Protecting Australia's rivers, wetlands and estuaries

"...the river and lagoons abound with fish and fowl..."

Explorer John Oxley's observations of the Lachlan River (Oxley, 1820)

"...nowadays the river has lost its charm. It's no longer a sweet smelling place."

Lance Parker, Hillston commenting on Lachlan River (Roberts and Sainty, 1996)

Protecting Australia's rivers, wetlands and estuaries of high conservation value

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Executive summary

Australia has a rich variety of different rivers, wetlands and estuaries that support a significant amount of its biodiversity and industry. Important social values of Australia's Indigenous and European culture are also intimately linked to the integrity of our rivers. Despite this, compared with terrestrial conservation (e.g. national parks and reserves, and regional forest agreements), there has generally been a lessor focus on conservation of these ecosystems in Australia.

This report presents a conceptual framework for the protection of riversd, river reaches andestuaries of high conservation value. It was developed in conjunction with State and Territory agenciesduring 2003 and 2004 and provides an important foundation for developing future approaches to the conservation of these key areas.

Many of Australia's rivers, wetlands and estuaries are affected by river regulation, catchment disturbance and pest species, and opportunities to effectively conserve riverine biodiversity and landscapes are limited.. There are opportunities to protect Australia's most important aquatic areas so that future generations do not have to pay the high costs of rehabilitation (e.g. as has happened for the River Murray). This may begin with a comprehensive national framework that identifies and protects rivers, wetlands and estuaries that have high, national conservation value. States and Territories are primarily responsible for their protection, but a national framework could support consistent identification and strategic investment in the protection of nationally important aquatic ecosystems.

All Australian governments have invested in programs and projects aimed at protecting rivers, wetlands and estuaries. There is national recognition of the importance of this issue across all jurisdictions. In 1994, the Council of Australian Governments (CoAG) agreed that the environment was a legitimate user of water. In 2004, CoAG agreed to the National Water Initiative (NWI), which will chart the future responsibilities and progress towards sustainable management of the nation's rivers and aquifers. Provisions in the associated intergovernmental agreement commit most governments to identify, protect and manage high-conservation-value rivers and aquifers and their dependent ecosystems.

To effect protection of high-conservation-value rivers and their dependent ecosystems, national conservation goals are essential. They may be used also to determine short-term and specific goals developed from a national vision statement for rivers. This recognises that it is not possible to single out high-conservation-value rivers or their dependent ecosystems and expect to protect only these and achieve conservation of their values. River conservation requires a network approach that recognises that many processes and organisms may use all parts of rivers and even different rivers during their lives. A protection framework focused on only high-conservation-value rivers will not work.

Rivers and dependent ecosystems with nationally high conservation values are a subset of the country's aquatic ecosystems. Conservation value is a relative measure, established through a comparison of all rivers and dependent ecosystems. This discussion paper focuses on ecological conservation values, but recognises that rivers also have considerable cultural, economic and ecosystem service values.

There are two key questions for this framework.

- *What rivers, floodplains, wetlands and estuaries are of high conservation value?*
- *How can these be protected?*

Elements of a national framework

A national framework of river protection could be built around three main elements:

1 nationally consistent collection of information on rivers, wetlands and estuaries, which will entail agreement on spatial scale and classification and evaluation systems for identification of rivers and dependent

ecosystems of high conservation value

2 protection schemes that operate at different scales such as:
   - a 'whole-of-river' approach that could include establishment of an 'Australian Heritage Rivers' system
   - protection of high-conservation-value rivers, river segments and dependent ecosystems (floodplains, wetlands, estuaries) in a national, State, regional and local context (using current legislative and policy tools; i.e. environmental flows, protected areas, natural resource planning and management, and incentives)

3 operational and institutional arrangements—coordinated programs involving jurisdictions in implementation of a national framework.

Nationally consistent collection of information

All rivers, wetlands and estuaries have conservation values, but we need methods to identify which of them have the highest national conservation value to assist decision makers to determine priorities.. To do this, we must first have a method that can operate at various and agreed spatial scales. To achieve a relative comparison of conservation value, consistent and agreed approaches to classification and evaluation are needed to work across all rivers, wetlands, floodplains and estuaries. The following conservation criteria could be utilised to assess high-conservation-value rivers and their dependent ecosystems.

The river or dependent ecosystem:

- is largely unaffected by the direct influence of land and water resource development
- is a good, representative example of its type or class
- is the habitat of rare or threatened species or communities, or the location of rare or threatened geomorphic or geological feature(s)
- demonstrates unusual diversity and/or abundance of features, habitats, communities or species
- provides evidence of the course or pattern of the evolution of Australia's landscape or biota
  OR
- performs important functions within the landscape.

Spatial framework

An agreed spatial framework is essential for undertaking national assessments.

Recommendations

a. *Use current drainage divisions, river basins and river segments for initial implementation of this framework. These map layers, and the sub-catchments and catchments they support, should be publicly available.*

b. *River ecosystem data should be labelled according to resolvable hierarchical scales, allowing for future evaluation and reassessment of classifications.*

c. *Develop a new hierarchical spatial framework for managing aquatic systems and rivers, based on topography and drainage networks and without the problems of current spatial layers.*

Classification and evaluation systems

Collation of all available attribute data for the criteria, and gap-filling where necessary, at the finest spatial scale possible (i.e. river segment), is important to make a national assessment of rivers, wetlands, floodplains and estuaries.

Recommendations

a. *Devlop agreed approaches for assessing criteria and use of attributes for rivers, river reaches and dependent ecosystems.*

b. *Develop agreed national classifications of rivers and dependent ecosystems, with agreed objectives, to support evaluation and assessment.*

c. *Apply a nationally agreed set of evaluation criteria and significance thresholds, compatible with Ramsar and National Heritage, with nationally available data, aggregated to the smallest resolvable scales of assessment (i.e. river segments and their sub- catchments). This could be done to assess all river segments to identify nationally important rivers, wetlands (greater than 200 ha) and large estuaries. This initial assessment could be reported at a range of scales, informing a national assessment but also State and regional assessments.*

d. *Establish long-term collection and storage of nationally consistent data on rivers and their dependent ecosystems that allows for comparison across the country.*

Protection scheme

Once identified, the challenge is to ensure protection of rivers, wetlands and estuaries at different scales and contexts. We propose consideration of a protection scheme with two approaches: establishment of an Australian Heritage Rivers system in conjunction with better use of existing protection mechanisms. There are generally sufficient mechanisms available within jurisdictions for protection of aquatic ecosystems, but implementation of a mulit-scale system would improve effectiveness at a catchment level.

Australian Heritage Rivers system

Potential candidate rivers could be identified that are of high conservation value, generally at a large scale (i.e. river basin, tributary river), using the methods identified above. While identification of candidates could be a national process, nominations for listing as Australian Heritage Rivers could also come from communities. Designation as an Australian Heritage River could signify sustainable use rather than a moratorium on development. There could also be parallel development of a process that identifies and assesses cultural values.

Recommendations

a. *Identify potential candidate river basins as Australian Heritage Rivers. This process could be done immediately, using current data, but nomination and designation would not occur without community support.*

b. *Identify institutional arrangements that would deliver an Australian Heritage River system, including current models, and whether there is a need for legislation. Essential steps in the arrangements would be nomination, designation, consultation and administration. The Canadian Heritage Rivers System is a model worth considering.*

c. *Largely unmodified river basins designated as Australian Heritage Rivers could be priority areas for funding river management plans that protect ecological values, prevent environmental problems, encourage uses compatible with protection of ecological values and promote understanding of ecological values and processes.*

Protecting nationally important rivers, river segments, floodplains, wetlands and estuaries using current mechanisms

There are many tools within jurisdictional, legislative and policy frameworks for protecting nationally important high-conservation-value rivers, wetlands and estuaries. These can be grouped under four, main, interrelated mechanisms: environmental flow management; protected area acquisition and management; natural resource management; and incentives. These preferably operate within a catchment planning and management framework that logically follows the rivers and recognises their connectivity.

Priorities for protection could be defined by working from quantitative national conservation targets for rivers, wetlands and estuaries. Actual protection may be effected through jurisdictional policies and management, and the regional bodies responsible for catchment management. The following recommendations for environmental flow management, protected areas, natural resource management and planning, and incentives could apply to rivers, river segments, floodplains, wetlands and estuaries identified as having high national conservation value.

