in dissolved oxygen. Turbidity showed moderate variation because it was occasionally up to 50% higher than the reference site range.

STEP 6: Apply weightings (optional)

6.1 Develop weightings for each indicator and/or measure – preferably working with stakeholders who have scientific understanding to achieve a consensus. It will simplify the process to weight only the indicators and assume that all measures are of equal weight for a particular indicator.

6.2 Enter weightings in the spreadsheet and multiply rating by weighting for each indicator and/or measure.

STEP 7: Add scores for measures

7.1 Add scores for individual measures (either unweighted or weighted) to derive a score for each indicator.

7.2 Add indicator scores to derive a score for each indicator and each criterion.

7.3 Evaluate each criterion based on percentage of total possible (this normalises criteria so that each criterion has the same weighting). Categories are based on:

Very high (>75%)
High (50–75%)
Medium (25–50%)
Low (<25%)

STEP 8: Summarise and report on evaluation

8.1 For an individual waterway unit, report the ratings for each criterion. Ideally, include descriptive information to support and amplify the rating. It is useful to have simple indices of ecological value, but it is also important that the answers are justifiable and understandable. This descriptive information will generally come from:

- information supplied by the proponent (for example, impact assessment studies);
- any additional information held by environmental, resource management or other agencies;
- the author's knowledge of the study area; and/or
- ecological values evaluation using the previous steps.

8.2 Individual criterion ratings can be combined to provide high-level information about waterways (ie. an overall ecological value). Waterway reaches could be assigned an ecological value based on their meeting all criteria, or meeting certain key criteria (such as presence of endangered species), or achieving a total score after being rated numerically. The method can be used to provide several different presentation formats, depending on the application (see Part B, section 9). For example, national-scale reporting may warrant a high level of aggregation, while reporting of local impacts of a weir proposal may require more detailed reporting of values at waterway reach scale.

High-level aggregation can be contentious because there is some doubt as to how meaningful the information is. For example, Boon (2000) argued that aggregation of individual criteria ratings into a single conservation value could be misleading. The author cited a case study where a river with low overall conservation value had high physical diversity, which should have been an important consideration in setting management priorities.

8 Worked examples of the method

Appendix B4 shows how ecological value could be assessed where there is little information and where specialist expertise is lacking. The table is designed for site-by-site use, with the collective information within a catchment being used to build a picture of ecological value. The analysis is not numeric and relies on the user to provide an overall assessment for each criterion, based on a series of yes/no responses.

Appendix B5 demonstrates a more elaborate assessment method. For brevity, the example covers one ecological value criterion: naturalness. Such a method would be useful for a panel of experts, where little measured information is available but where the experts use their knowledge to rate different indicators of the criterion. Different weightings could then be placed on different criteria, reflecting their relative importance in determining ecological value.

These two methods represent different points in a spectrum of approaches that could be used to assess ecological value. The simpler method can be used as a trigger for the more detailed version.

Appendix B6 provides an example of a method for calculating ecological value (again using only naturalness) where data are available. In this case an automated tool has been developed to calculate ecological value (as indicated by the tables) and is part of a geographic information system (GIS) that allows both interrogation of the information and a range of visualisations of the final product (eg. maps). Such a system also allows relatively simple updating when new information and/or methods become available.

9 Examples of outputs

A single rating for the *overall* ecological value of a waterway (very high, high, etc.) is only likely to be useful for broad-scale planning, which addresses questions about potential constraints on development (eg. which waterways in a catchment have values incompatible with in-stream development). It may also be a means of conveying complex information for high-level briefings where detailed information is not appropriate.

In other situations, particularly subcatchment planning or individual project assessments, the *criteria* which make up the ecological value of the waterway are more important. Coupled with GIS-based data and presentations, they not only help to explain why the waterway is significant, but also can give insights into potential management techniques. Table 5 and Figure 8 are examples of outputs. The table could be repeated for each reach or waterway, depending on the scale.

Figure 9 is an output from an analysis by the Queensland EPA in the Burnett River catchment. The GIS output is based on different criteria, but illustrates the type of mapping which can be produced. Another method is to display individual ecological values for each criterion using colour codes for the waterways (Figure 10).

Case Study: Determining Conservation Values in the Burnett River Catchment

A project was undertaken to trial the application of a 'conservation value' method developed by the Queensland EPA (1999a) to assess ecological and cultural heritage values of waterways in the Burnett River catchment. The key steps were:

- *Determination of the different river types that reflect ecological and geomorphological differences.* Classification of river types is needed for a comparison of conservation values across river types that takes into account the natural variation within river systems. The project undertook a detailed assessment of attributes important in differentiating river types.
- *Assignment of ecological (and cultural heritage) values using existing data sets.* GIS provided an automated process for undertaking this numeric process. The project assessed existing data for their suitability in satisfying the information requirements described in the guideline.
- *A ground truthing exercise* to validate the outputs of the desktop analysis at a limited number of sites (41).

The use of existing data restricted the extent to which the guideline could be applied. Although the method is potentially data intensive, the trial adapted the method to provide credible results despite large gaps in the data.

The attributes used to determine river types tended to be similar when the desktop and ground-truthed values were compared, but those used to derive conservation values differed considerably. Such a difference is to be expected, as the attributes chosen to describe conservation value were chosen because of their sensitivity to changed environmental conditions. Some of these changes are likely to be natural (eg. changes in flow conditions due to seasonal variation), while others reflect disturbance factors (eg. clearing of riparian vegetation). Consequently, it is important to recognise that conservation value is a 'snapshot' measure. Ongoing monitoring will be required to determine trends in changes to conservation values.

The trial highlighted the effectiveness of the method for guiding the user to the kinds of information that are required in order to effectively determine the conservation values of waterways. The GIS applications provided a powerful tool, allowing the relatively rapid assessment of conservation value following the more resource-intensive development phase, and can be updated. Figures 9 and 10 show examples of output.

(Source: Phillips et al. in prep.)

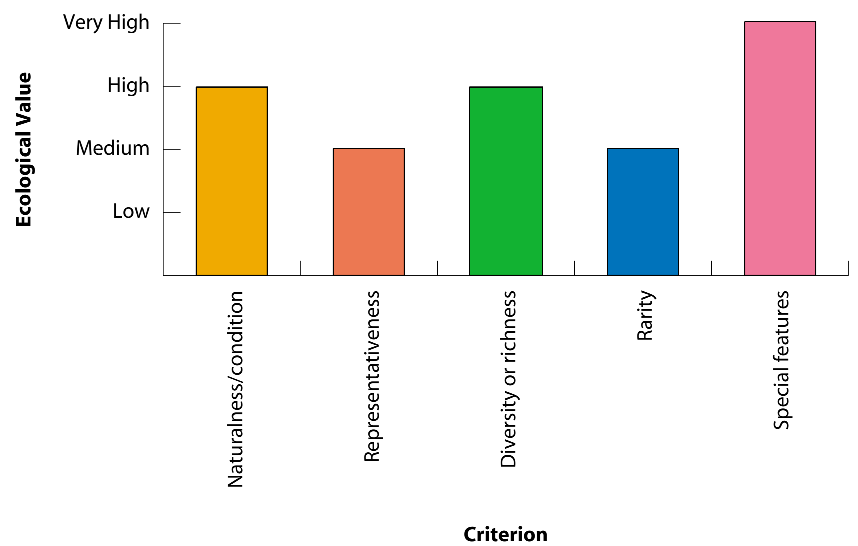


Figure 8. Example graphical representation of ecological value criteria scores.

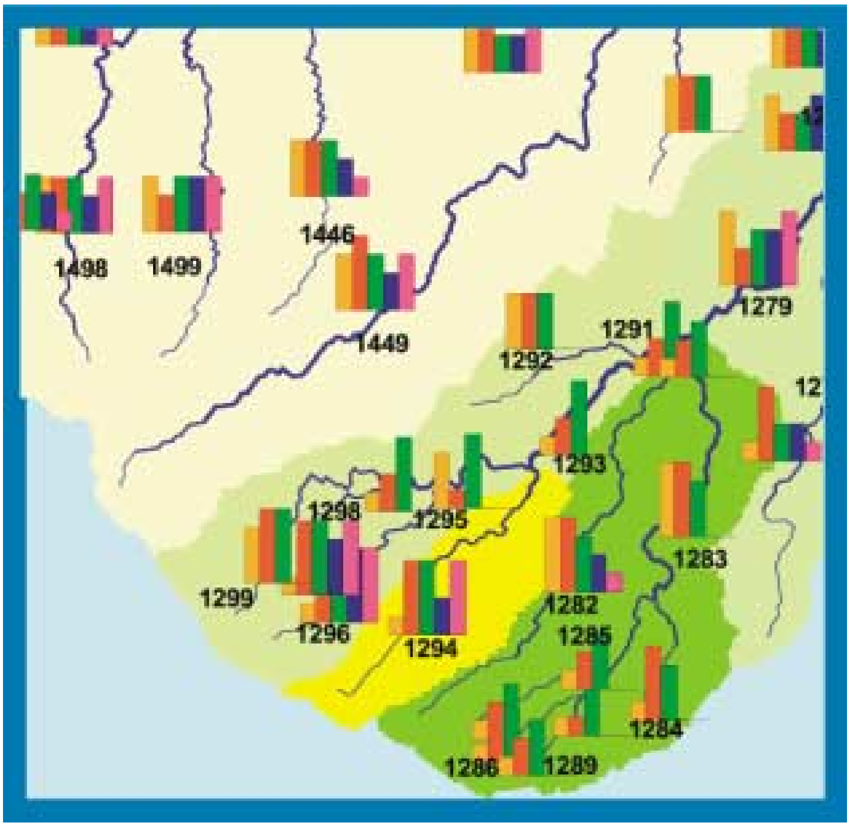


Figure 9. Example of comparative value scores for five criteria at different reaches (source: Redfern et al. 2000).

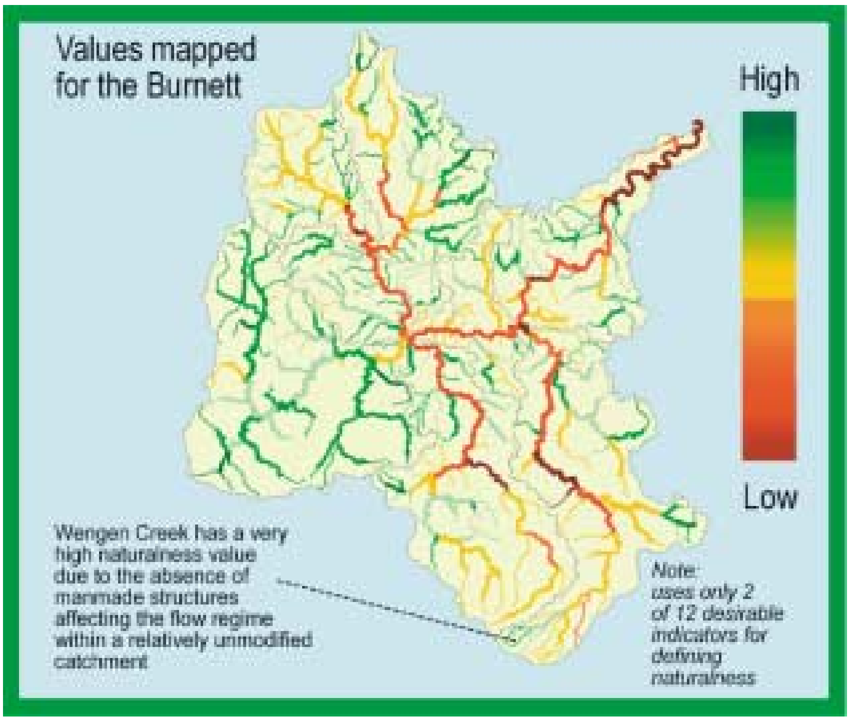


Figure 10. Example of representing individual ecological values (eg. naturalness) by colour coded waterways sections (source: Redfern et al. 2000).

Table 5. Example summary of ecological values (for Big River between Yellow Creek confluence and the tidal gate at Littletown).

Criterion	Value	Justification/Comments
Naturalness	High	In comparison to pre-European condition, the waterway has been slightly degraded, primarily due to limited clearing in the catchment. Channel condition, riparian vegetation and hydrology are largely unaffected, but water quality and in-stream biota have shown a slight decline over a long period of data collection. Most indicators suggest that the condition is relatively good compared to similar waterways in the region.
Representativeness	Medium	In comparison to rivers of similar type (upland coastal) in the region, the river lacks some of the typical biological features. This may be due to poorly drained and dispersive soils in the catchment and floodplain – influencing both riparian vegetation and water quality. The river has a hydrological regime which is a good example of a wet/dry seasonal pattern with a high degree of variability from year to year.
Diversity or richness	High	The *species* diversity of the waterway is high in terms of fish, aquatic macroinvertebrates and riparian flora. *Community* and *regional* diversity are considered to be moderate in comparison to other catchments within the bioregion. No information about *genetic* diversity is available, but a waterway of similar geomorphology and biology in an adjacent catchment is known to contain a hardyhead genotype known only to that waterway.
Rarity	Medium	Includes one of five minor rock gorges in the catchment, all of which contain alternating pool/riffle sequences. The waterway may be habitat for one or possibly two endangered fish species that have been collected downstream (Reference cited), but as yet no surveys have confirmed their presence within this waterway.
Special features	Very high	The floodplain has several major wetland systems that are permanent but dependent on seasonal inflows to sustain vegetation in the marginal areas. The river itself forms a drought refuge for floodplain wildlife and for migratory birds when preferred habitats are dry.

Appendix B1

Criteria and attributes suggested by Dunn (2000) for high ecological value rivers

Criterion	Attributes
1. Naturalness	1.1 undisturbed catchment 1.2 unregulated flow 1.3 unmodified flow 1.4 unmodified river/channel features 1.5 natural water chemistry 1.6 absence of interbasin water transfer 1.7 intact and interconnected river elements 1.8 natural temperature regimes 1.9 natural processing of organic matter 1.10 natural nutrient cycling process 1.11 intact native riparian vegetation 1.12 absence of exotic flora or fauna 1.13 habitat corridor 1.14 in-stream faunal community composition 1.15 natural ecological processes, including energy base and energy flow through food webs
2. Representativeness	2.1 representative river system or section 2.2 representative river features 2.3 representative hydrological processes 2.4 representative aquatic macroinvertebrate communities 2.5 representative in-stream flora or riparian communities 2.6 representative fish communities or assemblages
3. Diversity or richness	3.1 diversity of rock types or substrate size classes 3.2 diversity in-stream (eg. pools, riffles, meanders, rapids) 3.3 diversity of channel, floodplain (including wetland) 3.4 diversity of native flora or fauna species 3.5 diversity of in-stream or riparian communities 3.6 diversity of floodplain and wetland communities 3.7 diversity of endemic flora or fauna species 3.8 important bird habitat
4. Rarity	4.1 rare or threatened geomorphological features 4.2 rare or threatened ecological processes 4.3 rare or threatened geomorphological processes 4.4 rare or threatened hydrological regimes 4.5 rare or threatened invertebrate fauna 4.6 rare or threatened fish or other vertebrates 4.7 rare or threatened habitats 4.8 rare or threatened flora 4.9 rare or threatened communities or ecosystems 4.10 rivers with unusual natural water chemistry
5. Special features	5.1 karst, including surface features 5.2 significant ephemeral floodplain wetlands 5.3 dryland rivers with no opening to ocean 5.4 important for the maintenance of downstream or adjacent habitats such as floodplain/estuary 5.5 important for the maintenance of karst system or features 5.6 important for migratory species or dispersal of terrestrial species 5.7 drought refuge for terrestrial or migratory species 5.8 habitat for important indicator or keystone taxa 5.9 habitat for flagship taxa 5.10 refuge for native species and communities in largely altered landscapes

Appendix B2

Ecological value indicators and measures

Table B2.1. Naturalness – indicators and measures (indicators in ***bold italics*** are critical to measure; others are desirable).

Indicator[a]	**Examples of measures**[a]	
	Catchment scale[b]	**Local scale**
Catchment/linkages		
Catchment disturbance	• Land Use Factor (LUF)[c] • % of natural vegetation cover	
Connectedness of waterway elements	• Frequency of in-stream barriers that prevent fish passage (no./km) • Inundation from artificial lakes (% of waterway length) • Length of levee banks (% of waterway length) • % of former floodplain no longer flooded	• Presence of artificial barriers that prevent fish passage (yes/no) • Inundation from artificial lakes (% of waterway length) • Length of levee banks (% of waterway length) • % of former floodplain no longer flooded • Continuity of riparian zone
Hydrology		
Flow modification	• Total annual diversion (% of median flow) • Interbasin transfer (% of median flow) • Dams or major weirs (no./km)	• Floodplain inundation frequency • Bankfull flow frequency • Depth of baseflow
Water quality		
Water chemistry	• % of sites with natural water chemistry (aggregated from local measures)	• Variation from natural state for key variables (eg. nutrient loading, conductivity, turbidity, temperature) • Presence of toxicants
Flora/fauna		
Floral community composition and structure	• % of sites with natural floral composition and structure (aggregated from local measures)	• Aquatic (eg. species richness, community composition, % species tolerant to perturbation) • Riparian (eg. species richness, canopy cover, width, continuity) • Floodplain (eg. species richness, community composition, cover) • Habitat types
Absence of exotic flora/fauna	• % exotic species presence/cover (aggregated from local measures)	• Aquatic, riparian, floodplain (eg. % exotic species presence/cover)
Faunal community composition	• % of sites with natural faunal community composition (aggregated from local measures)	• Macroinvertebrates (eg. species richness, observed/expected ratios) • Fish (eg. species richness) • Other vertebrates (eg. species richness)
Ecological processes		
Natural ecological processes	• % of sites with natural ecological processes (aggregated from local measures)	• Primary productivity • Secondary productivity • Nutrient cycling • Energy flow • Composition of macroinvertebrate functional feeding groups • Fish – spawning, age distribution, composition of trophic status groups, composition of movement categories

Table B2.1. (cont'd) Naturalness – indicators and measures (indicators in ***bold italics*** are critical to measure; others are desirable).

Indicator[a]	**Examples of measures[a]**	
	Catchment scale[b]	**Local scale**
Geomorphology		
Channel features modification	• Channel geomorphology (eg. River Styles™, Fryirs and Brierley 1998)	• Bed aggradation/degradation • Bank erosion • Substrate types • Habitat types

[a] Measures (and therefore indicators) are generally relative to natural condition (or reference if natural condition is unknown)
[b] Where data are sufficient and consistent, catchment measures may be based on aggregation of local measures
[c] Weighted average land uses – see comments below (Australian Wild Rivers database)

Comments on naturalness measures

Catchment disturbance: Vegetation clearance is a crude indicator for a variety of impacts on waterways – such as water quality, hydrology and vegetation corridors. A complementary and more systematic approach is the Land Use Factor (LUF), which is a weighted combination of land uses to approximate the level of disturbance and impact on waterways (Australian Wild Rivers Project, Environment Australia 1999; Stein et al. n.d.)

Artificial barriers: This criterion needs careful evaluation, because different barrier effects can arise depending on the size and design of structures and on the nature of the affected processes (eg. fish movement, biotic drift and dispersion, sediment/nutrient transport). A critical factor is the proportion of the catchment's waterways affected by the structure. The Australian Wild Rivers project included differential 'weightings' for impoundment classes that can be used to help derive a rating for this measure (major structure 1.0, weir 0.3, lock/sluice gate 0.3, minor structure 0.3). Allowance also needs to be made for fishways and other design features, which may mitigate some impacts.

Floodplain extent: This is intended to indicate the natural spatial extent of the floodplain. Inclusion of levee banks is a measure of change in the upper bank morphology as well as of redistribution of floodwaters on a floodplain.

Flow: Many hydrological measures are possible and those suggested have been useful in the Queensland water resource planning process. Total diversion (% natural) and flooding provide simple benchmarks at catchment scale. Where better statistics are available (either historical or modelled), they should be used, particularly at subcatchment scale. For example, a weir used for emergency supply may divert a very low proportion of median annual flow, but in a small stream may substantially reduce the frequency and volume of low flows in dry periods. It would be valuable to use a low flow statistic in that case. Models such as the Integrated Quantity and Quality Model (IQQM) are useful in assessing naturalness. The model can assess the hydrologic deviation from a natural state, by simulating pre-disturbance conditions (such as vegetated catchments and unregulated flows). Median flows need supplementing with other information, depending on the type of river regime. In unregulated rivers, most of the stress tends to occur at low flows (<80th percentile). Regulated rivers may also require an additional indicator (such as monthly deviation from median) to reflect seasonal reversal of flow downstream of dams.

Water quality: There are many potential measures. The variables suggested are widely available, may affect ecology and are sensitive to human influences. In some circumstances, it may be appropriate to use other measures more suited to the context (for example, where a waterway is substantially affected by point-source pollution, measures relevant to the pollution source should be used). The statistic chosen to quantify the measures should include central tendency (median, mean or log mean) and variability (range or standard deviation). The statistics should be estimated over a sufficiently long period to account for natural variation, but not so long that the pattern of human influence has substantially changed within the period.

Macroinvertebrate and fish flow preference: This information provides a sensitive measure of changes in flow regime. However, the information is not readily available and both measures will need to be treated as 'desirable but not essential' until more becomes available. The relative occurrence of aquatic species tolerant to perturbation is a useful indicator of the degree to which the species composition has skewed towards species which are better adapted to unnatural stress (Chessman et al. 1997). Harris and Gehrke (1997) suggested that fish are a valuable indicator which can complement more common indicators, such as macroinvertebrates, for depicting biotic health.

Channel features: Interpretation needs to take into account natural variation. For example, some waterways are naturally unstable with relatively mobile beds. Accurate characterisation of the natural state may require substantial geomorphological investigations. Information can come from numerous sources, including field observations and site assessments, aerial photography and geomorphological classification. The River Styles™ classification has been applied in many New South Wales rivers and it includes channel assessment as a part of the method. (It could also be used to identify areas of high geodiversity and geomorphological naturalness and uniqueness.)

Table B2.2. Representativeness – indicators and measures (indicators in ***bold italics*** are critical to measure; others are desirable).

Indicator	Examples of measures[a,b]	
	Catchment scale	**Local**
Hydrology		
Hydrological processes	• coastal river system with monsoonal flow	• dryland stream with no ocean outlet
Water quality		
Water quality characteristics		• naturally acidic, highly mineralised
Flora/fauna		
Aquatic macroinvertebrate communities		• typical macroinvertebrate community for a particular waterway type
In-stream flora or riparian communities		• typical macrophyte community for a particular waterway type
Fish communities or assemblages		• typical fish community for a particular waterway type
Ecological processes		
Ecological processes		• seasonal productivity in billabongs
Geomorphology		
River system or section	• multichannel arid river basin	• confined tidal creek and coastal lagoon
River features		• sandstone waterfall • steeply incised arid gorge

[a] *Representativeness* is used here to mean representative of a type of feature, and examples are therefore likely to be in good condition. The term is equally applicable to common and uncommon structures and functions. Where there are few examples, there will also be rarity value.
Because the criterion can apply to common attributes, it is difficult to provide measures. Instead, examples have been used. Note that the number of potential examples is very large.

[b] A *waterway classification* for the study area is needed to describe waterway types against which to benchmark the representativeness of a particular reach or waterway system (see Part B, section 6 and Appendix B3). Classifications also exist for particular categories, such as water quality, hydrology and geomorphology and, depending on the context, one or more of these may be appropriate to use rather than the more comprehensive system used in Appendix B3.

Table B2.3. Diversity – indicators and measures (indicators in ***bold italics*** are critical to measure; others are desirable).

Indicator[a]	Examples of measures[b]	
	Catchment scale	**Local scale**
Hydrology		
Hydrological diversity within catchment	• Number of distinct hydrological regimes (eg. spring-fed stream, ephemeral stream, wetland, boggomoss)	
Flora/fauna[c]		
Genetic		• Allelic (composition) • Heterozygosity, polymorphism (structure) • Gene flow, genetic drift, mutation rate (function)
Species		• Richness • Frequency of occurrence • Relative abundance
Community		• Number of species per habitat (alpha diversity) • Species turnover between habitats (beta diversity) • Ecotones
Regional/landscape	• Total species in region (gamma diversity) • Environmental gradients, ecotones • Disturbance regimes	
Geomorphology		
Rock types, substrate size classes		• Microhabitat structure
In-stream habitats		• Habitat heterogeneity
Channel type/floodplain	• Number of distinct types in catchment	• Number of distinct types
Regional/landscape	• Geomorphic patterns	

[a] The ratings take into account naturally low diversity by using a comparison to reference sites.
[b] Adapted from Ward et al. (1999).
[c] Applies to endemic/native biota, including floodplain, wetland, riparian and aquatic environments.

Comments on diversity measures

Beta diversity is the reciprocal of the mean number of habitats per species; it is "in some respects, also a measure of the degree of connectivity between habitats". Ward et al. (1999) suggested that beta diversity "can provide a new perspective for understanding biodiversity in floodplain rivers and the influence of river regulation on biodiversity patterns."

Some of the examples provided above are already picked up in the indicator measures for other criteria (such as energy flow, connectivity, hydrology, geomorphic patterns and habitat heterogeneity). The most critical omissions are alpha and beta diversity, environmental gradients/ecotones, population succession/dynamics and all the genetic-level examples.

Table B2.4. Rarity – indicators and measures (indicators in ***bold italics*** are critical to measure; others are desirable).

Indicator	Examples of measures at catchment and local scales
Hydrology	
Hydrological regimes	• Frequency of occurrence of a particular hydrological regime (eg. ephemeral, permanent, spring fed, inland discharge)
Water quality	
Natural water chemistry	• Frequency of occurrence of a particular water chemistry type (eg. acid/tannic, mineral water, turbid, oligotrophic)
Flora/fauna	
Flora/fauna species	• Number of taxa protected by legislation, treaties or conventions • Number of taxa classified as endangered or of concern for conservation • Number of flagship taxa (eg. koala, platypus)
Invertebrate, fish or other vertebrate habitats	• Number of habitats protected by legislation, treaties or conventions • Number of habitats classified as endangered or of concern
Communities/ ecosystems	• Number of communities/ecosystems protected by legislation, treaties or conventions • Number of communities/ecosystems classified as endangered or of concern
Ecological processes	
Ecological processes	• Frequency of occurrence of a particular ecological process (eg. breeding activity in ephemeral lakes)
Geomorphology	
Geomorphic features and processes	• Frequency of occurrence of a particular geomorphic feature/type (hanging valley, meandering upland stream) • Frequency of occurrence of a particular geomorphic process (eg. silt jetty deposition, anastomosing channel)

Comments on rarity measures

The same rarity measures can be applied at different scales. For example, a particular attribute may be rare locally, uncommon regionally and common nationally. Legislation defines the scale (national, state) for some indicators, but most indicators require a knowledge of the scale benchmarks. For example, mapping of the distribution and abundance of coastal paperbark swamps in far northern New South Wales can be used to assess regional and local rarity.

Natural hydrology and water quality are inherently variable within and between streams. Determining rarity in the context of large spatial and temporal variability will be very difficult, except in reasonably obvious cases, such as thermal springs and acid lakes. The recommended approach at this preliminary stage is to consider a catchment-wide context over varying flow conditions (J. Platten, pers. comm. 1999).

The widespread practice of river regulation means that unregulated rivers have rarity value. However, to avoid double counting, regulation resulting in flow changes is only included as an indicator measure under the 'naturalness' criterion (Table B2.1).

Table B2.5. Special features – indicators and measures

Indicator[a]	Examples of measures[b]	
	Catchment scale	**Local scale**
Hydrology		
Maintenance of offshore habitat/ communities	• Prawn fishery	
Maintenance of karst systems		• Underground stream
Maintenance of groundwater-dependent systems	• Regional aquifer recharge from catchment	• Alluvial aquifer recharge from floodplain • Mound springs
Flora/fauna		
Migratory species habitat	• Regional riparian corridors	• Estuarine wetlands • Eel spawning areas
Dispersal of terrestrial species	• Riparian corridor linking terrestrial habitats	• Riparian corridor linking terrestrial habitats • Permanent water bodies in dry areas
Drought refuge		• Deep waterholes in an ephemeral stream
Habitat for important indicator or keystone taxa		• Indicator taxa (eg. sensitive to pollution, such as stoneflies) • Keystone taxa (eg. predatory fish)
Habitat for flagship taxa	• A series of pools supporting platypus • Aquatic macrophytes supporting lungfish reproduction	
Refuge for native species and communities in largely altered landscapes	• Remnant riparian bushland in a rural catchment	• Urban waterway/creek corridor

[a] Critical indicators are not identified because it is not meaningful to generalise about special features.
[b] Similarly, general measures are not appropriate for special features because of the specificity required. Consequently, the table provides examples and the user would need to make a judgment about whether a particular waterway was important for, say, 'dispersal of terrestrial species'.

Comments on special features measures

Indicator taxa are often those that are most sensitive to a given disturbance. They have limited resilience and are unlikely to be common except where conditions are good (ie. they can be locally common but regionally rare).

Appendix B3

Example of waterway classification

Classification assists in the comparison of different stream types and their ecological values. Numerous approaches have been used for stream classification, with the choice of approach being geared to specific objectives. Many use some combination of hydrology, river morphology and vegetation (aquatic and/or riparian).

The classification described below was required to support the assessment of three of the ecological value criteria – *rarity*, *representativeness*, and *naturalness*. It aims to reflect the ecological and geomorphological aspects of waterways that are relevant to aquatic and riparian flora and fauna. The types of attributes and indicators used in this method include:

- *Biogeography* – climate, geology, landform, soils, terrestrial vegetation;
- *Hydrology* – freshwater and tidal, flow regime;
- *Habitat* – morphology (eg. pools, runs, riffles, cascades); water characteristics (eg. permanence, depth, duration of inundation, quality); substratum (eg. sediment particle size); and
- *Aquatic flora/fauna* – dominant assemblages, diversity, abundance.

A sound basis on which to build the classification is provided by such contemporary methods as the River Styles™ approach (Fryirs and Brierley 1998), which currently utilises geomorphic units but is progressively adding biological aspects.

By combining indicators, a series of *waterway or river types*, called here 'bioregional aquatic systems' (BASs), can be described. The concept is based on the terrestrial construct of bioregional ecosystems (Sattler and Williams 1999), and the term has been adopted for this guideline.

In a trial of methods to classify waterway types and define conservation values in the Burnett River, south-east Queensland (Phillips et al., in prep.), a multivariate classification technique was used to define BASs. Table B3.1 is an inventory of BASs that were developed in that study.

Table B3.1. Bioregional aquatic systems (source: Phillips et al., in prep).

BAS	Description
1	high rainfall, steep gradient, large catchment area upstream, small distance to sea, mildly sinuous to regular channel type, large width:depth ratio, pools and riffle dominant habitats, fine substrates, predominantly coarse-textured soils in surrounding catchment, as well as consolidated bedrock, usually undulating to hilly with relatively shallow sedimentary soils in surrounding catchment
2	high rainfall, low gradient, large catchment area upstream, small distance to sea, mildly sinuous channel type, small width:depth ratio, pools dominant habitat, bedrock predominant substrate, predominantly consolidated bedrock, usually undulating to hilly with relatively shallow sedimentary soils in surrounding catchment
3	high rainfall, moderate gradient, small catchment area upstream, small distance to sea, mildly sinuous to irregular channel type, moderate width:depth ratio, pools dominant habitat, fine substrates dominate, predominantly coarse-textured soils in surrounding catchment
4	moderate rainfall, steep gradient, large catchment area upstream, small distance to sea, mildly sinuous channel type, moderate width:depth ratio, pools dominant habitat, sandy substrates dominant, predominantly coarse-textured soils in surrounding catchment
5	moderate rainfall, moderate gradient, moderate catchment area upstream, moderate distance to sea, mildly sinuous channel types, moderate width:depth ratio, glides/riffles dominant habitats, fine substrates dominant, predominantly coarse-textured soils in surrounding catchment
6	low rainfall, generally moderate gradient, generally moderate catchment area upstream, moderate distance to sea, mildly sinuous to irregular channel type, moderate width:depth ratio, pools dominant habitat, sand substrate dominant, predominantly coarse-textured soils in surrounding catchment
7	low rainfall, generally moderate gradient, moderate catchment area upstream, moderate distance to sea, irregular meander channel type, low width:depth ratio, pool dominant habitat, fine/sandy dominant substrate, predominantly consolidated bedrock, usually undulating to hilly with relatively shallow sedimentary soils in surrounding catchment
8	low rainfall, generally shallow gradient, moderate catchment area upstream, moderate distance to sea, irregular channel type, moderate width:depth ratio, glide dominant habitat, silt dominant substrate, predominantly consolidated bedrock, usually undulating to hilly with relatively shallow sedimentary soils in surrounding catchment

Table B3.1. (cont'd) Bioregional aquatic systems (source: Phillips et al., in prep).

BAS	Description
9	low rainfall, moderate gradient, generally small catchment area upstream, moderate distance to sea, mildly sinuous to regular channel type, large width:depth ratio, riffles dominant habitats, sandy substrates dominant, predominantly coarse-textured soils in surrounding catchment
10	moderate rainfall, generally shallow gradient, small catchment area upstream, great distance to sea, irregular meander channel type, small width:depth ratio, pool dominant habitat, sandy substrate dominant, predominantly consolidated bedrock, usually undulating to hilly with relatively shallow sedimentary soils in surrounding catchment
11	moderate rainfall, generally steep gradient, generally small catchment area upstream, great distance to sea, irregular channel type, large width:depth ratio, pool dominant habitat, fine substrate dominant, predominantly consolidated bedrock, usually undulating to hilly with relatively shallow sedimentary soils in surrounding catchment
12	high rainfall, generally steep gradient, small catchment area upstream, great distance to sea, regular channel type, small width:depth ratio, pool dominant habitat, fines dominant substrate, predominantly coarse-textured soils in surrounding catchment

Each BAS may represent a group of waterway segments. In unusual circumstances, a single waterway segment may be one BAS type. The purpose of the BAS classification is to assist with measuring three of the ecological value criteria by:

- nominating a reference waterway segment or segments for a particular waterway type (ie. BAS);
- comparing *naturalness* (or *condition*) of waterway segments within the BAS against the reference waterway segment(s) for that BAS;
- assessing the *representativeness* of a particular BAS by comparing waterway segments of similar BASs; and
- defining *rarity* in terms of waterway ecological and geomorphic structure (ie. the % occurrence of waterway segments representing a BAS compared to those representing other BASs within a catchment – a BAS represented by three waterway segments would be rarer than one represented by 20 waterway segments).

Spatial variation, the scale of assessment and the available data are all factors in determining the minimum size for a waterway segment and the level of detail of data at this scale. For example, a coastal floodplain river may have only a few distinctive types of reach when macro-scale data are assembled (eg. geology, climate, riparian vegetation cover). Hence, the derived BAS types will be few. This may be sufficient for a catchment-scale investigation. However, an investigation into the potential impacts of a weir would need to include further layers of data, such as diversity of riparian communities, channel form and water depth. The probable result would be to break down the 'catchment scale' BASs to a greater number of component BASs.

In other words, a BAS is defined from the data available, for the purposes and spatial scale for which the analysis is required. In this regard, the classification system is a means to an end – where the end is defining ecological value. The attributes used to define BASs should reflect the ecological values being investigated.

Temporal variation will affect classification (and ecological value). For example, a waterway subject to cyclonic rainfall may be ephemerally or permanently altered following a major flood. This would be most obvious at the river reach level, where localised changes in morphology (such as channel migration or sand slug deposition) could alter the classification. We will need to understand the characteristics of ephemeral (ie. allowing recovery to the former state) and permanent changes through further studies and data collection, if we are to refine the BAS approach further. Therefore, we prefer those attributes that have limited temporal variation or that best integrate it.

Appendix B4

Example of method for defining ecological value of a small creek where little information is available and where minimal specialist skills are required (adapted from Phillips et al. 2001)

Criterion	Question	Yes (Y), No (N), or Uncertain (n/a)	Overall Rating
Naturalness	Is the creek free from (or from signs of): • cattle disturbance (eg. stirring up of river bed and banks)? • rubbish? • poor water quality (eg. presence of scum or smell)? • clearing of native vegetation? • presence of weeds? • erosion (eg. banks slumping)? • dams or weirs (eg. reduction or loss of flows downstream, presence of weir pool)? • channel modification (eg. channel straightening)?	• *N* • *Y* • *Y* • *N* • *N* • *N* • *N* • *Y*	*Low*
Representativeness	In comparison with similar creeks in the district, is the creek a good example of typical: • flow patterns (eg. intermittent, but with permanent pools)? • water quality (eg. coloured by tannins) • native vegetation in the stream and on the banks (eg. dry rainforest)? • aquatic wildlife (eg. types of fish and birds)? • channel features (eg. low banks, sandy stream bed with occasional rock bars)?	• *Y* • *n/a* • *Y* • *n/a* • *Y*	*High*
Diversity	Using your local knowledge: • does this area support a large number of native species? • does this area have a range of in-stream habitats (eg. pool, riffle, run, waterfall etc.)? • are there a variety of native birds commonly seen/heard in this area? • are a variety of streamside plants found in this area?	• *n/a* • *Y* • *Y* • *Y*	*Moderate*
Rarity	Using your local knowledge: • does this area support a rare, threatened or vulnerable species (under legislation) or those that are known locally or regionally as being significant? • does this site have unusual natural features?	• *N* • *N*	*Low*
Special features	Using your local knowledge: • are there any features present in the stream which make it special? For example, does it contain a waterfall or other feature that is not common throughout the river system?	• *Y* *(floods support a wetland)*	*Moderate*

Comment

In this example, the highest value was representativeness. As noted earlier, this criterion is sometimes given a lower weighting. If the purpose of this assessment was to assist in biodiversity planning for the district, then diversity may be given a greater weight in the reporting process. A more detailed assessment of ecological values may be warranted where important indicators are lacking (such as aquatic wildlife in the example).

Appendix B5

Example of method for defining ecological value where little information is available and where specialist skills are required (scoring table for naturalness) (adapted from QEPA 1999a)

This example involves the derivation a naturalness rating for a single waterway reach. In order to keep the example brief, only the numerical (rather than descriptive) elements are included.

For each of the following indicator measures, assign a rating between 1 and 5 based on your expert knowledge. Multiply each rating by its assigned weighting to produce a weighted score. Sum across all indicator measures to produce an overall score. Range standardise[a] this score using the formula in the table to produce the final (0–100%) score. Assign a category based on the criteria indicated below. Complete tables for other criteria to develop an ecological value profile for your site.

Indicator measure	**Naturalness rating**					**Rating (R) (1 - 5)**	**Weighting (W) (also equals minimum possible score)**	**Weighted rating (R × W)**	**Maximum possible score (W × 5)**
	1	**2**	**3**	**4**	**5**				
Catchment disturbance									
	Extensively cleared				Uncleared	3	1	3	5
Artificial barriers – presence of dams or weirs, affecting ecological processes									
reach	1 dam or >3 weirs	1 weir			None	2	1.5	3	7.5
Water quality, *variation* from reference condition *or non-compliance* with appropriate standards for:									
Turbidity	High				Low	2	0.7	1.4	3.5
pH	High				Low	5	0.7	3.5	3.5
Conductivity	High				Low	4	0.7	2.8	3.5
Macroinvertebrates, variation from reference condition for:									
observed/expected ratio	High				Low	2	1.7	3.4	8.5
SIGNAL	High				Low	3	1.7	5.1	8.5
Fish, variation from reference condition for:									
species richness	High				Low	4	1.3	5.2	6.5
composition of trophic status groups	High				Low	1	1.3	1.3	6.5
Other aquatic/riparian fauna, variation from reference condition for:									
species richness	High				Low	2	5	10	25
Aquatic vegetation, variation from reference condition for:									
species richness	High				Low	4	2	8	10

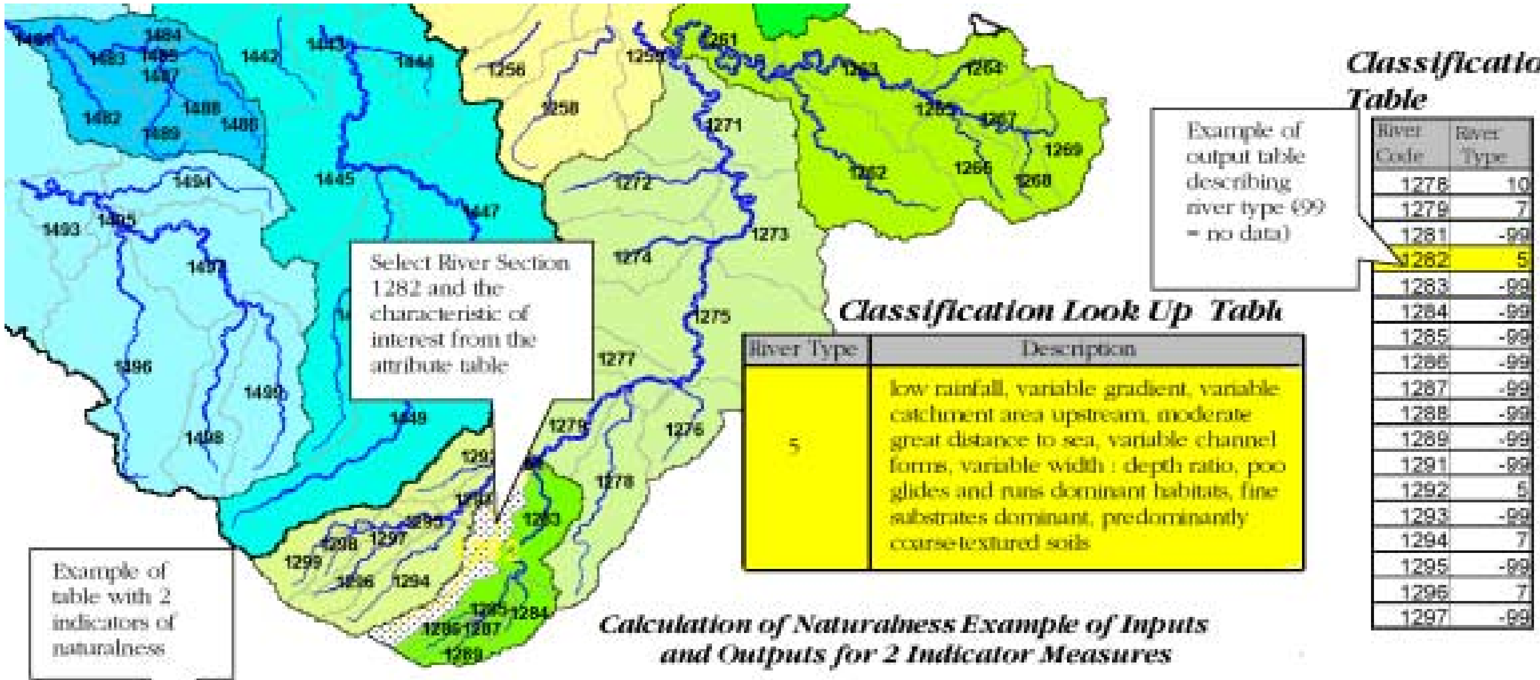
Indicator measure	Naturalness rating					Rating (R) (1 - 5)	Weighting (W) (also equals minimum possible score)	Weighted rating (R × W)	Maximum possible score (W × 5)
	1	2	3	4	5				
Riparian vegetation, variation from reference condition for:									
species richness	High				Low	4	0.8	3.2	4
structural composition	High				Low	4	0.8	3.2	4
width	<1 m				>100 m	2	0.8	1.6	4
continuity	Sporadic				Continuous	2	0.8	1.6	4
Carbon and nutrient cycling (variation of flux rates from reference condition)									
	High				Low	3	5	15	25
Ecological processes – degree of variation of process components from reference condition (eg. primary and secondary productivity, fish spawning, eutrophication, interspecies relationships)									
	High				Low	2	5	10	25
Channel quality:									
Banks	Highly eroded				Very stable	4	1	4	5
Bed	Highly aggraded/ degraded				Not aggraded/ degraded	4	1	4	5
TOTALS							**32.8 (C)**	**89.3 (B)**	**164 (A)**
% of Maximum Score (Range Standardised) = (1 – {B – C}/{A – C}) × 100%								**57%**	
Condition Value Category[b]								**high**	

[a] Range standardising simply converts the scores to the full 0-100% range (because the minimum individual score is not zero but one).
[b] % of Maximum Score: 0–25% = low, 26–50% = moderate, 51–75% = high, 76–100% = very high.

User-entered data

Appendix B6

Example of a GIS application for calculating ecological value (source: Phillips et al., in prep).



Classification Table

River Code	River Type
1278	10
1279	7
1281	-99
1282	5
1283	-99
1284	-99
1285	-99
1286	-99
1287	-99
1288	-99
1289	-99
1291	-99
1292	5
1293	-99
1294	7
1295	-99
1296	7
1297	-99

Classification Look Up Table

River Type	Description
5	low rainfall, variable gradient, variable catchment area upstream, moderate great distance to sea, variable channel forms, variable width : depth ratio, poo glides and runs dominant habitats, fine substrates dominant, predominantly coarse-textured soils

Calculation of Naturalness Example of Inputs and Outputs for 2 Indicator Measures

River Code	Class	Base Value (X)	Min Range (Xmin)	Max Range (Xmax)	Rating 1 - (X - Xmin) / Xmax - Xmin	Weight	Weight * Rate	Base Value (X)	Min Range (Xmin)	Max Range (Xmax)	Rating 1 - (X - Xmin) / Xmax - Xmin	Weight	Weight * Rate	Score	Category
								Flow Disturbance							
1278	10	0.380	0.000	0.680	2.7	1.0	2.7	0.746	0.000	1.000	2.0	1.0	2.0	34.6	2
1281	-99	0.368	0.000	0.680	2.8	1.0	2.8	0.000	0.000	1.000	5.0	1.0	5.0	72.8	3
1282	5	0.353	0.000	0.680	2.9	1.0	2.9	0.000	0.000	1.000	5.0	1.0	5.0	74.0	3
1291	-99	0.333	0.000	0.680	3.0	1.0	3.0	0.000	0.000	1.000	5.0	1.0	5.0	75.5	4
1292	-99	0.392	0.000	0.680	2.6	1.0	2.6	0.000	0.000	1.000	5.0	1.0	[illegible]	71.1	3
1293	-99	0.317	0.000	0.680	3.1	1.0	3.1	0.000	0.000	1.000	5.0	1.0	[illegible]	76.6	4
1294	7	0.303	0.000	0.680	3.2	1.0	3.2	0.000	0.000	1.000	5.0	[illegible]	[illegible]	77.6	4
1295	-99	0.309	0.000	0.680	3.1	1.0	3.1	0.000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
1296	7	0.266	0.000	0.680	3.4	1.0	3.4	0.000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
1297	-99	0.273	0.000	0.680	3.3	1.0	3.3	0.000	0.000	1.000	5.0	1.0	5.0	[illegible]	4

Part C – Ecological Sustainability Guideline

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1 Purpose

The purpose of the ecological sustainability guideline is to:

- provide a systematic, comprehensive and flexible method to describe the ecological sustainability of waterways and floodplains;
- support both conservation planning and development assessment.

The theme of this guideline is the development of a method that is technically credible as well as adaptable to a wide range of applications, users and data availability. This guideline examines several approaches to defining ecological sustainability that are relevant to waterway protection. It does not include a direct assessment of the economic or social sustainability of waterways. However, these elements are recognised and also discussed in relevant sections, particularly in relation to the measures required to maintain or rehabilitate waterways.

2 Scope

The guideline is designed for tidal and non-tidal waterways, wetlands, riparian zones and floodplains. It principally covers the biophysical aspects of waterways such as biology, hydrology and geomorphology. However, it also recognises that a variety of other social and economic factors relating to resource use will also affect sustainability. The guideline therefore incorporates discussion on how to better identify and manage these factors.

The guideline will support conservation planning, strategic assessments, and project-level impact assessments. It is intended to assist at all scales from reach through subcatchment to catchment.

Application of the guideline and a decision support tool is intended to produce outputs in a variety of forms (such as maps, graphs, spreadsheets and narratives) which describe and communicate the sustainability of waterways.

3 Concepts and limitations

3.1 What is ecological sustainability?

The World Commission on Environment and Development's Brundtland report, 'Our Common Future' (WCED 1990), has often been used as the basis for definitions of ecologically sustainable development. In that report, the concept was discussed as follows:

> Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present generation without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits – not absolute limits but limitations imposed by the present state of technology and social organisation on environmental resources and by the ability of the biosphere to absorb the effects of human activities.

Since then, this concept of 'sustainability' as been discussed in many forums, for many different industries and with differing degrees of success. The concept remains a fundamental component of government policy in Australia and the broader community regards it as a principle upon which resource management should rely.

This guideline adopts 'the mosaic approach' (see Smith and McDonald 1998) to define the concept of sustainability. Fundamentally, this involves describing three key components – ecological, economic and social sustainability:

- *ecological sustainability* requires that development be compatible with the maintenance of ecological processes;
- *economic sustainability* requires that development be economically feasible; and
- *social sustainability* requires that development be socially acceptable.

Clearly, the time scales upon which economic and social sustainability are considered are critical, and while this guideline does not attempt to apply parameters or criteria for either it does recognise their interdependencies, particularly in relation to cumulative impacts and feedback loops. Therefore, the guideline requires the setting of timeframes to achieve ecological protection/ rehabilitation as part of the sustainability assessment.

To apply the concept of sustainability to waterway management successfully, we need to use criteria that can accurately reflect the management unit in time and space, and that are measurable in a practical and cost-effective manner. That is, the focus of the sustainability framework is on aquatic ecosystems within a catchment context.

Therefore, sustainability, in an ecological sense, is defined as the ability of environmental systems (including biota and surrounds) to maintain their essential life functions in a healthy way. The term 'healthy' implies the ability of the system to persist with minimal unnatural stress or inhibition of natural functions. Concepts describing this include:

- ecological integrity – the protection of native biodiversity, essential ecological processes, and life support systems (Commonwealth of Australia 1992);
- the maintenance of life support systems and the achievement of a 'natural' extinction rate (Sutton 1999);
- maintaining and enhancing natural capital, avoiding overexploitation of renewable resources, and minimising waste (ANZECC 1991);
- maintaining the composition, structure, and processes of an ecological system (Committee of Scientists 1999); and
- 'intergenerational equity' – maintaining natural ecosystems and resources that have no known substitutes, and the loss of which would be detrimental for future generations (Young 1993).

In combination, these five concepts all contribute to the definition of sustainability used in this guideline. This approach does not attempt to 'operationalise' (Peters 1991) or provide a theoretical basis to sustainability; but it is legitimate to utilise it as a management goal and a platform in a process to develop operational definitions and theory, which in time will underpin the concept (Peters 1991).

Given the adoption of these concepts, this guideline presents a method to ensure that waterways in Australia are used in a sustainable fashion. The method requires the determination of the scale, stability and vulnerability of the target waterway in order to derive information suitable to assess both the current state and the trend in condition. The penultimate and final steps in the method call for stakeholder participation to work out acceptable courses of protection and/or rehabilitation.

3.2 Conceptual models of waterway structure and function

Conceptual models of ecosystem behaviour are important for understanding sustainability. They are also a valuable way to assess monitoring and research priorities.[1]

1. Unless otherwise cited, all of the italicised material in this section is quoted from: Ontario Workshop on Riverine Science Requirements, Watershed Science Centre, Trent University Canada. <http://www.trentu.ca/wsc/riverine_sci_brief.shtml#continuum>

Minshall et al. (1984) describe four major developments in stream ecosystem theory as:

- *progression from an individualistic to a holistic viewpoint;*
- *realisation of the critical linkage between a stream and its terrestrial environment;*
- *development of ideas on material cycling in open systems; and*
- *recognition of the importance of biotic interactions to the stream community.*

Some of the key concepts in this development are described below.

3.2.1 River continuum concept

The river continuum concept (Vannote et al. 1980) was an important, and still influential, step in the understanding of riverine ecology. It is an attempt to describe, in a qualitative manner, the structural and functional characteristics of stream communities along the entire length of a river. The concept describes a continuous gradient in the distribution of organic matter and macroinvertebrate functional groups from headwater to mouth.

In general, rivers are divided into three parts: headwaters (orders 1–3), medium sized streams (orders 4–6) and large rivers (order>6). The headwaters are strongly linked to surrounding riparian vegetation that provides shade (reducing primary production) and contributes large amounts of allochthonous detritus. As a result, the ratio of gross primary productivity to respiration of the aquatic community is low (P/R < 1). The aquatic invertebrate community is dominated by functional groups that process coarse particulate organic matter (CPOM), such as shredders and collectors.

Moving downstream, the influence of the riparian zone declines, shading is decreased and primary production increases (P/R > 1). Downstream transport of organic material is also important; the particle size shifts from coarse to fine and ultrafine (FPOM and UPOM). The aquatic invertebrate community is dominated by collectors and grazers, feeding on transported material and primary producers respectively. In large rivers primary production may be limited by depth and turbidity, reducing the P/R ratio (P/R < 1). The aquatic invertebrate community is dominated by collectors feeding on organic material transported downstream.

3.2.2 Flood pulse concept

The above concepts generally apply to constrained river systems; however, many systems routinely flood riparian areas. The flood pulse concept (Junk et al. 1989) describes a process in which nutrients are regularly exchanged between the river and the floodplain. The *ecological characteristics and productivity of both the river and the floodplain are linked and influenced by the frequency and duration of flood events.*

The concept states that the flood pulse is the driving variable of the system and that biotic and abiotic processes in the aquatic–terrestrial transition zone are primary regulators of species composition, food webs and nutrient dynamics. During recent years, there has been increasing emphasis on understanding land–water interactions, particularly within the context of the concepts of ecotone, landscape heterogeneity and patch dynamics. Floodplains are sometimes interpreted as ecotones between upland and rivers, and sometimes they are viewed as specific ecosystems (Max Planck Institut für Limnologie 2001).

3.2.3 Riverine productivity model

The riverine productivity model stresses the importance of local autochthonous production and allochthonous inputs to food webs of large rivers. It contends that carbon from local autochthonous sources is more easily assimilated than refractory carbon arising from the floodplains and tributaries. Further, it suggests that in periods outside flood pulses, the allochthonous material arising from the immediate riparian zone, which accumulates in slow flowing, shallow areas at the edges of rivers, is an important carbon source since it is available over long periods (WA Waters and Rivers Commission 2000).

All these models have in common an attempt to describe patterns at the stream scale using energetic parameters. Their applicability to Western Australian systems depends on river size and geomorphology. The river continuum concept seems most appropriate for headwater streams, but it is clearly inappropriate for rivers and creeks in the arid areas of the State. The flood pulse concept may be limited to large floodplain rivers with regular flood events, such as those found in the Pilbara and Kimberley region. The riverine productivity model is probably most relevant to large rivers with constricted channels and firm substrates in areas of high light availability. (WA Waters and Rivers Commission 2000)

3.3 Approaches to determining ecological sustainability

Very few studies have been undertaken specifically to develop a process to define the ecological sustainability of a waterway. A plethora exist that attempt to define societal progress towards achieving sustainability (see Yencken and Wilkinson 2000). These holistic approaches are often based on ‘energy’ or ‘metabolism’, with waterways and biodiversity being treated as stocks that have inputs and outputs (SOEAC 1996).

The examples of approaches reviewed below are generally not holistic, except for commissions of inquiry and strategic environmental assessments. Most are simply assessments of impact or, as is common in contemporary studies, reductionist approaches that aggregate studies of river reaches to build assessments of catchments. Most of these approaches focus on only a few components of waterways (eg. flow, water quality) and usually consider other elements, such as biodiversity, to be secondary.

There are few existing approaches that can specifically address sustainability from the reach level to the subcatchment and catchment levels, or integrate more than a few biophysical attributes. However, the following variety of approaches is the platform upon which this guideline has been developed and a description of each has been provided. Some approaches (or aspects of them) have been utilised more than others to derive this guideline (eg. benchmarking), but it remains useful to describe the main approaches used as an input to assessing waterway sustainability.

3.3.1 BACI designs

Before/after and control/impact (BACI) surveys ideally have the following features:

- the type, time, and site of impact should be known in advance;
- the impact has yet to occur; and
- controls should exist.

Controls for waterways would ideally be unmodified but biologically, hydrologically and geomorphologically similar streams. It is hard to locate suitable controls, and varied land uses make it harder. Many Australian rivers are heavily regulated and little ecological monitoring data associated with these systems is suitable for BACI designs. Additionally, little pre-dam monitoring has been carried out and what we have is of questionable quality. These deficiencies have led to the development of ‘benchmarking’ (see below).

3.3.2 Environmental flows

Environmental flows are those aspects of a streamflow regime that are important in maintaining the health and values of river-dependent ecosystems – including aquatic, riparian, floodplain and estuarine. The adequacy of environmental flows is a key factor in determining the system’s level of ecological sustainability (eg. Poff et al. 1997). The volume, seasonality, velocity, and rate of rise and fall of a flow event can all affect waterway health and values.

There are many methods for assessment of environmental flows and the choice depends mainly on the scale and

Applications of conceptual models in Australia

Case Study 1: Murray–Darling Basin Sustainable River Audit

The ***Murray–Darling Basin Sustainable River Audit*** (Whittington et al. 2001) examined all three models (Section 3.2) to assist in identifying the factors most important for "determining the structure and function of rivers":

> Conceptual models of river function are fundamental to the audit design, selection and interpretation of appropriate indicators, assessment tools and sampling programs. Models allow questions such as the following to be answered: What are the critical habitats and how do they change along the river system? How does our understanding of river function impact on sampling location and site selection?

The authors developed a conceptual model (general ecosystem model) which "assumes that if habitat, connectivity and metabolic functioning are maintained in a natural state, then a river's ecological integrity will be maintained". Eight functional process zone models were developed for the Murray–Darling Basin. Figure 11 shows an example for one zone.

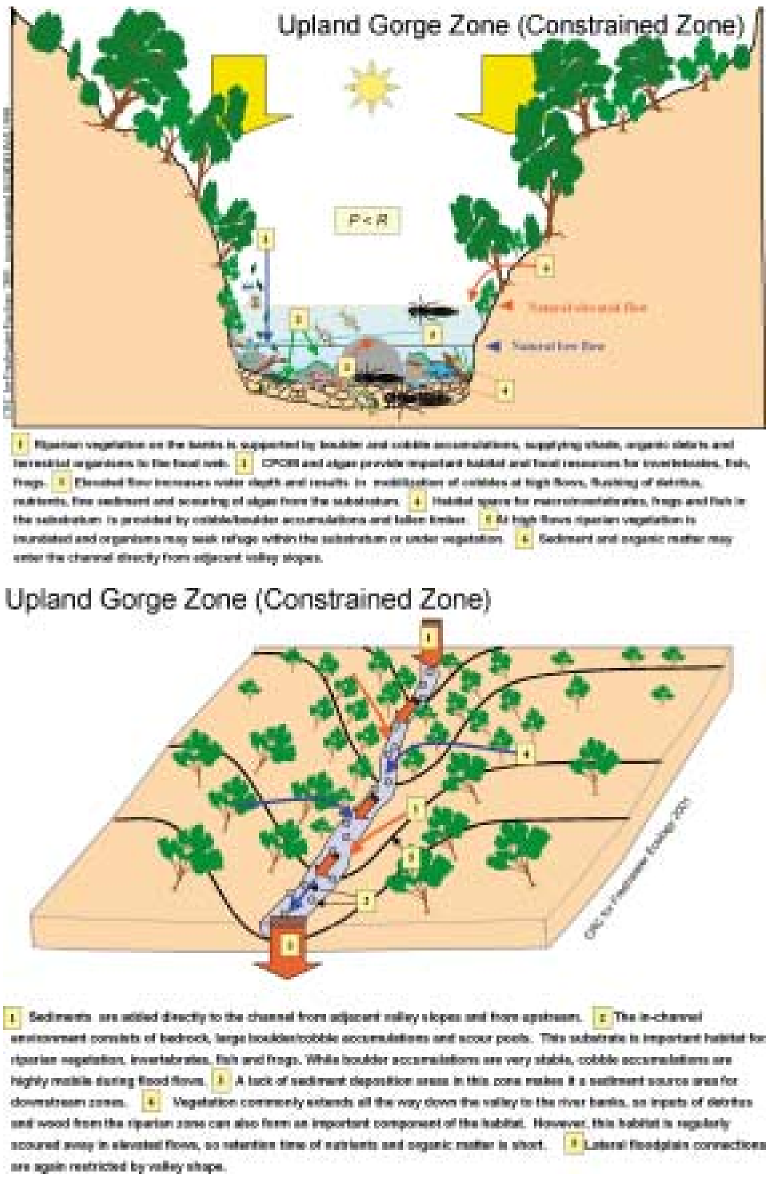


Figure 11. A conceptual model for one functional process zone of the Murray–Darling Basin.

Applications of conceptual models in Australia

Case Study 2: South East Queensland Regional Water Quality Management Strategy

Stage 2 of the **South East Queensland Regional Water Quality Management Strategy** (Dennison et al. 1999) developed a conceptual model of riverine, estuarine and marine waters around Moreton Bay. The model included functional zones based on 'geographical entities with common structural and functional characteristics'.

The model portrays the different sources and fates of nutrients and sediments, the significance of nitrogen as a major limiting nutrient and the predominance of benthic and pelagic processes in different functional zones. The initial model assisted with targeting research and monitoring, and was progressively refined as new information became available. The result has been increasing certainty about the processes governing sustainability in the Moreton Bay region. In turn, management decisions on wastewater and run-off have been made with the specific objective of repairing and protecting key structures and functions.

The simplified depiction of the model in Figure 12 was also an effective means of communicating system behaviour to the wider community and to decision makers.

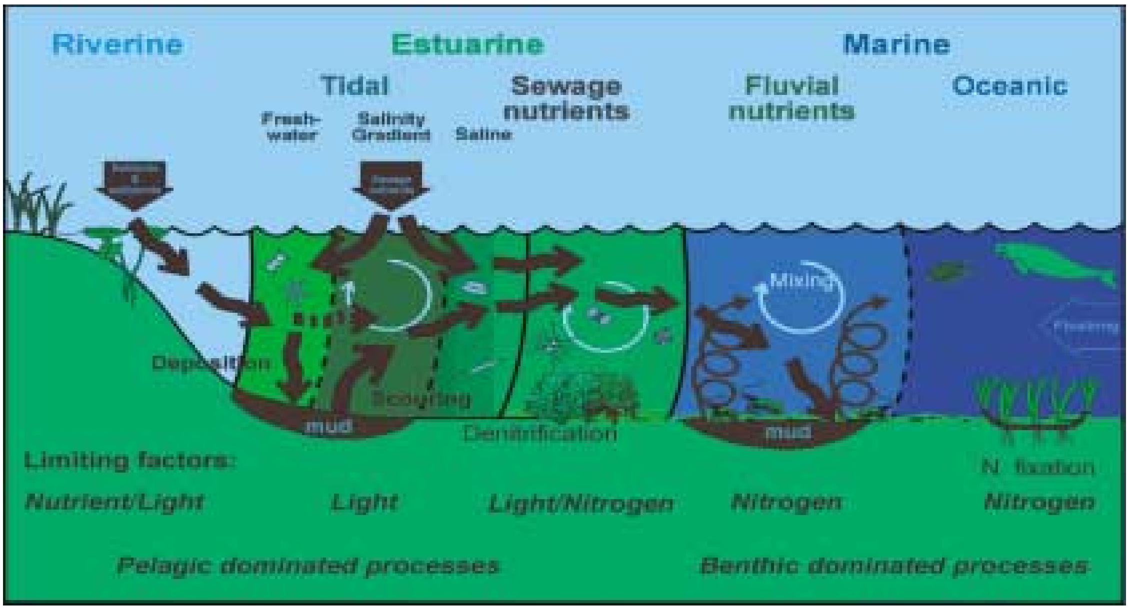


Figure 12. A conceptual model for Moreton Bay, Queensland.

purpose. Typical applications include determining dam releases to improve the health of downstream ecosystems, and assessing the environmental flow condition of a major catchment to determine whether additional water can be extracted.

The methods most relevant in discussions of ecological sustainability are those that consider the suite of components that make up the riverine ecosystem. These 'holistic' methods typically include:

- geomorphology;
- riparian, aquatic and floodplain vegetation;
- fish;
- invertebrates; and
- vertebrates such as birds, frogs, turtles and platypus.

Numerous recent evaluations of environmental flow assessment methods have been undertaken (eg. Arthington and Zalucki 1998; Brizga and Arthington 2001; King et al. 2000). Arthington and Zalucki (1998) divided holistic methods into two distinct types, top-down and bottom-up.

Bottom-up approaches
Bottom-up approaches lend themselves to situations where flows have been significantly modified, usually by a large dam. The expertise of the participants and the availability of data dictates the level of assessment. The scientific basis varies from a one-off visual inspection of sites by a scientific panel, to more systematic and detailed assessments using data on as many components of the ecosystem as possible.

Bottom-up approaches have the benefit of relating specific ecological requirements to specific flow events. This linkage makes the approach appealing to water managers because the objective for a specific flow event is clearly identified (eg. to allow the uninterrupted passage of a seasonal flood). This makes decisions to reserve such events justifiable in the face of competing demands for consumptive use. It also provides a simple basis for monitoring.

The *building block method* is a bottom-up approach developed in South Africa. The method was designed to make a 'block booking' of water for the environment during the initial planning stages of major water developments (Arthington and Zalucki 1998; Arthington 1998b). Consequently, the method does not give the full picture of a modified flow regime, which would comprise planned water releases, flow from unregulated tributaries, and spill from storages. Nevertheless, this method provides a consistent, structured and well-documented approach for identifying the most important and well-understood features of a river's flow, which should be maintained in a modified flow regime. The method assumes:

- natural biota function in both low and high natural flows;
- that combining the most important characteristics of both low and high flows will facilitate maintenance of natural biota and river processes; and
- that channel morphology depends on certain flows and that these are the ones that should be incorporated into the modified flow regime to maintain the natural structure.

Short-term information collection of waterway characteristics, such as catchment, flow regime, water quality, geomorphology, biota and hydraulics, culminate in an in-stream flow requirement (IFR) workshop. For sustainability planning, the approach would be to use each IFR site as a minimum or benchmark flow for river maintenance.

The *flow restoration method* (FLOWRESM) is another bottom-up approach that aims to provide flow recommendations for regulated waterways. The approach has been used in the Brisbane River in relation to environmental flow releases from Wivenhoe Dam (Arthington 1998a; Arthington et al. 2000). This application involved:

- daily time step simulation modelling (using an integrated quantity and quality model, or IQQM) of the river's unregulated flow regime;
- determining characteristics of the regulated flow regime under different water management and flow scenarios by use of the developed model;
- research to determine cumulative impacts;
- a workshop to define options for provision of environmental flows;
- developing alternative environmental flow scenarios and modelling these;
- assessing implications of each scenario, and developing a preferred option; and
- a monitoring strategy to determine ecological responses.

FLOWRESM has the advantage of comparing a range of potential environmental flow management scenarios.

A similar approach was suggested by Richter et al. (1997), stressing the need to recognise variability as a criterion for management decisions. The 'range of variability' approach assumes that variability – with characteristics such as timing, frequency, duration and rates of change – is critical for sustaining aquatic ecosystems. Annual river flow management targets are identified using '*statistical characterisation of ecologically relevant flow regime characteristics*'.

Top-down approaches
Bottom-up approaches have limited capability for assessing alternative water development scenarios, particularly at the basin-wide scale. *Benchmarking* is a top-down approach that attempts to overcome these limitations and can be used to set bounds on the maximum threshold for water development compatible with sustaining ecosystems (ie. 'acceptable' departure from natural flow regime).

The benchmarking method is based on comparisons with reference reaches subject to varying levels of impact as a result of water development. The reference reaches are selected to cover a range of levels of change to the natural flow regime. Geomorphological and ecological impacts in each of the reference reaches are assessed, and linkages to flow regime change examined. Once the linkages are documented, the reference reaches become 'benchmarks' (QDNRM 2001).

The method considers total flow within a river system, and therefore accounts for planned water releases, spill from storages and flow from unregulated streams. It is applicable to poorly-studied systems where the specific impacts of disturbances are difficult to assess.

The benchmarking method describes, in terms of flow quantity, variability and seasonality, the characteristics of the natural flow regime that are thought to be fundamental to ecological sustainability. Benchmarks against which level of change can be compared include pre-development flow conditions and severely impacted (unhealthy) systems.

The focus is on holistic river ecosystem health, rather than combining flow requirements of individual ecosystem components (eg. invertebrates, fish, riparian vegetation) for specific purposes. This is an important advantage over bottom-up approaches. However, as a consequence, the benefits of the resulting environmental flow regime are less easily defined, and therefore, more complex in terms of monitoring.

A generic benchmarking approach was proposed by ANZECC and ARMCANZ (2001) as a level of acceptable change from a reference condition when there are too few data for thresholds or trigger levels to be applied.

Historical natural variation of ecosystems can be used as a benchmark for predictability of their future behaviour. Boughton et al. (1999) suggest that when historical information does not exist, measurements of the current condition of pristine reference sites can be substituted. Another method is to use measurable sustainability as a criterion for a given resource, for example rate of soil loss exceeding rate of soil formation. Conversely, scientific knowledge of limits (eg. species extinction) can also be used to predict thresholds of unsustainability.

Combined approaches

Arthington et al. (1998) have proposed a three-tiered system combining both bottom-up and top-down assessments and involving a series of assessments and multidisciplinary workshops. Initial assessments focus at the broadest scale, and resources and time requirements increase as the scale reduces and more focused and quantitative assessments are necessary. This system has not yet been trialled.

3.3.3 Healthy Rivers Commissions of Inquiry

In New South Wales, a Healthy Rivers Commission was established to determine the status of the State's river catchments. While each inquiry had a different scope because of the different characteristics of each catchment, a set of common principles has been derived to underpin the management of a healthy river. The commission adopted a definition of river health that addresses both a river's environmental status and its ability to support the patterns of commercial activity and social amenity that communities want (Healthy Rivers Commission 2000). The principles to achieve this are:

1. Rivers must be managed as whole systems.
2. Rivers must be treated as assets with productive values to be sustained by carefully directed management and maintenance. Decisions about these must be governed by realistic assessments of their capabilities and recognition of their limitations. The sustainability of natural systems, including rivers, must receive a new priority and be treated differently in regional planning processes. Management plans must demonstrate that existing and proposed resource uses are within the capacity limits of rivers, and signal how the implementation of the directed actions will maintain the asset's productivity in economic, social and ecological terms.
3. Management plans must be more rigorous and more directive, and create obligations on entities possessing powers and resources that can be applied to river management.
4. Entities with river management responsibilities, powers and resources must be accountable and answerable for the condition of rivers at the conclusion of each cycle of planning, action and assessment. The 'accountable entity' must be answerable for the proper implementation of agreed management processes, where actual river outcomes are subject to a variety of uncontrollable external influences.
5. Government and communities must meet their obligations within explicit partnership arrangements for river management, based on unambiguous statements of their respective roles and responsibilities.
6. Well-designed strategies for managing rivers will inevitably involve an adaptive management approach, given the inherent uncertainties and lack of information on many matters.

This approach would usually require all stakeholders to agree to a river management framework – one that has the sustainability of the river at heart. The Clarence River inquiry placed special emphasis on the development of such an integrated management framework for the floodplain, given its size and its importance in that particular catchment. The framework is based on land and water management plans developed for inland irrigation areas, and its implementation as a resource planning/ partnership agreement is proposed. That is, it should be seen to:

- be both strategic and detailed, with clear obligations for all parties;
- have cost-sharing arrangements that are determined before it is finalised, with costs divided among landholders and local, State and national government;
- have clear audit, accountability and review requirements, including licences and contracts, binding landholders and other stakeholders to their obligations;
- have rigorous measures to protect the environment;

- have high degree of self determination by landholders; and
- have third-party comment and involvement.

Currently, there is no proposal to extend such an agreement to other issues on the coastal floodplain (eg. urban development) or to the whole catchment, but perhaps there is an opportunity to investigate this as part of a broader river sustainability assessment. For example, river flow planning should be seen in such a context – with a framework developed that includes (and is agreed to) by all stakeholders, and that is based on the principles of river health (see above).

3.3.4 Cumulative impacts

Cumulative impacts are those resulting "from individually minor but collectively significant actions taking place over a period of time" (Preston and Bedford 1988). Adverse cumulative effects are, in effect, a broader version of individuals justifying their actions by their minimal impact on a scale. Past impacts that may increase a system's vulnerability must be considered together with current impacts. Similarly, future developments can contribute significantly as cumulative impacts (Contant and Wiggins 1991).

Many different examples of cumulative impact have been described, including:

- time crowding (disturbances are so close in time that the system cannot recover between them);
- space crowding (disturbances are so close in space that the system cannot recover between them);
- synergisms (non-linear or compounding effects);
- time lags (long delays in experiencing impacts);
- indirect effects (secondary impacts resulting from a primary activity);
- nibbling (incremental or decremental effects);
- extension of impacts beyond immediate boundaries; and
- disruptions that result in ecosystems exceeding triggers and thresholds.

3.3.5 Environmental impact assessment

Environmental impact assessment (EIA) is a management tool adopted by many countries in the pursuit of sustainable development. Its effectiveness lies in its systematic consideration of environmental issues in the face of proposed development activities. With ever-expanding insight into the complex functional processes of ecosystems, the deficiencies in our attempts to manage them become exposed. EIA has mostly been used as project-level investigation: a project, deemed sustainable on its own, needs to be subject to further scrutiny that acknowledges the holistic nature of ecological systems. With a trend evident in some countries towards cumulative impact assessments, Australia urgently needs revised approaches to assess sustainability.

Much recent work has focused on methodologies for assessing cumulative impacts in waterways (Brinson 1988; Cairns 1990; Cocklin et al. 1992; Contant and Wiggins 1991; Court et al. 1994; Klopatek 1988; McCold and Saulsbury 1996; Risser 1988; Vestal et al. 1995; Weller 1988; Winter 1988), and, although advances are being made, the area needs ongoing refinement. Identification of all the contributing components, their interactions, their boundaries, their effects and level of contribution, are among numerous considerations of a complex issue. The need to include cumulative effects in environmental assessments is well accepted: the process of analysing cumulative effects enhances the traditional components of EIA (see section 3.3.4).

Research for evaluating cumulative impacts follows the general strategic steps set out by Vestal et al. (1995). Although it is difficult to make fine-scaled predictions, it is suggested that, because of better understanding of ecological systems, predictions of direction and possible magnitude of responses to a particular action are becoming more feasible. Key considerations in designing a systematic cumulative impact assessment (CIA) and management approach are that:

- CIA should be structured in terms of "goals for a resource and/or resource impact of concern";
- explicit time boundaries should be defined (past and future);
- explicit geographical boundaries should be defined from a landscape perspective, and should be large enough to encompass major factors causing variation;
- policy and technical tools should be identified, with particular attention given to identification of essential indicators; and
- institutional barriers that may limit the investigation should be identified so that deficiencies in the assessment are acknowledged.

CIA allows managers to view a specific project in the context of other developments. Although there is not yet a universally agreed framework for cumulative effects analysis, general principles have gained acceptance in some quarters. Cumulative effects need to be analysed from the perspective of the resource, ecosystem and community being affected, rather than from that of the proposed action. Scoping should limit the emphasis to meaningful effects – that is, to activities that will render the system unsustainable. The boundaries for evaluating cumulative effects should be expanded until the effect on the ecosystem is not significant, and should be determined by natural ecological boundaries rather than political or administrative boundaries (Council on Environmental Quality 1997).

3.3.6 Strategic environmental assessment

Strategic environmental assessment (SEA) is a systematic (or structured) procedure for ensuring the comprehensive consideration of environmental factors (Gill 1997; Therival et al. 1996). 'Strategic' implies the application of a carefully determined process to identify (or scope), articulate and develop shared understandings of environmental issues.

SEA is all about the application of a kind of 'best practice' procedure which can be applied the same way by development proponents and environmental planning and policy professionals, rather than relying on a more idiosyncratic or ad hoc internally developed process for interpreting prospective environmental issues. It facilitates both the identification of a wider group of stakeholders than otherwise might be consulted and the incorporation of their concerns and advice before plans progress to a less flexible stage. SEA produces a much more consultative environment for negotiations among stakeholders, and allows expert opinion to be part of the planning process.

SEA creates considerable cost-saving opportunities for all stakeholders (eg. developers and the public sector in their respective considerations of development proposals). Proponents can access an array of highly concentrated expert and other advice in relation to their proposals with the prospect of streamlining the documentation of projects and avoiding 'hidden surprises' later in the planning process.

However, stakeholders need to use professional, appropriately accredited consultants to undertake a formal SEA. It is not a 'do it yourself' process as, at the very least, stakeholders need the assurance of objective, third-party facilitation to get the most transparent and frank discussions.

A comprehensive stakeholder representation would typically include community and environmental interest groups, relevant scientific bodies/individuals, organisations with influence over the planning process and its monitoring, and indigenous interests. Section 6 of this guideline includes a guide to conducting an appropriate SEA. The SEA consultant would usually take responsibility for documenting the sustainability discussions, and their report would ideally be appended to the final sustainability assessment. The stakeholder resources and interest mobilised through the SEA process may be applied through subsequent stages of sustainability assessment and monitoring.

The SEA is intended as a key mechanism through which to articulate and collate information that would subsequently be incorporated in simulation modelling of prospective project impacts.

3.3.7 Common themes and deficiencies

It is clear that no one method is available to determine waterway sustainability across different scales. Equally, none exists that can consider all the components enhancing or impinging on waterway sustainability. The aim of the ecological sustainability guideline is twofold: first, to integrate the best of available methods; and second, to provide sufficient rigour to ensure the method is reproducible and applicable across Australia, while having the flexibility to accommodate gaps in the data. The method also has to be applicable to local, regional and national scales, which means that indicators chosen and the methods of aggregation must allow for comparison at various scales.

Additionally, the method should not only generate new information to bolster existing knowledge bases but should also reinforce the need to gather quality data. That is, monitoring is required to better understand the sustainability of our waterways and to allow assessment methods to evolve. This can only be achieved when monitoring data are fully incorporated into decision making.

3.4 Spatial and temporal scales

Much of the information relevant to ecological sustainability is likely to vary depending on where and when it is gathered. This is particularly true of river systems, where factors like water quality, flow and in-stream ecology are constantly varying in response to environmental factors like rainfall and life cycles. It is important to ensure that assessments are reliable and reflect natural variability. Part A, section 4.4.11 discusses issues in defining adequate spatial and temporal scales for ecological assessments.

The guideline requires adoption of assessments based on the appropriate temporal and spatial scales. Trends in the sustainability of a waterway can only be identified once an appropriate data set is assembled. For example, a sustainability assessment of pollutant discharge into a waterway may require sampling to be based on discharge schedule, climatic condition and diurnal variations. Equally, many non-point source pollutants may only need to be assessed using routine ambient water quality monitoring.

As a result of the connections within ecosystems, it is unlikely that any event can be considered in isolation, either in space or time (Allen and Star 1982). The effect of any episode is more realistically an incremental impact when viewed in the context of other past and current activities. Further, future proposals for change influence the consequence of any single impact at any point in space and time (Contant and Wiggins 1991), and this concept, though challenging, is essential for accurate consideration of the sustainability of an ecosystem. The scale of consideration for assessment needs to be extended sufficiently in space and time to account for the issues that are, or are likely to, contribute to the condition, and to accommodate the magnified size of that condition.

4 Criteria that define ecological sustainability

4.1 Stability

Stability refers to the ability of a system to maintain its structure and patterns of behaviour in the face of disturbance. It relates to inherent composition and the history of the system. A system's current 'health' will be a result of past influences and conditioning, as well as an indication of how successfully the system has coped against, or absorbed, past impacts. For example, a river may have naturally high levels of turbidity that reduces euphotic depth and minimises the opportunity of algal blooms. Additionally, an intact system may also have characteristics that give it strength (eg. biotic diversity, habitat diversity, stable banks, and productive and stabilising riparian vegetation).

Stability does not necessarily imply resistance to change. Many natural systems are constantly subject to processes like bank erosion and channel migration. Within natural ranges, these processes are essential to stream health and values. Stability arises from the system being able to maintain its integrity whilst undergoing continual or episodic changes.

Criteria used to determine the stability of a system include the ability of the receiving environment to absorb impacts without suffering irreversible change, the sustainability of land uses at and around the site, and the ability to support future uses (ANZECC 1996a). These criteria may be hard to ascertain as the question of sustainability relies on the extent of stability, so that the question becomes circular.

The capacity to tolerate anthropogenic (human) disturbance is a component of ecosystem stability that is simpler to understand than it is to measure (given the dubious value of some threshold frameworks). The environmental assimilative capacity of a waterway refers to the imposition of contaminants on receiving waters, with measures of acceptability dependent on which contaminants and how much (Stebbing 1992). Any level of disturbance that does not exceed the assimilative capacity of the planning or management region is deemed sustainable (Rees 1988). Historical response of the system to change, if available, will provide additional insight, along with comparisons with reference 'benchmarks'.

> Distinguishing between stability and vulnerability:
>
> … stability is a component of the natural system; vulnerability is a consequence of the changing regimes acting on that system.
>
> Commentary on the draft guideline, June 2001

4.2 Vulnerability

The vulnerability of a system refers to its susceptibility to change. Boughton et al. (1999) define ecosystem vulnerability as:

1. the likelihood that stressors to ecosystems will cause ecological processes and functions to vary beyond the range of natural variability, with
2. subsequent adverse effects on the ability of that ecosystem to provide ecological goods and services that the public has come to expect and desire.

Vulnerability is a measure of the tendency of a system towards unsustainable responses to a disturbance or change. Natural variation of ecosystems in the past can be used as a benchmark for predictability of their future behaviour (Boughton et al. 1999), providing an indication of vulnerability in the same way that it may imply stability.

Vulnerability is intimately associated with stability in the determination of sustainability. In other words, sustainability is a function of the degree of risk of a system to change and the strength of the system to resist this change and recover. Smith and McDonald (1998) illustrate this succinctly in an example for assessing the sustainability of agroecosystems (Figure 13).

The pressures exerted on a waterway directly contribute to the state of vulnerability, as increasing threat will increase the degree of risk. The size of the impact, and its interactions with other disturbances (be they past, present or planned), bring the concept of cumulative impacts to the fore once again. Their role with respect to 'scale' has previously been discussed.