Recommendations—environmental flow management

a. *Environmental flows for long-term sustainability of rivers and their dependent ecosystems need to be identified at catchment scales.*

b. *Environmental flows should be managed within an adaptive management framework that ensures the best environmental outcomes.*

c. *Targets for flow restoration may need to be developed with a focus on better management of flows and access to additional flows if required (e.g. improving water-use efficiency, purchase of water).*

Recommendations—protected areas

a. *Aquatic ecosystems should be considered for future acquisition of protected areas (e.g. national parks, nature reserves, conservation areas, or aquatic reserves), or nominations of important wetland areas (e.g. National Heritage, World Heritage and Ramsar sites). This may also include Indigenous protected areas.*

b. *Policies and management practices and* *documents for protected areas with rivers and dependent ecosystems should include how management or policies will meet long-term ecological outcomes of sustainability (e.g. upstream environmental flows, pest control strategies and impacts of catchment disturbance).*

c. These ecosystems could be the focus for the development of cooperative protective management arrangements with landholders (e.g. voluntary conservation agreements and other protected area programs).

d. They could be considered for heritage listing under the National Heritage List of the Environment Protection and Biodiversity Conservation Act 1999.

e. They could be listed under relevant threatened-species legislation as endangered or threatened ecological communities if they satisfy appropriate criteria.

Recommendations—natural resource management and planning

a. Statutory resource and land-use plans, including river- management plans, should assess and control potentially deleterious impacts on these ecosystems at catchment scales.

b. Environmental objectives in water plans should adequately acknowledge high-conservation-value rivers and their dependent ecosystems and water regimes that maintain their ecological values.

c. River-management planning of these areas needs to explicitly incorporate rivers and their dependent ecosystems within management plans, recognising catchment processes and hydrological connections.

d. For those aquatic ecosystems that cross management borders, river planning should incorporate all of a catchment, taking account of different jurisdictional water legislation.

e. Water-quality policies and management should link to planning, assessment and controls that protect identified aquatic ecosystems.

f. Introduction of exotic species (plants or animals) should be controlled in these aquatic ecosystems and their catchments.

g. River management planning should involve communities early and involve effective community consultation and communication.

h. Planning should be culturally sensitive (e.g. respect Indigenous decision-making and governance processes) and involve traditional owners for identified ecosystems.

i. For improved management, research and development should focus on threats that affect conservation values of high-conservation-value rivers, reaches and dependent ecosystems.

Recommendations—incentives

a. These ecosystems need to be identified and included in Australian Government, State and regional investment frameworks.

b. These aquatic ecosystems could receive priority in monitoring and assessment of ecological values (e.g. Rivercare, Water Watch, auditing).

c. These ecosystems could be a focus for tax and rate- relief programs and new incentive schemes for landholders committed to protecting these areas.

Making it happen

Implementation of the national framework would require cooperation between jurisdictions and the Australian Government. To that end, it could be best progressed under the aegis of the Natural Resource Management Ministerial Council and the National Water Initiative.

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Objectives

River conservation is difficult for many reasons, but the need for action is clear. A path forward that achieves stakeholder and public acceptance is crucial, but it must also effectively protect rivers. Existing mechanisms that strive to protect river values have sometimes succeeded, but have encountered significant difficulties or have failed. There is uncertainty as to whether the best conservation outcome has been achieved when the relative value of the system that has been protected is not considered, and management for conservation is not within a catchment context.

This discussion paper aims to identify key elements of a national framework that could assist Australian governments and communities in the protection of rivers and their dependent ecosystems of high conservation value. This framework takes a proactive approach to protection of rivers that are not yet degraded and identifies effective protective and restoration mechanisms for rivers or parts of rivers that are nationally important, even if degraded. The protection framework does not preclude economic development but it provides mechanisms that could assess potentially threatening developments and ensures that conservation targets inform river and catchment-management planning.

The ultimate objective of implementing such a framework is to protect Australia's high-conservation-value rivers, reaches, floodplains and estuaries—an objective requiring the cooperation of the States and Territories, which bear primary constitutional responsibility for land and water management. Consensus among jurisdictions on the essential elements of the framework of protection is important, followed by identification of what potential institutional and operational arrangements would give effect to a coordinated national approach. The framework needs to be sufficiently flexible to allow for application of different protection mechanisms among jurisdictions.

This proposed framework reflects discussions with jurisdictions and the deliberations of a national forum on the topic held in Canberra in 2004. Most responses from participants to the forum and information from discussions were recorded with a comment on how responses were considered (see Appendixes F & G). The authors hope this discussion paper provides a national framework that will garner support from all levels of government and the community and deal with the ongoing problem of degradation in the nation's high-conservation-value rivers.

Chapter 1. Introduction

Australian rivers: a brief history

Rivers are one of the most important natural features of the Australian environment. There are many different types of rivers in Australia, their character, dependent ecosystems, and unique flora and fauna determined by climate and geomorphology. Rivers in northern Australia are influenced by monsoonal rains; the arid interior receives sporadic, heavy rainfall from tropical cyclones, resulting in spectacular flooding (Puckridge et al., 2000; Roshier et al., 2001), while the southern parts of Australia receive more uniform rainfall in a temperate climate (Lake, 1995; NLWRA, 2002a).

Many Australian species thrive on highly variable flooding and drying regimes. The rivers that course through the continent bring water to areas that would otherwise be permanently dry, and their water supports tens of thousands of species, including algae, bacteria, plants, invertebrates, amphibians, reptiles, fish, birds and mammals, including people. Lake Eyre turns from the 'dead heart' of Australia into one of the most spectacular places on the continent when the rivers that feed it flow.

Rivers sustain billabongs, large floodplains, and lakes and estuaries, the nurseries of bountiful fisheries. Rivers are the home of red gum and coolibah trees. The spiritual role of rivers in Dreamtime stories of Aboriginal peoples is also very important. Rivers were the pathways for European explorers and subsequent colonists, and our largest rivers became important corridors of trade. Few Australian towns are far from a river, with many of them on a floodplain.

European settlers struggled to cope with the variability of river flow, suffering drought on one hand and the flooding of townships and agricultural lands on the other. The earliest colonists strived to improve the reliability of water supplies from rivers, and now few of the larger river systems in south- eastern Australia remain unregulated (Kingsford, 2000; Arthington & Pusey, 2003). Our ability to harness and use river flows for drinking water, industry, growing food and fibre, and producing electricity has produced wealth and improved our quality of life, but it has also contributed to considerable environmental problems in rivers.

Against this background of water-resource development, there is an increasing need to protect healthy, intact rivers from degradation. In Australia and elsewhere, there are three main threats to the ecological health of rivers and their dependent ecosystems: (i) alteration of flows; (ii) catchment disturbance and land-use change; and (iii) invasive pest species (Allan & Flecker, 1993; Richter et al., 1997). Water resource and catchment development, particularly in the highly populated and agriculturally developed areas of Australia, has caused immeasurable and sometimes irreparable damage to the ecology of rivers, much of which may take decades to be revealed.

1.1. Australian rivers in the 21st century

Many of Australia's distinctive and important rivers are severely degraded (Dunn, 2000; Kingsford, 2000; Arthington & Pusey, 2003). Australian rivers are under increasing pressure from over-extraction, pollution, catchment modification and river regulation (Ball *et al.*, 2001). Despite the findings of investigators and the introduction of the Council of Australian Governments' water industry reforms in 1994, those pressures continued to increase (Ball *et al.*, 2001).

All rivers within regions with intensive agriculture are degraded to some degree by human activity (Australian State of the Environment Committee, 2001). It is no coincidence that the most serious ecological problems occur in south-eastern Australia, particularly in the Murray–Darling Basin, where water resource and catchment development and the spread of pest species act together (Ball *et al.*, 2001; ASEC, 2001; NLWRA, 2002a). In the Murray–Darling Basin, only 3% of rivers remain largely unmodified (Norris *et al.*, 2001). The most widespread modifying factor identified is catchment disturbance (assessed on degree of vegetation clearance and the intensity of land use), while hydrologic disturbance (water regulation and extraction) affects more than half of the river reaches assessed (Norris *et al.*, 2001). Many of the major rivers have floodplain wetlands that are considerably reduced by declining river flows (Kingsford, 2000). Of the major river catchments in the Murray–Darling Basin, only the Paroo and Warrego remain largely unregulated by major government-built or private dams and are now the only catchments where most of the floodplain wetlands remain (Kingsford *et al.*, 2004b). Riparian vegetation is often dominated by introduced species, native fish populations are now about 10% of pre-European levels, largely replaced by exotic species such as European carp, *Cyprinus carpio* (Gherke & Harris 2001), and incidents of blue–green algal blooms are considerable and more frequent (Bowling & Baker, 1996).

1.1.1. Alteration of flows

Major impacts on rivers have been caused by alteration of flows through river regulation: the building of dams (and weirs), drainage and levees, floodplain development and water extraction. The primary impact of river regulation on the riverine environment is interruption of the natural flows of water, sediments, nutrients, energy and biota (Ligon *et al.*, 1995), leading to fundamental changes in channel characteristics, habitat availability and flow regime (Allan & Flecker, 1993; Bunn & Arthington, 2002). Alteration of the flow regime may include reversal of seasonality, attenuation of minor and moderate floods, reduced variability and altered rates of rise and fall of river levels (Walker, 1985; Maheshwari *et al.*, 1995; Kingsford and Thomas, 1995; Thoms & Sheldon, 2000). This affects the productivity and exchange of material between the floodplains and the river channel (Robertson *et al.*, 1999; Thoms, 2003).

Alteration of flows and reduced flooding has been shown to have ecological impacts on dependent ecosystems, affecting ecosystem services (Allan & Flecker, 1993; Lemly *et al*., 2000; Gillanders & Kingsford, 2002; Bunn & Arthington, 2002). In Australia, such impacts are particularly evident within the Murray–Darling Basin (Walker, 1985; Kingsford, 2000; Arthington & Pusey, 2003; Kingsford & Thomas, 2004).

Extensive floodplains, mostly located in the lowland parts of catchments, are the dominant type of freshwater-dependent ecosystem in the Basin (Kingsford *et al.*, 2004b). These are the areas where most biodiversity and dependent agrarian industries, such as grazing, reside. The diversion of water, predominantly for irrigated agriculture (NLWRA, 2001), in the upper and middle reaches of the catchments, deprives many of these floodplain ecosystems of water, resulting in major loss of biodiversity and ecosystem function (Kingsford, 2000).

1.1.2. Catchment disturbance

Catchment characteristics are the main factor influencing river flows. Alteration of catchments through grazing, vegetation clearing, urbanisation, mining and agriculture changes rivers (Richter *et al.*, 1997). For example, vegetation clearing alters physical habitat within riparian zones (Davis & Froend, 1999) and the hydrology of freshwater systems (Davis & Froend, 1999; Ogden, 2000; Malmqvist & Rundle, 2002). Sediment and nutrient loads from catchment disturbance have increased by an order of magnitude in many Australian river basins (NLWRA, 2002a). About 13% of native vegetation nationally has been cleared since European settlement, concentrated in large population centres and areas of agricultural production: the Murray–Darling Basin, the east coast and the south-west of Western Australia (NLWRA, 2002a). There are many examples of catchment disturbance and its impact on aquatic systems throughout Australia. The following examples illustrate some of the more severe impacts resulting from poor management and cumulative development of catchments.

- Faecal matter from poorly managed sewerage systems in adjacent rural and urban residential zones polluted Wallis Lake, on the central coast of NSW, one of the major fisheries of Sydney rock oysters: resulting in over 400 people contracting viral hepatitis A from contaminated oysters (Ebsworth & Ebsworth, 2001).
- Toolibin Lake, the last remaining example of a perched freshwater wetland in the south-east of Western Australia, is threatened by a rising watertable and increasing salinity caused by widespread clearance of native vegetation (Froend *et al.*, 1987; Boulton & Brock, 1999).
- The Great Barrier Reef World Heritage Area, one of the seven natural wonders of the world, is threatened by elevated sediment loads from Queensland coastal rivers in the wake of catchment clearing (Hendy *et al.*, 2003).
- In the Murray–Darling Basin, the ingress of nutrients from urban and agricultural areas, and extended periods of low or no flow intensified by high levels of water extraction, exacerbates development of potentially toxic, blue–green algal blooms (Ball *et al.*, 2001).

1.1.3. Pest species

Humans have a long history of the intentional or accidental introduction into ecosystems of exotic species that then become uncontrollable outside their natural range. Freshwater ecosystems in

Australia are no exception; in Australia there are now 20 species of exotic fishes and 65 species of exotic aquatic plants. Fifteen of these species are significant pests (Boulton & Brock, 1999). The following are some examples of pest species with the potential to have devastating effects on Australian freshwater and estuarine ecosystems.

- Eight NSW estuaries and at least one South Australian harbour are under threat from invasions of *Caulerpa taxifolia*, a noxious alga with the potential to grow rapidly and smother seagrass beds.
- Tropical rivers are at risk from a plethora of weed species: *Mimosa pigra,* whose seeds are spread by floodwaters (Cook *et al.*, 1996); rubbervine *Cryptostegia grandiflora,* which forms impenetrable thickets along watercourses; and *Parkinsonia aculeata,* found along watercourses, is one of the most troublesome weeds in the Northern Territory.
- Water hyacinth (*Eichhornia crassipes*), lippia (*Phyla canescens*), willows (*Salix* spp.) and alligator weed (*Alternanthera philoxeroides*) are among other weeds causing problems in riverine systems in parts of Australia.
- European carp (*Cyprinus carpio*) has spread throughout the Murray–Darling Basin in less than 40 years and is now a major aquatic pest species, competing with native fish, destroying aquatic vegetation and disturbing benthic sediments (Ball *et al.*, 2001). In a survey of fish communities in NSW in 1996–1997, 80% of the catch in the Murray catchment was made up of introduced species (Gherke & Harris, 2001).
- Other introduced vertebrate pests also threaten the ecological health of river ecosystems in Australia. including the cane toad (*Bufo marinus*), feral pigs (*Sus scrofa*), water buffalo (*Bubalus bubalis*) and banteng cattle (*Bos javanicus*).

1.2. Australian rivers: potential for national action

As a nation, Australia spends millions of dollars on degraded river systems and their catchments (e.g. $2.7 billion under the Natural Heritage Trust, $1.4 billion under the National Action Plan for Salinity and Water Quality, $0.5 billion on the Living Murray initiative). Communities and governments, supported by State and Australian Government funding programs, strive at local, catchment, regional and State levels to rehabilitate natural riverine environments and to sustain agricultural productivity. Such efforts usually aim to restore parts of already degraded environments rather than to protect high value intact or remnant ecosystems, and outcomes are patchy and difficult to quantify. The Prime Minister's Science, Engineering and Innovation Council has argued that it is 10 to 100 times cheaper to maintain ecosystems than to repair them (PMSEIC, 2002), yet relatively little is invested in the protection of our remaining, relatively undisturbed, functioning and diverse high-value aquatic ecosystems.

In the 21st century, Australia has an opportunity to learn from the past and build a framework that protects some of our most important ecosystems. While many of the rivers in the south-eastern, densely populated part of the continent are heavily developed, some rivers in the inland and northern half of the continent remain largely unexploited (Ball *et al.*, 2001; Stein *et al.*, 2001; NLWRA, 2002b; Dunn, 2003). There is growing recognition of the ecological value and conservation importance of these few, relatively unaffected rivers in Australia (Cullen, 2002: Hankinson & Blanch, 2002). As well, there is recognition of the importance of a national approach to aquatic ecosystems of national importance (e.g. estuaries; Smith *et al*., 2001). However, a framework for the protection of high-conservation-value rivers should encompass undeveloped river basins, as well as nationally important rivers, reaches, wetlands, floodplains and estuaries within developed river basins.

While attention has been given to the conservation of rivers, there has been relatively little concerted strategic activity in river conservation at the national level in Australia (Schofield *et al.*, 2000). Many rivers in the highly populated parts of Australia are under pressure from the cumulative impacts of development, and proposal to develop the resources of undeveloped, high-yielding river basins continue, including to develop Australia's tropical rivers. River regulation is known to produce long-term and predictable ecological consequences for rivers and their dependent ecosystems (Lemly *et al.*, 2000). Several authors predict that these large tropical and subtropical river systems with natural flow regimes will suffer ecological damage and biodiversity losses if large-scale water development takes place (Allan & Flecker, 1993; Puckridge *et al.*, 1998; Bunn & Arthington, 2002; Arthington & Pusey, 2003).

The National Water Initiative (NWI) is a comprehensive strategy driven by the Australian Government to improve water management across the country. The National Water Initiative recognises that Australia's highly variable and often scarce water resources are crucial for economic, social and environmental wellbeing.

The National Water Initiative parties agree that the outcome for the integrated management of environmental water is to identify within water resource planning frameworks the *environmental and other public benefits* sought for water systems. The parties agreed to establish effective and efficient management and institutional arrangements to ensure the achievement of environmental and other public benefit outcomes, including any special requirements needed to *sustain high conservation value rivers, reaches and groundwater areas*.