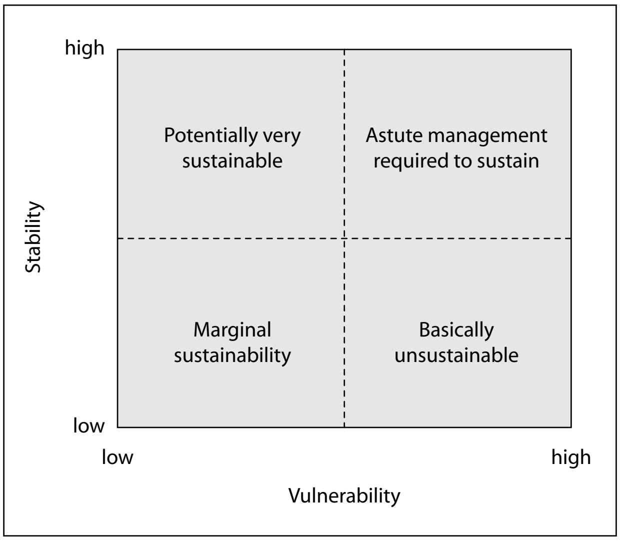


Figure 13. Categories of potential sustainability as a function of stability and vulnerability.

5 Indicators of ecological sustainability

5.1 Indicators and thresholds

The criteria specified in the previous section require the measurement of indicators that are relevant to ecological sustainability. These indicators should be easily and economically measurable , be precise, have a well-established response to disturbances, be stable over the period of measurement, be scientifically credible and be easily interpretable (Walker and Reuter 1996; Liston and Maher 1997).

The national water quality guidelines (ANZECC and ARMCANZ 2001) exemplify the use of indicators and thresholds in planning guidelines. The idea is that a threshold value is provided for an indicator (eg. an environmental contaminant). Any evidence of indicator values exceeding the maximum threshold value (or below the minimum threshold as the case may be) suggests the need for remedial action, as the threshold value is the critical load that the environment can sustain. Deficiencies in this approach are well recognised, as often thresholds are unknown, or they are site specific, or their response to cumulative impacts is unknown. Additionally, they must be defined in a measurable way and must be easy to evaluate. Predictive models, monitoring, toxicity testing, multivariate analyses, etc. can all be used to better refine thresholds.

Thresholds are the key step in the advance of qualitative conceptual models – like those being developed in the South East Queensland Regional Water Quality Management Strategy (Dennison et al. 1999) and the Murray Darling Basin Sustainable Rivers Audit (Whittington et al. 2001) – into quantitative active methodologies. One way of applying thresholds in sustainability models for waterways is the 'ecological edge', or the sharp drop from the cliff edge into 'unsustainability' without substantial forewarning (see line 1 in Figure 14).

It is important to recognise that as the trend moves away from 'natural conditions' a conversion from 'healthy' to 'unsustainable' occurs. For line 1, at some point a small change in some waterway characteristic results in a catastrophic change in waterway condition. It is critical to identify a measurable entity that alerts a decision maker/ resource manager when the edge is approaching, and that will allow for a change in direction before reaching the edge.

Scientists are not certain that there is always a definable edge and suggest that other combinations of gradual decline and/or thresholds (as indicated by lines 2, 3 and 4 in Figure 14) are possible. This would need to be reflected in the indicators chosen, where some may have threshold values and some reflect the gradual decline. If the 'ecological edge' is more fortunately an 'ecological transition' (Brizga et al. 1999), we need an indicator that immediately signals entry to this transition zone, again allowing alteration of course.

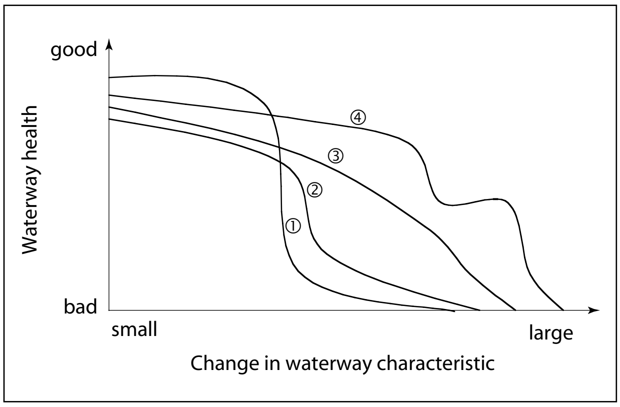


Figure 14. Different trajectories for changes in ecosystem health/value.

However, there are difficulties in determining thresholds and the mode of impact (Stebbing 1992). These include:

- determining causality (particularly with reference to the precautionary principle – ie. a margin of error is required regardless of evidence of impact);
- cumulative effects, which may not be simply additive, of a number of contaminants – eg. mixtures of chemicals may have additive (Hermens et al. 1984; Hermens et al. 1985), synergistic or antagonistic toxicities (Broderius and Kahl 1985; Zwart and Slooff 1987; Warne et al. 1989);
- identification of the responsible agent or agents when there are a number of suspects; and
- inability to reflect natural systems in controlled laboratory studies to determine toxic thresholds.

These limitations require environmental sustainability assessments to have large safety margins that often need to be adjusted 'retrospectively' on the basis of monitoring data. Unfortunately, once the threshold is reached the damage has already been done (Court et al. 1994), and this encourages reactionary rather than anticipatory planning (Young 1993). However, this has been recognised for some time, as the deficiencies in relying on the moment of 'stepping off the ecological edge' are obvious (Rapport et al. 1985). This guideline attempts to identify indicators of ecosystem condition and stakeholder response as part of trend analyses (see section 6 below). Early identification of deviations from sustainability might be seen in stakeholder responses rather than in ecosystem condition (eg. outdated sewage treatment technology versus evidence of water quality deterioration).

> New South Wales has used target setting for resource management, for example in the State Salinity Targets paper (DLWC 2000).
>
> Salinity targets will express the salinity conditions and actions in catchments by 2010 and will lay the foundations for salinity management well into the future. There will be two types of salinity targets:
>
> - end-of-valley target: a ***water quality target*** at the end reach of a river, expressing the overall salinity condition to aim for; and
> - within-valley target: a ***water*** or ***land-based target*** within a catchment, expressing the salinity level to aim for at the location.

5.2 Choice of indicators and model

The choice of indicator to use in the development of a predictive tool is important, as it needs to represent the changing character of the system and not just a select part of it. This is once again a matter of scale. The effectiveness of the chosen indicator and the effectiveness of its application as a predictive tool will determine how accurate the judgment of sustainability will be.

For example, the use of single measurement indicators relies on threshold-type guidelines for interpretation of ecosystem condition. Liston and Maher (1997) produced a table of recommended indicators for waterway condition in State of the Environment (SoE) reports. The indicators were based on ANZECC guidelines, State and Territory water quality guidelines, and SoE reports from different States. Ongoing development of new methods for identifying ecosystem condition, pressures and responses is being undertaken to address limitations of this approach (ANZECC 2000). These include a combination of indicators and modelling, composite indicators, and development of more novel techniques such as biomarkers and bioassays (Bunn 1995), community metabolism (Bunn et al. 1999), and passive abiotic samplers (Müller 2000). Increasing interest in measuring catchment and landscape-scale changes has taken advantage of advanced technologies such as satellite imagery, remote sensing and geographic information systems (GISs).

The selection of an appropriate suite of indicators is essential for the success of any assessment tool. A core set of indicators is included in Appendix C1, but this guideline recognises that regional variability should influence selection for particular waterways. Procedures for choosing environmental indicators have been discussed by many authors (see, for example, Hamblin 1998). When selecting sustainability indicators for any waterway, these criteria and characteristics should be considered carefully. Desirable characteristics of indicators include that they:

- are feasible to obtain;
- are scientifically credible;
- are understandable;
- provide early warning detection;
- enable the detection of temporal or spatial trends; and
- are cost effective.

The selection criteria for environmental indicators should also require that they:

- be applicable to the whole defined segment of the waterway (ie. spatial and temporal scale);
- be based on critical attributes of the waterway/ environment being measured; and
- relate directly to the stated resource quality objective and to the resource being monitored.

To ensure this, the following questions should be considered:

- What parameters adequately describe the resource under consideration?

- What parameters best demonstrate change in the pressure on or condition of that resource?
- How many lines of evidence are required to validate observed changes and the conclusions reached?

This guideline suggests a variety of indicators (see Appendix C1) that are consistent with SoE reporting, but also incorporates indicators derived from local research undertaken to test potential indicators with regional communities (eg. ACTFR 1996). The evaluation guideline (Part E) also provides further guidance on indicators.

The pressure–state–response (PSR) model, commonly used in SoE reporting, is adopted as the basis for sustainability assessments. The PSR model is based on causality: human activities exert *pressures* on the surrounding environment and thus change its *state*. Knowledge about the state of the environment may then elicit a *response* from society in the form of policy implementation, or changes in attitude, which complete the cycle and influence those human activities that exert pressure on the environment. The model's capacity for feedback enables it to account for both positive and negative forms of change. It is a model of the human–environment interaction and, as such, presents information in a way that facilitates an understanding of, and highlights the links between, the condition of the environment and human activity.

While the PSR model has the advantage of highlighting the links between human activity and the environment, it also tends to simplify this relationship by suggesting a simple linear relationship between cause and effect. This simplification should not obscure the complexity of ecological relationships or the difficulty in determining natural variability. The PSR model is a tool that aids in the logical presentation of information, and care should be taken when interpreting this information.

Indicators of *pressure* describe pressures, positive and negative, from human activities exerted on the environment – in this case, waterways. Pressure can also be exerted upon the environment from human inaction as well as action. Pressure indicators would usually relate to some measure of the rate of consumption or rate of use of the resource. Examples of pressure indicators include the amount of forest cleared per year, the volume of sewage output per year, or the fisheries catch per year. Pressure indicators provide a measure of the intensity of pressure on the environment or resource.

Indicators of environmental conditions relate to the quality or the current *state* of the environment. The Organisation for Economic Cooperation and Development (OECD) recommends that indicators of environmental conditions should be designed to give an overview of the state of the environment by providing data that reflects the current quality or quantity of the resource (OECD 1993). Examples of indicators of state include the area of forest remaining, the concentrations of nutrients in water samples, or the remaining fisheries breeding stock. Note that, in practice, the distinction between environmental conditions and pressures might be blurred and, because of the cost involved in measuring environmental conditions, indicators of pressure may be used as a substitute.

Indicators of *response* are measurements that refer to the degree to which society is responding to environmental change and issues of concern. Societal responses include both individual and collective actions aimed at mitigating, adapting to or preventing human-induced negative pressure. Such indicators also include actions taken to improve the preservation and conservation of the environment. Since responses are often reported qualitatively, particularly as a description of government or community response to a problem (eg. the development of Waterwatch as a response to waterway pollution), they may not be quantitatively measurable. However, it is possible to develop indicators of response effectiveness that, while not providing data on how effectively the response has addressed a problem, can provide an indicative measure. Examples may include the number of Waterwatch groups established, the number of catchment management programs or the number of fish species subject to quotas. Obviously, the real measure of effectiveness would be a decline in the pressure or an improvement in the state, yet it is still important to develop indicators that can provide a representative measure of whether a response is being initiated, or more importantly, actually implemented.

The combination of pressure, state and response indicators is critical to assessing sustainability. While it is often easier and more conventional to simply measure the state of a waterway, the data will not be sufficient to enable early predictions of reaching the 'ecological edge', as discussed previously. Compiling data on pressures and, importantly, responses provides additional information to help us understand trends and better predict the location of such an edge.

The following section explains more fully the significance of utilising a combination of indicators to define trends in sustainability.

6 A method of assessing sustainability of waterways

The following method of assessing the sustainability of waterways is based on five steps, which are also illustrated in Figure 15.

Step 1: Understand and classify the diversity of waterway types in the targeted area;
Step 2: Select the appropriate scale of assessment;
Step 3: Assess stability, vulnerability and responses using PSR indicators and thresholds;
Step 4: Chart trends by strategic environmental assessment; and
Step 5: Finalise conclusions by expert panel.

STEP 1: Understand and classify waterways

This component is considered in the ecological value guideline (Part B). To maintain consistency within these waterway protection guidelines, the method outlined in that guideline is recommended for identifying the different types of waterways in a catchment. That method should also be used to help identify the appropriate scale for assessment of the target waterway.

STEP 2: Select scales of assessment

It is critical that the nature of the proposed assessment is considered to identify the target waterway. A threat identification matrix may be a suitable conceptual tool, because it highlights the scales that might need attention. Figure 16 shows how such a tool could be used for waterway appraisal in relation to known proposed developments.

Using such a matrix is an important step in the sustainability assessment method. It becomes even more useful when temporal scales are added, to better consider cumulative threats/impacts. This can be done by repeating the matrix through different scales (eg. by compiling the threat matrix for different seasons or for different proposed levels of resource use, such as water extraction).

In a practical sense, selection of an appropriate scale within a study area may simply begin by deciding whether impacts are contained within a single reach. Appraise connections, potential feedback responses to the impact, obvious cumulative impacts (spatial connections), and potential cumulative impacts (past and future, or temporal connections). If the proposed target waterway is at the appropriate scale, the rest of the method can be applied directly. If the elements affecting sustainability are likely to be more extensive, the following steps may need to be applied at progressive scales of relevance (for example, at subcatchment scale with indicators reflecting responses at that level, as well as at reach scale with appropriate indicators). The duration of the impacts will also determine the indicator(s) for the duration of the monitoring period.

Long-term and extensive monitoring data should be the basis for defining and assessing scale-related issues. Accurately defining the appropriate scale of investigation requires analysis of ambient water quality and biophysical monitoring data sets. Such analyses will allow the catchment to be delineated based on criteria such as sediment yield, mixing zones and vegetation types.

STEP 3: Assess sustainability

Assess the two key elements: stability and vulnerability. It is useful to think of these two elements in relation to the PSR model, with stability equating to *state* and vulnerability equating to *pressures*. Appendix C1 and Part E give examples of indicators.

Stability

Assess the stability of the target waterway by considering the state indicators of waterway condition and the assimilative capacity of the system. Stability is the capacity to maintain state in the face of pressures, and the indicators should be interpreted in that way rather than as direct measures of stability. For example, a system adapted to highly variable streamflow may have a channel form that allows it to retain its natural geomorphology over a wide range of flow conditions. Therefore, streamflow variability would be most useful as an indicator of stability when coupled with an understanding of channel processes.

Vulnerability

Assess the vulnerability of the target waterway by considering pressure indicators. Interpret the indicators in context, because vulnerability arises from both the extent of change and the likely response of the system to that change. When indicator measures are outside natural ranges, the system is more vulnerable.

Responses

Consider response indicators in order to assess the level of response to waterway state and pressures.

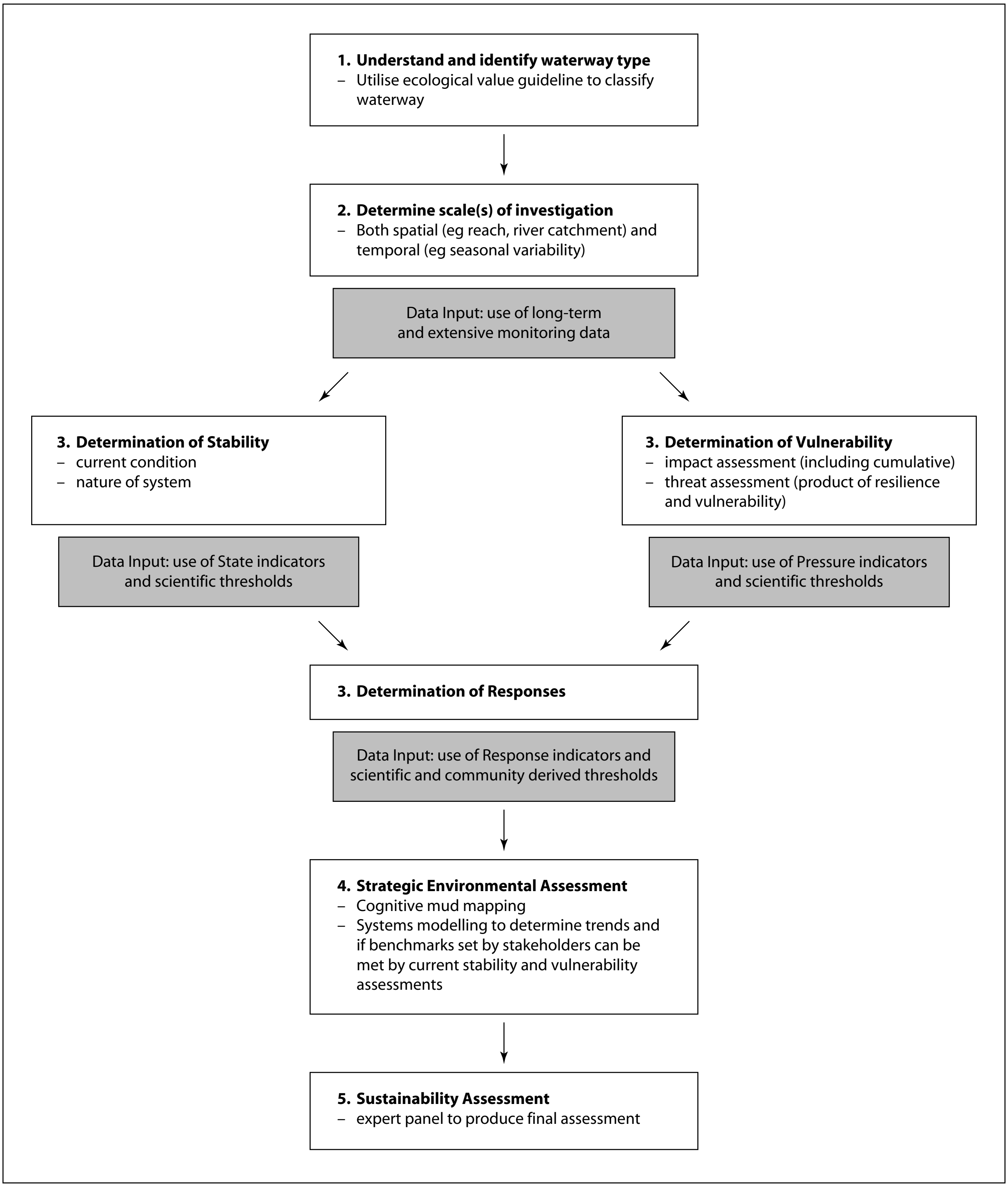


Figure 15. An ecological sustainability assessment method.

Thresholds for sustainability assessment should be objective and derived from scientific assessment. However, if data are unavailable, expert panel assessment may be required until sufficient data is collected, analysed and interpreted.

Nevertheless, it is also likely that thresholds for many response indicators will remain subjective and unique to specific catchments (eg. willingness to pay for pollution abatement).

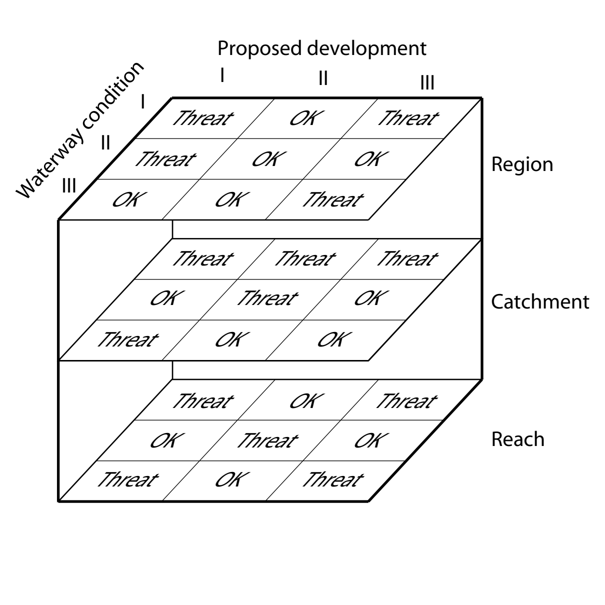


Figure 16. Threat identification matrix (adapted from Smith and McDonald 1998).

STEP 4: Chart trends

Sustainability assessment also involves applying the indicator data generated by the PSR model to 'charting trajectories of sustainability'. Indicator data need to be analysed so that trends in sustainability are understood. This is the only way to avoid tripping over the 'ecological edge' (see section 5.1 above).

There are several ways to chart such a trajectory, but strategic environmental assessment (SEA) is recommended. Alternative and less resource-intensive methods of distilling results from the PSR approach are also discussed below.

Charting sustainability trajectories

This guideline expands on the concept of the ecological edge by introducing potential recovery curves and recognising that a band of natural variability exists in the benchmark condition (Figure 17). Sustainability is defined as the propensity for the targeted waterway to remain within the band of natural condition (between lines A and B) or to have a trajectory that will recover waterway condition within an agreed timeframe (by manipulating pressures, state and responses).

In Figure 17 there are two axes that first need to be defined: the existing condition of the targeted waterway and the temporal scale. The existing condition can initially be derived from widely available and broad-scale 'health' assessments, such as data from the monitoring river health initiative of the National River Health Program (NRHP 1994). More refined estimates can subsequently be built from local/regional investigations, SoE reporting, and targeted sustainability assessments using this guideline. The temporal scale is a device to chart progress. In Figure 17, two lines illustrate

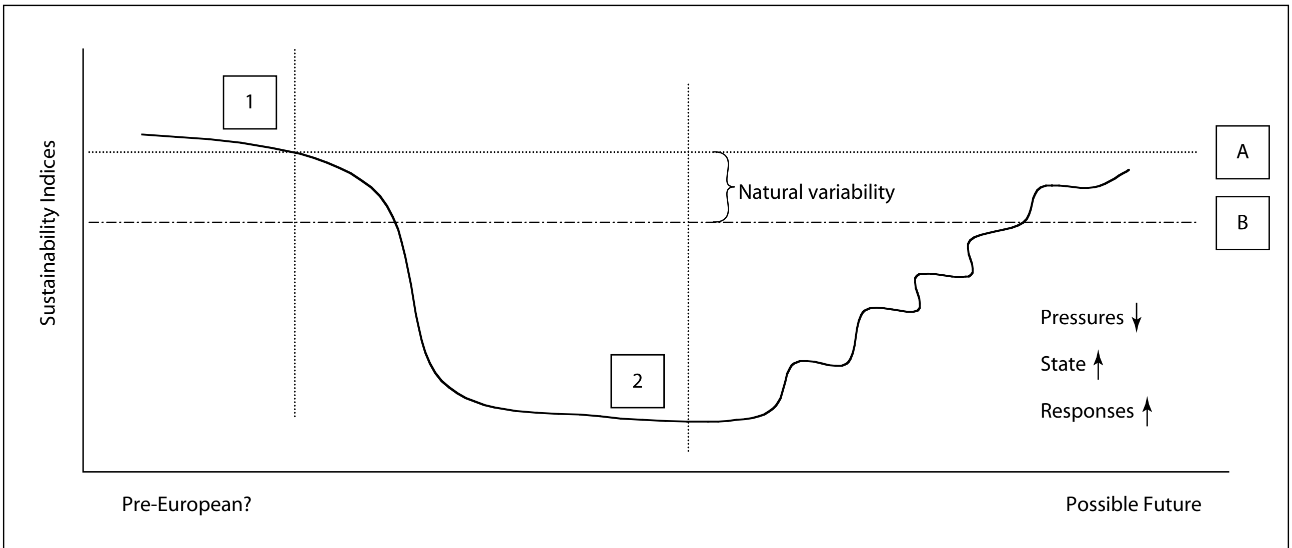


Figure 17. Charting sustainability trajectories with PSR data.

hypothetical waterways. Box 1 in Figure 17 shows a waterway still in 'pristine' condition, while box 2 shows a waterway in its poorest condition. In this example, it is notionally suggested that the edge was some time after European settlement. The sustainability trajectories can be used to illustrate the need for protection of waterways in some cases (eg. box 1) and rehabilitation in others (eg. box 2).

The benchmark condition (between lines A and B) indicates that a band of condition exists within the 'natural' or 'pristine' state. It is important to understand this variability to avoid likely false breaches of thresholds. For example, a waterway may naturally become stagnant late in summer or in the dry season. Water quality would degrade under such conditions, often resulting in low oxygen and/or high nutrient levels. Deriving the width of this band cannot be done by simply using broad-scale investigations. It requires more detailed assessment, akin to benchmarking studies undertaken for water allocation plans (see Arthington and Zalucki 1998). It is also possible to set agreed benchmarks below level B to assist in charting progress.

Charting the condition of the waterway through time – to prevent the condition slipping below level B or to recover the condition within an agreed timeframe – requires regular sustainability assessments. Both prevention and recovery depend on manipulating waterway state (stability), waterway pressures (vulnerability) and responses to the waterway condition.

For example, we might increase the stability (S) of a waterway by planting more trees or by fencing. We might reduce pressures (P) by limiting water extraction or reducing pollutant loads. We can increase response (R) levels through greater participation in community monitoring programs or implementation of water-use efficiency programs. Each of these elements in the PSR model will prevent waterway condition slipping below natural levels, or improve the trajectory to recover condition. Conversely, movements in the opposite directions will cause slippage or cause a decline in the recovery trajectory.

It is also important to recognise the need to impose a timeframe for manipulating P and R elements to achieve an acceptable waterway condition (S). For example, while there may be efforts to reduce pressures, the resulting impact on the trajectory may be minimal and many decades might be required to approach level B. Therefore, efforts to manipulate trajectories should *recognise an agreed timeframe*: while the trajectory is 'on track', it can be considered to be sustainable.

Clearly, we need a mechanism to allow the distillation of PSR indicators into a trajectory chart and to set agreed timeframes for prevention or recovery. Agreement on the timeframe is critical and requires stakeholder input from government, industry, community and other sources. Strategic environmental assessment is recommended for this purpose.

Strategic environmental assessment

SEA is a recent approach to project management that is now used widely. However, SEA is subject to diverse interpretation and approach. The following description of the method is consistent with recent 'large water resource development assessment' guidelines prepared for Agriculture, Fisheries and Forestry – Australia and now under consideration for formal implementation by the Federal Government. The major attributes of the recommended approach include:

- a consistently integrated appreciation of ecological, economic and community impacts and possibilities;
- a mechanism that integrates stakeholder consultation into project development at the earliest possible stage thus facilitating the most constructive application of diverse stakeholder feedback when it is needed most;
- a mechanism that has the potential to develop a high degree of community support and empathy for projects, given its role in facilitating effective dialogue among the greatest possible array of community/stakeholder interests (SEA systematically minimises misperceptions and the development of self-reinforcing antagonisms within an otherwise less than completely informed 'affected' community); and
- a mechanism that can provide very cost-effective project planning.

SEA works on the assumption that well-organised dialogue across a transdisciplinary group of stakeholders will generate greater insight into project implications and opportunities than could ordinarily be realised by individual assessment or by less cooperative groups operating in isolation.

The key steps in such an approach are:

1. *Stakeholder identification:* A systematic and iterative process to identify the diversity of stakeholders with an interest, authority or concern relating to the proposed assessment. For example, this may include aquatic ecologists, geomorphologists, chemists, engineers, and community groups.
2. *Assessment scoping:* A process of establishing the ecological and other criteria relevant to sustainability (ie. PSR model and indicators). The appropriate facilitation process involves the development of a simple influence map, a graphical construct that facilitates stakeholder interaction, learning and consensus. The end product is a stakeholder-derived picture of the condition of the waterway. Note that while this SEA mapping process does not involve quantitative analysis, the exercise will contribute to

the process of modelling/analysis in the following stages of sustainability assessment. For example, a cognitive mud map would be constructed to identify pressures in the catchment, how they relate to the state of the targeted waterway, and what responses are currently in place to counter these pressures. Scientific assessment of PSR indicators would be required to derive relationships, or to examine 'slippage' from benchmark conditions or requirements for recovery. The process could also decide on interim benchmarks (ie. below level B) that can be used as milestones towards achieving the agreed benchmark.

3. *Systems dynamics modelling:* This is recommended as the method for integrating the variety of aspects associated with the sustainability assessment. System dynamics modelling is as amenable to tracking response indicators as it is to incorporating pressure and state indicators and relationships between these elements; its overriding strength is in facilitating the consideration of explicit links between different dimensions. Output from this modelling will produce graphical representations of trajectories (see Figures C2.4 and C2.5 in Appendix C2) that can be manipulated by varying PSR indicators, applying weightings to indicators and varying time lines and benchmarks.

An example of the SEA approach directly applicable to sustainability assessment in this context is provided by Gill and discussed in Appendix C2 of this guideline.

It should be recognised that the system was applied with expert guidance from an independent consultant, and this approach should also be adopted for complex sustainability assessments. Many local governments now use this approach in catchment management and land-use planning. For more basic assessments, users of this guideline should undertake in-house training in the use of SEA and systems dynamics modelling.

A simplified approach

Some users (such as smaller catchment groups and local governments) will not have sufficient resources to utilise an SEA approach to the integration of data generated from the PSR method. A simplified approach has been developed as a rough estimate of sustainability (see Appendix C3). The scoring method is described in more detail in Part B (the ecological value guideline), the major difference being the use of other indicators.

The approach involves rating each target waterway on a scale of 1 to 5 for all relevant indicator measures and entering the rating on a spreadsheet. Wherever possible, determine ratings using measured data. Some of the rating scales will be difficult to interpolate and ratings will tend to be either 1 or 5. 'Yes/no' responses may be used for simple applications.

As with the ecological value guideline, the ranges adopted will be a matter for the user to define.

Scores for individual measures of each indicator (either unweighted or weighted) should be added to derive a score for each indicator and each criterion. Then evaluate each criterion, based on percentage of total possible (this normalises criteria so that each criterion has the same weighting).

STEP 5: Finalise conclusions

The sustainability of the targeted waterway should be evaluated in a final report through the establishment of an expert panel. The panel may need to determine and justify thresholds where scientifically valid criteria are yet to be established (particularly pressure indicator thresholds, such as human populations). It is likely that there will always be a need to subjectively assign thresholds or to make decisions based on data yet to be compiled. This final step should not be overly resource intensive, and should simply be the compilation of either the SEA or the more basic ranking approach.

Reporting should be consistent with the ecological value guideline. However, avoid aggregation of individual waterway assessments because of the complexities associated with assessment-specific considerations (eg. the narrow spatial focus of many response indicators).

7 Worked examples of the method

Appendixes C2 and C3 provide examples of the types of results that can be generated using this guideline. They are two extreme examples, to emphasise the benefits and limitations of the outputs.

Appendix C2 gives an example of two key SEA products – the cognitive mud maps that are agreed upon through stakeholder consultation, and graphical output from systems dynamics modelling. These two products are required to steer the sustainability assessment and to help document proposed action plans based on stakeholder participation.

Appendix C3 shows how sustainability could be assessed where there is little information and where specialist expertise is lacking. This table is designed only for site-by-site use. The analysis is not numeric and relies on the user to provide an overall assessment for each criterion, based on a series of yes/no responses.

Appendix C1

Ecological sustainability indicators (see Part E also)

The PSR approach requires indicators to demonstrate the severity or magnitude of the pressures on the waterway, the current state of the waterway, and society's response to issues of environmental concern.

An environmental indicator can be defined as *"a variable (physical, chemical, biological or socioeconomic) which, when measured, provides information about a particular attribute of the environment and/or the wider environment"* (Draft SoE Reporting Framework for Queensland, in Cosser 1996).

Indicators are developed for a particular purpose, and often have a significance that extends beyond the attributes directly associated with them. The OECD (1993) addresses two particular functions of environmental indicators:

- they reduce the number of measurements normally required for an accurate representation of a situation,
- they simplify the communication process by which information about the results is provided to the user.

An assessment of waterway sustainability requires the selection of indicators that can encompass the variety of issues that affect waterway health. This is likely to require the identification of indicators not limited simply to the waterway itself.

For example, indicators that reflect the state of soil resources in the catchment may need to be utilised to better understand waterway vulnerability. Indicators may also need to be identified that reflect non-biological issues, such as levels of pollution mitigation or how often swimming holes are closed due to poor water quality. Similarly, response indicators are generally not biological but socioeconomic, or relate to the 'effort' required to protect or rehabilitate a waterway.

There are eight key themes that relate to SoE reporting and indicators to assess waterway sustainability could be used from any of these themes, depending on the region, scale and type of assessment. The eight commonly cited themes are:

- atmosphere
- land and soil resources
- mineral and energy resources
- freshwater resources
- marine, coastal and estuarine environments
- biodiversity
- natural and cultural heritage
- human settlements

To this list could be added inland saline lakes. Clearly, not all indicators from all themes will affect waterway sustainability. However, the nature of a sustainability assessment does require the consideration of a wider group of indicators than that required for a more strictly defined assessment.

However, core sets of indicators have been identified and specifically derived for freshwater systems. The most comprehensive is the national set developed by Fairweather and Napier (1998). These indicators were identified to be the basis of national SoE reporting for inland waters, and other sets have also been identified for the eight main themes – for example, biodiversity (Saunders et al. 1998), land (Hamblin 1998) and estuaries and the sea (Ward et al. 1998). These indicators can provide a useful starting point to identify indicators appropriate to the waterway being assessed.

However, because these are national indicators they do not often address finer-scale variability and cannot easily be measured at the regional level. A further subset of indicators has been identified for local and community users (Alexandra et al. 1998), and these were specifically developed to address regional variability. *This approach should be used to identify indicators for waterway sustainability at the catchment, subcatchment and reach levels.*

For example, a SMART filter should be applied to the selection of indicators (Alexandra et al. 1998). SMART indicators need to be simple, measurable, accessible, relevant and timely.

Simple

- Easily interpreted, easily monitored, appropriate for local use, mappable.

Measurable

- Statistically verifiable, reproducible and comparable.
- Able to be combined with others to form indices.
- Able to show trends over time.

Accessible

- Regularly monitored, currently used by public and private managers, cost-effective, consistent with other regions, States/Territories and the national set.

Relevant

- Indicative of fundamental environmental functions, related to a highly valued environmental aspect.
- Related to environmental policies and management goals (regional, State and national).

Timely

- An early warning of potential problems.

Indicators can be selected based on such an approach. For the purpose of this guideline, examples of *state* (stability), *pressure* (vulnerability), and *response* indicators are presented below.

Possible indicators of stability of waterways

- rainfall
- evaporation
- streamflow and variability
- storage volume and capacity
- oxygen content
- nutrient content in water and sediments
- heavy metals
- organic content
- microbiological content
- groundwater level (and changes)
- groundwater salinity
- groundwater iron
- groundwater nitrate
- groundwater pesticides
- sediment deposition in channel
- bank condition
- stream substrate.

Possible indicators of vulnerability of waterways

- rainfall
- groundwater consumption
- reticulated water consumption per capita
- known patterns of use (eg. domestic, industrial, government)
- number of dams
- amounts extracted from rivers/streams
- projected water demand
- extent of contaminants in waste streams entering waterways (urban/rural)
- extent of soil runoff from cropping/construction activities
- area of land cleared in relation to land use
- number of lake/swimming hole closures
- number of bypasses of untreated or partially treated sewage
- estimated number and character of licensed discharges
- number of reported/detected water pollution incidents and prosecutions
- number of consumer complaints about reticulated water supply.

Possible indicators of responses to waterway stability and vulnerability

- number of water conservation programs in place
- overall percentage of water recycled/reclaimed in region
- ratio of actual cost to billed cost of water supplied
- reduction in water distribution losses
- percentage of households with water meters by urban area
- buffer strip replanting programs in effect
- extraction restriction programs/days per year restrictions implemented
- number of community monitoring/catchment management programs in place
- number of salinity/erosion problems
- improvements in sewage treatment methods
- effectiveness of licensing program.

These coarse indicators can be refined to be more targeted for use in specific assessments. For example, as part of the Alexandra et al. (1998) study, sets of indicators were ‘piloted’ in four regions of Australia. Each was based on local environments, pressures and responses. One pilot region was far north Queensland (ACTFR 1996). Comprehensive sets of indicators were identified, including response measures, and that study would be the ideal basis to determine appropriate indicators for a waterway sustainability assessment in that region of Australia. Similar studies that contain locally derived indicators are available across Australia (see Alexandra et al. 1998) and this guideline recommends that such studies be used to source the appropriate indicators.

Selection of the indicators should be part of the SEA process, usually during the cognitive mud mapping exercise. The selection of indicators, any weighting and any limitations can also be incorporated into the systems dynamics modelling of trends (see Appendix C2).

Appendix C2

Strategic environmental assessment

This particular application of strategic environmental assessment (SEA) was developed by Dr Roderic Gill, Director of the Centre for Ecological Economics and Water Policy Research at the University of New England. It was designed to demonstrate how regional development planning might be undertaken to consistently account for the so-called 'triple bottom line' of integrated economic, environmental and community sustainability. The example applies to the topical issue of power generation and its impact on the environment and community. The example is entirely hypothetical and was prepared only to illustrate the recommended SEA process to a number of resource management and policy agencies with jurisdiction in New South Wales. Further information about this case study can be obtained from the Centre for Ecological Economics and Water Policy Research website (www.une.edu.au/cwpr) by following the links to the centre's 'Upper Hunter' project.

The main intent of this exploration is to consider how the recommended process might apply. The discussion is not based on any real consultations, but clearly this approach can be used to determine the ecological sustainability of a waterway.

We recommend consultations with stakeholders who have been selected to make meetings as representative as possible. An initial stakeholder meeting draws on audience discussion to explore the issues systematically and holistically. We suggest using 'mud mapping' to promote and document discussion and to improve synergistic learning, particularly of conceptual and multifaceted subjects such as ecological sustainability.

A mud map with feedback

Figure C2.1 shows the first-step mud map. Note the operation of feedback, whereby one thing influences another and is, in turn, influenced by it. Feedback is dismissed by some economists and most regional modelling, but it is a real effect and central to the latest thinking in complexity theory, learning organisations and systems thinking. Far from being an effect we can assume away, feedback drives systems. It is at the core.

The hypothetical mud map proposes some rather realistic feedback loops at work within the system. For example, any specific *environmental flow allocation* of water feeds into the rather generic *ecosystem integrity* relationship in the mud map. Ecosystem integrity, in turn, feeds back into the flow of water into the ecosystem; it augments any *environmental flow allocation*. This relationship can go both ways, implying that a system stressed through imperfectly tuned environmental flow allocations can cause a self-augmenting decline in environmental 'resilience', or the capacity of the environmental system to sustain itself.

We do not know all there is to know about this kind of feedback; indeed, the unknowns in relation to the precise specification of environmental flows are generally regarded to be completely beneath the resolution of any ecosystem scientist's environmental modelling efforts. And, given the nature of complex systems, the detail that evades our models can often exert the most profound effects. Is it worse to assume this uncertainty away or to note its prevalence and proceed with caution? Our simple mud map recommends caution, given the hypothesised adverse impact of a less than well-tuned system on the 'capacity of the environment' to sustain electricity generation over the long term.

Add stakeholder-identified indicators

If the mud-mapping stage is likely to proceed to the construction of a quantitative learning environment simulation or system dynamics modelling formulation, the next step is to seek input from the same diverse stakeholder group, preferably through a second-round meeting, into how the various components in the mud map might be measured. We seek stakeholder advice on suitable indicators to apply (in the case of waterway sustainability, using regional PSR indicators). This stakeholder identification of indicators helps clarify the relationships specified in the otherwise entirely qualitative mud-map model. Through having the largest and most diverse group of people propose their own indicators, we can go some way towards ensuring that the ensuing results are meaningful to them. Figure C2.2 shows how the results of this second-round consultation might look like for our power generation/environmental flows case study. Note the proposal of an array of indicators, including *tourism spending in region*, *hedonistic valuation of residential properties* and *visitation statistics over time*, for the cluster of relationships to do with changing environmental amenity. In a waterway sustainability assessment, regional indicators might be *volume of water abstracted*, *length of intact riparian vegetation*, *number of active conservation groups*, and so on.

The mud maps propose a number of relationships around the general area of *amenity value of local environment*. The centre's ongoing work in the upper Hunter region of New South Wales strongly articulated the links among amenity values and tourism, and even effects such as 'livability' and 'community spirit'. These relationships are hard to quantify, but they are immensely important to the continued sustainability of the regional social fabric. Actually, the representation of these 'softer relationships' is a comparative advantage of the learning environment scenario testing that we recommend as part our particular interpretation of SEA. To show how this might be the case, and to illustrate the potential of the more quantitative components of the method, we will now progress to a proof-of-concept simulation formulation of these less quantifiable aspects of the story. We will indicate how our recommended decision-support approach could add another layer of support for policy decision makers when grappling with complex environmental issues. This is particularly important when considering the less definable aspects of waterway sustainability, such as the willingness of community groups to replant riparian zones or of farmers to fence stock out of riparian areas. Each of these attributes/indicators is important when assessing potential sustainability options.

A hypothetical learning environment/ system dynamics model

The learning environment simulation in Figure C2.3 refines the mud map in Figure C2.2, and indicates a strong evolutionary relationship between the two different depictions of the same story. In accordance with the recommended decision-support arrangements, the simulator should be developed through continued interaction with the same group of stakeholders that formulated the original mud maps. The simulator should be based on the combined input of expert and stakeholder interests to capture the collective, synergistically enhanced learning of the diverse stakeholders participating in the process. The learning environment simulation is not designed for prediction, but as a mechanism through which to leverage the collective learning of the group by more thoroughly exploring those relationships and impacts important to the assessment. This 'systematic system-exploration process' is intended to ensure a consistently holistic appraisal of any situation under review. It is a toolbox for systems analysis. Indeed, the system dynamics modelling framework, of which this is an application, has a major international track record for just this purpose.