1.2.1. Commitments

Successive Australian governments have committed to the protection of high-conservation-value ecosystems, including aquatic systems, through a range of measures including (but not limited to):

- Ramsar Convention 1971
- World Charter for Nature 1982
- Agenda 21 1992 (Rio Earth Summit)
- Intergovernmental Agreement on the Environment 1992
- United Nations International Convention on Biological Diversity 1992
- National Strategy for the Conservation of Australia's Biological Diversity 1996
- Natural Heritage Trust.

Similarly, government and non-government initiatives in all Australian jurisdictions increasingly recognise the need for protection of high-value rivers. Such initiatives include:

- the Prime Minister's Science, Engineering and Innovation Council recommendations for managing Australia's inland waters and measures for protection of heritage rivers
- the National Water Initiative 2004 (CoAG, 2004 <www.coag.gov.au/meetings/ iga_national_water_initiative.pdf>, accessed 18/8/04),
- Land & Water Australia projects by Bennett *et al.* (2002) and Dunn (2000), proposing methods to identify and protect high conservation value rivers
- the Living Murray's focus on protecting significant ecological assets
- the Natural Resource Management Ministerial Council 2004 plans for inclusions of freshwater environments in the national reserve system (Discussion paper: Directions for the National Reserve System—a Partnership Approach, <www.deh.gov.au/parks/nrs/directions/ index.html>, accessed 18/8/2004)
- Conservation Guidelines for the Management of Wild River Values 1998
- bilateral and multilateral agreements for the protection of the Paroo River and Lake Eyre Basin
- the marine park reserve system to protect high-value estuaries
- the Australian Capital Territory's river corridors
- the New South Wales' process to nominate wild rivers in national parks and reserves
- the Northern Territory's protection measures for the Daly River
- Queensland's wild rivers policy election commitment
- South Australia's commitment to the Lake Eyre Basin Agreement and the Living Murray initiative
- Tasmania's project on the conservation of freshwater ecosystem values
- Victoria's heritage river system
- Western Australia's wild rivers documentation and state of rivers reports.

1.2.2. Context for protection of high- conservation-value rivers

As well as these commitments, a considerable body of knowledge exists supporting the protection of high- conservation-value river ecosystems.

- 'Wild Rivers' was a national program initiated with the primary objectives of identifying and encouraging the protection of rivers that remained largely unaltered by European settlement (Stein *et al.*, 2001). It did not specifically identify high-conservation-value ecosystems or include wetland ecosystems. The wild rivers database used nationally available information to indicate the potential level of disturbance from human activities, but additional information is required to adequately assess the impacts of alteration of flows by dams and extractions relative to other threats. Although lists of wild rivers were produced for each jurisdiction (<http://www.heritage.gov.au/anlr/ code/arc-maps.html>, accessed 18/8/2004), protection of identified rivers and river reaches never eventuated.
- In 2001, the principles and tools for protecting Australian rivers were reviewed (Phillips *et al.*, 2001). This provided a comprehensive guide for the systematic protection of rivers, primarily for managers, but it did not focus on high-

conservation-value rivers. It advocated three levels of protection planning: conservation, sustainable use, and remaining use. It also provided guidelines for assessing ecological value, determining sustainability using a pressure– state–response model, selecting appropriate planning or protection tools and setting priorities for protection, and evaluating effects of development.

- In 2004, there was an extensive independent review of existing Australian mechanisms for protection of freshwater ecosystems (Nevill & Phillips, 2004). It advocated the need for comprehensive inventories of Australia's freshwater ecosystems so that key areas could be identified for a comprehensive, adequate and representative system of aquatic protected areas. It also considered the importance of protecting high-conservation-value rivers.
- In 2004, a discussion paper was released by the Natural Resource Management Ministerial Council in relation to the future of the national reserve system (NRMMC, 2004; <www.deh.gov.au/parks/nrs/directions/index.html>, accessed 18/8/2004). Freshwater reserves were identified as an emerging issue for the national reserve system. The paper recommends the identification and mapping of freshwater systems, and a review of the comprehensiveness, adequacy and representativeness of the reserve network for freshwater biodiversity.
- The *Directory of Important Wetlands in Australia* lists wetlands of international and national significance in Australia. It was compiled by jurisdictional contributors (ANCA, 1996; <www.deh.gov.au/water/wetlands/database/index.html>, accessed 18/8/2004) and provides an indication of key wetland assets. The directory uses the Ramsar definition of wetlands, which includes rivers and subterranean aquatic ecosystems. These lists were compiled using criteria modified from the Ramsar convention, but not applied objectively or comprehensively across all wetlands. As the list was assembled using the bioregional framework for terrestrial ecosystems, there are problems with overlapping catchment communities and with wetlands not set in a catchment framework for management.
- Australia is a signatory to the Ramsar Convention, and currently has a total of 64 listed wetlands, covering an area of almost 7.4 million ha. The nomination and management of Ramsar sites is the responsibility of the State or Territory in which they are located. These listed wetlands are distributed among different rivers and systems, but tend to be within current protected areas because of the relative ease of nomination processes where the site is already protected. While these wetlands have status as 'wetlands of international importance', they do not necessarily represent the highest conservation value wetlands or rivers at a national, State or Territory level, nor have they been subject to a consistent and systematic comparative assessment process.
- Wetland policy and funding processes have seldom adequately included the importance of river flows for long-term sustainability. For example, there is relatively poor coverage of the importance of river flows in the *Directory of Important Wetlands in Australia*, and no jurisdictional or national wetland policies adequately deal with the overriding importance of flows and their effects on biodiversity and wetland health.
- In 1994, CoAG agreed on a course of management for Australia's water resources. This included recognition that the environment was a legitimate user of water. In 2004, CoAG agreed to the National Water Initiative (NWI), which will chart the future responsibilities and progress towards sustainable management of the nation's rivers and aquifers. Provisions in the intergovernmental agreement (<www.coag.gov.au/meetings/250604/iga_national_water_initiative.pdf>, accessed 18/8/2004) on the NWI commit parties (all States and Territories apart from Tasmania and Western Australia) to identify, protect and manage high-conservation-value rivers and aquifers and their dependent ecosystems.
- Rivers of outstanding importance to the Australian community as a whole may be nominated under the new heritage provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Under these provisions, anyone may submit a nomination for a river to be considered for inclusion on the National Heritage List. The Australian Heritage Council will assess the natural or cultural heritage values of nominated places against specific criteria and make recommendations to the Minister for the Environment and Heritage. The final decision on listing will be made by the Minister (<www.deh.gov.au/heritage/national/index.html>, accessed 18/8/2004).

1.3. Why do we need a national framework?

There is no comprehensive or systematic protection of rivers of high conservation value in Australia or its constituent jurisdictions. However, four jurisdictions currently have or will have established individual approaches for wild or heritage rivers. Victoria has protected 18 rivers under its *Heritage Rivers Act 1992* (Appendix E). The Australian Capital Territory has established major river reserves. New South Wales has a commitment to designate parts of rivers within national parks and reserves, under the *National Parks and Wildlife Act 1974* (Appendix E). Queensland has a commitment to identify and protect wild rivers by designation of particular rivers (Appendix E). In contrast to the well-established system of conservation of terrestrial environments through reservation of lands, and progress on marine protected areas, there are few good models that have been adequately applied to the conservation of freshwater aquatic environments. In some parts of the country, whole river basins may be protected by virtue of land protection measures, such as the wilderness protection areas in Tasmania, large national parks in Queensland (e.g. Jardine River) and the Prince Regent Basin biosphere reserve in Western Australia.

In most areas, protection and management of rivers is delivered through a combination of environmental planning and assessment, environmental protection (water quality), vegetation management, water and river management, threatened species and wildlife protection legislation, and incentive-based restoration programs. In some cases these mechanisms have succeeded in protecting river values, but in many important instances they have encountered significant difficulties or have failed. Where protection has been successful, there is uncertainty whether the best conservation outcomes have been achieved, because the relative value of aquatic systems is unknown and because the conservation of rivers or ecosystems is seldom managed within a catchment context.