Note also that not all the elements of the mud map (Figure C2.2) are included in the computer simulator (Figure C2.3). The simulator is able to capture exactly the same detail, but a pragmatic approach usually generates a focus on the more relevant elements of the wider story depicted in the mud map – particularly those elements that are less tractable for alternative quantitative assessment procedures such as economic or scientific modelling.

Simulation runs

Any simulation run may consider and combine different 'decision variable' settings. Figures C2.4 and C2.5 present the 'results' for two very different scenarios.

The first results (Figure C2.4) pertain to a 20-year run for the situation roughly 'as is', though with various kinds of natural variability built in (such as drought events and some other, we hope realistic, 'system shocks'). The results reflect a shock from a drought event in the first three years of the run. This 'water stress' event pushed electricity generation and associated power-generation employment below usual levels, though both recovered over time (roughly in line with a gradual improvement in 'ecosystem integrity' over the 20-year simulation). As is often the case with simulators of this kind, effects such as ecosystem integrity are expressed in terms of a simple index value. What matters is the direction of movement, not the number. An upward trend would generally be regarded as being towards sustainability; a downward trend would suggest the opposite. However, more-detailed indicators of system integrity or sustainability can be used in the modelling.

The next run (Figure C2.5) involves a simple 'twisting of the dial' for water allocation to power generation to 1000 million litres per day (this is not a serious policy option for any operation that we know of). The results indicate an intuitive decline in every parameter. One very special feature of this simulation and its associated mud map is a proposed feedback loop between the 'integrity of the environment' and the carrying capacity of ecosystem services to sustain power generation into the long term. Most conventional economists' models lack this kind of feedback loop, largely because the methods used in such analyses preclude the explicit consideration of feedback relationships. However, if stakeholders' intuition strongly supports a feedback relationship like this, the feedback loop should be represented – and our learning environment approach can accommodate the testing of intuitive ideas to an unlimited degree. Note that the downward trend in power generation 'kicks in' because of the proposed feedback between the unreasonably high allocation of water proposed for that run and the long-term capacity of the ecosystem to sustain such pressure.

While we can place little confidence in the numbers generated from this hypothetical simulation exercise, it illustrates the process involved and shows how the whole method might look when applied to any similar story.

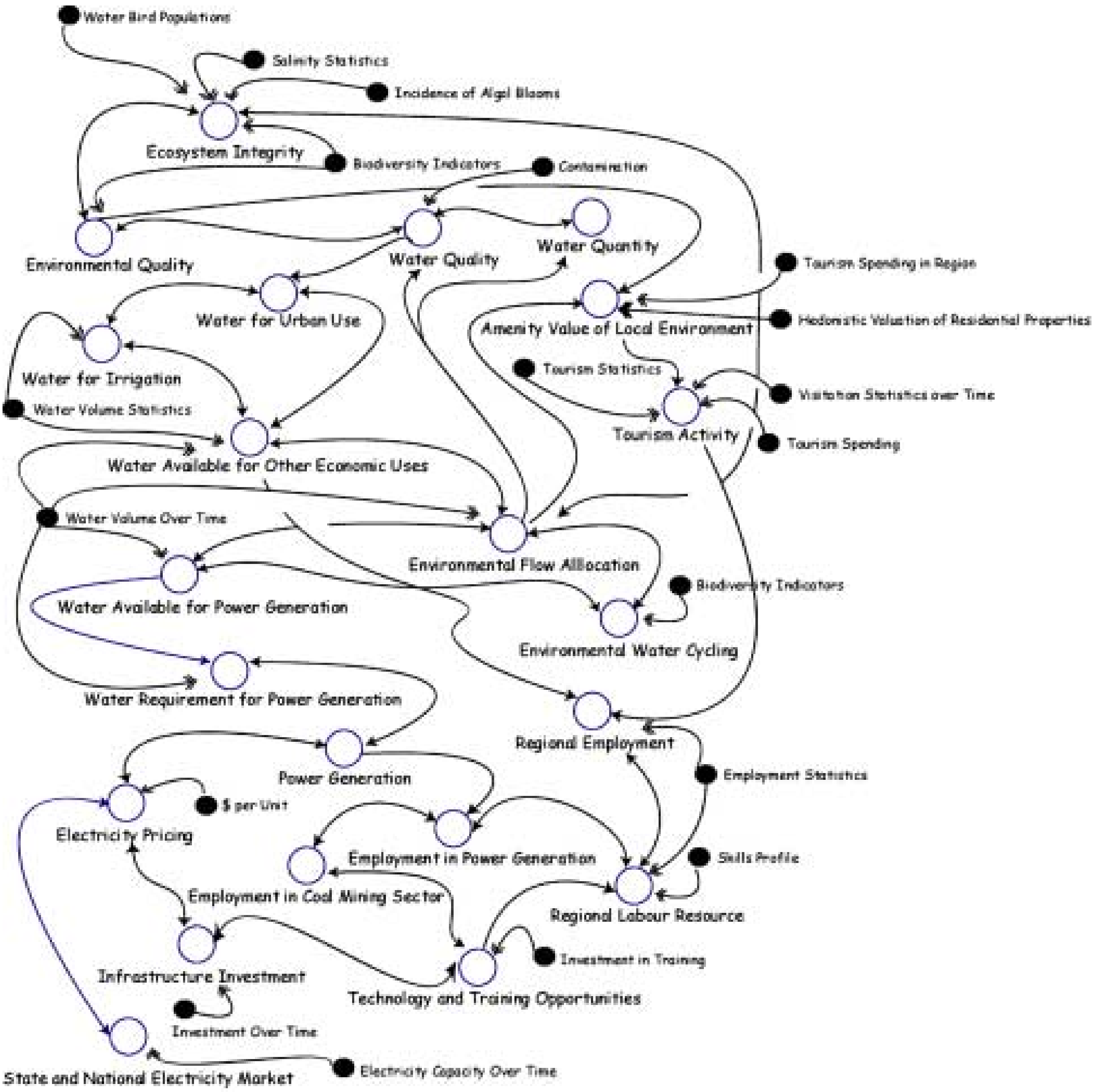


Figure C2.1. Hypothetical mud map for environmental flow – electricity generation relationships.

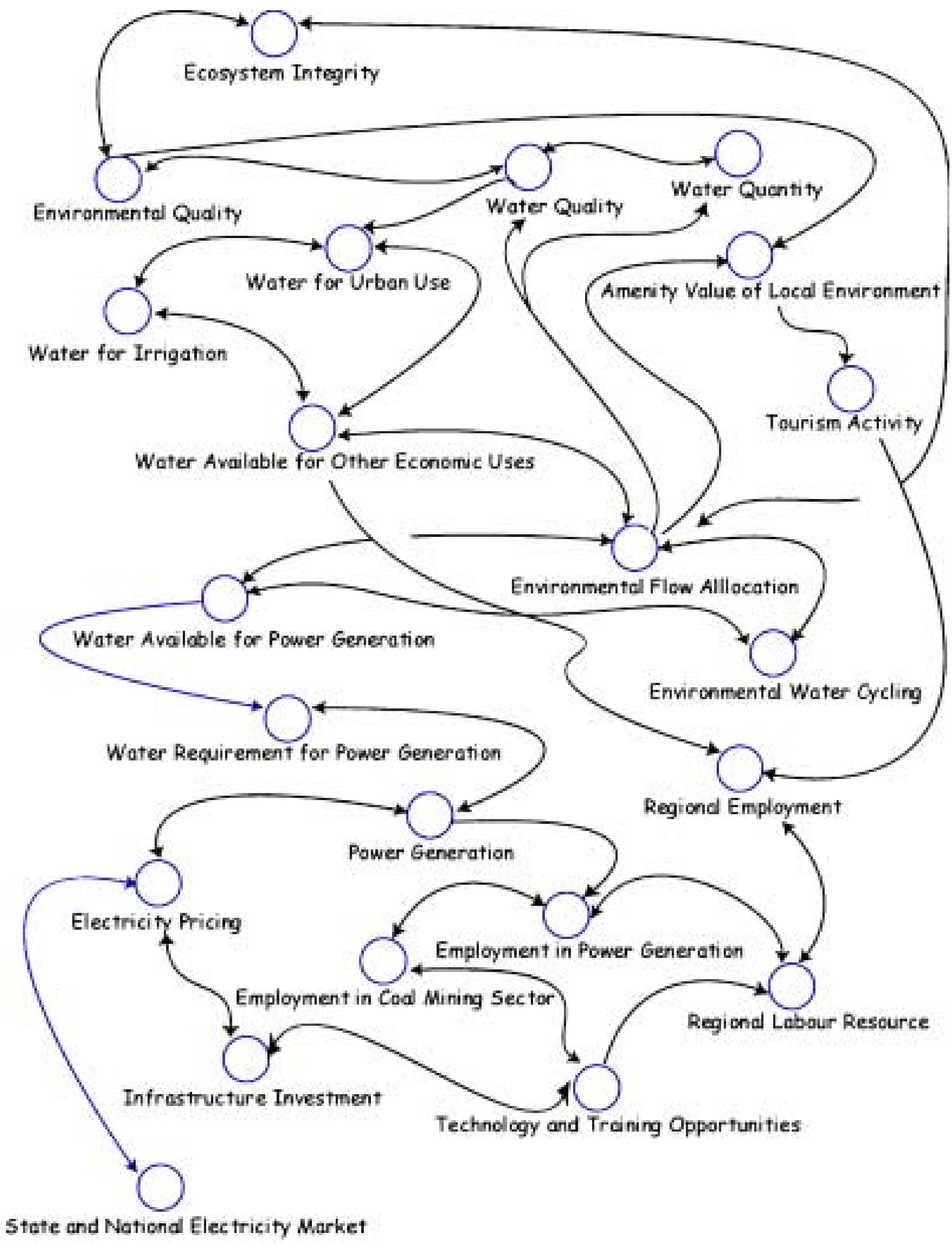


Figure C2.2. Mud map with indicators to support the development of a formal learning environment.

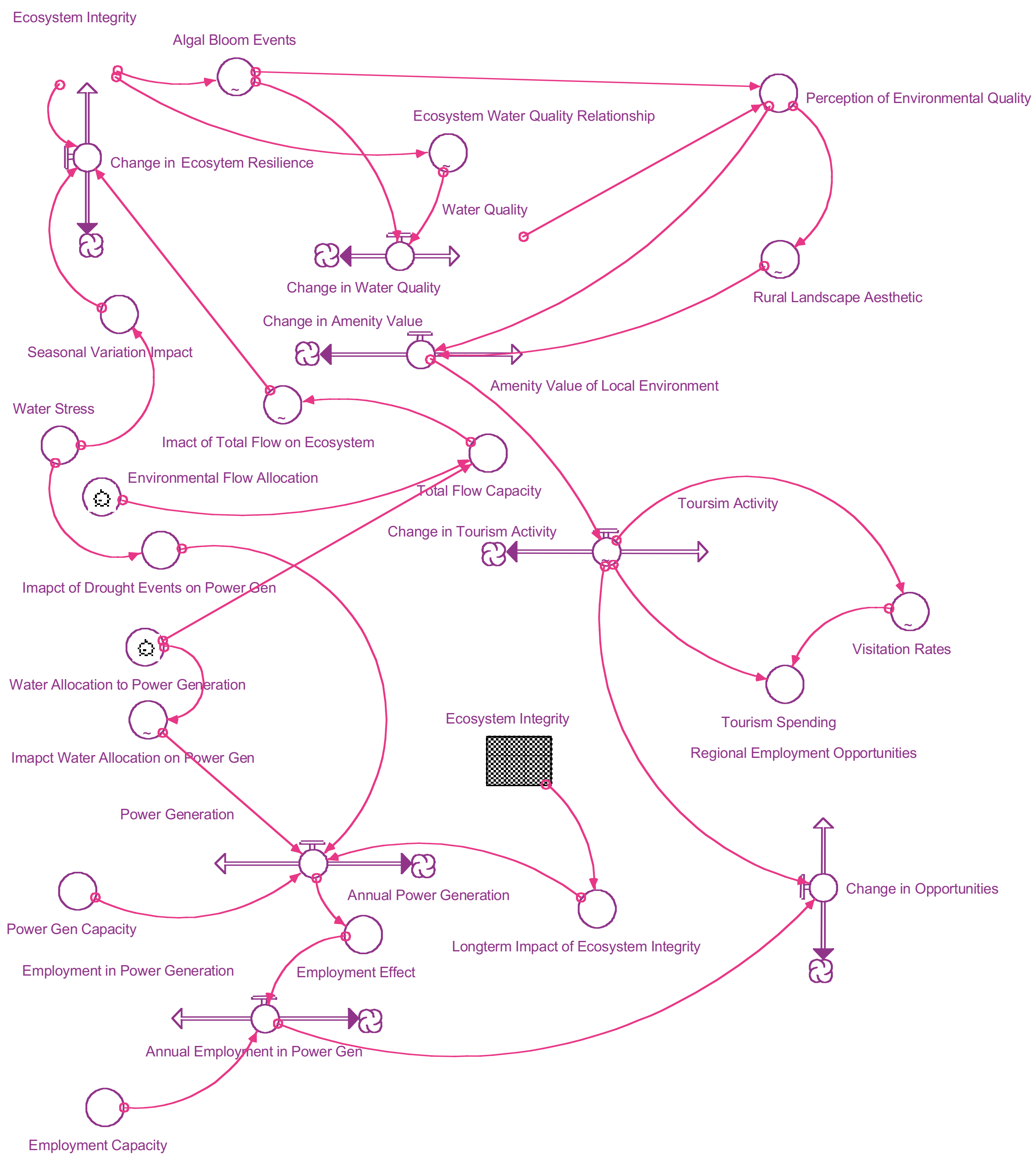
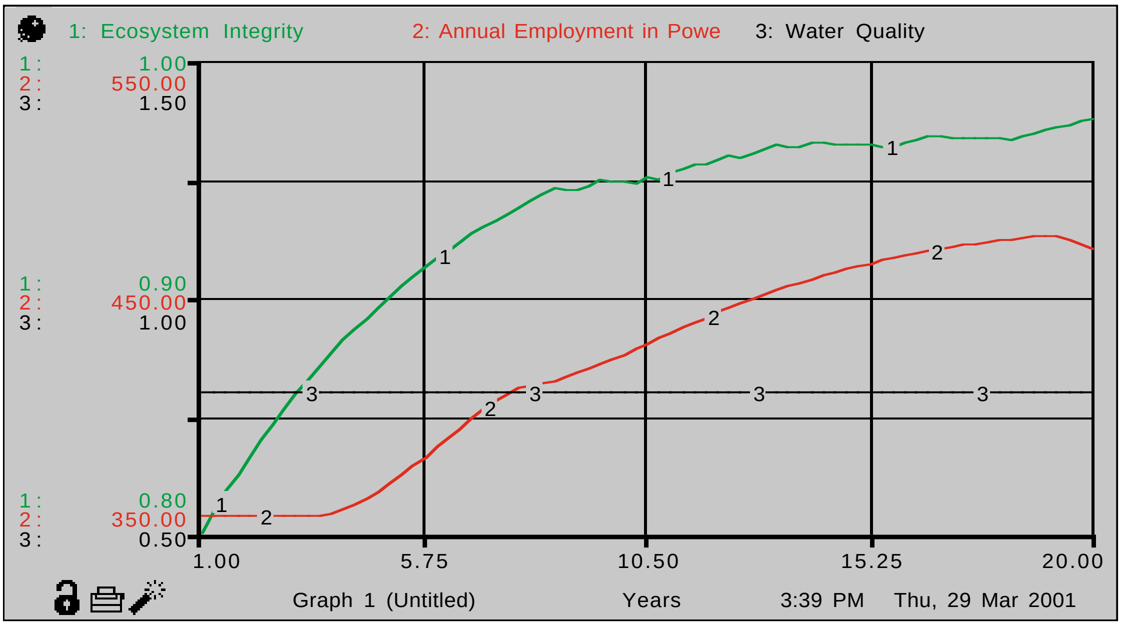


Figure C2.3. A simple learning environment simulator iteration of the mud map.



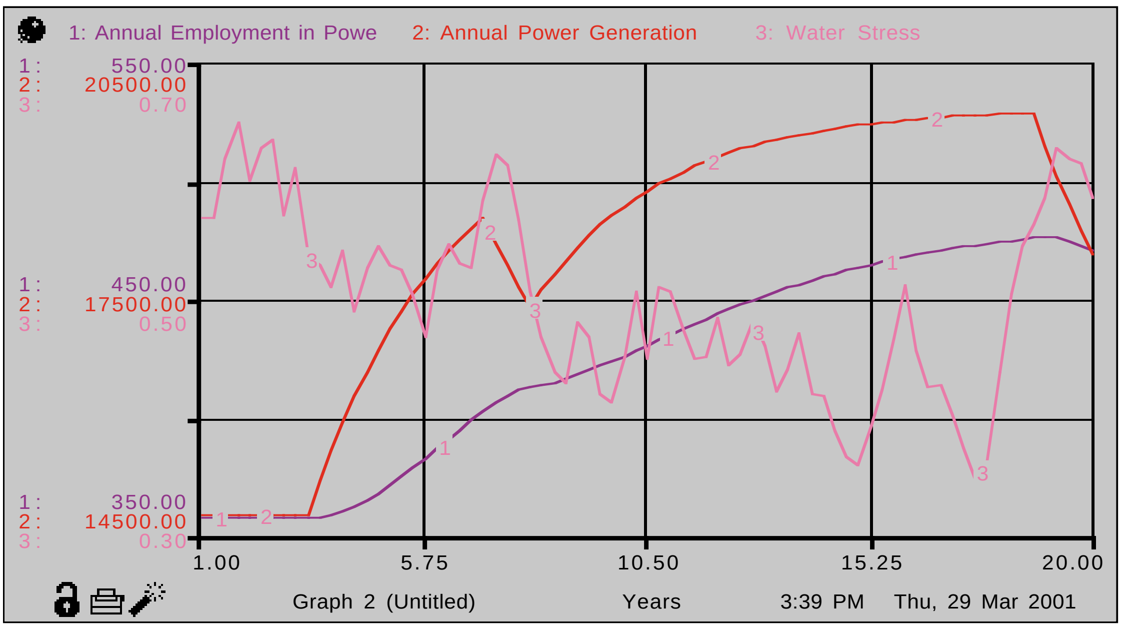
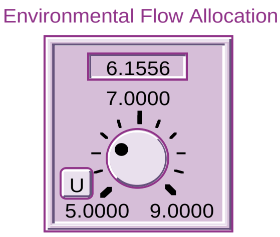
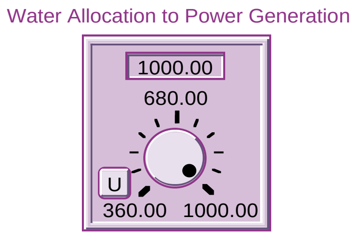
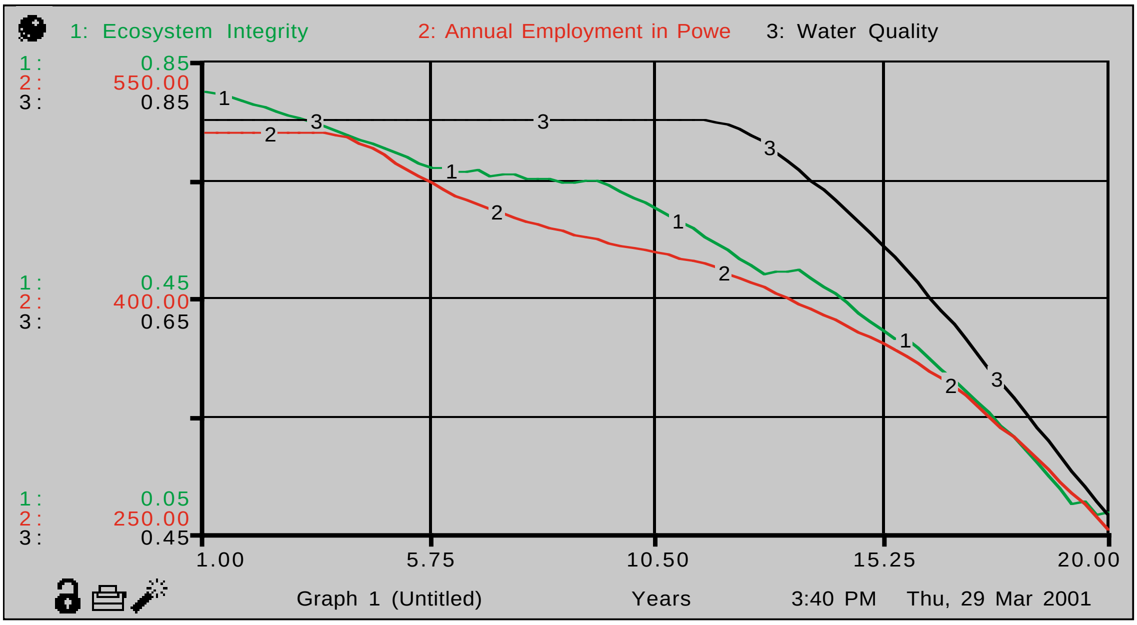


Figure C2.4. Current situation simulation run.







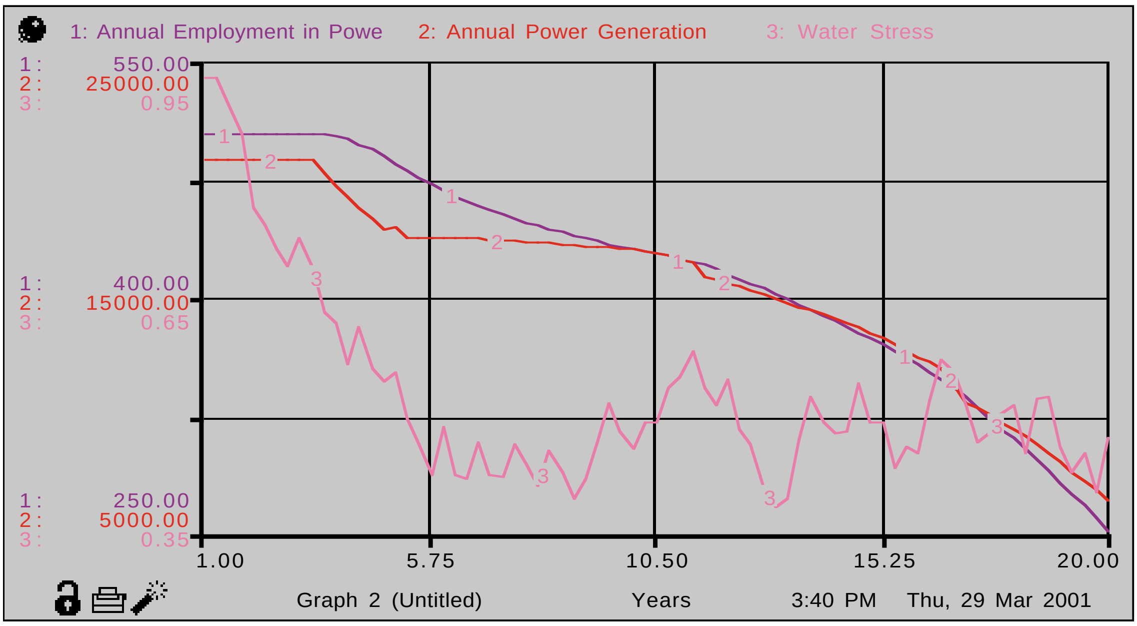


Figure C2.5. 1000 megalitres per day water allocation for power generation simulation run.

Appendix C3

Example of method for defining sustainability of a small creek, where little information is available and where minimal specialist skills are required

Each study should define its own indicators, suitable to that study. The overall rating for each indicator can simply be based on a 1 to 5 scale. It is not recommended to sum the individual scores, but to track change in the indicators through time.

Criterion	Question	Yes (Y), No (N) or uncertain (n/a)	Overall rating
Stability	• Has rainfall followed a normal pattern? • Does streamflow resemble its natural variability? • Is the stream naturally fast flowing? • Is there significant dilution most of the year? • Are oxygen concentrations normal for the time of day/season? • Are nutrient concentrations in the water and sediments normal for the type of river reach, its flow regime, geomorphology and biota? • Is the organic content within a normal range for the type of river reach? • Is the waterway naturally turbid? • Are groundwater levels (and changes) within the normal range? • Is groundwater salinity naturally high? • Is there evidence of sediment deposition in the channel? Is this natural for this type of reach? • Is the bank condition close to a natural condition? • Is the stream naturally shaded? • Is the stream substrate natural?		
Vulnerability	• Has rainfall followed a normal pattern? • Is groundwater consumption high? • Is reticulated water consumption per capita high? • Has the pattern of land use changed? • Are there a large number of dams upstream? • Is a high proportion of flow extracted from the river/stream? • Is there an increase in water demand? • Are there a high number of salinity/erosion problems? • Are there many contaminants in waste streams entering waterways (urban/rural)? • Is there an increase in soil run-off from cropping/construction activities? • Have there been lake/swimming hole closures? • Have there been bypasses of untreated or partially treated sewage? • Is there an increase in the number and character of licensed discharges? • Have there been any reported/detected water pollution incidents and prosecutions? • Have there been any consumer complaints about reticulated water supply?		

Criterion	Question	Yes (Y), No (N) or uncertain (n/a)	Overall rating
Responses	• Is there a high overall percentage of water recycled/reclaimed in the region? • Is the actual cost of water supplied close to billed cost? • Can there be a reduction in water distribution losses? • Is there a high percentage of households with water meters in urban areas? • Are there buffer strip replanting programs in effect? • Are there extraction-restriction programs implemented? • Are there a high number of community monitoring/catchment management programs in place? • Are there improvements in sewage treatment methods planned? • Is the regional licensing program effective?		

Part D - Planning Guideline

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1 Introduction

A Rehabilitation Manual for Australian Streams (Rutherfurd et al. 1999) states:

> The first rule of rehabilitation is to avoid the damage in the first place! It is easy, quick and cheap to damage natural streams. It is hard, slow and expensive to return them to their original state. Usually we are not capable of returning anything approaching the subtlety and complexity of the natural system. For this reason, the highest priority for stream rehabilitators is to avoid further damage to streams, especially streams that remain in good condition.

Recently, Cullen (2001) has called for a system of river reserves which he advocates

> …will do four things. It will protect some internationally unique river systems for the enjoyment and education of Australians. It will help meet Australia's international obligations on protecting biodiversity. It will allow the development of benchmarks of river health so that we can assess how developed rivers change over time. It will allow rivers to act as biological 'seeding' sources for rivers downstream that are degraded, helping to restore downstream rivers to a healthy state.

The Council of Australian Government's (COAG) water reform agenda gives similar recognition to protection of the natural values of waterways. Given that the reforms are being implemented, it is timely to give guidance on instruments and processes for waterway protection planning.

The planning guideline is intended for anyone who is interested in the protection of waterways, including government planners and policy makers, waterway managers, community groups and individuals.

2 Purpose

The guideline provides information and guidance on the instruments and associated planning processes for protecting waterways' ecological values. It is meant to help protect a waterway's existing ecological values, regardless of their position in the continuum from undisturbed to highly modified systems.

As a guide to developing a vision and plan for waterway protection, it gives users direction and background information on planning and a guide to obtaining further information. We do not intend it to be prescriptive, and hence we do not, for example, provide an exhaustive list of instruments (such as legislation) from all States.

As there is limited reference material focusing on waterway protection, this guideline builds largely on work undertaken by Dunn (2000) and the Queensland Environmental Protection Agency (Phillips et al. 2001). The former document has been cited in the ecological value guideline, and the latter reviews "principles and tools for the protection of rivers".

The planning guideline also aims to complement existing frameworks and tools for river restoration, notably Koehn et al. (1999), which developed a planning framework aimed principally at restoring rivers, and Rutherfurd et al. (1999), which provides a step-by-step guide to river rehabilitation.

3 Scope

The guideline examines the planning elements of the protection activities outlined in the conceptual framework (Part A), and is intended to integrate with and complement existing waterway planning.

It can be applied to tidal and non-tidal waterways, wetlands, riparian zones and floodplains. It covers biophysical aspects – biology, hydrology and geomorphology – and may extend to other values that are supported by, and consistent with, protection (for example, some forms of recreation).

Our focus is on ecological matters. While the guideline does not directly include the social or economic dimensions of waterway protection planning, we try to provide the relevant ecological inputs to these key elements of the decision-making process (as outlined in the conceptual framework).

4 Waterway protection planning and how it fits in with other waterway planning

Waterway protection planning is *not* another layer of planning, but an opportunity to include protection in any planning activity relevant to waterways.

Protection ranges from conservation of representative sections of high ecological value waterways, through the planning for their sustainable use, to protection of remaining values of degraded waterways.

There are many instruments and processes for waterway planning (these are detailed in Sections 5 and 6 of this guideline, respectively). Some are *holistic* and look at protection of waterways on a State or catchment basis; others are more *specific* and address waterways' components or values.

Component-specific approaches involve protecting the key components of waterway health, including the flow regime (water quantity), physical structure (habitat), water quality, aquatic flora and fauna, riparian vegetation, and associated floodplain and catchment features.

Value-specific approaches, introduced in this guideline, aim to protect ecological values (ie. naturalness, representativeness, rarity, diversity and special features).

There is obvious overlap between the component-specific and value-specific methods. Planners have typically used a 'reductionist' approach to manage these elements, but the challenge is to make all planning and management complementary. This includes being aware of the holistic vision for a waterway's ecological values, understanding threats to such values and a waterway's response to the threats, and then integrating all relevant planning and management activities.

This section explores holistic and specific waterway planning and their integration. There are some general concepts that can help to make any planning exercise as integrated and holistic as possible.

Holistic planning

Planning strategies at a State level, like the South Australian State Water Plan (SA DWR 2000) and the Victorian River Health Strategy (Doolan 2000), and at catchment scale, like the Murray–Darling Basin Integrated Catchment Management strategy (MDBMC 2001), provide opportunities to be holistic. These processes and instruments allow us to address both the component/value-specific issues and the necessary integration of resulting activities.

Component/value-specific planning

Component/value-specific planning instruments and processes are responses to difficulties in managing the complexities of waterway systems. The examples of instruments in Section 5 of this guideline reflect the 'reductionist' approach to planning and relate to protecting the key components of waterways.

Protecting ecological values is analogous (and complementary) to protecting specific components of waterways. The ecological value guideline (Part B) provides methods to identify values of waterways based on naturalness, diversity, rarity, representativeness and special features. Considering protection of ecological values will similarly result in the appropriate mix of planning instruments to protect the specific values identified. For example, the protection of naturalness will include the protection of the naturalness of hydrological features and the naturalness of riparian vegetation. The protection of diversity will include protection of all relevant forms of diversity within the waterway (eg. protection of species diversity) with relevant nature conservation legislation. The protection of representativeness and rarity will include protecting representative areas of waterways. Lastly, the protection of special features of waterways will use instruments that are specific to the identified features.

How are we then to guide our planning? It is widely recognised that key influences on the waterway (that is the catchment, waterway and floodplain factors) should be addressed in a whole-of-catchment context.

Protection of waterways is likely to occur at a range of scales, for example at a the levels of the State (rivers policy), catchment (catchment planning), waterway sections (designation of national parks) and individual properties. For planning at scales less than the entire catchment, considering the whole-of-catchment context ensures resolution of catchment-scale issues. For planning activities broader than catchment scale, the catchment remains a useful and generally realistic management unit.

Government, industry, landholders and the community generally have responsibility for waterway management. We need to recognise this if we are to improve evaluation and management.

Case Study: South Australia's State Water Plan (2000)

South Australia's State Water Plan (2000) is a good example of both reductionist and holistic approaches. Its reductionist approach (commonly used throughout Australia for waterway management) includes specific management actions for riparian zones, wetlands, floodplains, estuaries, groundwaters, water allocation and water quality. The plan also recognises the need for a holistic approach and the challenge will be in implementing the methods proposed to achieve this, including:

- where catchment water management boards (CWMBs) exist, catchment management plans will be the key integrating plans;
- where there are no CWMBs, the South Australian Government will work with local government to promote the introduction of integrated management of water bodies in either local water management plans or development plans (South Australia is developing good linkages between its State Development Strategy and its State Water Plan); and
- in the development of natural resource management legislation.

Management ranges from national to local levels, but whatever the scale or the number of stakeholders, we need common goals for protection, sustainable use and, where needed, rehabilitation of waterways. Doolan (2000) discussed the management framework and the roles at different levels of management in the context of development of a Victorian River Health Strategy (see Appendix D1). Consideration of the different roles is important in the scale of planning and in achieving the right mix of instruments for waterway protection. The hierarchy of roles and scales is also reflected in the planning instruments discussed in the next section.

The challenge is to be aware of all relevant planning activities and opportunities to achieve desired outcomes, and to 'network' actively when we undertake any protection planning activity. This includes researching relevant planning activities, interacting continually with relevant stakeholders, and providing appropriate links to related activities. Section 6 explores this further.

In summary, there are many instruments, and processes for using them, available for any particular planning activity aimed at waterway protection. These range from:

- holistic to component-specific or value-specific approaches; and
- conservation of representative sections of high ecological value waterways, through the planning for sustainable use of waterways, to the protection of remaining values (and repair) of degraded waterways.

The following sections provide information on:

- choosing of the right 'mix' of instruments; and
- general processes for using these instruments, and how these can incorporate waterway protection, including the 'visioning', plan development and setting of priorities for protection.

5 Instruments for planning waterway protection

5.1 Selecting the right 'mix' of planning instruments

Appendix D2 gives examples of planning instruments available to protect waterways. Dunn (2000) suggested that there was no single instrument that would effectively protect ecological values of waterways, and a combination of instruments would need to be considered case by case. Young et al. (1996) recommend such an approach, suggesting that a single-instrument or single-strategy approach is unlikely to be adequate. All have strengths and weaknesses and none is sufficiently flexible or resilient to successfully address all threats to ecological values in all temporal, spatial, ecological, social, economic and institutional contexts. In most circumstances, we need a mix of instruments tailored to specific goals.

Values will be best protected if we understand the unique features of waterway systems and use them to underpin goals. Unique features include:

- The non-renewable nature of waterways. Although the physical components of a waterway system (such as water and sediment) may be replaceable, the biotic components once lost may be irreplaceable, as many species are not even scientifically known.
- The poorly understood functioning of waterway ecosystems. The impacts of the loss of species and the ways in which ecosystems respond to such losses remain largely unknown.

The remainder of this section discusses a range of instruments for protecting the ecological values of waterways. As there are few instruments specific to waterway protection, we include examples of instruments used in other ecosystems: such instruments may provide for complementary protection for waterways' ecological values. Although an assessment of the effectiveness of each example is beyond the scope of this guideline, we comment below on the applicability of each instrument.

5.2 Range and examples of planning instruments

Instruments that might be used to protect waterways can be categorised as:

- legislative mechanisms;
- non-legislative instruments, such as agreements, policies, strategies, programs and codes of practice;
- national, State, regional, catchment and river plans;
- voluntary property-based mechanisms;
- financial and other motivational mechanisms; and
- voluntary action groups.

Appendix D2 gives examples of each from various jurisdictions, and includes a description of how the instrument is applied and a brief discussion of each group of instruments. This list is by no means exhaustive and is aimed at guiding the reader in the kinds of instruments and outcomes possible.

Table 6 gives a summary of the types of instruments and their potential users, a description of what each instrument can achieve, some examples of specific outcomes and examples of existing instruments.

The relevance of these instruments to users depends on the management framework under which the user operates. For example, government agencies would be the most likely to use legislative instruments for protection of waterways, water quality or water quantity. In contrast, individual landholders have an opportunity to protect ecological values through voluntary activities such as property management planning.

5.3 Selecting planning instruments

Processes for protecting waterways need to consider all waterway users, including current and future generations, the wider community and the environment, as well as those people currently in the local area. Effective protection will be implemented using a 'mix' of instruments that reflect these diverse interests and needs. Sapsford (1998) provides a summary that identifies such a 'mix' of instruments as being:

- *robust* – deliver relatively predictable results in situations of uncertainty about ecological value;
- *precautionary* – minimise the chance of serious or irreversible consequences due to uncertainty;
- *flexible* – able to be adapted to changing knowledge;
- *equitable* – operating without advantage or favour across all groups and generations;
- *cost-effective* – achieve their outcomes in ways that minimise the overall costs of doing so;
- *acceptable* – are seen by the community as legitimate means of promoting conservation, are incorporated into everyday life, assist in motivating people and have social and political support;
- *durable* – create ongoing incentives for innovation towards improving ecological value; and
- *informative* – encourage active self-monitoring and the dissemination of information.

No single instrument demonstrates all these features, which should therefore be regarded as a checklist against which to evaluate a mix of instruments. The preferred mix of instruments is likely to depend on local circumstances, and all instruments have strengths and weaknesses. The key is to find the optimal mix of instruments to meet both local circumstances and national and State goals. Finding an optimal mix will be easier if all stakeholders have a good understanding of instruments for their particular context.

5.4 Links to other protection activities

Any activities to protect waterways should be appropriately linked to protection/conservation efforts on land through which the waterway flows. Actions need to be integrated at different geographic scales. The piecemeal application of protection tools (land acquisition, riparian restoration, etc.) will not work if efforts are not coordinated across both geographical and political boundaries, as the scale of protection (and remediation) activities will be simply too small to have more than a local effect. Sapsford (1998) suggests that protection/conservation is a decentralised activity and is the outcome of a range of individual and collective actions. As a result, it relies as much on motivation and shared goals as on rules and controls. Protection and conservation require an integrated approach because of the multifaceted nature of the issue.

Table 6. Potential instruments available to assist with planning for waterway protection.

Instrument	Who uses it?	What can it achieve?	Examples of specific outcomes	Examples of instrument [relevant table in Appendix D2]
Legislation	Government	protection of waterways	• protection of land adjacent to waterways; restrictions on developments in catchments of such areas	– *Heritage Rivers Act 1992* (Vic) [Table D2.1]
		protection of flora/fauna	• declaration of protected areas (eg. Fish Habitat Areas, National Parks, Marine Parks, Nature Reserves) • protection of significant species, habitats, ecosystems	– *Nature Conservation Act 1980* (ACT) – *Fisheries Act 1982* (WA) [Table D2.2]
		protection of water quality	• establishment of ICM framework • retention and management of native vegetation • management of point and diffuse pollution sources • consideration of potential impacts of proposed developments	– *Native Vegetation Act 1991* (WA) – *Environmental Protection Act* (Qld) [Table D2.3]
		protection of water quantity	• development of environmental flow allocations	– *Water Act 1989* (Vic) [Table D2.3]
Agreements	Government	preservation of habitats	• preservation and maintenance of wetlands	– Ramsar Convention [Table D2.4]
		preservation of species	• protection of migratory species	– JAMBA/CAMBA [Table D2.4]
		promotion of adoption of environmental protection instruments	• provide assistance in adopting environmental protection instruments	– Rio Declaration (Agenda 21) [Table D2.4]
		promotion of cooperation in environmental matters	• promote intergovernmental cooperation on environmental matters	– Intergovernmental Agreement on the Environment [Table D2.4]
Policies	Government	establishment of environmental values/ objectives of waterways	• aid planning for waterway and associated catchment use	– State Policy of Water Quality Management (Tas) – Swan–Canning EPP (WA) [Table D2.5]
Strategies/ programs	Government	establishment of guidelines	• national strategy and guidelines for water quality management	– National Water Quality Management Strategy [Table D2.6]
		establishment of principles	• biodiversity principles	– National Local Government Biodiversity Strategy [Table D2.6]
		management of off-reserve values	• identification of management needs of off-reserve values	– National Endangered Species Program [Table D2.6]

Table 6. (cont'd) Potential instruments available to assist with planning for waterway protection.

Instrument	Who uses it?	What can it achieve?	Examples of specific outcomes	Examples of instrument [relevant table in Appendix D2]
Codes of Practice	Government Industry	guidance on management of activities to prevent/minimise environmental impacts	• erosion and sediment control plan	– Erosion and Sediment Control Code of Practice 1998 (NSW) [Table D2.7]
National, State, Regional, Catchment, River Plans	Government, catchment authorities, community/ non-government organisations, individual landholders	guidance on planning and management of national resource management issues	• planning and resultant implementation actions to address salinity and water quality issues	– National Salinity and Water Quality Action Plan (COAG 2000) [Table D2.8]
		guidance on planning and management of State water management issues	• holistic planning to provide direction for water planning and management activities	– South Australian State Water Plan (SA) [Table D2.8]
		catchment planning activities to manage/protect ecological values	• planning and implementation activities to manage the catchment to maintain/enhance ecological and geomorphological processes and biodiversity	– Victorian CMA's Nutrient Management Plans (Vic) – Salinity Strategy (NSW) – River Styles™ (NSW) [Table D2.8]
		waterway planning activities to manage/protect ecological values	• planning and implementation activities to manage riverine activities to maintain/enhance ecological values	– River Management Plans (NSW) [Table D2.8]
Voluntary property-based instruments	Individual landholders	voluntary agreements to protect conservation values of significant land/ vegetation/river section	• establishment of conservation covenant	– Conservation Covenant (Tas) [Table D2.9]
Financial and other motivational instruments	Catchment authorities, community/ non-government organisations, individual landholders	increase in awareness	• environmental education programs	[Table D2.10]
Voluntary action	Government, catchment authorities, community/ non-government organisations, individual landholders, participants	funding of protection measures	• riparian zone revegetation program	– Natural Heritage Trust [Table D2.11]
		various activities undertaken in relation to waterway management, eg. lobbying, surveys, monitoring, rehabilitation, education, awareness campaigns	• local management of waterways	– National Rivercare Program [Table D2.11]

6 Processes for planning waterway protection

6.1 General waterway planning processes

The complexity of waterways makes it difficult to predict impacts on them with certainty (see Part C, the sustainability guideline). Therefore, in accordance with the 'precautionary principle', most waterway management uses an adaptive planning and management process shown generically in Figure 18. This process aims to protect waterway values and achieve ecologically sustainable use of waterways and their catchments by allowing a controlled and precautionary level of use, measuring the impacts, refining understanding of the system based on this increased knowledge and then, if sustainable, allowing further cycle(s) through the process to establish primary and subordinate uses. This process can also apply when waterways have been degraded and 'repair' (ie. rehabilitation/restoration) plans are being developed, implemented and their effectiveness reviewed.