Conservation efforts in Australia have traditionally focused on terrestrial systems; 9.2% of Australia's total land area is protected within formally declared areas, as defined by the International Union for the Conservation of Nature (IUCN) (NLWRA, 2002b). Conservation value in an ecological sense has been widely applied to terrestrial ecosystems, contributing to reserve design and planning (Margules & Pressey, 2000). Conservation planning has evolved over time, moving from protection of scenic and recreational values towards conservation of species and communities. Over a similar period, conservation of rare species (often vertebrates with high popular appeal or attractive higher plants) has evolved towards conservation of communities and ecosystems. While protected areas have played an important role in securing biodiversity and the future of significant landscape components and vegetation communities, legislation and policies increasingly seek to mitigate potentially threatening processes (e.g. climate change, clearing, salinity) in a broad bioregional and catchment context. These changes in terrestrial conservation planning reflect advances in our knowledge of native species, their habitats, and the complex linkages and landscape-scale processes that drive and sustain our ecosystems.

To support future consideration of conservation of aquatic systems in this context in 2003/04 States, Territories and the Austrlian Government participated in the development of a conceptual framework for the protection of high conservation value rivers, river reaches and estuaries.

A protection framework for the conservation of the ecological values of aquatic systems can profit from the lessons learnt from terrestrial conservation. That is, an effective framework should focus on:

- conservation of habitat, ecosystem function and process to protect biodiversity rather than preservation of iconic species;
- systematic identification of priorities; and
- strategic application and integration of a range of suitable protection measures (protected areas, land-use planning and threat management) to effect conservation within a landscape context.

There are some significant advantages in adopting a national framework (see Box 1). As well as the plethora of potential measures for protection, there is no integrated framework showing where and at what scale such measures can be most effectively utilised, or how governments could reward good management through investment. All governments are investing considerable funds in the management of natural resources for conservation (e.g. Natural Heritage Trust, National Action Plan for Salinity and Water Quality) and high-conservation-value rivers need to be considered as priorities in such management. A national framework could clearly identify and strategically target management efforts at high- conservation-value rivers and help to establish interrelationships among various delivery bodies. It could help cross-border management of rivers and allow for better balancing of short-term gains against long-term degradation costs at a national level. It would assist in state-of-the-environment reporting and land and water management auditing, from jurisdictional to national scales.

1.4. Key concepts

A significant impediment to communication and discussion about the management of rivers is inconsistency in the meanings ascribed to technical terms used. This problem is often exacerbated by legislative and policy differences among jurisdictions. An agreed terminology for river protection is essential. Box 2 outlines the main terms used in this discussion paper.

Box 1: Reasons for a national framework

Prevention is better than cure—A national framework for the protection of rivers would help forestall degradation of national environmental assets that are becoming increasingly difficult and expensive to rehabilitate for future generations.

Strategic national investment—A national framework could help ensure that the limited resources available for river conservation are strategically targeted at nationally important rivers and dependent ecosystems, and provide the opportunity for a nationally coordinated support program.

National conservation—A national approach would allow a more comprehensive understanding of the need for conservation action that otherwise may be underestimated by regional or jurisdictional studies.

National and international obligations—Through treaties and conventions, the Australian Government has international responsibilities for rivers, dependent ecosystems and particular migratory species that depend on rivers and their dependent ecosystems (e.g. migratory wading birds), and biological diversity.

Consistent methodology—An agreed methodology would be useful in the setting of national conservation priorities and for consistent auditing at different scales. It would allow for strategic planning and for identification of high-conservation-value rivers and ecosystems at different spatial scales. It would also allow for state-of-the-environment reporting and auditing of natural resources at different spatial scales. This would allow different community and government groups to adopt a common currency, making assessment more consistent.

Sharing knowledge—A national framework would provide a way of sharing successful mechanisms for assessment and protection. Jurisdictional information systems can be enhanced by linkages established through a national framework.

Cross-border river management—Many of Australia's rivers basins straddle State borders. Cross- border river management continues to be problematic, primarily because each State or Territory has different priorities, policies and legislation. A national framework could assist with whole-river and basin management of high-conservation-value rivers.

Natural region boundaries—With a national framework, planning and assessment need not be limited by administrative boundaries and may conform to more natural boundaries of plants and animals.

Delivery relationships—Many different government and community groups are involved in the management of rivers, including catchment management authorities, regional bodies, local Aboriginal communities, government agencies and local government. A national framework could build essential synergies among different groups responsible for delivering programs for high-conservation-value rivers.

Box 2: Key terms

Rivers are complex but essentially linear bodies of water draining, under the influence of gravity, from elevated areas of land towards sea level.

Dependent ecosystems include river segments, wetlands, riparian zones, intermittently or seasonally inundated floodplains, estuaries and connected groundwater systems (e.g. karst). They also include temporary or permanent wetlands that may fill from local rainfall or groundwater. They include ephemeral streams and creeks and 1st and 2nd order streams.

Spatial scales for rivers are consistent with nationally accepted terminology. Drainage divisions, basins, catchments and sub-catchments are best defined topographically, reflecting the hydrology of rivers. Currently available and agreed spatial systems do not always respect this tenet. This paper refers to the Australian Water Resources Commission 12 drainage divisions covering Australia, and the 245 river basins, used in the National Land and Water Audit, because these are widely used and agreed upon. River segments and reaches and sub-catchments are any other nested smaller-scale parts of rivers, within the river basins.

Conservation value encompasses the conservation of cultural and ecological values of rivers. It is a measure of relative significance (Dunn, 2000). This discussion paper focuses primarily on ecological value, while recognising that the framework may be usefully adapted to recognise cultural values. Ecological values within the broad context of 'conservation value' are attributes of river system ecology that should be protected, maintained or restored for present and future generations.

Conservation criteria are broad categories of conservation importance for which rivers and their dependent ecosystems could be assessed to determine if they are of high conservation value. They are applied in an ecological sense in the discussion paper.

Attributes are actual measures that would be used for each conservation criterion and could be developed into a score that would allow high-value-conservation rivers and their dependent ecosystems to be identified. These equate to the 'indicators' used by Bennett *et al*. (2002).

High conservation value describes rivers or their dependent ecosystems (river segments, floodplains, estuaries) whose conservation value is objectively assessed and ranked highly, based on proposed criteria and national assessment.

Tools and mechanisms refer to the ways in which data may be collected and integrated, and the ways in which rivers may be protected through policy, management and legislation.

Protection means taking care of a place by managing impacts to ensure that natural values, ecological integrity and connectivity are maintained (Australian Natural Heritage Charter [1996]; Bennett *et al.*, 2002). Different mechanisms exist for protection at different scales, tailored to the context of threats to rivers.

Protected areas, as defined by the IUCN's six categories [see appendix in Nevill & Phillips (2004)] include jurisdictional national parks and conservation reserves, Ramsar sites, aquatic reserves and local- government reserves.

Jurisdictions are the State and Territory governments, which are primarily responsible for land and water management in Australia, local governments and the Australian Government.

Regional bodies are statutory or non-statutory bodies set up by the State and Territory governments to manage catchments and deliver funding for natural resource management. They include catchment- management authorities.

1.5. Conservation planning and protection

Conservation of biodiversity is the widely adopted nature conservation objective of many international conventions, national governments, state agencies and non-government organisations (Redford *et al*., 2003). Rigorous conservation planning leads to a vision that describes general conservation outcomes that may be easily communicated (Fig. 1). For example, the vision for the protection of the natural environment and biodiversity of the Cape (floristic region) in South Africa was to have "effectively conserved, restored wherever appropriate, and delivering significant benefits to the people of the region, in a way that is embraced by local communities, endorsed by government and recognised internationally" by 2020 (Pressey *et al*., 2003). Based on this model, a potential vision for protection of all rivers could be:

> *By 2020, riverine biodiversity, rivers, and their dependent ecosystems in Australia will be effectively protected and restored, where appropriate, delivering significant benefits to local people and the Australian community.*

Implementation of this vision depends on assessment of all rivers and dependent ecosystems to identify those of high conservation value. Such an assessment has the added benefit of identifying conservation values and appropriate management needs within all rivers. The Canadian Heritage Rivers System adopts a similar vision that focuses on "outstanding rivers" (Appendix D). A vision can then be translated into specific goals and measurable results, applied at different spatial scales, through conservation planning and management mechanisms (Fig. 1). In an operational sense, there are usually specific goals relating to conserving species (threatened or all species), ecological communities, ecological and evolutionary processes, natural features or sustainable use (Groves *et al*., 2000; Redford *et al*., 2003). Sometimes communities or ecological systems become the focus because they are assumed to be effective surrogates for sustaining biodiversity (e.g. St Louis River Citizens Action Committee, 2002).

Goals can be tied to quantitative targets, based on the best available information, to measure progress, effectiveness and accountability for conservation decisions (Margules & Pressey, 2000). They are more likely to initiate conservation actions by clearly specifying what planners are aiming for (Nix *et al*., 2000). Trade-offs between conservation and competing land uses can be made explicit (Pressey *et al*., 2003). Aims need to be focused so they recognise that some features may need greater levels of protection than others and do not potentially generate a false expectation that limited conservation action is sufficient (Pressey *et al*., 2003). Targets can apply to distributions of populations, species, communities or ecological systems (Smith *et al*., 2002; Pressey *et al*., 2003; Weitzell *et al*., 2003). Methods are available to set credible targets (Pressey *et al*., 2003) for better-known species or systems that represent biodiversity, but uncertainty will always necessitate review.

Until relatively recently, management of natural resources was approached through a dichotomous process: areas were either protected (e.g. national parks, conservation reserves) or they could be developed given adequate safeguards (e.g. environmental assessment, land-use planning provisions and management plans). There is now a realisation that ecologically sustainable management is much more difficult — conservation and land and water management are inextricably linked. Further, many conservation reserves dependent on rivers were not adequately managed, because conservation managers had no control over the water (Barendregt *et al*., 1995; Kingsford & Thomas, 1995; Kingsford, 2003).

To deal effectively with the major pressures on rivers and their dependent ecosystems, some key principles should be applied to management and protection of national rivers or dependent ecosystems (Box 4).

The challenge is particularly difficult for rivers where ecosystems are connected for sometimes more than a thousand kilometres. For effective protection of high- conservation-value rivers and their ecosystems, it becomes essential to tailor the protective mechanisms to the potential pressures. Following on from the broad categories of pressures that affect conservation values of rivers, it is possible to broadly define the types of protection measures that can be used (Box 5). The extent to which chosen mechanisms are implemented will depend on a variety of factors and, in particular, the level of protection the community or government wishes to afford a specific high- conservation-value river or its dependent ecosystem. This applies where measures may restrict water- resource development and/or land-use changes.

Natural resource management agencies have a strong interest in clear policy drivers that support the conservation of high-conservation-value river ecosystems. A national framework could foster involvement, understanding and commitment from communities and the various levels of government, by providing clear strategic direction for river conservation.

Box 3: Explanation of Figure 1

1. A vision statement provides an easily communicated description of desired conservation outcomes.
2. An evaluation system, based on agreed criteria and significance thresholds, identifies high-conservation-value rivers and dependent ecosystems and informs the selection of goals for conservation planning. Thresholds used for Ramsar (a convention for protection of wetlands of international importance) and the *Directory of Important Wetlands in Australia* (DIWA) may be used to inform this process.
3. Goals specify the values or features of rivers that are the focus of the conservation plan.
4. Targets make conservation goals operational and describe conditions necessary for persistence of desired values and features.
5. Evaluates whether targets for representation and design have been achieved by existing protection mechanisms, measures progress towards goals and identifies additional conservation needs.
6. A complementary set of priority areas that represents all remaining features according to the specified targets, preferably while minimising opportunity costs, is identified and prioritised for conservation action using criteria such as uniqueness, capacity for protection and vulnerability.
7. The Australian Heritage Rivers system protects whole basins of high conservation value.
8. Existing jurisdictional protection mechanisms, including reservation, are employed for other high-conservation-value rivers, river segments and dependent ecosystems. A conservation strategy could coordinate and provide direction for existing national (e.g. NRSMPA—National Representative System of Marine Protected Areas (<http://www.deh.gov.au/coasts/mpa/nrsmpa>, accessed 18/8/ 2004); NRS—National Reserve System, <http:// www.deh.gov.au/parks/nrs>, accessed 18/8/2004) and jurisdictional programs.
9. Monitoring and review are necessary to ensure the desired characteristics of high-conservation-value rivers are being maintained and to review the adequacy of goals and targets.

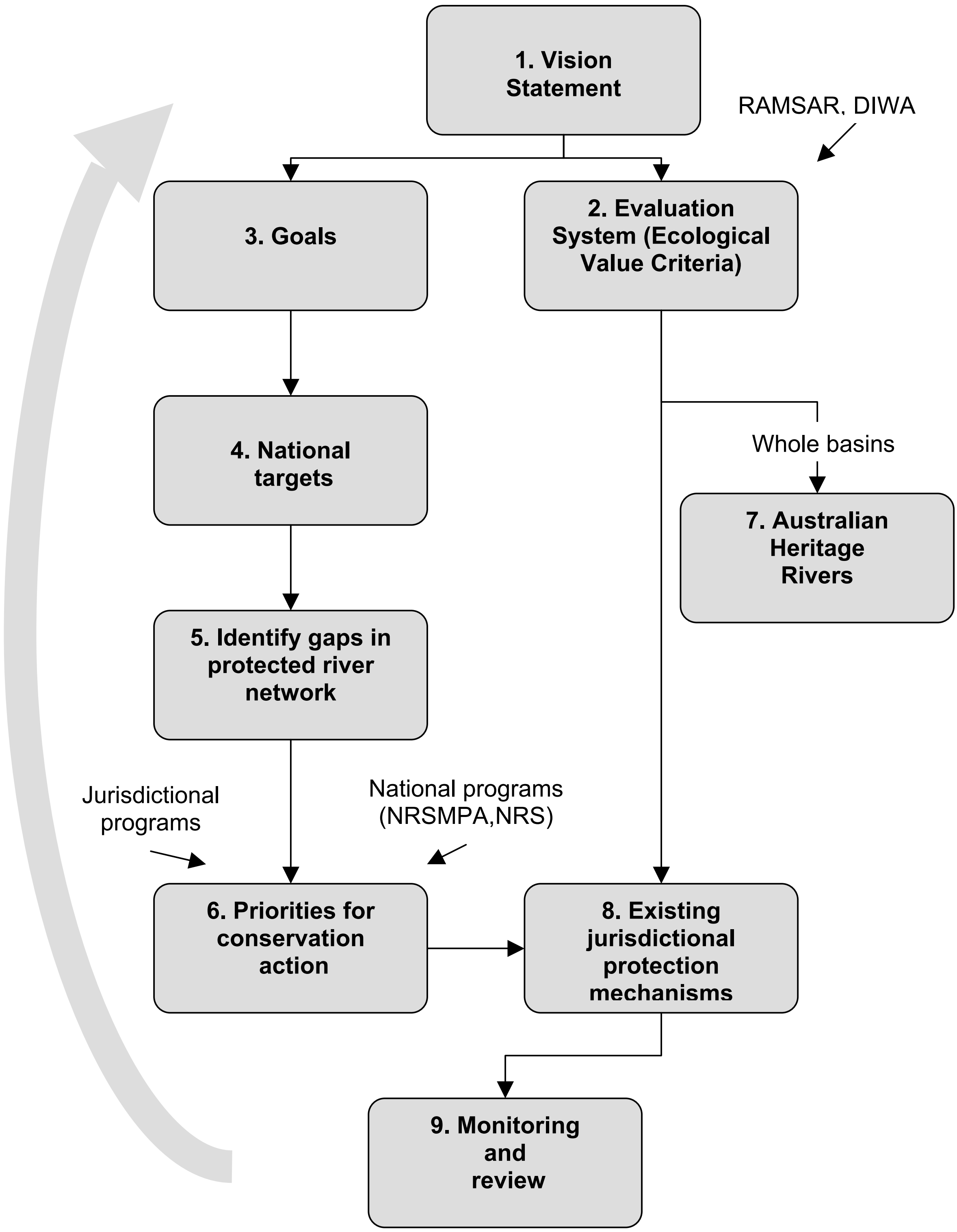


Figure 1. Parts of a national conservation strategy for rivers and dependent ecosystems. See Box 3 for explanation. Consultation and communication are essential at every stage.

Box 4: Proposed management principles for protection of high-conservation-value rivers, river reaches and dependent ecosystems

- Management of threats should be the main focus, using a catchment framework at an appropriate scale, and which recognises linkages between site values and catchment processes.
- Management approaches should, wherever possible, use available jurisdictional mechanisms, rather than develop new processes.
- Management plans, adopting protection of ecological assets and processes as the key defining goals and objectives, should take account of existing threatening processes, as well as guard against future detrimental processes.
- River flows should be protected at a level and regime that sustains all in-stream, floodplain and estuarine processes and functions (including long-term processes).
- Management should explicitly recognise the interdependence of surface river flows and subterranean catchments. Connected aquifers are part of the river.
- All proposed activities that affect ecological processes and values of identified systems should be adequately assessed and managed at a catchment scale if appropriate.
- Investment activities in restoration should target the nationally important high-conservation-value rivers, river segments and dependent ecosystems, prioritised according to imminence of threat and irreplaceability.
- Shared responsibilities between different tiers of government and the community should be developed and coordinated to protect rivers and dependent ecosystems that are nationally important.