The generic process in Figure 18 is reflected in a number of waterway planning processes, including:

- the National Water Quality Management Strategy (ARMCANZ and ANZECC 1994);
- the *National River Restoration Framework* (Koehn et al. 1999); and
- *A Rehabilitation Manual for Australian Streams* (Rutherfurd et al. 1999).

These processes are described in Appendix D3.

The planning process for protecting (and repairing) waterways needs to involve all stakeholders, including the community, relevant industries and planners, and to use the best information available. The steps in the process are:

- identify or establish a common vision/goal for the waterways;
- develop and implement an appropriate plan;
- monitor the plan's progress in relation to achieving the vision/goal; and
- if necessary, revise the plan.

This is a dynamic process allowing for continuing improvement.

This guideline focuses on the steps of *establishing the vision* and *developing the plan*, but recognises that implementing the plan and monitoring and reviewing it are also key steps in the process.

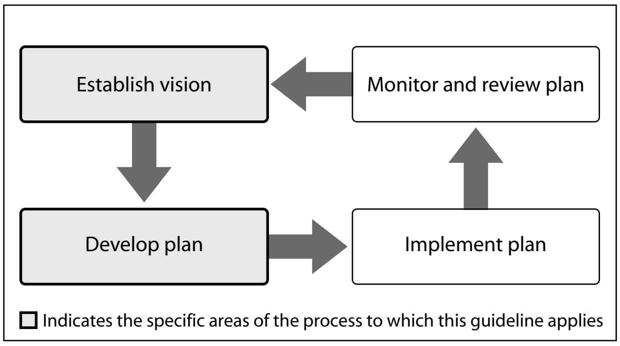

Figure 18. Adaptive planning and management process

6.2 Special features of planning for waterway protection

Planning for waterway protection is categorised in this guideline into three levels, namely:

- *conservation* of representative sections of high ecological value waterways;
- *sustainable use* of waterways; and
- *protection of remaining values* of degraded waterways.

The last level overlaps with planning repair (ie. restoration, rehabilitation) activities for degraded waterways.

In Australia, there is a growing awareness of the need to conserve representative sections of waterways with high ecological value (e.g. Cullen 2001). This parallels the use of 'zoning' in national and marine parks for protection of representative terrestrial and marine conservation values respectively.

The National Water Quality Management Strategy, the planning process of which is shown in Appendix D3, has as its objective the sustainable use of waterways. Integrated catchment management (ICM) provides an opportunity to plan for sustainable use on a catchment basis (see Part C, the sustainability guideline). Once such ICM plans have been agreed, the evaluation guideline (Part E) is intended to assist with evaluating development plans and project impact assessment to demonstrate ecological sustainability.

The protection of remaining values of degraded waterways (for example, threatened species) also needs specific plans addressing those values. Such planning should be integrated with 'repair' activities for degraded waterways. Koehn et al. (1999) and Rutherfurd et al. (1999) have developed planning processes/frameworks (Appendix D3) to assist with such 'repair' activities.

The guideline can therefore assist in developing, for example:

- State rivers policies prioritising representative areas of waterways – eg. the Victorian River Health Strategy (Doolan 2000);
- water quality management strategies, incorporating sustainable use of a catchment as well as protection of the high ecological values of waterways – eg. the South East Queensland Regional Water Quality Management Strategy (SEQRWQMS 2000); and
- river restoration/rehabilitation plans with complementary protection actions – eg. Queensland's Draft Mary River and Tributaries Rehabilitation Plan (Stockwell 2000).

Planning processes for waterway protection need to accord with other planning processes and add a 'protection' dimension. This requires complementary vision statements, objectives, planning and management priorities and actions, and monitoring as the plan is implemented.

Determining ecological values is important in determining the vision and subsequent goals for waterways, and both ecological value and sustainability are important considerations in determining protection priorities.

Socio-economic factors, such as development pressures, public attitudes and political will, are key inputs to adapting priorities into feasible, defensible and acceptable program. Ecological considerations need to be combined with social and economic considerations as indicated in Part A, section 3.

6.3 Establishing a vision

A vision identifies the overall common purpose to be achieved, and should be negotiated with stakeholders.

The 'protection' component of the vision should include relevant statements in line with the three levels of protection, namely:

- conservation of representative sections of waterways;
- sustainable use; and
- protection of remaining ecological values.

Table 7 gives examples of vision statements for the three levels of protection.

A vision provides the overarching direction for planning within which stakeholders would be expected to detail their vision by identifying values they want to protect and setting goals and benchmarks for specific values.

Table 7. Establishing a vision.

Level of protection	Examples of vision statements
• Conservation of representative sections of waterways	representative sections of high ecological value waterways will be conserved
• Sustainable use	development within the catchment will be adaptively managed to ensure protection of the waterways' ecological values and their ecologically sustainable use
• Protection of remaining ecological values	in degraded waterways, protection of remaining ecological values will be afforded appropriate priority

The ecological value guideline shows how to identify ecological values of particular waterways and this is discussed further in the next section.

The Draft Mary River and Tributaries Rehabilitation Plan (Stockwell 2000) provides an example of a catchment management committee setting a vision (and priorities, as discussed below and in Appendix D5) for both protection and repair.

6.4 Developing a plan

Developing a 'protection' plan involves consideration of all three levels of protection, each necessitating protection actions. The steps, which are shown diagramatically in Figure 19, include:

1. identifying the scope of the protection plan;
2. defining ecological values of the waterway;
3. identifying the goals/objectives of the protection plan;
4. defining ecological sustainability of the waterway, including:
   - defining sustainability limits of the waterway;
   - identifying current and potential threats; and
   - assessing the risk of current and potential threats;
5. assessing protection options and priorities (leading to protection actions);
6. identifying tasks required to implement the agreed protection plan; and
7. finalising and distributing the protection plan to all stakeholders to implement.

Each of these steps is discussed below.

STEP 1: Identify the scope of the protection plan

It is essential that the scope of the protection plan be established at the beginning of the planning process. Scoping sets the boundaries for what can be achieved and also aids identification of constraints (and actions to

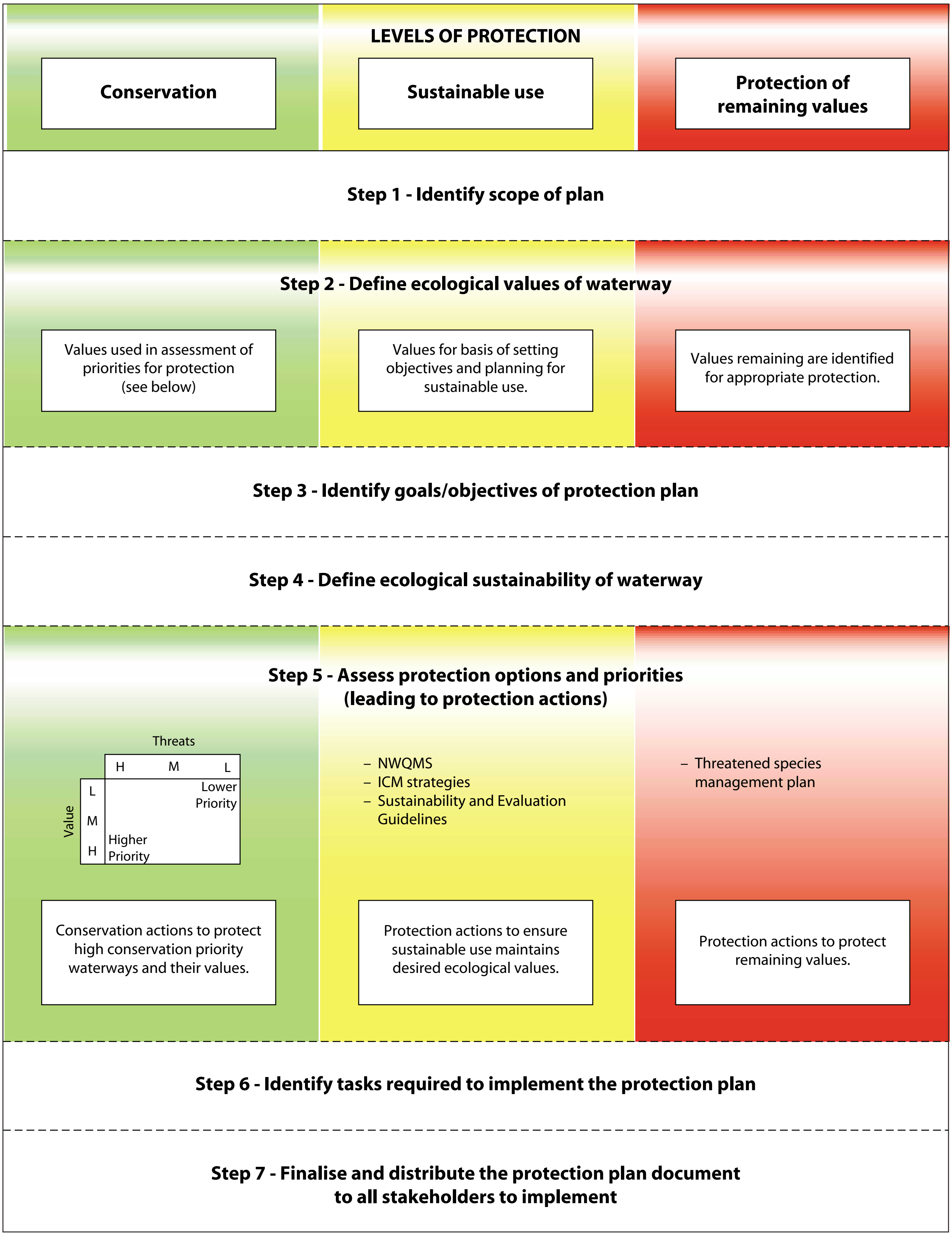

Figure 19. Developing a protection plan.

overcome them). Scoping typically involves consideration of:

- desired outcomes;
- potential impacts to be assessed;
- priorities and how they will be addressed;
- geographic boundaries and scale issues;
- context (biophysical, socio-economic and jurisdictional);
- other related planning exercises;
- resources available to develop the plan, including scientific, participatory and managerial tools, as well as funding and timing;
- stakeholders involved; and
- roles and responsibilities.

STEP 2: Define ecological values of the waterway

A vision must translate to specific goals/objectives, which must relate to the ecological values.

There is no single methodology for determining ecological values of waterways. The chosen methodology will be influenced by the end-use of the assessment, availability of information to address the criteria, time and resources available to undertake the assessment, and skills of the practitioners.

The ecological value guideline, based on reviews by Dunn (2000) and Phillips et al. (2001), outlines a number of methods used to determine ecological value.

For the three levels of protection in the vision, use the identified ecological values in the following ways:

- *for conservation of representative sections of waterways*, to provide information on waterways of high conservation value (this is used in the assessment of conservation priorities presented below);
- *for all waterways*, to assist in determining the sustainable uses and impact levels, for example to assist in determining appropriate environmental values and water quality objectives (see Appendix D4, which discusses the relationship between ecological values and environmental values as defined in the National Water Quality Management Strategy); and
- *for degraded waterways*, to identify particular remnant values of the waterways that need protection.

STEP 3: Identify goals/objectives of the protection plan

Once the vision statement has been endorsed and ecological values defined, the next step is to translate them into meaningful ecological goals/objectives for execution through a protection plan.

The vision statement(s) needs to be detailed to list goals based on more specific assessments of ecological values, for example:

- priorities for waterway conservation (these might derive from ecological value assessments of waterways and priority setting, as presented below);
- goals for protecting specific components of the waterway (eg. riparian vegetation, aquatic macroinvertebrates and macrophytes, fish, habitats); and
- protection of extant ecological values (eg. rare and threatened species).

As outlined below, the protection plan should include actions to achieve goals, and success in achieving goals will need to be measured against preselected benchmarks.

STEP 4: Define ecological sustainability of the waterway

The ecological sustainability guideline (Part C) includes a method to assess the ecological sustainability of waterways. It is based on a strategic environmental assessment process and has the following steps:

Step 1: Understand and classify the diversity of waterway types in the targeted area.

Step 2: Select the appropriate scale of assessment.

Step 3: Assess stability, vulnerability and responses using pressure–state–response indicators and thresholds.

Step 4: Chart trends using strategic environmental assessment.

Step 5: Finalise conclusions by expert panel.

This method includes defining the sustainability limits of the waterway by assessing its stability and vulnerability. It also includes identifying and assessing the risks of current and potential threats to waterway values. Examples of such threats include:

- in-stream barriers;
- clearing of vegetation and changes in land use;
- cattle access;
- point or diffuse source pollution from land uses;
- weed infestations (riparian and aquatic);
- exotic fauna species;
- overfishing;
- sand and gravel extraction; and
- sedimentation.

Such threats should be considered in terms of short and long-term time frames, so that longer-term sustainability issues can be accommodated.

STEP 5: Assess protection options and priorities (leading to protection actions)

Assessing protection options

(a) *Conservation of representative sections of waterways*
The 'priority-setting process' developed below sets conservation priorities based on ecological value and sustainability/threats, in line with the conceptual framework for these guidelines.

After the relative ecological values, threats and priorities have been identified, planning processes can be used to identify alternative instruments. These should be assessed to determine an agreed mix of actions to protect the identified values, taking into account the scale of the plan, threats, available resources, timing, and so on.

Such planning processes are used by government and catchment management and other planning groups. The types of instruments relevant to conservation of representative sections of waterways include the holistic instruments (eg. State rivers policies) supported by relevant component and value-specific instruments (where they are needed to achieve protection of, for example, natural flows).

(b) *Sustainable use*
Assessing protection options is an integral step in all ICM planning studies. These studies typically determine the values of the waterways (ecological value guideline), establish sustainability thresholds/targets to maintain these values, assess current and future threats (sustainability guideline), evaluate alternative management options and develop plans for mitigating current threats and managing future threats. Examples of such planning include:

- the New South Wales Salinity Strategy (DLWC 2000);
- the Murray–Darling Basin Integrated Catchment Management strategy (MDBMC 2001);
- the Victorian CMA's Water Quality and Nutrient Management Plans, for example the Draft Ovens Basin Water Quality Strategy (DNRE 1998); and
- the South-east Queensland Water Quality Management Strategy (SEQRWQMS 2000).

The types of instruments relevant to sustainable use of waterways include the holistic instruments (eg. catchment planning) supported by relevant component and value-specific instruments to achieve the identified protection objectives.

Once these plans/strategies are in place, the evaluation guideline (Part E) is intended to assist with evaluating development plans and project impact assessments to demonstrate ecological sustainability.

(c) *Protection of remaining ecological values*
Once remaining ecological values and threats to these values have been identified, alternative instruments to protect these values should be identified and assessed. This will then determine an agreed set of actions to protect the values, taking into account threats, available resources, timing, and so on.

The types of instruments relevant to this form of protection are more likely to be value and component-specific, relating to the particular remnant values, such as threatened-species management plans.

Priority-setting processes

The aim in setting priorities should be to maximise the ecological outcome (ie. protecting the values of the waterway) from the actions, consistent with the vision or goal. In this guideline, conservation priorities result primarily from consideration of ecological values and threats to those values, with social, economic and cultural outcomes subordinate.

Some examples follow as background to a recommended method for setting priorities for protecting waterways.

Example: New South Wales' Stressed Rivers Assessment (DLWC, 1998)

The New South Wales' Stressed Rivers Assessment (DLWC 1998) considered both hydrological and environmental stress on waterways to produce the prioritised action matrix shown in Appendix D6. The 3x3 matrix is a combination of two stresses, hydrological and environmental, and suited the primary objective of the process, which was to prioritise management actions for 'stressed' systems.

The classification process also attempted to identify all sub-catchments that have special conservation value. This may relate to the presence of threatened or high-value species, high-value wetlands, or high levels of biodiversity. Special conservation values may also reflect pristine or near pristine condition of waterways. Indicators of environmental value were developed and assessed by the National Parks and Wildlife Service and NSW Fisheries. Indicators included overall physical disturbance level of waterways (Australian Heritage Group database), presence of wetlands, national park (or similar), riparian vegetation, water birds, threatened species, fish species diversity, and absence of alien fish species. Based on these data, the agencies assigned an environmental value, high conservation value or no identified conservation value to each sub-catchment.

In this initial classification, the New South Wales Government needed a rapid assessment. However, New South Wales is currently revising the high conservation value assessments and, in the process, developing a more robust assessment method.

A similar matrix approach combining two 'stressors' was used by the United States Environmental Protection Agency (USEPA 1989) to assess the potential for eutrophication in their east coast estuaries. The two axes of the matrix represented the soluble (water) and particulate (sediment) nutrient stresses. One slight difference to the New South Wales matrix was that it did not attempt to 'box' various estuaries into the cells of the matrix. Rather, it placed the status of each estuary in the matrix 'space'. This allowed the matrix to perform two functions: first, to show the relative status of the various estuaries, and second, to show the implications for the status of changes in levels of both forms of nutrients. The latter function can be more easily understood by stakeholders who are able to help solve the problem.

The conceptual framework for waterway protection is based on a similar 'matrix' concept but combines 'value' × 'stress' rather than 'stress' × 'stress' (see Figure 20).

This process is similar to a simplified framework based on 'value' and 'risks to sustainability' that has been used for priority setting for Melbourne waterways (Heron et al. 1999) and described in Appendix D7. The Heron et al. technique used a rating system based on descriptors for four indicators of value and six indicators of threat. The overall risk for each waterway was determined by the product of the total value score and the total risk score. The consequences of risks were then assessed as a means of identifying priorities and strategies. An interesting feature of the approach was the flexibility of the analysis/outputs, which apparently helped to identify specific management responses (eg. weed control).

By adopting the 'value' and 'threat/risk to sustainability' matrix, conservation priorities can therefore be developed by combining the ecological value guideline (to derive the position on the 'value' axis) and ecological sustainability guideline (to derive the position on the 'threats' axis). The resulting matrix can then assist with both:

- deriving protection priorities (using the relative positions on the matrix) and categorising appropriate management responses; and
- assessing the consequences of:
  1. threatening processes (using an appropriate risk assessment methodology); and
  2. 'repair' actions

  by plotting the resultant 'trajectory' on the matrix that results from the increased pressure on or 'repair' of the system.

Data deficiencies: Priority setting may be difficult where data are limited or absent. In such situations the use of an expert panel can be an effective compromise.

STEP 6: Identify tasks required to implement the waterway protection plan

From the assessment in the previous step of options and priorities for all three levels of protection, a set of protection actions and priorities results. Once these are determined and endorsed by stakeholders, the tasks required to implement them must be defined and assigned to appropriate stakeholders for action. The agreed actions will then be incorporated as protection components of the final waterway management plan.

STEP 7: Finalise and distribute the protection plan document for implementation

All the previous steps need to be consolidated in a document that can be used by all stakeholders. This will allow everyone to see clearly all roles and responsibilities, and will facilitate the implementation of the tasks to achieve the shared vision.

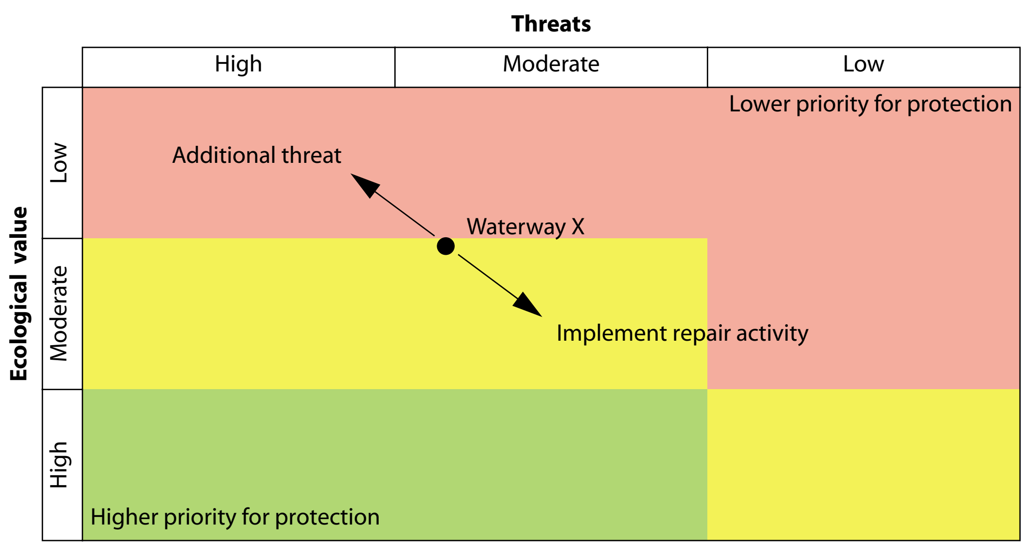

Figure 20. Example of a conservation priority-setting process.

7 The challenge: balancing conservation, development and repair activities

The challenge in waterway management is to get the balance right between protection/conservation, sustainable development and repair activities. There is mounting argument that Australia needs to do more to protect its waterways (see article on next page).

This guideline is focused on the protection/conservation end of the waterway management continuum. It recognises that further ecologically sustainable development will occur in Australia and that significant investments (eg. Natural Heritage Trust funding) are being made in the rehabilitation of degraded waterways.

The guideline advocates that, in all water planning activities, the stakeholders should consider all three activities distinctly and use this document to guide their waterway protection planning.

Benefits of a healthy river system flow through – reserves would help protect pristine waterways

A statement by Professor Peter Cullen, chief executive of the Cooperative Research Centre for Freshwater Ecology and recipient of the Prime Minister's Environmentalist of the Year 2001 Award, from The Australian*, August 2001*.

Most people realise that our rivers are one of our most important natural assets and need to be protected from further degradation. We are spending billions of dollars trying to repair the damage we have done to our catchments and their rivers without paying much attention to protecting those that have not yet been damaged.

It is important that we identify river systems that are still in good condition and prevent further degradation or loss of biodiversity.

It is my belief that we need to establish a national system of heritage river reserves, similar to national parks, although ones where we allow present land uses to continue. We should prohibit further extraction of water from these designated rivers or intensification of land use in their catchments as the first step towards protecting them.

A system of river reserves will do four things. It will protect some internationally unique river systems for the enjoyment and education of Australians. It will help meet Australia's international obligations on protecting biodiversity. It will allow the development of benchmarks of river health so that we can assess how developed rivers change over time. It will allow rivers to act as biological 'seeding' sources for rivers downstream that are degraded, helping to restore downstream rivers to a healthy state.

The states have established processes for identifying rivers with high conservation value. The Paroo River and Coopers Creek are examples of relatively undamaged rivers in Queensland, and the Ovens in Victoria. Other important and relatively unspoiled rivers worthy of attention include the East Alligator in the Northern Territory, the Clarence in New South Wales and the Fitzroy in Western Australia.

In return for designation that gives longer-term protection, landholders and managers could be given access to funding for actions that improve river health. These might include the building of fish ladders to allow free movement of fish through weirs and restoration work to restore and protect riverbank vegetation. The Federal *Environmental Protection and Biodiversity Conservation Act* would be a suitable legislative vehicle, but it must be done in partnership and cooperation with the states.

The trouble with the current state approach is that it leaves the designated rivers vulnerable to pressure with a change of policy or government. It doesn't provide the long-term protection we need to guarantee the health of these rivers. The current protection is limited, and the pressures to 'develop' these water resources will increase as water becomes scarce and the price of it continues to escalate, or even during a big drought. Pressures on state ministers in these situations can be intense.

What we need now is a formal system of designation that provides ongoing protection for these rivers, without affecting present farming in those catchments.

Why should it be a national priority to protect the freshwater biodiversity we have left? Because we are fast losing the biodiversity from some rivers – 50 per cent of our wetlands have already been lost. These are rich storehouses of biodiversity. Sixteen per cent of our amphibians and nine per cent of our freshwater fishes are extinct, threatened or vulnerable.

Biodiversity is vital for our continued health and prosperity. Apart from its role in helping to provide fresh drinking water, biodiversity in rivers also helps to alleviate floods, remove pollutants, trap sediments and moderate toxic algal blooms. These are the valuable services that river ecosystems provide for us.

Biodiversity of rivers can also be important for biotechnology. The patent for polymerase chain reaction, a technique that dramatically boosted the biological revolution, sold for $US300 million ($588 million). This technique rests upon enzymes isolated from heat-resistant bacteria in thermal springs. The economic benefits to society are invaluable.

Scientists, policy makers and managers who attended the recent Fenner 2001 conference on aquatic biodiversity agreed on two other national priorities for protecting aquatic biodiversity. First, to develop a coordinated approach to manage the effect of invasive exotic species, such as carp, and second, to increase the investment in determining what freshwater biodiversity is left and where it resides.

We already have numerous strategies and plans in place, but they need to be translated into action by government, managers and the community. Without action, we will be left with the best-documented extinctions in history.

Appendix D1

Management roles for waterways

Doolan (2000) discussed a management framework for waterways from the national to local level in the context of the Victorian River Health Strategy. Consideration of the roles at different levels of management is important in the context of the scale of planning for waterway protection and achieving the right 'mix' of planning for waterway protection. Appendix D2 provides examples of a range of planning instruments that could potentially be used to protect waterways.

Doolan (2000) outlined the following roles at different levels of waterway management:

National role

- funding to States, groups and individuals to achieve national objectives;
- facilitates interstate coordination;
- invests in development of national principles, best management practices, tools, research and development to facilitate improved management; and
- ensures Australia meets its international obligations.

State role

- sets State-wide policy and strategic directions;
- establishes legislative and regulatory frameworks;
- establishes institutional arrangements;
- invests in provision of advice, research and monitoring, planning, extension, on-ground works and enforcement functions;
- implements State responsibilities under nationally agreed strategies; and
- provides funding to groups and individuals to achieve State and regional priorities.

Regional role

- develops regional strategies and action plans;
- provides advice to State on regional resourcing priorities;
- coordinates and implements work programs;
- provides incentives and support for groups and individuals; and
- provides mechanisms for community involvement in natural resource management.

Local government role

- incorporates waterway management objectives, priorities and actions into statutory planning processes; and
- provides local support for local action groups.

Landcare (community) groups' role

- smaller-scale waterway and catchment management projects.

Landholders' role

- land stewardship.

Appendix D2

Examples of instruments relevant to the protection of waterways

Table D2.1. Examples of legislative protection of waterways.

Instrument	Jurisdiction	How does it work?
Heritage Rivers Act 1992	Victoria	Provides for the protection of public land – in particular, parts of rivers and river catchment areas in Victoria with significant nature conservation, recreation, scenic or cultural heritage attributes. Requires that a management plan be prepared. Restrictions on developments.
Wild and Scenic Rivers Act 1968	United States	Establishes the National System. Declares a national policy to preserve certain rivers and their immediate environments, maintain free-flowing conditions, protect water quality and fulfil other vital national conservation purposes.
National Parks and Wildlife Service Act 1974	NSW	Can declare wild and scenic rivers, as well as national parks.
Beach Protection Act 1968	Queensland	Provides for the surrender of land specifically for the purposes of beach protection and coastal management.
Resource Management Act 1991	New Zealand	Establishes process for managing natural resources. Can establish a Heritage Order to protect the heritage characteristics of a particular place. May include special cultural, architectural, historical, scientific, ecological or other interest. May include part of the land surrounding a protected place.

There is a considerable range of legislation that could potentially influence conservation outcomes for waterways. However, there is very little direct legislative protection of waterways in Australia, with the Victorian *Heritage Rivers Act 1992* and the New South Wales *National Parks and Wildlife Services Act 1974* being the only examples known to date. Legislation that results in the establishment of national parks or other conservation areas may result in the protection of waterways, but such legislation does not specifically identify the importance of waterways in their own right. Some waterways may receive protection if they flow through a national park or other protected area, although protection of waterway values is not guaranteed unless upstream and downstream activities are also managed to maintain such values.

Table D2.2. Examples of legislative protection of flora and fauna.

Instrument	Jurisdiction	How does it work?
Fisheries Act 1982	Western Australia	Can declare fish habitat protection areas.
Fisheries Act 1968	Victoria	Provides basic powers to protect threatened fish species listed under the *Flora and Fauna Guarantee Act*.
Tasmanian Fisheries Act 1959	Tasmania	All freshwater species are protected.
Fisheries Act 1982	South Australia	Freshwater fish can be protected. Aquatic reserves can also be declared.
Australian Capital Territory Fishing Act 1967	Australian Capital Territory	Provides a range of controls and regulations for fish species. Contains limited protection for endangered species of aquatic habitat.
Fisheries Act 1999	Northern Territory	Can declare fisheries management areas.
Fisheries Act 1994	Queensland	Aims to conserve fish stocks, key fish habitat, threatened species, populations and ecological communities of fish, and promote viable commercial and recreational fishing. Can declare fish habitat areas, which can be used to protect specific fisheries values.

Table D2.2. (cont'd) Examples of legislative protection of flora and fauna.

Instrument	Jurisdiction	How does it work?
Marine Parks Act 1982	Queensland	Establishes marine parks
New South Wales Fisheries Management Act 1994	NSW	Aims to conserve fish stocks, key fish habitat, threatened species, populations and ecological communities of fish, and promote viable commercial and recreational fishing.
Nature Conservation Act 1980	Australian Capital Territory	Threatened species of fish and invertebrates can be listed.
Threatened Species Conservation Act 1995	NSW	Aims to conserve threatened aquatic species (excluding fish) such as frogs, platypus and aquatic plant species.
Nature Reserves	Australian Capital Territory	The entire length of the Murrumbidgee River in the ACT is managed as a series of nature reserves and offers a degree of protection to the surrounding riverine environment.
Environmental Protection and Biodiversity Conservation Act 1999	Common-wealth	Provides protection for nationally threatened species and ecological communities and for Ramsar Convention wetlands/habitats.
Wilderness Protection Act 1992	South Australia	Allows for the identification and establishment of wilderness areas.
National Parks and Wildlife Act 1970	Tasmania	Includes all threatened wildlife across all land tenures.
National Parks and Wildlife Conservation Act 1975	Common-wealth	Establishes national parks
Victorian National Parks Act 1975	Victoria	Establishes national parks
National Parks and Wildlife Act 1972	South Australia	Allows for the protection of habitat and wildlife through the establishment of reserves (both on land and in State waters).
Territory Parks and Wildlife Act 1977	Northern Territory	Provides protection for non-fish species of freshwater aquatic life.
Environmental Protection Act 1986	Western Australia	Can declare threatened species.
Threatened Species Protection Act 1995	Tasmania	Includes all threatened species of flora and fauna on any land tenure
Wildlife Act 1975	Victoria	Aims for the protection and conservation of, sustainable use of, and access to wildlife.
Nature Conservation Act 1992	Queensland	Allows for the listing of threatened species, communities and habitats. Allows for designation of protected areas.
Flora and Fauna Guarantee Act 1988	Victoria	Aims to guarantee that all taxa of flora and fauna and ecological communities in Victoria can survive and flourish and retain their potential for evolutionary development in the wild. Can list species, communities and threatening processes, which conveys specific management actions.
World Heritage Properties Conservation Act 1983	Common-wealth	By nominating areas, the Commonwealth Government is obliged to ensure protection. For areas over which it has no 'title', the process relies on negotiation and funding and regulating Commonwealth decisions in and affecting such areas.
IUCN Threatened Species	Common-wealth	The IUCN Red Lists of Threatened Species are compilations of plant or animal species categorised as critically endangered, endangered or vulnerable according to IUCN Categories of Threat.

Although there appears to be considerable opportunity for the protection of species through legislation, few aquatic species are actually included. Generally, this is a consequence of lack of information on relative significance, which stems from a lack of knowledge about relative distribution, abundance and ecology, as well as poor taxonomic resolution of many aquatic fauna and flora groups. In addition, some of the fisheries legislation is targeted at preserving recreational and commercial fisheries rather than at conservation.

Given the complexities of aquatic environments, there is a need to consider legislative protection of aquatic communities/ecosystems rather than simply concentrating on individual species. Such an approach is used in some legislation, for example the *Environment Protection and Biodiversity Conservation Act 1999.*

Table D2.3. Examples of legislative protection of water quality/quantity.

Instrument	Jurisdiction	How does it work?
Catchment and Land Protection Act 1994	Victoria	Provides a framework for integrated management and protection of catchments. Encourages community participation.
Conservation and Land Management Act 1984	Western Australia	Enables inland waters to be declared as parks.
Native Vegetation Act 1991	South Australia	Aims to retain native vegetation and encourage its management.
Environmental Protection Act 1994	Queensland	Contains provisions for the management of both point and diffuse water pollution sources.
Environment Protection Act 1970	Victoria	Regulates environmental management activities.
Water Act 2000	Queensland	Establishes a framework for allocating water for environmental needs and for developing land and water management plans.
Water Management Act 1999	Tasmania	Provides for the development of water management plans, which address environmental flow requirements
Water Management Act 2000	NSW	Provides for the development of water management plans, which can include identification of zones in which development must be controlled.
Water Resources Act 1997	South Australia	Catchment water management boards and water resources planning committees must prepare a water allocation plan, which must include an assessment of the quantity and quality of water required by the ecosystems that depend on the water resources. Must also include an assessment of any detrimental effects of taking water.
Water Act 1992	Northern Territory	Includes permitting for water use and management of water quality.
Water Act 1989	Victoria	Aims to protect and enhance the environmental qualities of waterways and their in-stream uses and to protect catchment conditions.
Water Pollution Act 1984	Australian Capital Territory	Regulates pollution.
Planning and Environment Act 1987	Victoria	Ensures consideration of potential environmental impacts of proposed developments.
Environmental Protection Act 1997	Australian Capital Territory	Ensures consideration of potential environmental impacts of proposed developments.

Protection of water quality/quantity is a potentially powerful instrument for protecting values of waterways, as both are key features of sustainable waterway systems. Legislation relating to water quality and quantity can be found in all States and Territories, although recognition of and commitment to the need to maintain and protect ecological values varies considerably.

Table D2.4. Examples of agreements relevant to the protection of waterways.

Instrument	Jurisdiction	How does it work?
The Convention on Wetlands of International Importance (Ramsar Convention)	All	Entered into force in Australia in 1973. Originally targeted at preserving important habitat for migratory species. Widened and renamed in 1990 to reflect the preservation and maintenance of wetlands.
Bilateral agreements with both Japan (JAMBA) and China (CAMBA)	All	Protect species of birds that migrate between signatory countries.
World Heritage Convention 1972	All	Defines criteria for designation of areas/sites that contain the most important and significant natural habitats where threatened species of outstanding scientific or conservation value still survive.
Agenda 21	All	Action plan to assist nations in the adoption of environmental protection instruments.
Intergovernmental Agreement on the Environment (IGAE) 1992	All	Documents matters agreed between Commonwealth , States/Territories and local government to share responsibility for the environment.
International Convention of Biological Diversity (signed 1992, ratified 1993)	All	Provides a framework for global action to conserve and sustainably use biological diversity, taking as its primary aim the conservation of the maximum possible biodiversity for the benefit of present and future generations and for its intrinsic value.
Regional Forestry Agreements (RFAs)	All	Seek to conserve the full suite of environmental and heritage values that forests can provide for current and future generations by ensuring the forest conservation reserve system is comprehensive, adequate and representative, and through complementary ecologically sustainable management of forests outside reserves in regions to which RFAs apply.

Australia's National Strategy for Ecologically Sustainable Development (NSESD) acknowledges the national and international dimensions of sustainable development. The NSESD calls for a policy framework to support the efficient and environmentally responsible development of the nation's resources. Within the framework of the NSESD, a number of strategies and plans provide a focus for particular resource issues, including the National Strategy for the Conservation of Australia's Biological Diversity, the National Water Quality Management Strategy and the Council of Australian Governments' (COAG) Water Reform Framework. There are various agreements and policies addressing protection of waterways/wetlands of national or international importance, for example the Ramsar Convention (Ramsar Convention Bureau 1971).

Table D2.5. Examples of policies relevant to the protection of waterways

Instrument	Jurisdiction	How does it work?
Water Quality Management Policy 1997	Tasmania	Establishes water-based environmental values.
Water Environment Protection Policy	Australian Capital Territory	Establishes environmental values for waterways.
Environmental Protection (Water) Policy 1997	Queensland	Provides a framework to prevent or reduce harm to waterways. Includes a process for identifying environmental values.
State Policy of Water Quality Management	Tasmania	Establishes water quality objectives including protected environmental values (values or uses of the environment for which it is determined that a given area of environment should be protected).
Environmental Protection (Swan and Canning Rivers) Policy	Western Australia	Provides a framework to prevent or reduce harm to the rivers

Table D2.6. Examples of strategies/programs relevant to the protection of waterways.

Instrument	Jurisdiction	How does it work?
National Water Quality Management Strategy (ARMCANZ/ANZECC)	All	Adopts a consistent approach to the whole of the water cycle. Sets out the national framework within which States and Territories will develop appropriate action plans for the water in their region. Has established water quality guidelines for fresh and marine waters.
National Biodiversity Conservation Strategy	All	Developed in parallel with the Convention on Biological Diversity. Aims to bridge the gap between current effort and effective identification, conservation and management of Australia's biodiversity.
National Local Government Biodiversity Strategy	All local governments	Sets out a national plan to enable biodiversity conservation to become a mainstream function of local government. Local government is generally responsible for planning and developing control. It focuses on 'off-reserve' biodiversity management.
National Strategy for Ecologically Sustainable Development	All	Has protection of biodiversity and maintenance of essential ecological processes and life support systems as one of its three core objectives. A key element is management of biological diversity on a regional basis.
Canadian Heritage Rivers System	Canada	River must have outstanding natural, cultural and/or recreational values and a high level of public support, and it must be demonstrated that sufficient measures will be put in place to maintain values. The goal is to establish a system that reflects the diversity of Canada's river environments.
Biosphere Reserves program (UNESCO)	All	Establishes reserves servicing three complementary functions – conservation, development and logistic support. Conserves natural resources and special natural qualities.
Draft Strategy for Conservation of Australian Species and Ecological Communities Threatened with Extinction (DEST)	All	National approach to the protection of rare, vulnerable and endangered species.
National Endangered Species Program	All	Contributes to the off-reserve management of biological diversity.
National Reserve System Program	All	Includes development and refinement of methods for identification of protective areas and incentives for State and Territory cooperation and development nationally of consistent management principles for protected areas. Will help to achieve a national representative system of protected areas.
National Wetlands Program (Environment Australia)	All	Aims to promote the conservation of Australia's wetlands through a variety of actions, such as management planning for wetlands listed under the Ramsar convention, management oriented research, surveys, training programs and awareness training.
State Revegetation Strategy	South Australia	Aims to establish regional plans to incorporate revegetation and management of existing vegetation into land management plans.
ACT Nature Conservation Strategy	Australian Capital Territory	Includes management of degradation of aquatic systems through development and implementation of environmental flows, management of urban and industrial sources of pollution, through protection of riparian vegetation and through controls on exploitation of fauna/flora and minimisation of risks of introduced species.

The above examples represent a range of strategies and programs, currently in place, that broadly aim to protect values relevant to waterways (eg. the National Local Government Biodiversity Strategy). They are found at all levels of government, as well as at international levels.

Table D2.7. Examples of codes of practice relevant to the protection of waterways

Instrument	Jurisdiction	How does it work?
Mineral Exploration Code of Practice 1999	Tasmania	Provides an outline of current procedures that must be followed to obtain an approval, including controls and monitoring procedures.
National Code of Practice for Recreational and Sport Fishers	All	Voluntary agreement addressing four main areas of fishing responsibility – looking after fisheries, protecting the environment, treating fish humanely and respecting the rights of others.
Erosion and Sediment Control Code of Practice 1998	NSW	Requires preparation of an erosion and sediment control plan, including management of vegetation removal.
Code of Practice for Sustainable Cane Growing 1998	Queensland	Voluntary code that includes provision of advice about protection of remnant and riparian vegetation.
Code of Practice for Ecotourism Operators	All	Relates to encouraging sustainable and ecologically sensitive use of resources.
Forest Practices Code	Tasmania	Provides guidance on actions to be taken to minimise impacts on aquatic environments during forestry activities.

There are many activities that potentially affect waterway values. Codes of practice are intended to encourage signatories to comply with responsible standards of environmental management, including water/waterway protection.

Table D2.8. Examples of national, State, regional, catchment and river plans.