Box 5: Protection mechanisms in relation to key pressures

Alteration of flows

- River management planning in different jurisdictions can protect essential flows to high-conservation-value rivers and their ecosystems. For effective flow protection to a high-conservation- value river or dependent ecosystem, near-natural flow regimes need to be maintained.
- Protected areas can be used to effect control over access to water or modification of the floodplain. Some rivers and their flows may be totally within a protected area.
- Environmental assessment can be designed to protect high-conservation-value areas from impacts of alteration of flows at different spatial scales. This should identify the potential cumulative impacts of small developments as well as large developments.
- Mechanisms that increase environmental flows to degraded iconic sites of national importance can be used to restore ecological health of high-conservation-value rivers and dependent ecosystems.
- For restoration activities, incentives could be used to purchase flow allocations, works that rehabilitate floodplain areas or increase ability to manage environmental flows (e.g. removal of‘chokes’ that restrict channel capacity and constrain the delivery of downstream flows).

Catchment disturbance

- Local and regional environmental planning can ensure catchment areas, essential for protection of high-conservation-value rivers or ecosystems, are not affected by inappropriate development.
- Protected areas can control inappropriate development (causing degradation) in areas in the catchment that could affect high-conservation-value rivers or ecosystems.
- Environmental assessment of potentially detrimental catchment processes (e.g. mining, clearing, urbanisation) can protect high-conservation-value rivers and dependent ecosystems. It should identify the impacts of not only large developments, but also the potentially cumulative impacts of small developments.
- Incentives for restoration activities should target critical catchment areas, including riparian zones and floodplain wetlands, that are important for high-conservation-value rivers and their dependent ecosystems.

Pest species

- Control programs, including catchment-based quarantine measures, and funding (e.g. biological control) can prevent the introduction of invasive species or focus on the management of weeds or feral animals affecting high-conservation-value rivers and dependent ecosystems.
- Environmental risk assessment can test the potential for exotic species deliberately introduced, particularly plants, to invade high-conservation-value rivers and dependent ecosystems.
- Application of quarantine legislation seeks to avoid further introductions of pest species, including aquarium species, to high-conservation-value rivers and dependent ecosystems.

Chapter 2. A national protective framework

2.1. Principles of a national protective framework

A national protective framework for rivers and dependent ecosystems could be built on the following principles.

- The national framework should seek to protect those rivers and dependent ecosystems of high conservation value.
- Identification of high-conservation-value rivers and nationally important freshwater ecosystems should be based on scientific assessment using nationally agreed criteria.
- The evaluation and ranking of the conservation value of rivers should recognise the multiple spatial scales of aquatic ecosystem organisation.
- Evaluation and ranking of conservation of rivers should allow iterative analysis, accommodating further assessment and evaluation as new data become available.
- High-conservation-value rivers should be managed to sustain their ecological values and integrity.
- Protection mechanisms need to recognise that rivers and their ecosystems require catchment-based management: a river reach, floodplain wetland, dependent aquifer or estuary cannot be managed or protected in isolation from its catchment.
- A national framework should integrate and coordinate current arrangements and seek to support and augment them where necessary, rather than replace or downgrade existing programs of conservation.
- A national program should build on institutional and administrative arrangements currently in place for delivery of natural resource management, avoiding duplication.

2.2. Developing a national approach

A working group (see authors and acknowledgments section) with experience in river management and conservation developed the main elements of this discussion paper. Some members of the working group are involved within jurisdictions in the conservation of rivers and dependent aquatic ecosystems. Others have wide experience in the theory and practice of conservation management of aquatic ecosystems. Development of the main elements of the paper occurred over a series of meetings within the group. These were considerably augmented by workshops held in various jurisdictions across Australia (Appendix F) and a national forum where the essential elements of the approach proposed were debated (Appendix G). This discussion paper represents a culmination of these deliberations, within the context of national and international obligations and the current state of knowledge in the area.

2.3. Elements of a national protective framework

A national framework of river protection could be built around three main elements:

1. nationally consistent collection of information on rivers, wetlands and estuaries, which will entail agreement on spatial scale and classification and evaluation systems for identification of rivers and dependent ecosystems of high conservation value
2. protection schemes that operate at different scales such as :

   a 'whole-of-river' approach that could include establishment of an 'Australian Heritage Rivers' system

   protection of high-conservation-value rivers, river segments and dependent ecosystems (floodplains, wetlands, estuaries) in a national, State, regional and local context (using current legislative and policy tools; i.e. environmental flows, protected areas, natural resource planning and management, and incentives)
3. operational and institutional arrangements— coordinated programs involving jurisdictions in implementation of a national framework.

2.4. Nationally consistent river information

The availability of data and the capacity to make valid comparisons among sites are particularly problematic for aquatic systems. The Australian State of Environment Report (ASEC 2001) and the National Land and Water Resources Audit (NLWRA 2001) identified major deficiencies in our knowledge of the extent and condition of inland aquatic systems. Further, the taxonomy and ecology of many groups of aquatic taxa remain poorly known (Cullen & Lake, 1995; Kingsford & Norman, 2002), restricting efforts at objective assessment. Existing pockets of good data at local or regional scales cannot readily be combined to provide a national viewpoint. In particular, there is a lack of information about aquatic ecosystems in relatively undisturbed remote catchments: those that are most likely to satisfy our first evaluation criterion (see below).

There is a need to invest in the long-term collection and collation of ecological and biophysical data for objective assessment of condition and value. To objectively identify high-conservation-value rivers at the national scale will require relative assessment across jurisdictions.

There is little jurisdictional support for a centralised national system of data management and application that might replace existing data systems (Appendixes F and G). Most jurisdictions have well-established systems of data collection and management that do not need to be duplicated at a national level. In contrast, there is some support for a consistent approach to collection of river information (Box 6).

A nationally consistent river information system would help identify and manage nationally important high-conservation-value rivers and component ecosystems. With appropriate adjustment of attributes and significance thresholds, State and regional natural resource managers could also apply the framework to identify jurisdictional and regional high-conservation-value assets.

Three main elements, the foundation of agreed protocols, could make up an agreed nationally consistent information system:

1. a spatial framework
2. a classification system
3. an evaluation system.

2.4.1. *Spatial framework*

A consistent and applicable spatial framework is essential for river protection and assessment at different scales. It could operate across jurisdictional boundaries that might otherwise restrict the ecological or management frameworks for rivers (Kingsford *et al.*, 1998). The Australian continental limits define the spatial extent of the national framework, although a few patterns and processes may extend beyond the national border (e.g. fish (Unmack, 2001) and waterbirds (Halse *et al.*, 1996; Kingsford & Norman, 2002)).

> **Box 6: Rationale for nationally consistent information**
>
> **Comparable assessment—**High- conservation-value rivers and component ecosystems can be consistently identified across jurisdictions.
>
> **National importance—**Attributes can be evaluated comprehensively for national significance.
>
> **Links among databases—**Jurisdictional databases could be linked, enhancing their utility (e.g. assessment and modelling may require data beyond jurisdictional boundaries).
>
> **State, national and international targets—** Reporting against national targets (e.g. National Action Plan for Salinity and Water Quality, Ramsar) may be easier. This may also include state-of-the-environment reporting.
>
> **Investment—**Nationally strategic investment in high-conservation-value rivers could be targeted.
>
> **Gap analysis—**It would be possible to clearly identify gaps in information that need to be filled for detailed assessments of rivers.
>
> **Management of cross-border rivers—** Management of rivers that cross jurisdictional borders could use consistent information.

Potential scales for assessment and protection range from the whole river to individual river segments. Parts of rivers (e.g. wetlands) and riparian zones can be managed primarily for biodiversity conservation, while it is also possible to 'protect' some entire river systems from other threats (e.g. water-resource development) through river management. For example, Coongie Lakes and Currawinya Lakes are areas set aside specifically for biodiversity conservation on Cooper Creek and the Paroo River, respectively, and river agreements currently protect them from alteration of flows.

Rivers are currently defined in a nested hierarchy of units, each operating within characteristic spatial and temporal scales (Table 1). We propose use of three spatial scales for a national framework: drainage divisions, river basins and river segments (see Figs 2 and 3). Catchments are topographically defined areas draining to a specified outlet. Whereas a river basin refers to all of the area draining to a river mouth or a terminal lake, catchments may be delineated for streams of any size at any points along their length. Catchments may be subdivided into smaller areas known as sub-catchments. Ideally, after the river segment, topographically defined sub-catchments and catchments are the best scale for assessment. This is explained better in the case study (Fig. 4). Catchments provide a reasonable size unit for assessment and management while recognising within-basin heterogeneity. However, nationwide delineation of waterway units at these scales has been developed only recently (Hutchinson *et al.*, 2000; Stein, 2003) and is not yet widely recognised.