Instrument	Jurisdiction	How does it work?
National Salinity and Water Quality Action Plan	Commonwealth, State and Catchment Management Boards	Targeted national strategy to address salinity and water quality problems
Cape York Peninsula Land Use Strategy	Queensland	Multipartner project to provide a sound basis for decisions about future land use on the peninsula.
South Australian State Water Plan	South Australia	State-wide plan to address all water planning and management issues.
Victorian Catchment Management Authorities' Nutrient Management Plans	Victoria	Catchment plans to address accelerated eutrophication of waterways by developing appropriate nutrient management actions.
Salinity Strategy	NSW	State-wide plan to address increase in salinity levels in NSW waterways.
River Styles™ Assessments	NSW	Geomorphic assessments of river forms and processes, providing a biophysical basis to prioritise river management strategies.
Catchment Management Plans (Catchment Management Boards, Committees etc.)	All	Catchment plans to manage catchment activities that affect waterways' ecological values.
River Management Plans (Water Management Committees)	NSW	Undertake planning activities to manage the river and associated catchment to maintain/enhance ecological processes and biodiversity.
Water Resouce Planning process	Queensland	Identifies environmental flow provisions.
Investigations (Environment Conservation Council)	Victoria	Carries out investigations into balanced use/development of land, water, flora or fauna resources on public land. Must take account of the need to conserve and protect.
Investigations/Inquiries (Healthy Rivers Commission)	NSW	Independent commission set up in 1996 to make public inquiries into selected NSW river systems. Helps community make informed choices about how to protect and use rivers.

Although waterway protection is likely to occur mainly at a reach level, a catchment-level approach allows for a more holistic identification and management of values and threats to them. This is reflected in national and State initiatives such as the National Salinity and Water Quality Action Plan (COAG 2000) and the South Australian State Water Plan (SA DWR 2000). There are many examples of catchment-level planning processes that address waterway values, although many of these relate to maintaining condition rather than ecological value *per se* (that is, they do not consider other aspects relevant to conservation, such as diversity and rarity). Better planning can lead to better waterway management. There are many examples of catchment and river management plans throughout Australia.

Table D2.9. Examples of voluntary property-based instruments.

Instrument	Jurisdiction	How does it work?
Joint Management Areas, Protected Areas Management Scheme Agreement	Northern Territory	Established to encourage conservation of wildlife on Aboriginal land. Duration fixed or definite. Provisions for financial assistance, advice and signage.
Land for Wildlife	Victoria	Provides a framework for the support of voluntary management of wildlife habitat on private land. Does not involve landholders entering into agreements with government.
Land for Wildlife	Queensland	Voluntary, non-binding scheme that encourages and assists landholders to provide for wildlife on their properties.
Conservation Agreements	NSW	Initiated by the NSW National Parks and Wildlife Service after identification and assessment of values, but entered into with the consent of the landholder. The agreements are in effect covenants, as they run with the land title and bind subsequent owners. There may be restrictions on land use, access or management.
Conservation Covenant	Tasmania	Private landholder consents to private wildlife sanctuary being proclaimed (*National Parks and Wildlife Act 1970*). Voluntary agreement to implement management plan. Conservation covenant permanently binding.
Conservation Covenant Program	Victoria	Aims to conserve areas on private land that are ecologically significant, of natural beauty or of historical interest. Also aims to conserve wildlife and native plants. Voluntary agreement. Registered on title and binds all future owners.
Heritage Agreements	South Australia	Apply to vegetation and coastal waters. Conservation areas are leased to the State.
Nature Refuge and Conservation Agreement Schemes	Queensland	Landholder can declare part of all of property as a nature refuge. Voluntary agreement tailored to suit management needs of a particular area and needs of landholder to maintain production and economic land uses.
Private Sanctuary	South Australia	Landholders may nominate land as a private sanctuary. Can retract from nomination. No financial gain.
Wildlife Refuges, Wildlife Management Areas	NSW	Can be proclaimed if considered suitable by NSW National Parks and Wildlife Service and voluntarily accepted by landholder. Technical assistance sometimes provided in return.

Voluntary programs are often favoured over binding contractual arrangements or compensatory measures as instruments for conservation on private property. Contractually binding management agreements are not as prevalent in Australia as voluntary agreements. Most States and Territories operate voluntary schemes to protect specific habitats or to restrict farming practices. Regulatory agreements operate in some States. Even voluntary management agreements that offer financial incentives are not widespread, probably because of the ongoing funding requirements of such agreements. The financial assistance applicable as part of many of the voluntary management schemes offered by States and Territories is sometimes provided on the costs of material associated with the work required. A conservation covenant is a legally binding agreement between two or more parties to protect an area, either for a specified amount of time, or in perpetuity. They can be achieved without acquiring ownership of the land and are used in a number of States.

Table D2.10. Examples of financial and other motivational instruments.

Instrument	Examples
Charges and levies	• National Park fees
Grants	• Natural Heritage Trust (Commonwealth) • Landcare (Commonwealth) • Rivercare (Commonwealth) • Land Protection Incentive Scheme (Victoria) • National Estate (Commonwealth) • Community Salinity Grants (Victoria) • Save the Bush (Commonwealth)
Removal of perverse incentives (ones inducing behaviour that results in a loss of or threat to ecological value)	• taxation advantages for clearing of native vegetation • below-cost irrigation water pricing
Tax policy	• donations, rate relief
Education	• environmental education programs
Information supply	• revegetation guidelines

Financial instruments can include both incentives (eg. grants, compensation, payouts, etc.) and disincentives (eg. charges for activities, etc.). The use of financial instruments varies considerably throughout the country. Motivational instruments focus on provision of information and education. Information provision is essential, for only with adequate information can decision makers arrive at decisions that do not lead to unintended consequences (Young et al. 1996).

Table D2.11. Examples of voluntary action groups and programs.

Voluntary action group	Jurisdiction	How does it work?
Australian Conservation Foundation	All	Objective is to work towards a society that protects, sustains and restores the environment.
Bushcare	Queensland	Supports community, local government and industry projects on private or public land that take action to conserve remnant native vegetation, to improve the management of native vegetation, and to enhance revegetation efforts. Emphasises biodiversity conservation as an integrated component of sustainable land use.
Conservation Council of South Australia	South Australia	Umbrella organisation for approximately 60 members' groups whose purpose is conservation and protection of the environment.
Inland Rivers Network	NSW	Coalition of environment groups and individuals committed to conserving the biological diversity, natural functioning and health of the inland rivers, wetlands and groundwater of the Murray–Darling Basin.
Murray–Darling 2001	Murray–Darling Basin	This program aims to reduce, or where possible reverse, the underlying rates of natural resource degradation in the Murray–Darling Basin through an integrated catchment management approach.
National Landcare Program	All	Provides support for natural resource management projects with a production-oriented or nature conservation focus. Aims to increase knowledge about resource degradation and assist in developing economically viable and ecologically sustainable land use.
National Rivercare Initiative	All	The aim of this program is to ensure progress towards the sustainable management, rehabilitation and conservation of rivers outside the Murray–Darling Basin and to improve the health of these river systems, through the provision of funding.
Queensland Conservation Council	Queensland	Umbrella organisation for conservation groups in Queensland working for the protection and promotion of Australia's natural environment and biodiversity.
Ribbons of Blue	WA	Environmental education program aimed at increasing community awareness about local water quality and taking action. Part of the Waterwatch Program.
Rivercare New South Wales	NSW	Offers funding, technical advice and support, and information and educational material promoting best-management practices for the riverine environment.

Table D2.11. (cont'd) Examples of voluntary action groups and programs.

Voluntary action group	Jurisdiction	How does it work?
Threatened Species Network	All	Community-based network that aims to increase public awareness and involvement in the protection and recovery of threatened species.
Waterwatch	All	Raises community awareness of the natural environment and the 'wise use of natural resources' ethic in communities, and encourages on-ground community-based activities and networking.
Wilderness Society	All	National, community-based environmental advocacy organisation whose mission is to protect, promote and secure the future of wilderness and other high conservation areas.
Wildlife Preservation Society	All	Interested in the conservation of flora, fauna and habitats.
World Wildlife Fund	All	Mission is to preserve biodiversity by promoting the sustainable use of natural resources.

Programs such as Landcare are essential for ensuring practical, relevant decision making for natural resource management in rural Australia. By involving community members who naturally link social, economic and environmental aspects of their lives and who have a vested interest in change, an integrated and sustainable approach to natural resource management and rural development can be achieved. There are also many groups dedicated to the maintenance and enhancement of natural resources who form a significant resource for use in enhancing the conservation planning process. One example of such a group is the National Rivercare Program.

Appendix D3

Examples of planning processes for waterways

Figures D3.1–D3.3 provide examples of planning processes:

- Figure D3.1 illustrates Queensland's activities in implementing the National Water Quality Management Strategy (NWQMS);
- Figure D3.2 shows the basic steps for developing and implementing a plan for restoring a waterway as defined by Koehn et al. (1999) in their National River Restoration Framework.
- Figure D3.3 illustrates the 12-step procedure Rutherfurd et al. (1999) propose for stream rehabilitation.

Superimposed on each figure are the four steps in the adaptive planning and management process shown in Figure 18, namely:

- establish vision;
- develop plan;
- implement plan; and
- monitor and review plan.

To date, implementation of the NWQMS has largely focused on the 'sustainable use' level of waterway protection (see Part D, section 6). However, catchment planning using the process below could easily incorporate the other 'conservation' and 'protection of remaining values' levels of protection.

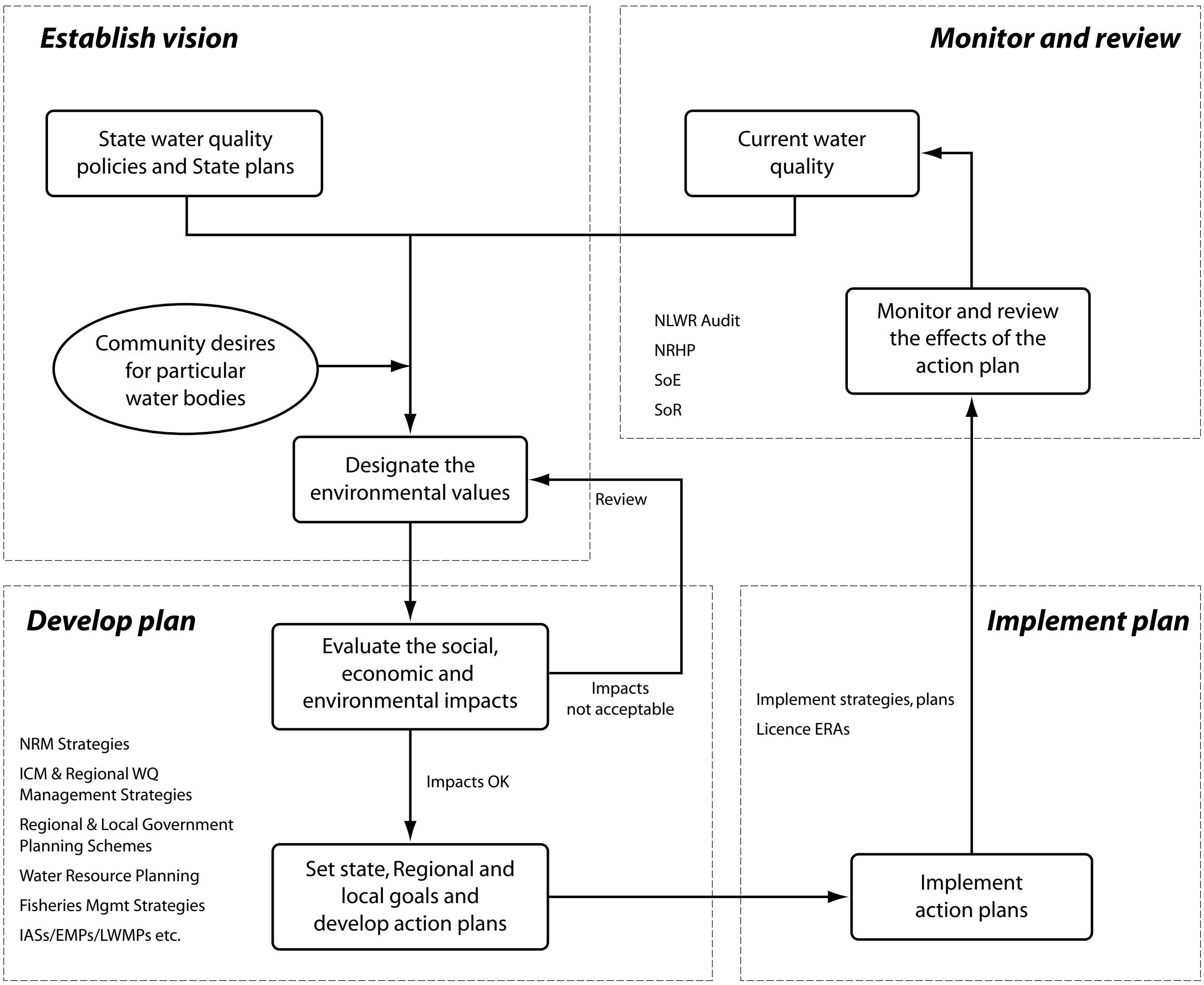

Figure D3.1. Queensland implementation of the National Water Quality Management Strategy.

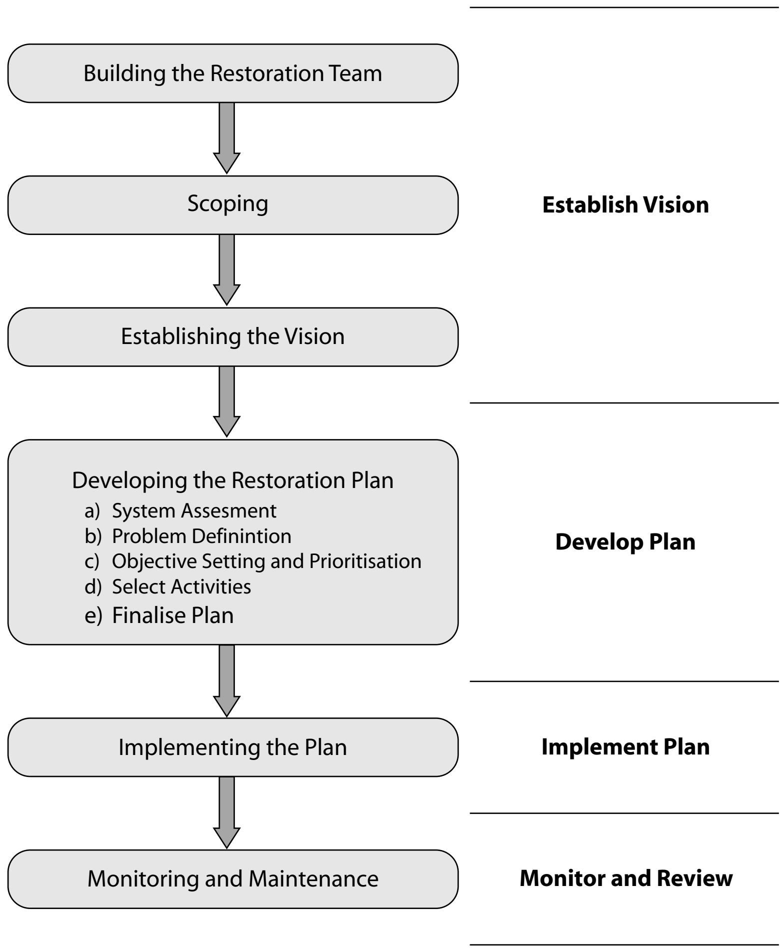

Figure D3.2. Basic steps in the National River Restoration Framework (Koehn et al. 1999).

This process and the following one have a primary focus on river *restoration*. However, their scoping, visioning, assessments, prioritisation and management actions all closely relate to similar steps for river/waterway *protection*. These processes therefore provide opportunities to incorporate appropriate protection of waterways.

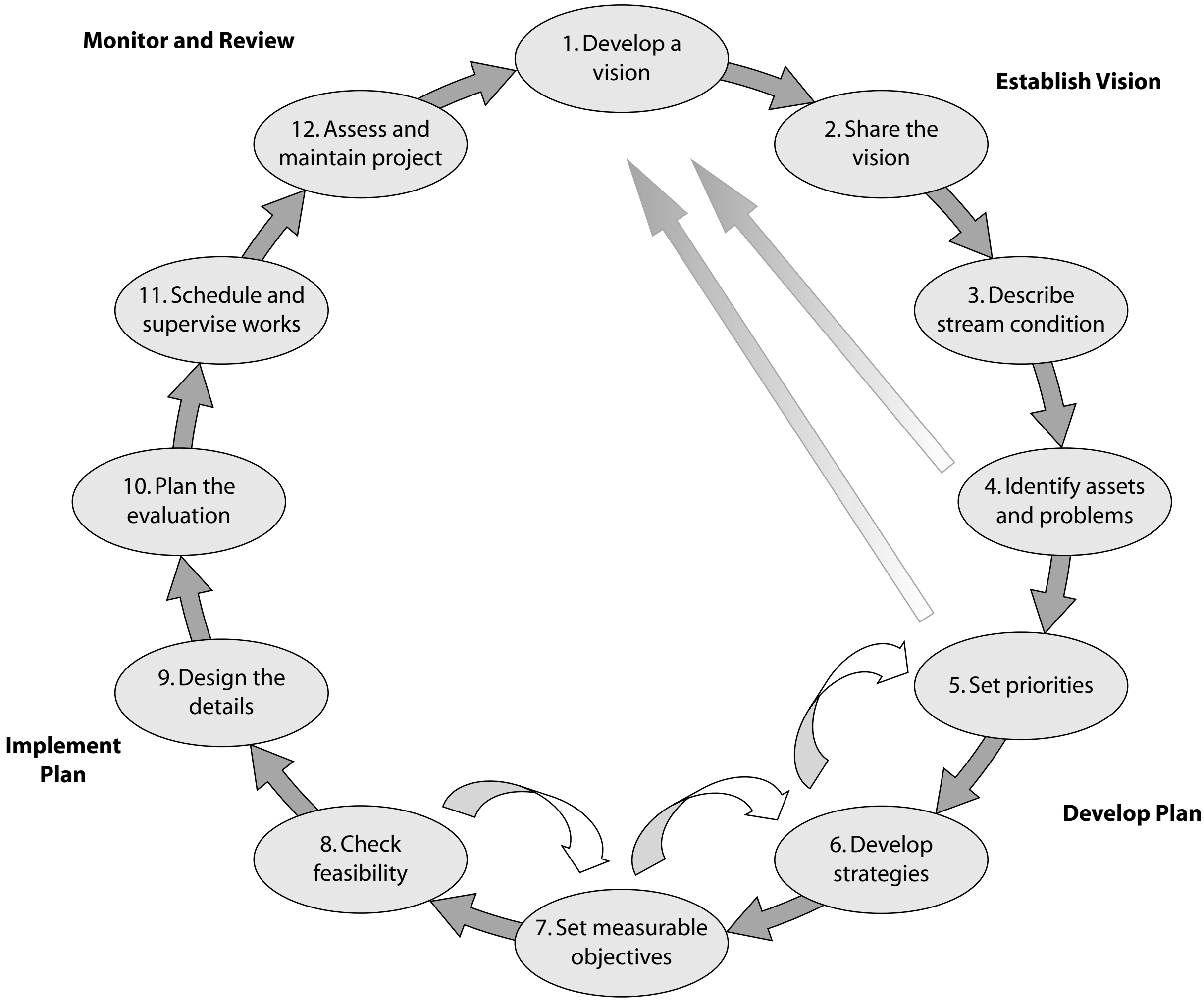

Figure D3.3. Flow chart summarising the 12-step stream rehabilitation procedure of Rutherfurd et al. (1999).

Appendix D4

What do environmental values and ecological values mean?

These two terms have arisen in the context of waterway management and the following is an attempt to show their origins, provide a definitional context for each and show how one relates to the other.

Environmental values

'Environmental values' are commonly used in the ARMCANZ and ANZECC (1994) National Water Quality Management Strategy (NWQMS) documents, and they are defined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2001) as:

> … particular values or 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. They were often called 'beneficial uses' in the water quality literature but this term has lost favour because of its exploitative connotations. For this reason, the term 'environmental value' has been adopted by the NWQMS.

In keeping with COAG's requirement for the implementation of the NWQMS, jurisdictions have embodied the concepts of environmental values and water quality objectives, based on the national guidelines, in their water (quality) management legislation and policies.

The many possible environmental qualities, characteristics or uses that could be recognised in a waterway are grouped into following broad environmental values in the guidelines:

- *Aquatic ecosystems* – maintenance or enhancement of the biological integrity of aquatic ecosystems.
- *Primary industries* (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods) – includes suitability for stock watering and irrigation, protection of environmental health to a suitable level for aquaculture operations, and protection of human health in the consumption of recreationally and commercially harvested aquatic foods.
- *Recreation and aesthetics* – suitability for primary and secondary contact recreation, as well as aesthetic enjoyment.
- *Drinking water* – includes suitability for treatment before supply for consumption.
- *Industrial water* – water quality guidelines are not provided for this environmental value.
- *Cultural and spiritual values* – water quality guidelines are not provided for this environmental value.

The national guidelines for protection of aquatic ecosystems are subdivided into three categories/ ecosystem conditions and recommend threshold levels of acceptable change for each (see quotation below). The guidelines also provide data or advice to assist jurisdictions to make their own informed decisions on the three alternative levels of protection.

> Three ecosystem conditions are recognised:
>
> 1. *High conservation/ecological value systems*. Effectively unmodified or other highly valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations…
> 2. *Slightly to moderately disturbed systems*. Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation and marine systems would have largely intact habitats and associated biological communities.
> 3. *Highly disturbed systems*. These are measurably degraded ecosystems of lower ecological value…
>
> The third ecosystem condition recognises that degraded aquatic ecosystems still retain, or after rehabilitation may have, ecological or conservation values, but for practical reasons it may not be feasible to return them to a slightly to moderately disturbed condition.
>
> A level of protection is a level of quality desired by stakeholders and implied by the selected management goals and water quality objectives for the water resource. The water quality objectives may have been derived from default guideline values recommended for the particular ecosystem condition, or they may represent an acceptable level of change from a defined reference condition; it can be formalised as a critical effect size. Where appropriate, the reference condition is defined from as many reference sites as practicable using pre-impact data where appropriate. The reference condition could correspond to one of the three recognised condition levels described above, depending upon the desired level of protection.
>
> Key stakeholders in a region would normally be expected to decide upon an appropriate level of protection based on the community's long-term desires for the ecosystem. The NWQMS *Implementation Guidelines* (ARMCANZ and ANZECC 1998) outline a framework for how this might be achieved. The philosophy behind selecting a level of protection should be (1) maintain the existing ecosystem condition, or (2) enhance a modified ecosystem by targeting the most appropriate condition level. (Thus the recommended level of protection for 'condition 1 ecosystems' (above) would be *no change* beyond any

natural variability.) This is the starting point from which local jurisdictions might negotiate or select a level of protection for a given ecosystem: in doing so, they might need to draw upon more than the general scientific advice provided in these guidelines. A number of other factors, such as those of a socio-economic nature, might need to be included in the decision-making process.

Ecological (and conservation) values

As Australian waterways have become degraded, considerable resources have been expended on river rehabilitation. However, there is an increasing focus on protecting waterways and avoiding the need for rehabilitation.

Land and Water Australia has funded several projects aimed at the protection agenda, including 'Identifying and Protecting Rivers of High Ecological Value' (Dunn 2000) and this project. Dunn provides the following notes on terminology in relation to identifying waterway values:

> 'Ecological value' for rivers is taken in its broadest sense. It includes not only the aquatic biota (fish, invertebrates, macrophytes) but also the biota of the riparian or foreshore zone, the river habitats and geomorphology. It is also taken to include the river processes, both physical and biological, and the roles a river may play in sustaining other systems such as karst, estuary, floodplains and wetlands.
>
> 'Conservation value' is sometimes used interchangeably to highlight the significance of such values in river management. There are, however, important other conservation values of rivers which are not covered in the present report. These include scenic and aesthetic values, Aboriginal cultural values and historic values, and values held by present day communities through their sense of association with the river system. All these other values should be considered in assessing conservation value as a whole.

Discussion

The term 'ecological value' closely aligns with protection of *aquatic ecosystems*, which in turn is one of the 'environmental values' (in the national guidelines). The 'ecological value' of a waterway provides more information on the current status of the aquatic ecosystems environmental value, in terms of the protection the system requires. Indeed, by using a more detailed specification of 'ecological values' when first working with the community to identify their aspirations for the *aquatic ecosystem* environmental value, the process could lead to a more reasonable and detailed expectation for this value. It could also help in any subsequent negotiations in resolving the 'agreed' *aquatic ecosystem* environmental value after social and economic considerations are included (see Figure D3.1, which shows the process for managing water quality).

The tools that are now being developed for evaluating ecological values of waterways in Dunn's work and in this project will provide an objective method for evaluating relative ecological values of waterways and the components of these values. These may well assist in refining the next version of national guidelines, for example, in defining guidelines for particular ecological values/levels of protection and perhaps replacing terms such as 'high conservation/ecological value systems', 'slightly to moderately disturbed systems' and 'highly disturbed systems'.

Appendix D5

Draft Mary River and tributaries rehabilitation plan (Source: Stockwell 2000)

The Mary River Catchment Coordinating Committee is developing a rehabilitation plan for the Mary River. The plan identifies ecological values, along with threats to the values and actions to be taken to maintain the values. Table D5.1 provides an example of the criteria used to determine various priorities. Priority category 0 has the highest priority from the perspective of protecting high-value river systems. It is intended that this prioritisation be reviewed in the context of social and cultural outcomes (Stockwell 2000).

The premise behind the approach in Table D5.1is that it is better to protect the high-value, highly threatened areas of rivers than the low-value, relatively unthreatened areas.

Table D5.1. Biophysical reach prioritisation categories

Priority category	Criterion used to set priority
0	Protecting reaches of good condition throughout
1	Protecting and restoring reaches of regional conservation significance
2	Protecting and rehabilitating reaches of local conservation significance
3	Protecting deteriorating strategic reaches
4	Improving linking/close reaches and isolated islands
5	Improving moderately damaged reaches with moderate to high recovery potential
6	Highly degraded reaches with little chance of natural recovery

This premise is consistent with that recommended by Rutherfurd et al. (1999). Their approach recommends the protection of the good before the restoration of the bad.

Appendix D6

New South Wales Stressed Rivers Assessment (Source: DLWC 1998)

	Low environmental stress	Medium environmental stress	High environmental stress
High proportion of water extracted	*Category U1* Despite high levels of water extraction the river seems reasonably healthy. However, more detailed evaluation should be undertaken to confirm. It is also likely that conflict between users may be occurring during critical periods.	*Category S3* Water extraction is likely to be contributing to environmental stress.	*Category S1* Water extraction is likely to be contributing to environmental stress.
Medium proportion of water extracted	*Category U2* There is no indication of a problem and, therefore, such rivers would be a low priority for management action.	*Category S4* Water extraction may be contributing to environmental stress.	*Category S2* Water extraction may be contributing to environmental stress.
Low proportion of water extracted	*Category U4* There is no indication of a problem and, therefore, such rivers would be a low priority for management action.	*Category U3* Environmental stress is likely to be due to factors other than water extraction and, as stress is not high, these rivers would be a low priority for management action.	*Category S5* While environmental stress is likely to be due to factors other than water extraction, the high level of environmental stress means it is important to ensure extraction is not exacerbating the problem.

Figure D6.1. Matrix of stress classifications and management categories. (Dark shading indicates categories with high combined stress rating. Lighter shading indicates categories with medium combined stress rating. Absence of shading indicates categories with low combined stress rating.)

Appendix D7

Melbourne Water's environmental risk assessment and priority-setting model (Source: Heron et al. 1999)

Another example of a priority-setting process is illustrated by the Environmental Risk Assessment and Priority Setting Model (ERAPSM), which has been developed by Melbourne Water. The model was developed in response to a need to determine waterway management activities in an environment of competing projects and limited resources (Heron et al. 1999). It is a computer-based model that interrogates information on waterway condition and calculates ratings for waterway threat, value, risk and benefit of waterway management activities according to specified rules. It uses an environmental risk-based approach to the management of waterways. Environmental risk is a function of the extent and severity of environmental threats to a waterway and the values of the waterway; the greater the risk, the greater the potential loss of values due to threatening processes. Figure D7.1 illustrates the contribution of ERAPSM to a priority-setting framework (shaded boxes).

The model uses rules to derive numerical value scores (ranging from 1 to 5). For example, a value score of 1 (very low) would be applied to a river reach where bank vegetation was largely exotic or had been cleared. Reach risk is calculated as the sum of all value scores multiplied by the sum of all threat scores. The higher the score, the higher the risk of losing the river values and hence the higher the priority for managing the threatening process. Because information is collected at the reach scale, risk can be calculated at various scales by integrating scores.

ERAPSM provides many data sorting and selection tools that can be activity specific. For example, it has been used to assist in developing a weed management works program. Priority-setting rules were established using a forum as part of an 'activity strategy' for weeds.

The rules required that:

- the highest proportion of funding should be given to waterways that exhibited high-value vegetation and moderate weed threat; and
- some funding should be provided to waterways that exhibited high-value vegetation and low weed threat.

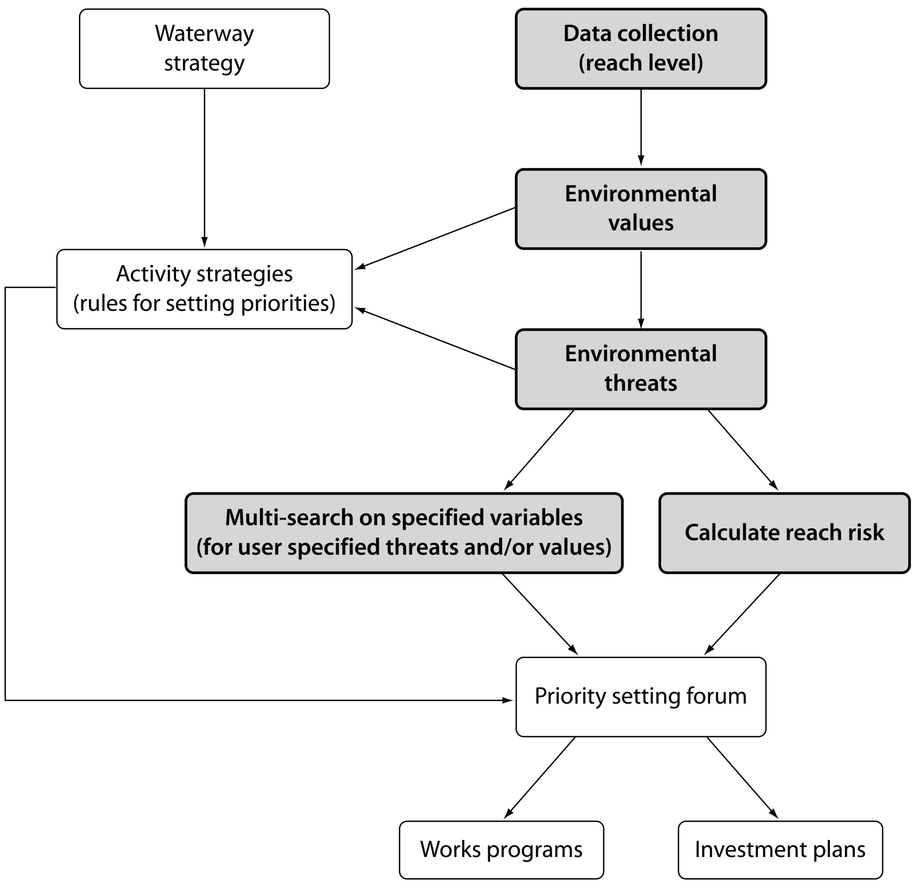

Figure D7.1. Contribution of ERAPSM to priority-setting framework (adapted from Heron et al. 1999).

Part E - Evaluation Guideline

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Dane Moulton

1 Introduction

Waterways and floodplains are affected by patterns of land use, water use and in-stream activities. A host of activities can influence these patterns, including government policy, regulation, planning, programming, development construction and operational management.

Evaluation of these activities allows decisions to be made with an understanding of their social, economic and ecological implications. Most Australian jurisdictions attempt to judge outcomes on the basis of the 'sustainability' of these three factors. There is still debate about the meaning of this term and whether there are degrees of sustainability. However, there seems to be broad agreement that it is desirable to achieve social, economic and ecological sustainability through our planning and evaluation processes.

At the strategic level (policy, planning, programming), environmental assessment processes are not usually prescribed by legislation and often occur without specific procedural guidance. Although techniques such as strategic environmental assessment (SEA) can support these processes, their deployment in Australia has not been systematic. The *Environment Protection and Biodiversity Conservation Act 1999* provides for agreements on strategic assessments, but contains limited procedural guidance.

At the project level (individual development proposals), legislative requirements for environmental assessment abound in the various Australian jurisdictions. Many development control systems are supported by published guidelines on environmental assessment, which tend to follow a checklist approach. Although helpful at the scoping stage, they are of limited assistance for the detailed preparation or evaluation of environmental impact statements.

There is no set of performance criteria available to demonstrate that a proposed land/water plan or development proposal will be ecologically sustainable. Some measures of sustainability (eg. the flow requirements for fish populations) are slowly becoming more defined but the scientific data are not comprehensive. However, it may be possible to define more precisely the natural elements important to sustainability and clarify techniques and measures for assessment. In turn, this can help to identify appropriate levels of development and management.

2 Purpose

The purpose of the evaluation guideline is:

> To provide a systematic, comprehensive and flexible method for evaluating the impacts of development plans and projects on the ecological sustainability of waterways and floodplains.

The guideline is intended to provide information about the ecological sustainability of plans or projects that can be evaluated by the community and governments. It is not intended to assist with social or economic evaluation, but it will provide more credible information for decision making.

The evaluation guideline will help with recommendations for:

- ranking of options at catchment scale (and in some cases identifying any that are potentially unsustainable on ecological grounds);
- the acceptability of the environmental impacts of proposals at subcatchment and individual project scale; and
- the level and content of environmental assessment, whether project based or strategic.

The guideline provides a greater level of detail for measuring ecological sustainability than is available in the more generic frameworks currently used to support environmental impact assessment (eg. DUAP 1996).

3 Scope

The guideline covers the natural aspects of aquatic and related terrestrial systems – physical, chemical and biological. The terrestrial focus is on floodplain and catchment interactions with waterways.

The ecological component of the evaluation process is paralleled by social, economic and engineering components that lie beyond the scope of this guideline. These other components are often the provinces of several government agencies and are usually brought together by a coordinating agency (the assessment manager). Figure 21 details the ecological component and shows how it fits into the overall decision process, which draws on all of the sectoral inputs.

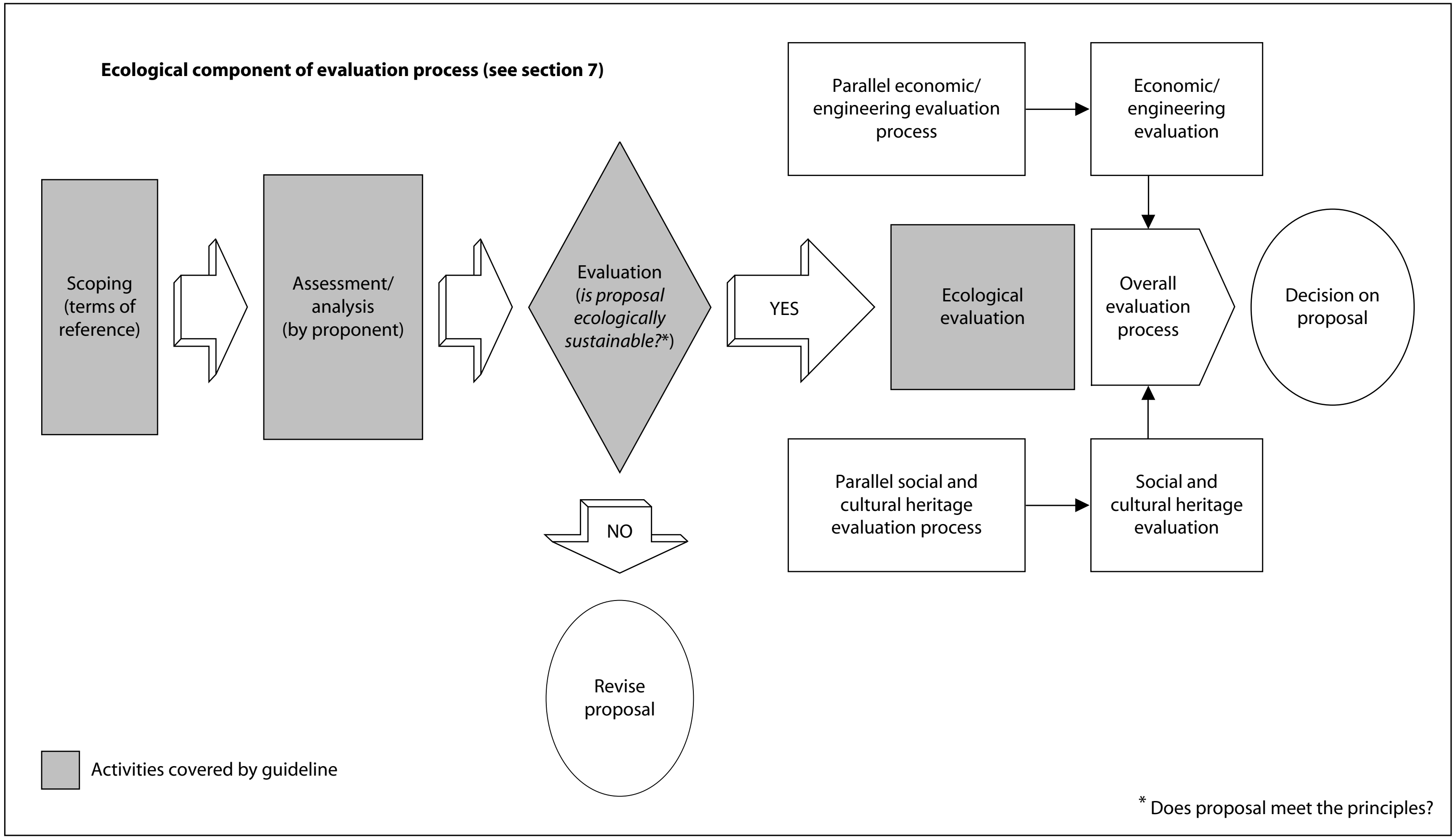

Figure 21. Context of, and process for, ecological component of evaluations.

A key point about the process is that ecologically unsustainable plans, projects or project options should be identified early in the overall evaluation process so that they can be revised before being considered further. Similarly, plans or projects would be revised for social, economic or engineering reasons.

3.1 A basis for ecological impact assessment and evaluation

The conceptual framework (Part A) introduces a simple model describing the contribution to ecosystem health that can be made by planning and development evaluation. The framework is shown in Figure 2, with the place of this guideline indicated. The information required to apply this guideline comes from:

- a checklist for developing terms of reference for environmental assessments (Part E, Appendix E1);
- ecological value criteria and indicators (Part B, Appendix B2); and
- ecological sustainability criteria (Part C, Appendix C1).

3.2 Establishing management priorities

The conceptual framework and planning guideline (Parts A and D) outline an approach to priority setting that combines ecological value and sustainability. The priorities can be addressed by integrating ecological values with actions for protecting and/or repairing waterways. Ecological evaluation is most applicable to protection, because it is the means by which decision makers can be informed of the impacts of development plans or project proposals, and identifies any need to protect all or part of a waterway. However, repair activities are also part of ecological evaluation, because they often form part of mitigation actions (such as compensatory habitat or environmental flows).

> Consider an example where a sewage treatment plant is proposed adjacent to an estuary of moderate ecological value. The estuary is already under stress, some of its key processes show evidence of being unstable, and several ecosystem components are vulnerable to threats from catchment development. Blue-green algal blooms occur occasionally and the estuary's water quality is slow to recover after floods.
>
> In conducting an impact assessment, it is critical to identify those impacts of the proposal that are the greatest threat to specific ecological values (such as the potential for higher nitrogen loads to allow planktonic and epiphytic algae to dominate primary production, at the expense of natural seagrasses and macroalgae). This provides a more credible basis for recommending whether further effluent discharges can be sustained, and how the discharges should be managed.

4 Concepts and approach

4.1 Defining an acceptable development

The critical question for ecological impact evaluation is 'what constitutes an acceptable development?' Acceptability is used here in a predominantly technical rather than political sense. In other words, the ecological assessment is about defining whether a proposal maintains ecological values and is ecologically sustainable. Integration with the economic, social and equity considerations in the decision-making process should follow, rather than precede, consideration of ecological impacts. Otherwise, projects with sufficient economic/social benefits could be deemed acceptable, regardless of the level of environmental harm. Figure 21 shows this 'filtering process', in which only those proposals that are ecologically (and in a similar way, socially and economically) sustainable proceed to an overall evaluation.

To address the ecological 'acceptability' question, this guideline recommends assessment against the principles for waterway protection suggested in Part A, section 5. These principles are reproduced in section 5 of this guideline. Simply put, the acceptability of a development is determined in the context of the level of protection and/or use proposed for a waterway. In a waterway of high ecological value for which a higher level of protection is proposed, a development would only be considered acceptable if it did not diminish those values. This suggests that all functions and structures associated with the waterway would need to be retained in their natural condition.

In other waterways for which some alteration of structures and functions may be acceptable, a development must demonstrate that essential processes and key structural elements will not be compromised. The planning guideline (Part D) provides further discussion on the level of protection proposed for waterways (higher-level protection, ecologically sustainable use, etc.)

The principles used in Table 8 have been developed for the two levels of waterway protection, recognising that all would be the subject of assessment against ecological sustainability criteria, while some higher-value waterways would have additional principles to ensure their continued protection.

The impact assessment process can help to meet the principles and assist proponents and decision makers to:

- base decisions on sound environmental information (ie. proposals must include sufficient information and analysis);
- address cumulative impacts;
- apply the precautionary principle in cases where uncertainty exists (eg. due to inadequate data or insufficient knowledge on impacts);
- minimise avoidable impacts and the risk of unforeseen impacts;
- involve stakeholders, addressing their legitimate concerns in the assessment processes;
- conform with government legislation, and conservation and environment policy (international, national, State and local); and
- use best environmental practice for planning, design, construction and operation.

Evaluation against these principles should take into account any proposed mitigation, including techniques such as rehabilitation, compensatory habitat provision and environmental flow provisions. The corollary is that certain projects may be evaluated as unsustainable, but can be made sustainable through mitigation.

Case Study: Ord River Irrigation Area Stage 2 (Western Australia)

The Western Australian Environmental Protection Agency (EPA) provided advice and recommendations to the Minister for the Environment regarding the proposed export-based raw sugar industry near Kununurra in the Kimberley region. This involved assessing the acceptability of clearing approximately 34,000 hectares and the potential consequent loss of biodiversity.

The EPA recognised that biodiversity has two key aspects – its intrinsic value at the individual species, species-assemblage and genetic levels, and its functional value at the ecosystem level.

The terms of reference for the environmental impact statement required consideration of biological diversity, including:

- comparison of a number of development scenarios to evaluate protection of biodiversity at the species and ecosystem levels;
- no extinctions of known species of plant or animal, and acceptable risks to threatened species;
- no association or community of indigenous plants to cease to exist;
- comprehensive, adequate and secure representation of scarce or endangered habitats within the project area and/or in biologically comparable areas in Western Australia and the Northern Territory; and
- the project area to include a comprehensive and adequate network of protected conservation areas and linking corridors.

In evaluating the proposal, the EPA adopted the following biodiversity objectives:

- maintain biological diversity (meaning the different plants and animals and the ecosystems they form) at the levels of genetic diversity, species diversity and ecosystem diversity;
- protect species listed under relevant Western Australian, Northern Territory and Commonwealth legislation; and
- retain 30% of all vegetation associations and communities mapped within the project area.

Biodiversity protection targets set by the EPA were based on thresholds. Species loss appears to accelerate exponentially at the ecosystem level when less than 30% of the natural vegetation extent remains, and stream reserves should generally be around 200 metres wide.

The project evaluation attempted to determine whether there will be any change in environmental values and the links between various ecosystem components, and whether the effects will be so great as to destroy the values and attributes of those components. In terms of links between ecosystem components, important ecosystem drivers that relate to the proposal included seasonal flow regimes, hydro-geomorphological processes and groundwater levels.

As a result of the evaluation by the EPA and other stakeholders, the project outcomes are expected to be:

- increased buffer areas to include additional riparian vegetation;
- a buffer management plan to protect the environmental values of the buffer and designate responsibilities for management;
- reservation of 'conservation initiative areas' by the Western Australian and Northern Territory governments, including protection of a nature reserve of high conservation value;
- a flora and fauna survey plan aimed at conserving and protecting listed species, vegetation associations and communities, and aquatic fauna species;

- levees designed to enable natural flooding and permit surface water ingress; and
- farm units designed to reduce flow velocities and potential erosion effects.

Although the development of the project will change several watercourses and modify habitat over the long term, the impacts are not expected to be significant, provided that comprehensive and effective protection/management is in place.

(Source: WA EPA 2000)

4.2 Levels of assessment

The two types of assessment considered under the generic heading of 'environmental assessment' are:

- strategic environmental assessment (plans, policies and programs); and
- environmental impact assessment (projects).

Strategic environmental assessment (SEA) helps scope projects and compare options by integrating stakeholder involvement with the planning phase (NLWRA 1999). This allows a more systematic approach to assessing the social, economic and environmental ramifications at a higher level, where data requirements are generally less intensive.

Environmental impact assessment (EIA), featured in all Australian jurisdictions, usually analyses significant potential impacts in some detail. Proponents develop the products (eg. environmental impact statements or reviews of environmental factors) by following terms of reference usually set by government, often with stakeholder input. In most cases, EIA encompasses social, economic and environmental factors.

Figure 6 (Part A) is a schematic of the relationship of these guidelines to the environmental component of the overall assessment process. It is the same process (scoping, analysis and evaluation) shown in the first three boxes in Figure 21, but is expanded to show more detail about the use of guidelines and the difference between processes at catchment scale (SEA) and project scale (EIA).

The process shown in Figure 6 can be applied at any scale, but the types of recommendations should be different. At catchment scale, it is more likely that the *relative* ecological sustainability of different projects will be the main output. This is a reflection of the level of detail usually available at catchment planning scale. At project or subcatchment scale, the *absolute* ecological sustainability is the desired output. It is feasible at catchment scale to identify unsustainable projects, but in practice, limitations on data are likely to make this difficult to justify.

4.3 Data and knowledge gaps and the precautionary principle

The biophysical data assembled to support planning and project assessments (ie. during SEAs and EIAs) should be presented with specific aim of determining performance against the principles for waterway protection (see Table 8), and hence address impacts on ecological values and sustainability. This will provide reviewers with a consistent framework for evaluating the information.

Both SEA and EIA usually rely on existing information, supplemented with study-specific data and analysis by relevant experts.

In some cases, plans or project proposals may be prepared in the absence of key data to identify values and sustainability. The impact assessment needs either to fill those gaps or to specifically acknowledge the uncertainties that result. An undesirable outcome would be underestimations of ecological value and long-term sustainability caused by incomplete understanding of a given area or waterway. The precautionary principle, one of the key principles in the National Strategy for Ecologically Sustainable Development, gives guidance on decision making in situations of scientific uncertainty (Commonwealth of Australia 1992):

> Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

Approach to the precautionary principle

While the precautionary principle is often considered in the evaluation of proposals, it is open to a wide range of interpretations. The Intergovernmental Agreement on the Environment (COAG 1992) gives some further direction on its application:

> In the application of the precautionary principle, public and private decisions should be guided by:
>
> (i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and
>
> (ii) an assessment of the risk-weighted consequences of various options.

The complexity involved in interpreting the precautionary principle is reflected in the range of publications in which the principle is reviewed, including O'Riordan and Cameron (1994), Harding (1996), Deville and Harding (1997) and Harding (1998). We recommend these sources for a detailed discussion, and provide below a brief outline of the main considerations in applying the principle and in informing decision making.

The precautionary principle deals with situations where decisions are made under scientific uncertainty. Harding (1996, pp. 16–17) notes that:

> The precautionary principle goes beyond the aim of conventional risk management that seeks to prevent damage to the environment once the risk of that damage is known or proved. Rather it suggests that in particular circumstances it is not satisfactory to wait until damage has occurred, but that we should take action to prevent damage.
>
> In defining this principle, three terms are important in determining the circumstances in which caution should be applied and the extent of that caution:
>
> - 'Threats of serious or irreversible environmental damage' – particular care is required where one or more outcomes could have extremely adverse implications for the present or future generations and/or where no known substitutes exist for the resource being used.
> - 'Scientific uncertainty' – where the range of possible outcomes associated with the activity cannot be predicted with confidence. This uncertainty may exist over the nature of the problem, its cause, or its potential impact.
> - 'The measures to prevent environmental degradation' – considerations range from prospects of prevention to cost-effectiveness.
>
> The precautionary principle is not about 'zero risk' as some groups fear. Nor does it mean that decisions which may lead to irreversible damage should not be taken. Rather it requires that we give prominence to consideration of possible but uncertain impacts in conjunction with a range of other matters (social and economic benefit) in making decisions on resource use.

Hence, decision makers need to establish a procedure for determining whether, how, and when precautionary measures are applied in the proposal evaluation. Deville and Harding (1997, pp. 24–44) outline a detailed set of steps/questions, summarised below, to assist in this regard:

Step 1 – Are precautionary measures needed?

- are threats serious or irreversible?
- is there scientific uncertainty?

Step 2 – How much caution is needed?

- how significant (ie. serious/irreversible) is the threat?
- how uncertain are we about the threat?

Step 3 – What precautionary measures can be applied?

Step 4 – What precautionary measures should be applied?

The evaluation of ecological impacts from proposals will often involve levels of scientific uncertainty. Where an evaluation is made of a range of different scenarios or options, the nature of information collected may only be sufficient for a relative comparison of the ecological effects, rather than a definitive assessment against ecological sustainability and other principles. In most jurisdictions, a staged approach to evaluation can be used by proponents to gain staged 'approvals', with data requirements becoming progressively more stringent as a preferred option emerges.

A staged approach to decision making is one way in which caution can be built into the evaluation process, as long as decisions made early in the process (eg. favouring a particular option) can be revisited and, if necessary, reviewed following more definitive assessments of that option. This is also consistent with the adaptive planning and management process discussed in Part D, section 6.

It is usually only at the detailed impact assessment stage that a more informed judgment about ecological sustainability can be made. However, detailed impact assessment may not lead to absolute certainty for the evaluation/decision-making process.

These guidelines have been developed to help practitioners evaluate proposals under differing levels of scientific certainty, and they address several of the above steps (notably steps 1 and 2) in the precautionary decision-making procedure by providing:

- *A planning guideline* (Part D) for waterway protection that helps establish priorities for protection on basis of waterway ecological values and sustainability (threats). Waterways with known high ecological value and low sustainability (high threat) are at greater risk from impacts of further development, and may therefore be the subject of more rigorous review and decision making on proposals. The identification of ecological values and sustainability (threats) is a key to decisions about protection, and can also assist as a guide to the level of caution necessary when evaluating proposals.
- *A tiered evaluation structure* (Table 8 and Appendixes E1 and E3 of this guideline) for assessing impacts against waterway protection principles, using performance criteria, performance indicators and measures. This can reduce uncertainty in the evaluation/decision-making process by requiring proponents to provide information relevant to the principles of ecological decision making; and

- *Approaches that can be used for evaluating sustainability* (section 6 below and Part C), depending on the nature of the assessment required, information availability, uncertainty, etc. For example, where information is inadequate, an expert panel may be an acceptable alternative.

The nature of precautionary actions and measures (steps 3 and 4) adopted and applied will depend on particular circumstances. Precautionary measures can occur throughout the evaluation process (eg. early collection of key information, particularly for locations of high sensitivity/ecological value; allowance of a factor of safety in the assessment of impacts; early adoption of mitigation measures in the design/operation of a proposal; staged development with adaptive management) and in conditional approvals. Appropriate precautionary measures should become more apparent when we address the level of certainty and significance of impacts associated with a proposal.

4.4 Cumulative impacts

Cumulative impacts are a problem for impact assessment processes and their outcomes, partly because the tools and techniques for evaluation are usually inadequate. The combined impacts of multiple developments may be greater than the sum of the impacts of the individual developments. In other words, if considered in isolation (spatially or temporally), impacts that arise from all the developments may be underestimated. Typical examples are:

- fragmentation of habitat at regional scale;
- disruption of movement corridors;
- encroachment of exotic species;
- modification of natural flow regimes;
- accumulation of pesticide residues in sediments and organisms;
- reduction in biodiversity (eg. genetic diversity); and
- reduction in organic and sediment loads to estuaries.

Additionally, secondary impacts, such as non-linear ecological responses and synergistic effects, can be classed as cumulative (Environment Australia 1994).

Three types of cumulative impact arise in particular contexts:

Type 1, when assessing impacts of a proposal when the waterways and land systems have been modified (ie. temporal cumulative impact);

Type 2, when comparing proposals where multiple developments are being considered for largely unmodified land and water systems (ie. spatial cumulative impact); and

Type 3 (a combination of types 1 and 2),when considering multiple proposals in an area of modified land/water systems.

Type 1 cumulative impacts are conceptually simpler in that they are effectively incremental changes that affect a modified baseline. The process is to assess the incremental change for a range of indicators and then to compare the resulting condition of the environment with appropriate evaluation criteria.

The first challenge is to obtain an environmental data set that provides a sufficient basis for understanding past cumulative impacts. Usually, this requires information about the nature of changes and responses over time. State of environment reporting helps, particularly where more detailed information has been assembled for a catchment and its waterways.

The second challenge is to choose criteria that relate to an *appropriate* reference condition. Simplistically, this comes down to a choice of references – generally either natural or modified condition.

If *natural* condition is chosen, the proposal can only be ecologically sustainable if the cumulative impacts are within natural sustainability thresholds. If a system has been modified to the point of unsustainability, then no further adverse impacts would be acceptable. The drawback of this approach is that the history of modification in some areas means that comparison with natural condition may be not only difficult but impractical. Some systems may have been so extensively modified that the concept of sustainability, relative to natural conditions, is spurious.

If *modified* condition is used as the reference level, then proposals are measured against the biophysical systems that exist now. This is a pragmatic approach that attempts only to conserve existing values. The problem with it is that the benchmark or reference condition may deteriorate over time, so that each new proposal is evaluated against a downward trend in environmental condition. In effect, this would ignore cumulative impacts.

A way to avoid this is to set an agreed reference state and ensure that future development maintains that state. This is the approach used in many environmental policies, where changes (impacts) are measured against a reference date (for example, greenhouse policy is couched in terms of acceptable change against cumulative emission levels in a base year). This approach acknowledges that change has occurred, but does not accept further change beyond defined thresholds. In some cases, conservation planning leads to the identification of a reference state that improves on current condition (that is, planning identifies desired outcomes).

An added complication is the potential for some impacts to lag, so that all the effects of a development may not become apparent for years or decades. Further developments considered during this lag period will not be assessed against the true reference condition.

Type 2 cumulative impacts place most demands on the impact assessment process. Typically, only the individual impacts of each proposal are assessed, whereas the total impact should be examined as if the multiple proposals are actually one. Impact assessment should be applied to each proposal *as well as* a combination of all proposals.

However, the nature of cumulative impacts is much more complex to assess (eg. habitat fragmentation, genetic diversity, regional migration) and requires more resources. A key is the establishment of terms of reference that target cumulative impacts and set out the requirements so that they can be taken on board by the proponent in producing SEAs and EIAs.

The most complex situation (*type 3*) arises where contexts of both type 1 and type 2 apply. Given that very few waterways are free of unnatural influences, type 3 contexts arise more often than those of type 2. However, the issues raised in the discussion about types 1 and 2 are probably sufficient to cover the combined situation.

Approach to cumulative impacts

Many techniques have been used for cumulative assessment, with varying degrees of success. No single technique is a panacea, but most can be used effectively at specific points of the assessment and evaluation process (eg. Council on Environmental Quality 1997; Walker and Johnston 1999).

Appendix E2 gives an outline of suggested modifications to a generic environmental assessment process to cover cumulative impacts. This approach relies on natural resources planning and associated data collection to assess the regional conservation priorities of water and land systems. The method includes a number of examples of techniques provided by Fletcher (2001).

Case Study: West Moorabool River (Victoria) cumulative effects analysis

Analysis of cumulative change was used to evaluate the effectiveness of recent management in maintaining catchment health in the West Moorabool River, Victoria. Recommendations for future management are also discussed, along with the need for considering cumulative effects in day-to-day catchment management in order to define environmental problems and the requirements to address them.

The analysis examined long-term, large-scale change using condition assessments to help to identify reach or catchment-scale priorities, assembling data on hydrology, water quality, physical condition (river and riparian) and catchment characteristics.

Hydrology

Analysis:

- All inflows and outflows of the catchment were audited to produce a mass balance, and net and gross yields calculated. The proportional difference between these flows shows the level of water use and can determine alterations to the natural flow regime. Trends in mass balance components over time may reveal catchment changes.
- Streamflow trends were examined by fitting a relationship between rainfall and run-off (to account for rainfall trends) and examining the residuals of this relationship over time.

Findings:

Approximately 38% of available run-off was stored or diverted between 1972 and 1990, and post-drought recovery of streamflow was delayed, due to major on-stream storages (reservoirs) and on-stream/off-stream farm dams. The latter have had an obvious cumulative effect on eventual streamflow.

The river was flow-stressed (eg. no flow during most summers, despite the presence of catchment run-off). A streamflow management plan is being developed to provide a defined entitlement to water for the environment.

Water quality

Analysis:

- One method to determine trends over time correlates water quality against time, followed by a re-examination of trends with potential influences of streamflow changes removed.

Findings:

Most water quality indicators satisfied relevant policy, although nutrient concentrations generally did not meet Victorian guidelines. Electrical conductivity was significantly increasing across the catchment and is now a priority in the regional (Corangamite) catchment strategy (1997) to mitigate the impacts of salinity.

Physical condition (river and riparian)

Analysis:

- Aerial photography and satellite imagery (vegetation cover, presence of stream movement and obvious erosion) was undertaken with quantitative analysis of old maps and surveyor's notes;
- Proportion of intact vegetation (against evidence of pre-European condition) is often useful;
- Indicators of land use, including proportions of land uses, land disturbance (dams, etc.), land tenure and trends in slope were measured. Data included symptoms of change (dominant land use, percentage of impervious area, vegetation cover and type) and factors influencing the rate of change (mean slope, geology and soil type);
- Relationships between the condition of the riparian zone and land use were analysed using ANOVA to identify the key land uses that influence changes in riparian condition, where time is declared as a factor in the analysis.

Findings:

The degraded nature of the riparian zone and adjacent catchment was the most obvious sign of environmental change over time (low native cover and relatively high exotic invasion). Physical signs of human impact (roads etc.) slowly increased over time and were significantly related to low native cover and high exotic invasion.

The strongest factor in predicting vegetation cover was the presence of grazing nearby (highly related to low intactness and decreasing cover over time). Land tenure was also influential in that reserved forest and water reserves had relatively high intactness, freehold land had the lowest native cover and Crown frontages (retained for public purposes) had the greatest exotic invasion.

Conclusions

Quantitative relationships between changes in each of the factors analysed can be complex, although qualitative assessments can be made to a level that may provide sufficient direction for management action.

Methods were dictated by data and required modification/improvement to accommodate data gaps. Undertaking an inventory of catchment condition and processes can help avoid overly simplistic attempts at rehabilitation, by focusing on past and current condition. Long-term data is important for examining change in condition and understanding condition before disturbance.

(Source: Fletcher et al. 1999)

5 Criteria, indicators and measures used in evaluation

The goal and principles for waterway protection (reproduced below from the conceptual framework) have been developed to differentiate two levels of protection for waterways – ecological sustainability for all waterways and greater protection afforded to those waterways having higher ecological value.

GOAL:

To maintain the ecological values of waterways and floodplains

ECOLOGICAL PRINCIPLES:

For all waterways and floodplains:

1. Maintain natural structures and functions[a] that are essential to waterway health.
2. Prevent serious and irreversible loss of natural[b] diversity.
3. Mimic natural streamflow characteristics to support the health of target species/communities.
4. Protect rare or threatened structures and functions.
5. Conserve representative examples of waterways and their natural features.

Greater protection for waterways and floodplains of high conservation priority:

6. Maintain the integrity of natural structures and functions[a] that contribute to ecological value.
7. Maintain natural[b] diversity.
8. Maintain natural streamflow characteristics.

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[a] Includes species, taxa, communities, habitats, geomorphic features and natural processes

[b] Includes flora, fauna, geomorphology, water quality and hydrology

The guideline applies to all stages of the development process (planning, options comparison, impact assessment, design, construction and operation), with highest use expected in the first three of these stages. It is intended also to enable consideration of the cumulative effects of development (spatial and temporal change).

The hierarchy and tiers developed in Table 8 and shown graphically in Figure 22, are as follows:

- the *waterway protection principles* grouped by common themes, such as rarity and streamflow;
- *performance criteria* for each principle, which are framed as desired outcomes (eg. avoid disruption of essential ecological processes);
- *performance indicators* (one or more for each criterion), specifying how each performance criterion might be met (eg. provide for effective movement of target organisms); and
- a further set of *measures* to assist practitioners in determining whether a performance indicator is met (eg. do water infrastructure barriers provide for fish passage?).

The performance criteria and indicators need to be measurable. Highly specific measures are difficult to develop because of limitations on current knowledge. However, there has been significant progress on indicators and, for some issues, measures, so the structure can accommodate further improvements.

An assessment against the principles should take into account the mitigation actions proposed to minimise impacts from a development proposal. That is, assessment of a project's impacts should take into account the net impacts of the project *after* accounting for mitigation measures. Such measures might include:

- restoration of selected areas that have potentially high conservation priority;
- compensation for long-term adverse habitat changes (eg. sedimentation, scouring) by habitat creation and/or restoration;
- revegetation of cleared areas in or adjacent to the waterway;
- creation, rehabilitation or protection of habitat equivalent to that lost through development;
- relocation, fencing or other measures to aid recovery of affected fauna; and
- use of agricultural, urban and industrial best-management practices during construction and operation (eg. minimisation and control of water and airborne contaminants, erosion and sediment control).

Consequently, Table 8 does not include specific principles/performance indicators for mitigation measures.

Other important issues requiring consideration in the evaluation/assessment process include:

- *Development type.* Impacts may vary according to the type of development proposed, and the selection of measures used to evaluate a particular proposal must be sensitive to the expected impacts of the proposal;

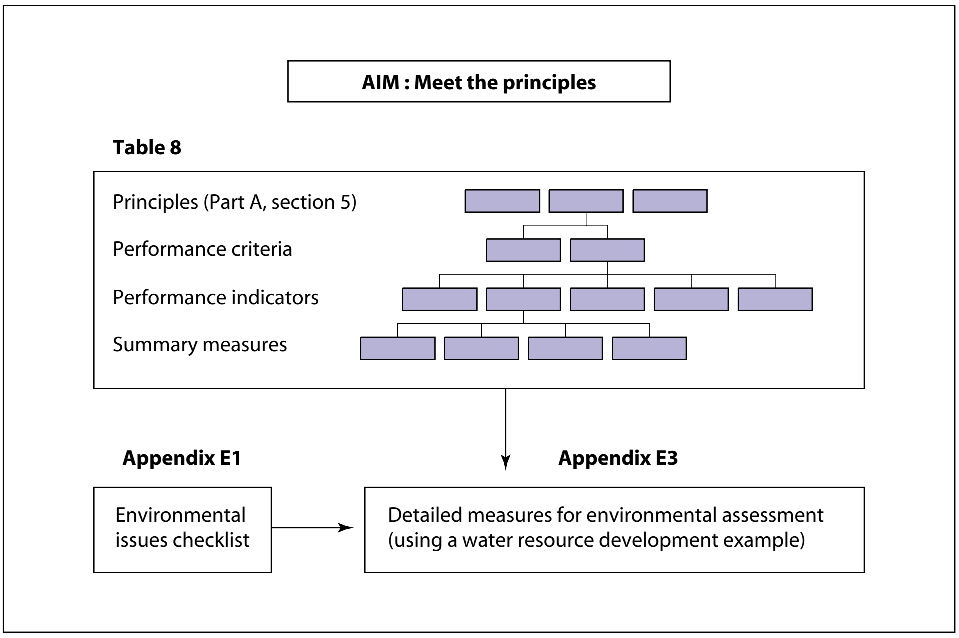

Figure 22. Tiered evaluation structure using principles, criteria, indicators and measures.

- *Spatial coverage of information collection and assessment* (local, regional, etc.). It is important that impacts be assessed at various spatial scales, so that the significance of impact is identified not just in the immediate impact zone, but also at a broader (eg. catchment or bioregional) scale. This helps determine cumulative effects of various proposals throughout a region;
- *Periods for which the information is required*. It may be necessary to determine a reference point for assessment of temporal change and therefore to collect environmental information at various stages of impact, from natural/pre-European, through current condition, to condition after impacts of the proposal. This assists in assessing change over time, and can therefore be an important input to cumulative impact assessment;
- *The type* (qualitative, quantitative) *and detail of information required* and *the accuracy of information collected* relative to the stage of the assessment (preliminary options evaluation, formal impact assessment, etc.). In the early stages of a planning process (eg. a regional-level comparison of water infrastructure options), the range and detail of data collected is likely to be less than that required for a detailed impact assessment of a specific proposal. Even where information on the same subject matter (eg. presence of endangered species) is sought/collected, the data's certainty/reliability is likely to be lower at earlier stages of the planning process, and it may need refining or correcting after more definitive investigations have been carried out.

These considerations are discussed in Appendix E3.

For brevity, the measures in the final column of Table 8 are somewhat general, and are supported by a more detailed measures provided in Appendix E3. The measures may also be common to more than one performance indicator, and the same measure can therefore appear more than once in the table. Appendix E3 also provides further discussion of how the measures might be used, including an example of assessing water-infrastructure proposal impacts on waterways in a catchment. While Appendix E3 uses a water infrastructure example, the approach could nevertheless be adopted for any development proposal (or options analysis) with a potential impact on waterways.

Table 8. Principles, performance criteria, indicators and measures for evaluation of proposals.

WATERWAY HEALTH AND INTEGRITY

Principle 1 (All waterways):
Maintain all structures and functions that are essential to waterway health
Principle 6 (High conservation priority waterways):
Maintain the integrity of all structures and functions that contribute to ecological value

Performance criteria	Performance indicators	Examples of measures (see Appendix E3 for further examples/detail)
1. Avoid disruption of essential ecological processes caused by losses in the number and quality of habitats.	1. Maintain essential habitat for the entire life cycle of target organisms (breeding, feeding, etc.)	• In-stream/off-stream aquatic habitat type (riffle, pool, wetland, etc.) by location, length/area, number • Terrestrial ecosystem type and status by area • In-stream/off-stream aquatic and terrestrial ecosystems/habitats: – with expected/known significant ecosystem functions – with expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats – known or with potential to contain rare and threatened or other special flora and/or fauna species/taxa/communities • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement) • Water quality (physico-chemical and biological indicators) • In-stream/off-stream aquatic and terrestrial habitats (location and area)
	2. Provide for essential movement requirements of target organisms by using best-practice techniques (fishways, riparian corridors, etc.)	• In-stream/off-stream aquatic and terrestrial ecosystems/habitats (location and area): – known to play or with potential to play an important role in riverine and landscape connectivity – with expected/known occurrences of flora/fauna that rely on upstream, downstream, or lateral movement for completion of life stages (breeding, recruitment, etc.) • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/infested with exotic vegetation • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Name and location of water infrastructure barriers with functional/non-functional/no fishways • Name and location of other physical barriers to, or impeding influences on, fish movement (eg. road crossings) • Location/extent of waterways that are impounded/non-impounded • Degree of habitat fragmentation (considering longitudinal and lateral connections relative to natural condition)
2. Avoid impacts, on land and waterways, that affect essential ecosystem services	1. Allocate water supply consistent with maintaining values.	• Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures)

Table 8. (cont'd) Principles, performance criteria, indicators and measures for evaluation of proposals.

Performance criteria	Performance indicators	Examples of measures (see Appendix E3 for further examples/detail)
	2. Maintain sediment supply for waterway, estuary and beach/ coastal requirements	• Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement) • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Location/extent of waterways that are impounded/non-impounded
	3. Maintain or improve bed and bank stability and minimise variation from natural conditions	• Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement) • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • In-stream/off-stream aquatic habitat type (riffle, pool, wetland, etc.) by location, length/area, number • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Location/extent of waterways that are impounded/non-impounded
	4. Maintain natural rates of nutrient and organic materials supply and essential linkages between nutrient/ organic sources and sinks.	• Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Water quality (physico-chemical and biological indicators, including sediments/nutrients) • Hydrological indicators relative to natural condition (including indicators for flows providing floodplain linkages) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Location/extent of waterways that are impounded/non-impounded • Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement)
	5. Ensure water quality meets acceptable objectives related to protection or maintenance of aquatic ecosystems (target organisms).	• Water quality (physico-chemical and biological indicators) • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) Other measures as relevant to the ecological value under consideration, for example: • In-stream/off-stream aquatic and terrestrial ecosystems/habitats: – with expected/known significant ecosystem functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats

Table 8. (cont'd) Principles, performance criteria, indicators and measures for evaluation of proposals.

Performance criteria	Performance indicators	Examples of measures (see Appendix E3 for further examples/detail)
3. Maintain the physical and biological integrity of stream bed and banks.	1. Avoid changes in aggregative or degradative processes from natural conditions, particularly where these affect essential aquatic processes and water quality	• Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement) • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Location/extent of waterways that are impounded/non-impounded • In-stream/off-stream aquatic habitat type (riffle, pool, wetland, etc.) by location, length/area, number • In-stream/off-stream aquatic and terrestrial ecosystems/habitats with expected/known significant ecosystem functions • Water quality (physico-chemical and biological indicators)
	2. Protect sensitive bed and bank areas from intensive human activities	Measures to address both the sensitivity/significance of the receiving waterway and the processes potentially affected by human activities, for example: • In-stream/off-stream aquatic habitat type (riffle, pool, wetland, etc.) by location, length/area, number • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • In-stream/off-stream aquatic and terrestrial ecosystems/habitats: – with expected/known significant ecosystem functions – known or with potential to contain rare and threatened or other special flora and/or fauna species/taxa/ communities – with expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement) • Water quality (physico-chemical and biological indicators)
4. Preserve all natural processes, including energy and nutrient transfer for *high conservation priority* waterways	1. Prevent unnatural disruptions to energy and nutrient flows by maintaining natural rates of nutrient and organic materials supply and linkages between nutrient/organic sources and sinks	• Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Water quality (physico-chemical and biological indicators, including sediments/nutrients) • Hydrological indicators relative to natural condition (including indicators for flows providing floodplain linkages) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Location/extent of waterways that are impounded/non-impounded • Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement)

Table 8. (cont'd) Principles, performance criteria, indicators and measures for evaluation of proposals.

Performance criteria	Performance indicators	Examples of measures (see Appendix E3 for further examples/detail)
	2. Prevent unnatural disruptions of natural relationships between and within species	Relevant measures to address both the disruption to processes, and corresponding effects on structure and interrelationships, for example: • In-stream/off-stream aquatic and terrestrial ecosystems/habitats: – with expected/known significant ecosystem/habitat functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats – known or with potential to contain rare and threatened or other special flora and/or fauna species/taxa/ communities • Water quality (physico-chemical and biological indicators) • In-stream/off-stream aquatic and terrestrial habitats (location and area) known to play or with potential to play an important role in landscape connectivity • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures)
	3. Maintain continuity of existing riparian corridors	• Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Location/extent of waterways that are impounded/non-impounded • In-stream and off-stream habitats that have expected/known occurrences of flora/fauna that rely on upstream, downstream, or lateral movement for completion of life stages (breeding, recruitment, etc.) • Degree of habitat fragmentation (considering longitudinal and lateral connections relative to natural condition)
	4. Minimise unnatural sediment deposition or erosion that compromise ecological processes or water quality	• Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement) • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Location/extent of waterways that are impounded/non-impounded • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • In-stream/off-stream aquatic habitat type (riffle, pool, wetland, etc.) by location, length/area, number • In-stream/off-stream aquatic and terrestrial ecosystems with expected/known significant ecosystem functions • Water quality (physico-chemical and biological indicators)

Table 8. (cont'd) Principles, performance criteria, indicators and measures for evaluation of proposals.

Performance criteria	Performance indicators	Examples of measures (see Appendix E3 for further examples/detail)
	5. Minimise impacts (eg. turbidity and salinity) on the capacity of aquatic processes to maintain water quality	• Water quality (physico-chemical and biological indicators) • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation Other measures as relevant to the environmental value under consideration, for example: • In-stream/off-stream aquatic and terrestrial ecosystem/habitats: – with expected/known significant ecosystem functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats

NATURAL DIVERSITY

Principle 2 (All waterways):
Prevent serious and irreversible loss of natural diversity
Principle 7 (High conservation priority waterways):
Maintain natural diversity

Performance criteria	Performance indicators	Examples of measures
1. Prevent significant reduction in diversity of waterways resulting from exotic or unnatural species/ communities	1. Avoid major new influences on ecosystem components (eg. exotic species, blue-green algae)	• In-stream/off-stream aquatic habitat type (riffle, pool, wetland, etc.) by location, length/area, number • Terrestrial ecosystem type and status by area • In-stream/off-stream aquatic and terrestrial ecosystems/habitats (location and area): – with expected/known significant ecosystem/habitat functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats – known or with potential to contain rare and threatened or other special flora and/or fauna species/taxa/ communities • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Water quality (physico-chemical and biological indicators)
	2. Avoid displacement of species through habitat changes	Relevant indicators will depend on the nature of the expected change and would include ecosystem structure and process measures as for indicator 1 above

Table 8. (cont'd) Principles, performance criteria, indicators and measures for evaluation of proposals.

Performance criteria	Performance indicators	Examples of measures
2. Protect natural resources from contamination	1. Ensure chemical/ contaminant releases to the environment are not injurious to aquatic ecosystems	• Water quality (physico-chemical and biological indicators) • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation Other measures as relevant to the ecological value under consideration, for example: • In-stream/off-stream aquatic and terrestrial ecosystems/habitats: – with expected/known significant ecosystem functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats
3. Preserve the diversity of *high conservation priority* waterways	1. Maintain ecosystem productivity	In the absence of direct productivity measures, suggested indirect measures based on structural integrity and naturalness of ecosystem processes, for example: • In-stream/off-stream aquatic ecosystem/habitat type (riffle, pool, wetland, etc.) by location, length/area, number: – with expected/known significant ecosystem functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats • Terrestrial ecosystem type and status by area • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Water quality (physico-chemical and biological indicators) • In-stream and off-stream aquatic and terrestrial habitats (location and area) known or with potential to contain rare and threatened or other special flora and/or fauna species/taxa/communities
	2. Maintain the diversity of ecosystem structures and functions	Measures to address both structure and function as for indicator 1 above
	3. Conserve the diversity and integrity of habitats	Measures as for indicator 1 above
	4. Maintain habitat connectivity	• In-stream/off-stream aquatic and terrestrial ecosystems/habitats (location and area): – known to play or with potential to play an important role in landscape connectivity – with expected/known occurrences of flora/fauna that rely on upstream, downstream, or lateral movement for completion of life stages (breeding, recruitment, etc.) • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Name and location of water infrastructure barriers with functional/non-functional/no fishways • Name and location of other physical barriers to, or impeding influences on, fish movement (eg. road crossings) • Location/extent of waterways that are impounded/non-impounded • Degree of habitat fragmentation (considering longitudinal and lateral connections relative to natural condition)

Table 8. (cont'd) Principles, performance criteria, indicators and measures for evaluation of proposals.

STREAMFLOW ***Principle 3 (All waterways):*** *Mimic natural streamflow characteristics to support the health of target species/communities* ***Principle 8 (High conservation priority waterways):*** *Maintain natural streamflow characteristics*

Performance criteria	Performance indicators	Examples of measures
1. Provide a streamflow regime that sustains populations of target species	1. Provide adequate flooding to support floodplain and wetland productivity	• Off-stream aquatic habitat type (wetland, etc.) by location, length/area, number • Off-stream aquatic and terrestrial ecosystems/habitats: – with expected/known significant ecosystem functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats – with potential to contain rare and threatened or other special flora and/or fauna species/taxa/communities • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Water quality (physico-chemical and biological indicators) • In-stream/off-stream habitats that have expected/known occurrences of flora/fauna that rely on upstream, downstream, or lateral movement for completion of life stages (breeding, recruitment, etc.) • Degree of habitat fragmentation (considering longitudinal and lateral connections relative to natural condition)
	2. Provide sufficient low flow in perennial waterways	As for indicator 1 above, but concentrating on in-stream ecosystems particularly reliant on low flows. In addition: • Location/extent of waterways that are impounded/non-impounded
	3. Provide flows with timing, duration and quantity sufficient to sustain the entire life cycle of target species	As for indicator 1 above, with additional considerations including: • Name and location of water infrastructure barriers with functional/non-functional/no fishways • Name and location of other physical barriers to, or impeding influences on, fish movement (eg. road crossings)
	4. Retain sufficient habitat to support viable populations	Depending on populations subject to investigation, measures to include habitat structure and hydrological indicators as for indicators 1–3 above, and particularly addressing populations of significance, for example: • In-stream/off-stream aquatic and terrestrial ecosystems/habitats: – with expected/known significant ecosystem functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats – known or with potential to contain rare and threatened or other special flora and/or fauna species/taxa/communities

Table 8. (cont'd) Principles, performance criteria, indicators and measures for evaluation of proposals.

Performance criteria	Performance indicators	Examples of measures
	5. Ensure that the relationship between flows and water quality is within natural variation	• Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures) • Water quality (physico-chemical and biological indicators)
2. Maintain natural streamflow characteristics in *high conservation priority* waterways	1. Ensure that no structures are placed in the waterway or floodplain that alter natural flow characteristics	• Name and location of water infrastructure barriers with functional/non-functional/no fishways • Name and location of other physical barriers to, or impeding influences on, fish movement (eg. road crossings) • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows, etc.) • Lengths, locations and extent of waterways with significant changes in hydrological condition (based on relevant hydrological measures)
	2. Ensure that any abstraction of surface or ground water does not impact significantly on natural flow characteristics	• As for indicator 1 above

RARE and THREATENED BIOTA or ENVIRONMENTAL FEATURES

Principle 4 (All waterways):
Protect rare or threatened structures and functions

Performance criteria	Performance indicators	Examples of measures
1. Maintain the conservation status of species, taxa, communities, populations, habitats, ecological processes or geomorphic features.	1. Ensure no adverse change to any species, communities or habitats listed under relevant legislation	• In-stream/off-stream aquatic and terrestrial ecosystems/habitats (location and area): – known or with potential to contain rare and threatened or other special flora and/or fauna species/taxa/communities – designated in plans/policies for protection/special management (eg. wetland reserves) or in protected estate (parks, nature refuges, etc.) • Terrestrial ecosystem type and status by area
	2. No net loss of regionally threatened ecosystems or habitats	As for indicator 1 above
2. Maintain existing protected natural areas	1. Retain all existing areas of conservation and scientific reserves, national parks, etc.	• In-stream/off-stream aquatic and terrestrial habitats (location and area) designated in plans/policies for protection/special management (eg. wetland reserves) or in protected estate (parks, nature refuges, etc.) • Terrestrial ecosystem type and status by area

Table 8. (cont'd) Principles, performance criteria, indicators and measures for evaluation of proposals.

Performance criteria	Performance indicators	Examples of measures
3. Maintain the total area of waterways and floodplains that are of *high conservation priority*	1. Retain all areas with very high rarity value	• In-stream/off-stream aquatic habitat type (riffle, pool, wetland, etc.) by location, length/area, number • In-stream/off-stream aquatic and terrestrial ecosystems/habitats (location and area): – known or with potential to contain rare and threatened or other special flora and/or fauna species/taxa/communities – with expected/known significant ecosystem functions – having expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats • Terrestrial ecosystem type and status by area
	2. Ensure no net loss of areas with very high naturalness/condition, or biodiversity value	As for indicator 1 above

REPRESENTATIVE EXAMPLES

Principle 5 (all waterways)

Conserve representative examples

Performance criteria	Performance indicators	Examples of measures
1. Protect areas, structures or functions that are particularly representative of their type	1. Ensure that adequate representative examples occur in protected areas	• In-stream/off-stream aquatic habitat type (riffle, pool, wetland, etc.) by location, length/area, number • Terrestrial ecosystem type and status by area Both the above to be assessed in the relevant spatial context (eg. catchment, bioregion)
	2. Prevent impacts of development on areas of high representativeness value	As for indicator 1 above
2. Conserve natural resources	1. Preserve natural resources required for the health and viability of flora and fauna	Measures to relate to the particular flora/ fauna under consideration. These may include, for example: • Length of riparian zone in good structural condition/not infested with exotic vegetation or in poor structural condition/ infested with exotic vegetation • Geomorphology measures relative to natural condition (addressing channel morphology, hydraulics and sediment movement) • Hydrological indicators relative to natural condition (eg. measures of flow variability, low flows)

6 Approaches for evaluating ecological sustainability

Table 8 attempts to break down complex constructs into measurable components. The next step is to ensure that the information can be synthesised so that the *overall* impacts of a project are evaluated. It is possible that a project could meet all performance criteria, but still be unsustainable overall because of synergistic or antagonistic effects. In combination, several proposals could together be unsustainable because of their cumulative impacts, even though each proposal has sustainable impacts.

The ecological sustainability guideline provides a critique of methods for assessing sustainability, including cumulative impacts, at both strategic and project levels.

Various analytical approaches exist for testing the application of the principles, including:

- *threshold analysis* (application of a series of thresholds, above which impacts are deemed to be unsustainable, for each performance criterion);
- *scoring system* (summated numerical product of rating and weighting for each performance criterion); and
- *expert panel* (based on a subjective assessment by a multidisciplinary expert panel, assembled specifically for individual proposals and planning the studies).

6.1 Threshold analysis

The threshold system is based on direct (eg. from toxicity studies) or derived (eg. from modelling) understanding of the relationships between the responses of ecological and geomorphological indicators to specific environmental modification. It has the advantage of being measurable against benchmarks, where exceedance constitutes unsustainability for a particular indicator. Its drawbacks are shortfalls in data and complexities of ecological processes that do not lend themselves to simple indicators – particularly where synergistic and antagonistic effects are involved. Interpretation of the outcomes of such analyses can be difficult to translate into decisions, for example, in determining how many individual benchmark exceedances constitute overall unsustainability.

6.2 Scoring (rating/weighting)

A scoring system has much the same set of pros and cons as threshold analysis, except that the weightings can be used to develop an overall sustainability score that reflects the importance of different ecosystem structures and functions. It is equivalent to applying a multi-objective decision support system (MODSS) only to ecological data.

Ratings and weightings for each measure are combined to give scores for each performance indicator and in turn, for each criterion and principle. As with a MODSS, this is useful for comparative assessment of different proposals. However, in order to decide whether a proposal is sustainable, target scores would need to be identified at an appropriate level of the hierarchy.

A project with an ‘acceptable’ overall score may have several discrete elements that are unsustainable. Unless thresholds are introduced, results could be misleading. Note that this approach is no less subjective than the non-numeric techniques, because judgments need to be made about weightings and rules of combination. Scoring systems also allow for simple sensitivity analysis by altering the weightings for the measures.

A significant uncertainty is the assumption that scoring overall sustainability is valid. In practice, this is questionable, given the varying geographic contexts of proposals and the expertise needed to interpret the synergistic and antagonistic factors inherent in natural systems. In other words, it would be very easy to become immersed in the detail of measuring criteria, and lose track of the broad principles involved.

The main advantage is that this approach allows a more reproducible result because the variables are numerically combined. A scoring system may be most useful for comparative evaluation of several alternative projects. This comparative approach has been used successfully in a number of States and Territories – often in combination with economic and social criteria.

6.3 Expert panel

The panel option relies on a number of experts from relevant disciplines making judgments about the degree to which principles, or performance criteria, are being met. Expert panels can be effective when supported by threshold analysis or scoring approaches (such as MODSS).

The advantage is that the panel can potentially integrate large amounts of information and can draw on individual skills and experience to make judgments about sustainability. With sufficient research and monitoring data available, this would take much better account of interactive (synergistic and antagonistic) effects. This approach is less reductionist and can accommodate variability in information availability in different catchments. Consequently, it should deliver the most *valid* outcomes if the panel process is well managed.

However, the approach is also the most subjective and could easily be influenced by the choice of experts and the quality of the data. Unless managed with some rigour, the process could be open to criticism and conclusions questioned.

6.4 Comparison of approaches

To provide some indication of relative strengths, a simple comparison between the approaches is shown in Table 9.

Table 9. Comparison of approaches for evaluating sustainability

Test	Threshold analysis	Scoring system	Expert panel
Transparency	◆◆	◆◆◆	◆
Reproducibility	◆◆	◆◆	◆
Subjectivity	◆◆	◆◆	◆◆
Validity	◆	◆	◆◆◆
Compatibility with MODSS	◆◆	◆◆	◆
Efficiency	◆◆	◆◆	◆
Effectiveness	◆◆	◆	◆◆◆

◆ *poor* ◆◆ *average* ◆◆◆ *good*

None of the approaches stands out as the best performer in this analysis. However, the scoring system is difficult to justify because it could easily be mismanaged and assumes that a single system can be applied to widely differing contexts. When used alone, it also fails to deal with an unsustainable impact or combination of impacts.

A combination of threshold and expert panel systems appears to be the most robust approach, providing the greatest validity, at the expense of some transparency. It also offers greater effectiveness in that those involved with the expert panel will be in a strong position to justify their conclusions about sustainability. Peer review could also be introduced to provide an independent perspective.

To date, the expert panel approach has a high level of support and has been used in a number of Australian jurisdictions for catchment and regional planning studies. However, it has received only limited use in project evaluations. Although the effort and resources involved in conducting a panel process are considerable, it could prove to be more efficient overall. Project-level decisions are often impaired by the fact that the data prepared in the EIA are not specific enough to support conclusions about ecological sustainability. This is precisely where expert debate can inform stakeholders, as well as provide a credible basis for evaluating sustainability.

7 Process for evaluation

As outlined in section 5, the scope, detail and reliability of information, and the rigour of evaluation, may vary according to the stage of the process. However, the main steps outlined below are considered applicable to both broad and specific assessments. The key points of the process are to:

- establish principles and performance criteria/ indicators to be used for the evaluation;
- ensure that the terms of reference (ToR) are scoped, so that the SEA/EIA provides all the required information and assessments to the detail required and in a format suitable for evaluation against relevant principles;
- include consideration of cumulative impacts (ie. both spatial and temporal aspects) – see Appendix E2 for further discussion of this issue; and
- use a multidisciplinary and interactive approach to the evaluation.

STEP 1: Scoping: drafting terms of reference

- Use a checklist (see example in Appendix E1 and detail in Appendix E3) to scope the range of issues for which information is likely to be required to enable assessment of the impacts of the proposal on ecological values and against the principles. This should also include consideration of cumulative impacts (particularly in relation to past, present and future activities), spatial and temporal boundaries, and threatening processes (see Appendix E2).
- Confirm governing principles, performance criteria and indicators against which the proposal will be evaluated (see Table 8 for suggested principles and performance criteria/indicators).
- Identify the detailed measures considered necessary to address the range of issues and the governing principles and criteria for the proposal, and the spatial and temporal extent over which information may be required (see Appendix E3 for a sample list of measures potentially relevant to a water infrastructure proposal).

- Include relevant requirements in a ToR for the proposal, including (where possible) the measures to be assessed and how they will be used by decision makers to review the proposal's performance against the adopted principles.
- If considered appropriate, specify whether the proponent is required (or encouraged) to employ any particular approach for assessing the ecological sustainability of the proposal (see section 6 for a summary of some approaches).

STEP 2: Assessment: undertaking the SEA/EIA

- During the proponent/consultant's preparation of an SEA or EIA (including scoping, information collection and preliminary report drafting) actively work with the proponent (and/or consultant) to ensure that the information is collected on the stipulated measures, and that assessment is made in a manner that allows reviewers to evaluate the proposal against principles, performance criteria and indicators.
- Proponent/consultant to collect/assemble information in a manner enabling evaluation against overarching principles and against performance criteria and indicators, and as stipulated in the ToR for the project (see the example in Appendix E3).
- SEA/EIA to identify and quantify the proposal's impacts on the ecological values.
- SEA/EIA to explicitly address cumulative impacts (see Appendix E2):
  - analysing different future scenarios;
  - analysing ecological impacts of different future scenarios; and
  - including specific analysis for cumulative impacts (over time and space).
- SEA/EIA to compare relative effects of proposal (taking into account mitigation commitments) against any sustainability thresholds for the measures (as identified as part of the SEA/EIA, or from other relevant studies/sources).
- SEA/EIA to assess these impacts against principles and performance criteria/indicators.

STEP 3: Evaluation: reviewing the SEA or EIA

- The coordinator (assessment manager) should issue the SEA/EIA and any supporting information to relevant expert reviewers for assessment.
- Undertake an expert workshop(s) to assess and discuss the information provided, and the conclusions in the SEA/EIA. Undertaking expert workshops or using individual expertise may require the establishment of an expert panel for the assessment and/or evaluation steps.
- Reviewers should assess the SEA/EIA against the ToR and stated principles, including consideration of the accuracy and precision of techniques for assessing cumulative impacts (see Appendix E2).
- Prepare a review report assessing the adequacy of the SEA/EIA and the proposal's compliance with adopted principles and performance criteria/indicators.

Expert panel involvement

The need for, role and composition of any expert panel is likely to depend on:

- the skills of staff in reviewing agencies;
- the skills of individuals involved in preparation of SEA/EIA reports; and
- the level of knowledge available about the impacts of the proposal on the ecological values.

Where there is insufficient expertise in a particular issue, it may be more appropriate to seek input from an expert in that field rather than appoint a panel. Conversely, if the assessment of a proposal yields unclear outcomes with limited information, and the impacts are expected by reviewers to be significant, then seeking the best professional judgment of an expert panel may be more appropriate.

Appendix E1

Scoping checklist: example of ecological issues

This is a suggested initial scoping checklist to use in considering the range of ecological issues and impacts to waterways/floodplains from a development proposal. It can be further built on by developing a more extensive suite of measures linked to principles against which the proposal will be assessed (Appendix E3 gives an example).

Aquatic ecosystems

In-stream aquatic habitat type – riffles, runs, cascades, glides, natural pools, etc.

In-stream aquatic habitat with:

- rare and threatened (under legislation) or other special flora/fauna species/taxa/communities
- higher biodiversity, numbers or percentage of endemic species than unimpacted similar habitats
- significant ecosystem functions
- protected area designation
- groundwater-reliant ecosystems

Off-stream aquatic habitat type – wetlands, billabongs, mound springs, etc.

Off-stream aquatic habitat with:

- ephemeral or permanent wetlands
- rare and threatened (under legislation) or other special flora/fauna species/taxa/communities
- higher biodiversity, numbers or percentage of endemic species than unimpacted similar habitats
- significant ecosystem functions
- protected area designation
- groundwater-reliant ecosystems

Habitat connectivity/fragmentation/disturbance (in-stream and off-stream)

Terrestrial (including riparian) ecosystems

Terrestrial habitat, particularly those with:

- 'endangered' and 'of concern' regional ecosystems
- rare and threatened (under legislation) or other special flora/fauna species/taxa/communities
- higher biodiversity, numbers or % of endemic species than unimpacted similar habitats
- significant ecosystem functions
- protected area (eg. national park) designation
- groundwater-reliant ecosystems

Habitat connectivity/fragmentation/disturbance

Hydrological features

Medium to high flow features/indicators, for example:

- mean annual flow (% of natural)
- median annual flow (% of natural)
- frequency of floodplain inundation (% of natural)
- frequency of bankfull flows (% of natural)
- frequency of mid-channel flows (% of natural)
- 1-in-2 year average recurrence interval (ARI) daily flow (% of natural)
- annual proportional flow deviation (compared with natural)

Baseflow/no flow features

Important ecological flow features (eg. trigger flows for breeding)

Fluvial processes/geomorphology

Sediment transfer features (size, amount)
Erosion/sedimentation patterns
Channel condition/features
Links to estuarine/coastal zone

Water quality

Biological indicators (eg. fish, macroinvertebrates)
Physico-chemical indicators (eg. nutrients, chemicals)

Appendix E2

Outline of suggested modifications to the typical environmental assessment process for cumulative impact assessment

Scoping phase

- identify potential impacts from the proposal
- identify potential cumulative impacts from past, present and future activities (eg. using matrices, checklists, network or systems analysis)
- determine spatial and temporal boundaries for the ecological assessment, based on potential cumulative impacts
- identify threatening processes arising from cumulative impacts
- specify key cumulative impacts to be addressed in the assessment

Assessment phase

- determine magnitude and significance of cumulative impacts
- analyse different scenarios (including project alternatives and future activities) of cumulative effects, using techniques such as risk assessment, trend analysis, GISs and simulation modelling (eg. to determine habitat changes, cumulative toxicity, loss of connectivity)
- assess ecological impacts of different scenarios (eg. using carrying-capacity analysis, habitat change)
  Additional steps for type 1 cumulative impacts (over time):
  – determine appropriate reference condition (natural, modified, desired future condition);
  – assess impacts of proposals against reference condition
  Additional steps for type 2 cumulative impacts (multiple proposals):
  – assess impacts of individual proposals against current condition
  – assess overall impacts of different combinations of proposals (based on likely scenarios and accounting for mutually exclusive proposals)

Evaluation phase

- evaluate the accuracy and precision of the assessment techniques
- evaluate overall impacts on ecosystem integrity and sustainability

Fletcher (2001) suggested a number of specific techniques to support environmental impact assessment, including:

- *Hydrology* – eg. mass balance modelling over time; ‘hydrologic disturbance’ indicators and differences between natural (predicted) and observed flows; and statistical measures of flow variability.
- *Water quality* – eg. trend analysis of relationship between flow and quality; generalised additive model; analysis of land use and water quality relationships (temporal and spatial).
- *Flora* – eg. statistical analysis of the relative importance of different land use changes on catchment condition.

Appendix E3

Evaluation example: Ecological assessment of a water resource development proposal (with detailed examples of measures)

Purpose

This example and its accompanying tables are provided to support Table 8 of this evaluation guideline. The example has been developed to demonstrate how the principles, performance criteria and performance indicators in Table 8 can be addressed and interpreted through the use of a range of quantitative and qualitative measures. While Table 8 provided a summary example of measures, this appendix goes into greater detail about suggested measures that might be used. The more specific set of information requirements is intended to assist planning and impact assessment (IA) practitioners by specifying the issues and measures they have to address in a planning study, options evaluation or project IA. It is also intended to help reviewers and decision makers determine the magnitude of impact arising from proposals, and ultimately, whether such proposals meet ecological sustainability and other principles (see also Part C, the ecological sustainability guideline).

This evaluation example includes a large table (Table E3.3), with supporting notes, that lists:

- the ecological measures that might be addressed in a planning evaluation of a number of water infrastructure proposals or a more detailed impact assessment for a water resource development proposal (note that social, economic and cultural indicators are not included, but would also need to be considered in the IA and decision-making process);
- the different locations ('zones') of the project area (upstream storage, downstream flow-affected zone, water use zone) for which information might be required to assess different impacts of the proposal; and
- other broader areas (eg. catchment) for which information might be required to assess regional-level impact.

To show how information on measures might be tabulated, two short 'completed' tables (Tables E3.1 and E3.2) are also provided.

Scope of the example

Development type

The measures in this example have been developed with regard to a generic *water infrastructure* (eg. dam, weir) *and associated water use proposal*. However, to enable assessment of any proposal's performance against principles and performance criteria and indicators in Table 8, this approach to developing measures could be adopted using modified measures for the particular type of development (eg. tourist development, transport corridor) or plan with potential to affect waterways. It should be recognised that no two developments or receiving environments are the same, and the relevance and importance of measures may vary according to the circumstances.

Spatial coverage

Table E3.3 has been designed to guide requirements for:

- the collection of information in relation to the particular areas affected by the proposal; and
- the collection of information at a broader spatial scale (subcatchment, catchment, bioregion), which will assist in identifying regional and possible cumulative impacts on natural systems of water resource development and associated proposals.

Type of information required

Table E3.3 includes requirements for:

- qualitative data (eg. statements on the significance of habitat for particular species/communities, identification of areas with expected higher biodiversity); and
- quantitative data (areas of particular vegetation/ habitat types, etc.).

Depending on the stage in the planning–IA process for which evaluations are being undertaken, the detail and reliability of information collected may vary (see below).

Phase of planning or impact assessment process

Table E3.3 could be used to inform decision making at various stages of the planning process, including from:

- catchment planning and subcatchment studies (eg. as a scoping assessment of a range of development options); through to
- project-specific impact assessment.

The level of certainty/reliability and detail of information collection may be lower at initial scoping stages than at the full IA stage. Nevertheless, the use of the measures in initial phases may point to particular issues for which information is poor, and for which greater effort may be required in subsequent IA phases to determine impacts of the proposal.

Application

Such a table of information measures could be developed to:

- assist practitioners and decision makers in their respective roles (planning study/IA preparation, review, and decision making) during the planning/IA process, for example through incorporation of measures into the terms of reference (ToR) for the proposal;
- assist community or other stakeholder groups in reviewing and commenting on the development of proposals for water-resource development assessments; and
- reduce repetition of effort in identifying information requirements for such studies.

Interpreting Table E3.3

Table E3.3 includes:

Column 1: The measures to be identified/measured.

Columns 2–4: Zones related to the water resource development proposal (upstream inundation, downstream altered flow zone, water use zone) for which information on a particular indicator/attribute is required (✓);

Columns 5–7: Requirements for information on broader-scale measures (eg. subcatchment, catchment, bioregion). These are provided to enable an assessment of the relative proportions of an indicator or attribute's coverage through the broader area, and the area subject to the development proposal. For example, this might enable us to say that 10% of threatened vegetation type 'A' throughout the catchment is within the zone of inundation from a proposed dam. Such an approach enables a broader-level appreciation of the spatial significance of impacts arising from the proposal, and also enables consideration of the cumulative impacts of further proposals on regional features.

Scenarios for which information is required

To assess change in natural ecosystems from natural through to current and possible future levels of development, it would be ideal to have information available for each of these stages/times of development. However, it may be difficult to obtain information on a range of measures for the natural (or pre-European) stage, although some of these (eg. hydrological measures) may be able to be modelled or estimated.

A further consideration relates to the degree to which potential impacts can be mitigated. In order to quantify this mitigation potential (and the commitments of the proponent to mitigation) and enable subsequent review of the effectiveness of mitigation strategies, we suggest identifying the anticipated environmental change with and without mitigation.

To allow an assessment of the proposal's impacts on the existing environment, information would be required about each indicator/attribute of the table for three scenarios (four, if comparison with pre-European conditions is to be made):

- the existing environment (ie. the situation prior to the proposal);
- the environment after impacts from the proposal (without any mitigation); and
- the environment after impacts from the proposal (with mitigating measures, such as revegetation and other activities).

Information for these three scenarios could be collected and incorporated into three separate tables (existing, impact with no mitigation, impact with mitigation), or through incorporation of each scenario into one table. Worked examples for two measures (one aquatic and one terrestrial) are shown below as an indication of how the table might be filled in, using the former approach.

Table E3.1. Worked example (for aquatic measure: impounded waterways) (Figures in **bold** are those that change as a result of proposal).

Existing situation

Measure	**Information required for which zone of proposal?**					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment**	**catchment**	**bioregion**
Total length of waterways (km):						
Freshwater impounded	**0**	**0**	same as downstream zone	**100**	**100**	not calculated
Freshwater unimpounded	**70**	**100**		**300**	**600**	
Freshwater total	70	100		400	700	
Estuarine	nil	30		80	300	
Grand total (fresh + estuarine)	70	130		480	1000	
Waterways as % of catchment total:						
Freshwater impounded	**0%**	**0%**	same as downstream zone	**10%**	**10%**	not calculated
Freshwater unimpounded	**7%**	**10%**		**30%**	**60%**	
Freshwater total	7%	10%		40%	70%	
Estuarine	0%	3%		8%	30%	
Grand total (fresh + estuarine)	7%	13%		48%	100%	

Impacts without mitigation

Measure	**Information required for which zone of proposal?**					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment**	**catchment**	**bioregion**
Total length of waterways (km):						
Freshwater impounded	**50**	**20**	same as downstream zone	**170**	**170**	not calculated
Freshwater unimpounded	**20**	**80**		**230**	**530**	
Freshwater total	70	100		400	700	
Estuarine	nil	30		80	300	
Grand total (fresh + estuarine)	70	130		480	1000	
Waterways as % of catchment total:						
Freshwater impounded	**5%**	**2%**	same as downstream zone	**17%**	**17%**	not calculated
Freshwater unimpounded	**2%**	**8%**		**23%**	**53%**	
Freshwater total	7%	10%		40%	70%	
Estuarine	0%	3%		8%	30%	
Grand total (fresh + estuarine)	7%	13%		48%	100%	

Table E3.1. (Cont'd) Worked example (for aquatic measure: impounded waterways) (Figures in **bold** are those that change as a result of proposal)

Impacts after mitigation

Measure	**Information required for which zone of proposal?**					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment**	**catchment**	**bioregion**
Total length of waterways (km):						
freshwater impounded	**45**	**20**	same as downstream zone	**165**	**165**	not calculated
freshwater unimpounded	**25**	**80**		**235**	**535**	
freshwater total	70	100		400	700	
estuarine	nil	30		80	300	
Grand total (fresh + estuarine)	70	130		480	1000	
Waterways as % of catchment total:						
freshwater impounded	**4.5%**	**2%**	same as downstream zone	**16.5%**	**16.5%**	not calculated
freshwater unimpounded	**2.5%**	**8%**		**23.5%**	**53.5%**	
freshwater total	7%	10%		40%	70%	
estuarine	0%	3%		8%	30%	
Grand total (fresh +estuarine)	7%	13%		48%	100%	

Interpretation of worked example for aquatic measure (Table E3.1)

The information in Table E3.1 could be used in a various ways to identify absolute and proportional impoundment impacts throughout the various impact zones and wider areas. Some examples of such use include the following assessments.

Existing situation

- Currently, there is 70 km of waterways (all freshwater and all unimpounded) in the *proposed inundation zone*. This equals 10% of all the freshwater streams/rivers (700 km) in the catchment, or 7% of the total length of freshwater and estuarine waterways (1000 km) in the catchment. The table also enables the proportion of the subcatchment totals to be identified. Similarly, further information on habitat types in this area (eg. riffles, pools, etc.) could be collected to identify lengths of waterway types in the inundation zone relative to their representation throughout the subcatchment/catchment, etc.
- The 100 km of freshwater (again, all currently unimpounded) in the *downstream flow impact zone* represents one quarter of all the freshwater streams in the subcatchment (100 of 400 km), 14% of all freshwater streams in the catchment (100 of 700 km) and 10% of all waterways in the catchment (100 of 1000 km). The 30 km of estuary in this zone is almost 40% of all estuaries in the subcatchment (30 of 80 km), 10% of the catchment's estuaries (30 of 300 km) and 3% of all catchment waterways.
- Importantly, the combined total of 170 km unimpounded freshwater streams in these two zones forms a large proportion (170 of 400 km = 43%) of all waterways in the subcatchment and a very high proportion of its remaining unimpounded freshwater waterways (170 of 300 = 56%), given that 100 km of freshwater waterways is already impounded. Such figures can assist in identifying cumulative spatial effects from developments.

Impacts without mitigation (eg. before bunding of certain areas, storage management rules, etc.)

- Without any mitigation, 50 km of waters in the *upstream zone* would become impounded, leaving only 20 km of this zone unimpounded. This 50 km represents an additional 12.5% of all the (freshwater) waterways in the subcatchment (50 of 400 km), 7% (50 of 700 km) of all freshwater streams in the catchment, and 5% of total catchment (1000 km) waterways.
- In the *downstream flow impact zone*, there is some further impoundment impact identified (perhaps because of the need for a downstream regulating weir to operate in conjunction with the larger upstream dam). Hence this zone changes from having 100 km of freshwater streams unimpounded to having 80 km unimpounded and 20 km impounded.
- Combining the two (upstream and downstream) impact zones, there is a predicted increase in total impounded waterways from zero kilometres under the existing situation to 70 km. This is 10% of all freshwater streams in the catchment (70 of 700 km) and 7% of all waterways in the catchment (70 of 1000 km). The corresponding reduction of unimpounded waterways from the combined impact zones (70 km) can similarly be identified.
- Changes in impounded/unimpounded proportions carry through to the subcatchment and catchment columns, allowing consideration of impacts at a broader scale. For example, the extent of impounded reaches in the subcatchment is predicted to increase from 100 km (existing situation) to 170 km. This is an increase from 10% to 17% of all waterways in the catchment. Unimpounded waterways have been correspondingly reduced.
- At the catchment level, the predicted reduction in unimpounded waterways (from 600 km to 530 km) means that unimpounded waterways would account for 53% of all waterways in the catchment, a decline from 60% in the existing situation. Project-level impacts can be considered in a broader spatial context using this example, which assists in addressing cumulative impacts.

Impacts after mitigation (eg. after bunding, development of storage operational rules)

- After some limited mitigation, the degree of impact in the *upstream zone* is reduced to from 50 km to 45 km, but no mitigation is evident in the *downstream zone*. The (minor) change resulting from this mitigation is also identified in the subcatchment and catchment columns.

The above examples relate only to impoundment effects. Effects from altered flows, in particular, may extend downstream from the impact zone of the impoundment.

Table E3.2. Worked example (for terrestrial measure: endangered regional ecosystems.)

Existing situation

Measure	**Information required for which zone of proposal?**					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment**	**catchment**	**bioregion**
Area (ha) of *endangered* regional ecosystem (by type):	100 ha type A 30 ha type B	20 ha type A 1 ha type C	400 ha type C 200 ha type D	800 ha type A 100 ha type B 500 ha type C 200 ha type D	1000 ha type A 100 ha type B 700 ha type C 200 ha type D	8000 ha type A 1000 ha type B 5000 ha type C 2000 ha type D

Impacts without mitigation

Measure	**Information required for which zone of proposal?**					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment**	**catchment**	**bioregion**
Area (ha) of *endangered* regional ecosystem (by type):	5 ha type A 5 ha type B	20 ha type A 1 ha type C	200 ha type C 100 ha type D	705 ha type A 75 ha type B 300 ha type C 100 ha type D	905 ha type A 75 ha type B 500 ha type C 100 ha type D	7905 ha type A 975 ha type B 4800 ha type C 1900 ha type D

Impacts after mitigation

Measure	**Information required for which zone of proposal?**					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment**	**catchment**	**bioregion**
Area (ha) of *endangered* regional ecosystem (by type):	20 ha type A 20 ha type B	20 ha type A 1 ha type C	385 ha type C 190 ha type D	720 ha type A 90 ha type B 485 ha type C 190 ha type D	920 ha type A 90 ha type B 685 ha type C 190 ha type D	7920 ha type A 990 ha type B 4985 ha type C 1990 ha type D

Interpretation of worked example for terrestrial measure (Table E3.2)

Existing situation

- Currently, there is 100 ha of type A vegetation in the *proposed inundation zone*. This is 12.5% of that vegetation type (800 ha) in the subcatchment, 10% of its catchment extent (1000 ha), and 1.25% of its extent (8000 ha) in the bioregion. Similar calculations can be made here and for the 'impacted' scenarios for type B vegetation;
- The 400 ha of type C vegetation currently in the *water use zone* represents 80% of that vegetation type in the subcatchment, 57% of its catchment extent, and 8% of that vegetation type in the bioregion. Again, similar calculations can be made here and for the 'impacted' scenarios for type D vegetation.

Impacts without mitigation (eg. before revegetation, protection of key stands of habitat, etc.)

- Without any mitigation, 95 ha of type A vegetation would be affected by *inundation*, leaving only 5 ha. The predicted loss of type A vegetation in the inundation zone carries through to the subcatchment, catchment and bioregion columns, which show the reduced type A extent (705 ha, 905 ha, and 7905 ha respectively). Proportional figures can also be calculated to identify change resulting from the proposal.
- There is no change predicted for key vegetation types in the *downstream zone of altered flows*. This may, for example, be because those vegetation types are not sensitive to the type of altered flows resulting from the proposal.
- Some 200 ha of type C vegetation is predicted to remain after impacts from *water use* activities without any mitigation. The reduction in type C vegetation (200 ha) similarly leads to reduced type C figures for subcatchment, catchment and bioregion aggregations, and proportional changes can be calculated accordingly.

Impacts after mitigation (eg. after revegetation, protection of key stands of habitat)

- After mitigation, 80 ha of type A vegetation would be affected by *inundation*, leaving 20 ha. This represents some improvement compared with expected impacts without mitigation (only 5 ha would remain). The amended figures for this vegetation type carry through to figures for the subcatchment (720 ha), catchment (920 ha) and bioregion (7920 ha).
- After mitigation there is a notable reduction in impacts to type C vegetation affected by *water use* activities, with 385 ha of the current 400 ha expected to remain. This improvement relative to the no-mitigation scenario is also reflected in figures for subcatchment, catchment and bioregion aggregations.

Table E3.3. Suggested measures for ecological evaluation of water infrastructure proposal, by location

Measure	Information required for which zone of proposal?					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment[a]**	**catchment[a]**	**bioregion[a, b]**
AQUATIC HABITAT						
Total length of waterways (km):	*see worked example*					
freshwater	✓	✓	✓	✓	✓	
estuarine	✓	✓	✓	✓	✓	
total	✓	✓	✓	✓	✓	
Name and location of water infrastructure barriers with:						
functional fishways	✓	✓	✓	✓	✓	
non-functional fishways	✓	✓	✓	✓	✓	
no fishways	✓	✓	✓	✓	✓	
Name and location of other physical barriers to, or impeding influences on, fish movement (eg. road crossings)	✓	✓	✓	✓	✓	
Name, lengths and locations (AMTDs) of impounded waterways	✓ *see worked example*	✓	✓	✓	✓	
Lengths and locations (AMTDs) of unimpounded waterways:	*see worked example*					
freshwater	✓	✓	✓	✓	✓	
estuarine	✓	✓	✓	✓	✓	
total	✓	✓	✓	✓	✓	
Unimpounded waterways as % of total waterway length:	*see worked example*					
freshwater	✓	✓	✓	✓	✓	
estuarine	✓	✓	✓	✓	✓	

Table E3.3. (cont'd) Suggested measures for ecological evaluation of water infrastructure proposal, by location

Measure	Information required for which zone of proposal?					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment[a]**	**catchment[a]**	**bioregion[a, b]**
Biological indicators, including, as relevant: • macroinvertebrates • fish • other aquatic fauna • macrophytes	✓	✓	✓	✓	✓	
Water quality – naturalness/condition (identified for appropriate locations throughout the study area): Physico-chemical parameters, eg. • nutrients • DO • chemicals, heavy metals • temperature, etc.	✓	✓	✓	✓	✓	
In-stream aquatic habitat (location, length/area, number)						
• riffle habitats	✓	✓	✓	✓	✓	
• in-stream natural pools	✓	✓	✓	✓	✓	
• backwater habitats	✓	✓	✓	✓	✓	
• anabranch (island) habitats	✓	✓	✓	✓	✓	
• cascades and waterfalls	✓	✓	✓	✓	✓	
• point bars – outer edge	✓	✓	✓	✓	✓	
• rock/sand bars – within stream channel	✓	✓	✓	✓	✓	
Identification of particular in-stream aquatic habitats (location, length/area, number) that:						
• are known to contain rare and threatened (under legislation) or other special flora/fauna species/taxa/communities	✓	✓	✓	✓	✓	
• have potential to contain rare and threatened (under legislation) or other special flora/fauna species/taxa/communities	✓	✓	✓	✓	✓	
• contain or support threatened regional aquatic ecosystems	✓	✓	✓	✓	✓	
• have expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats	✓	✓	✓	✓	✓	

Table E3.3. (cont'd) Suggested measures for ecological evaluation of water infrastructure proposal, by location

Measure	Information required for which zone of proposal?					
	Upstream inundation zone (eg. weir, dam)	Zone of altered flows downstream of dam/weir	Water use zone (eg. irrigation)	subcatchment[a]	catchment[a]	bioregion[a, b]
• have expected/known significant ecosystem functions	✓	✓	✓	✓	✓	
• have expected/known occurrences of flora/fauna that rely on upstream, downstream or lateral movement for completion of life stages (breeding, recruitment, etc.)	✓	✓	✓	✓	✓	
• are designated or identified in plans/policies for protection/special management (eg. representative rivers, coastal reserves, wetland reserves)	✓	✓	✓	✓	✓	
• provide important ecosystem support roles for, or links to, areas designated or identified in plans/policies for protection/special management (eg. representative rivers, coastal reserves, wetland reserves)	✓	✓	✓	✓	✓	
• contain or support expected/known groundwater-reliant ecosystems	✓	✓	✓	✓	✓	
Off-stream aquatic habitat (location, length/area, number):						
• billabongs	✓	✓	✓	✓	✓	
• mound springs	✓	✓	✓	✓	✓	
• wetlands	✓	✓	✓	✓	✓	
Identification of particular off-stream aquatic habitats that:						
• are known to contain rare and threatened (under legislation) or other special flora/fauna species/taxa/communities	✓	✓	✓	✓	✓	
• have potential to contain rare and threatened (under legislation) or other special flora/fauna species/taxa/communities	✓	✓	✓	✓	✓	
• contain or support threatened regional aquatic ecosystems	✓	✓	✓	✓	✓	
• have expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats	✓	✓	✓	✓	✓	
• have expected/known significant ecosystem functions	✓	✓	✓	✓	✓	
• have expected/known occurrences of flora/fauna that rely on lateral movement for completion of life stages (breeding, recruitment, etc.)	✓	✓	✓	✓	✓	

Table E3.3. (cont'd) Suggested measures for ecological evaluation of water infrastructure proposal, by location

Measure	**Information required for which zone of proposal?**					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment[a]**	**catchment[a]**	**bioregion[a, b]**
• are designated or identified in plans/policies for protection/special management (eg. Ramsar wetlands, coastal reserves, wetland reserves)	✓	✓	✓			
• provide important ecosystem support roles for, or links to, areas designated or identified in plans/policies for protection/special management (eg. representative rivers, coastal reserves, wetland reserves)	✓	✓	✓	✓	✓	
• contain expected/known groundwater-reliant ecosystems	✓	✓	✓	✓	✓	
Degree of aquatic habitat fragmentation (low, medium, high – considering both longitudinal and lateral connections relative to natural condition)	✓	✓	✓	✓	✓	
HYDROLOGICAL INDICATORS *(sample indicators only – indicators selected need to be hydrologically and ecologically relevant to circumstances, and node selection should enable spatial interpretation of change in flow conditions arising from one or more proposals)*						
General indicators: • Mean annual flow (% of natural) at relevant specified nodes	✓	✓	✓[c]	✓	✓	
• Median annual flow (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• Annual proportional flow deviation[d] (compared with natural) at relevant specified nodes	✓	✓	✓	✓	✓	
Variability: • Flow regime class (flow seasonality)	✓	✓	✓	✓	✓	
• Monthly flow variability (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
High flows and floodplains: • 1.5-year ARI daily flow (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• 2-year ARI daily flow (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• 5-year ARI daily flow (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• 10-year ARI daily flow (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• 20-year ARI daily flow (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• Frequency of floodplain inundation (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	

Table E3.3. (cont'd) Suggested measures for ecological evaluation of water infrastructure proposal, by location

Measure	Information required for which zone of proposal?					
	Upstream inundation zone (eg. weir, dam)	**Zone of altered flows downstream of dam/weir**	**Water use zone (eg. irrigation)**	**subcatchment[a]**	**catchment[a]**	**bioregion[a, b]**
• Specific measures relevant to flow requirements for flora/fauna that rely on upstream, downstream or lateral movement for completion of life stages	✓	✓	✓	✓	✓	
In-channel and low flows: • Frequency of bankfull flows (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• Frequency of half bankfull flows (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• 80% daily exceedance for each month (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• 50% daily exceedance for each month (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
• Low-flow event frequency (% of natural) at relevant specified nodes	✓	✓	✓	✓	✓	
Lengths, locations (AMTDs) and extent of waterways with (and without) significant change in hydrological conditions:						
• freshwater	✓	✓	✓	✓	✓	
• estuarine	✓	✓	✓	✓	✓	
• total	✓	✓	✓	✓	✓	
GEOMORPHOLOGY *(including channel morphology, hydraulics, sediment movements) – to be addressed for both freshwater and (where relevant) estuarine systems*						
Channel morphology *Freshwater* reaches – compared to natural (high, medium, low, or some other ranking method), taking into account: • areas directly affected by barriers (eg. dams/weirs, bridges, fords) • locations affected by other activities (eg. extraction/quarry activity, stock) • areas of apparent widespread erosion/aggregation and vegetation loss/encroachment *Estuarine* reaches – compared to natural. As above.	✓	✓	✓	✓	✓	

Table E3.3. (cont'd) Suggested measures for ecological evaluation of water infrastructure proposal, by location

Measure	Information required for which zone of proposal?					
	Upstream inundation zone (eg. weir, dam)	Zone of altered flows downstream of dam/weir	Water use zone (eg. irrigation)	subcatchment[a]	catchment[a]	bioregion[a, b]
Aquatic/hydraulic habitat *Freshwater* reaches – compared to natural, taking into account any: • effects of flow changes on particular habitat types (eg. promoting an increase in fast or slow water habitat) • changes in the permanence of habitats (eg. increased/more sustained baseflows leading to greater permanence of aquatic habitats) • changes in tidal extent/nature (eg. increase in non-tidal area due to barrages) *Estuarine* reaches – compared to natural. As above.	✓	✓	✓	✓	✓	
Sediment transport *Freshwater* reaches – compared to natural, taking into account any: • changes in sediment inputs from upstream sources (eg. resulting from sediment trapping in upstream dams/weirs) • changes in sediment transport processes (eg. high flow frequency/duration) *Estuarine* reaches – compared to natural. As above	✓	✓	✓	✓	✓	
TERRESTRIAL (INCLUDING RIPARIAN) HABITAT:						
Total terrestrial area (ha)	✓	✓	✓	✓	✓	✓
Total area (ha) of natural terrestrial vegetation (including riparian)	✓	✓	✓	✓	✓	✓
Length and area of riparian vegetation	✓ (left bank, right bank, combined banks)	✓ (left bank, right bank, combined banks)	✓ (left bank, right bank, combined banks)	✓ (combined banks)	✓ (combined banks)	
• composed of native vegetation in good structural condition	✓	✓	✓	✓	✓	
• infested with exotic vegetation and/or composed of vegetation in poor structural condition	✓	✓	✓	✓	✓	
Area (ha) of *Endangered*[b] regional ecosystem (by type, eg. *x* ha of Endangered type a, *y* ha of Endangered type b, etc.)	✓ **see worked example**	✓	✓	✓	✓	✓

Table E3.3. (cont'd) Suggested measures for ecological evaluation of water infrastructure proposal, by location

Measure	Information required for which zone of proposal?					
	Upstream inundation zone (eg. weir, dam)	Zone of altered flows downstream of dam/weir	Water use zone (eg. irrigation)	subcatchment[a]	catchment[a]	bioregion[a, b]
Area (ha) of *Of Concern*[b] regional ecosystem (by type, eg. *x* ha of Of Concern type a, *y* ha of Of Concern type b, etc.)	✓	✓	✓	✓	✓	✓
Area (ha) of *Other*[b] regional ecosystem (by type, eg. *x* ha of Other type a, *y* ha of Other type b, etc.)	✓	✓	✓	✓	✓	✓
Identification of *particular terrestrial habitats* (location and area, in hectares) that:						
• are known to contain rare and threatened (under legislation) or other special flora/fauna species/taxa/communities	✓	✓	✓	✓	✓	✓
• have potential to contain rare and threatened (or other special) flora/fauna species/taxa/communities	✓	✓	✓	✓	✓	✓
• contain or support Endangered[b] or Of Concern[b] regional ecosystems (cross-check of above information)	✓	✓	✓	✓	✓	✓
• have expected/known higher natural biodiversity, numbers or % of endemic species/taxa/communities than unimpacted similar habitats	✓	✓	✓	✓	✓	✓
• have expected/known significant ecosystem functions	✓	✓	✓	✓	✓	✓
• are designated or identified in plans/policies for protection/special management, etc. (eg. national parks, State forests, other protection or controlled use)	✓	✓	✓	✓	✓	✓
• contain expected/known groundwater-reliant ecosystems	✓	✓	✓	✓	✓	✓
• play a potentially important role in landscape connectivity	✓	✓	✓	✓	✓	✓
Degree of habitat fragmentation (low, medium, high – based on connectivity – separation, patch shape/integrity, and size breakdown of habitat clumps)	✓	✓	✓	✓	✓	
Total area (ha) of natural terrestrial vegetation (including riparian) in protected estate (parks, nature refuges, properties under conservation agreement)	✓	✓	✓	✓	✓	✓

Table E3.3. (cont'd) Suggested measures for ecological evaluation of water infrastructure proposal, by location

Measure	Information required for which zone of proposal?					
	Upstream inundation zone (eg. weir, dam)	Zone of altered flows downstream of dam/weir	Water use zone (eg. irrigation)	subcatchment[a]	catchment[a]	bioregion[a, b]
Locations and areas of protected estate containing						
• Endangered[b] ecosystems	✓	✓	✓	✓	✓	✓
• Of Concern[b] ecosystems	✓	✓	✓	✓	✓	✓

[a]Information for the (shaded) subcatchment, catchment and bioregion columns has to be collected once – for 'existing situation'. This existing information set can then be used to enable assessment of regional /cumulative impacts that occur from the development proposal (ie. before mitigation and after mitigation).

[b]The categories 'endangered', 'of concern' and 'other' have been established for terrestrial ecosystems in Queensland based on their estimated extent . 'Endangered' means less than 10% of pre-European coverage remains, or that the ecosystem is rare (original extent less than 1000 ha) and subject to a threatening process, or is a naturally restricted (original extent less than 10,000 ha) ecosystem that has been reduced to 10–30% of its natural distribution. An 'Of Concern' ecosystem has between 10% and 30% of its pre-European coverage remaining, or is a rare ecosystem not subject to a threatening process, or is a naturally restricted ecosystem subject to a threatening process. 'Bioregion' is the primary level of biodiversity classification, based on broad landscape patterns that reflect the major structural geologies and climate, as well as the major changes in floristic and faunistic assemblages. The terms may have different meanings in different States/Territories, and may need to be adapted to particular circumstances within each State or Territory (Sattler and Williams 1999).

[c]The need to assess changes in hydrological indicators primarily relates to the hydrological impact zone in the main channel, downstream from the water infrastructure. Altered stream flows resulting from the use of water also relate mainly to the main stream channel. Changes in flow regime should also, where relevant, include an estuarine reporting node(s) to identify change in flows reaching estuaries.

[d] Annual proportional flow deviation (APFD) is a derived measure that summarises changes in natural flow regimes associated with water resource development. It has been used in both New South Wales and Queensland water resource planning.

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