We recommend instead, use of the existing Australian Water Resource Commission (AWRC) drainage basin framework. Analysis at drainage division scale or river basin scale immediately allows nationwide assessment and identification of high-conservation-value rivers. In many cases, AWRC's river basins are broadly equivalent to catchment scale, but there are exceptions. Spatial information for drainage divisions, river basins and river segments is readily available (<http://www.ga.gov.au/ download/>, accessed 18/8/2004), with the two former scales widely used currently in river management. Finer scales (e.g. microhabitat) than river segments are impractical for large-area assessment. Even for small- area studies, the temporal instability of smaller units makes them unsuitable as planning or reporting units (Table 1). Similarly, it is not practical to use river reaches: lengths of channel with uniform channel morphology or a consistent pattern of alternating channel morphologies (Calvert *et al.*, 2001) (Table 1). River reaches are a common unit of description for both fluvial geomorphologists and aquatic ecologists, but usually require low-level aerial photography or field survey to identify (Brierley *et al.,* 1996; Frissell *et al.*, 1986). The high-resolution environmental data (e.g. terrain, geology) for more-automated reach delineation are not available continentally. However, river reaches and sub- catchments will be integral to reporting on river segments.

2.4.1.1. Drainage divisions

Drainage divisions are the largest units in AWRC's spatial framework (AUSLIG, 1997; Geoscience Australia, 2003) (Fig. 2c and 4) and are useful for national reporting. Until reviewed and updated (Box 7), drainage divisions provide the coarsest scale for a national framework for river protection. They are aggregations of river basins primarily defined by discharge points, climate or geography (AUSLIG, 1997; Geoscience Australia, 2003a).

2.4.1.2. River basins

River basins or catchments are the next-finest spatial scale in the hierarchy (Fig. 2b) and are widely used in natural resource planning and management. Primarily based on catchments of the major river systems, they also include catchment areas of small, independent coastal or inland drainage systems (Kingsford *et al.*, 2001). River basins are generally distinct and temporally stable geomorphic units, representing patterns of freshwater connectivity (Fig. 3). They may act as dispersal barriers for obligate freshwater species (Tait *et al.*, 2003). The current delineation of river basins is an adequate spatial framework for assessing relative ecological value, but has shortcomings (Box 7). Updated national catchment boundaries are essential for rigorous analysis of river protection and management (Norris *et al.*, 2001).

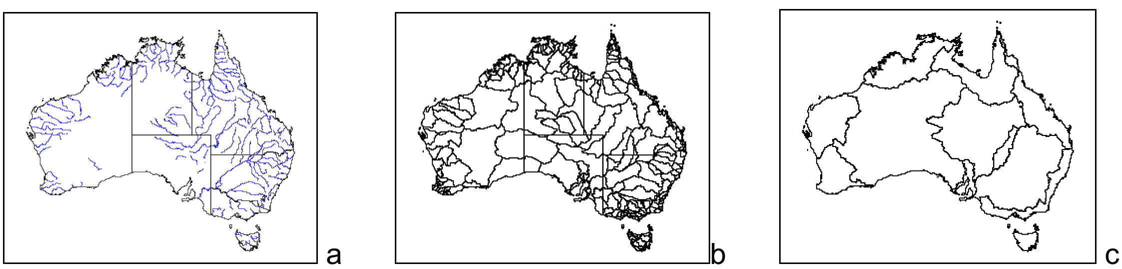


Figure 2. Australia's (a) major rivers, (b) 245 large river basins and (c) 12 major drainage divisions.

Table 1. A hierarchy of spatial units, comprising a drainage division.

Scale	**Description**	**Time scale of continuous potential persistence[a] (years)**	**Linear spatial scale (stream length)[a]**		**Applicability at continental scale**
			Small streams (m)	**Large streams (km)**	
Micro-habitat	Patch of similar flow velocity, substrate and cover	$10^{1-}10^{0}$	0.1	0.1	Not possible
Habitat/ bedform	Areas of relatively homogeneous bed material, flow velocity and depth	$10^{0-}10^{1}$	0.1–10	0.1–10	Not possible
Reach	Length of river exhibiting relatively homogeneous channel characteristics or a consistent pattern of repetitive/alternating characteristics	$10^{1-}10^{2}$	10–100	10 –100	Not possible currently, prohibitive resource requirements
Segment (link)	Portion of stream and its floodplain (including associated wetlands), bounded by tributary junctions, major waterfalls or lakes. The area of land draining to a segment or group of segments is a sub-catchment	$10^{3-}10^{4}$	100–1000	100–1000	Currently possible[b]
Catchment	The area of land drained by a stream to a particular point (e.g. a tributary junction). May include internal sub-catchments	$10^{4-}10^{5}$	> 1000	> 1000	Currently possible[b]
River basin	All of the catchment area that drains to a river mouth or terminal lake[c]	$10^{5-}10^{6}$	1–100 km	1000–10,000	Currently possible[b]
Drainage division	Grouping of river basins according to discharge point, geography and/or climate	$10^{5-}10^{6}$	na	> 10,000	Currently possible[b]

a Adapted from Frissell *et al.* (1986) and Calvert *et al.* (2001). Spatial and temporal scales are indicative only; actual values are appropriate to catchment size.

b At map scales of approximately 1:100,000 to 1:250,000.

c AWRC uses the term “river basins’ to indicate a mix of sub-catchments, catchments and basins.

Box 7: Problems associated with existing hierarchical spatial data

1. Drainage divisions and river basins (AUSLIG, 1997) are well established as a catchment framework for planning and management, but have some problems.
2. here is a lack of adherence to topographically defined hydrological boundaries and errors in boundary location, with some boundaries delineating convenient administrative units, rather than catchments. For example, the Murray River forms the divide between river basins within the Murray–Darling Basin drainage division and the boundary between the Paroo and Warrego rivers severs a distributary that links the river basins (Kingsford *et al*., 2001).
3. River basins can represent a confusion of spatial scales. They include topographically defined basins (e.g. the Fitzroy River in Queensland), catchments of major rivers (e.g. the catchments of the major rivers of the Murray–Darling Basin) but also sub-catchments (e.g. the lower Avon River in Western Australia)
4. Drainage divisions are currently defined on the basis of broad regional proximity and climatic zones, and do not necessarily reflect river basin affinities in terms of geomorphology, hydrology, biogeography or past connectivity.
5. River segments exist as GEODATA TOPO-250K mapped streams (Geoscience Australia, 2003b) and as links in the stream networks delineated from a digital elevation model (DEM) for the National Land and Water Resources Audit (NLWRA) Assessment of River Condition (ARC) (Norris *et al*. 2001), <http://www.deh.gov.au/erin/edd/>, accessed 18/8/2004) and for the National Land and Water Audit set of nested catchments (Hutchinson *et al*., 2000).
6. There is significant variability in mapped drainage density among GEODATA 1:250,000 map sheet tiles attributed to cartographic interpretation. The revised data (Geoscience Australia, 2003b) did improve the consistency but some problems with streamline mapping remain.
7. The GEODATA stream coverages cannot be used for automated hydrological analyses, such as catchment delineation, and they are not readily compatible with the grid-based methods of drainage analysis of a DEM (Jenson & Domingue, 1988; Mark, 1988; Hutchinson & Dowling, 1991; Jenson, 1991; ESRI, 1996). For example, the GEODATA mapped streams were not used for the ARC because they did not always coincide with the valleys defined in the DEM, forcing errors and artifacts in the computation of other terrain derivatives (Norris *et al*., 2001).
8. The ARC stream network includes only large streams (minimum catchment area of 50 km^2) within the Intensive Landuse Zone (NLWRA, 2002a).
9. Anabranching streams and distributary channels are not represented in the stream networks delineated from the DEM using conventional methods.
10. Channel networks are not well defined by the DEM in some flat areas.

2.4.1.3. River segment

River segments are the finest scale in the hierarchy of a national framework, but they are the least well-developed or adopted scale within jurisdictions or nationally. River segments are the hierarchical level most useful for landscape-scale analysis (Maxwell *et al*., 1995), allowing for relative assessment within catchments. A fine scale for assessment and protection is necessary, as assessment at coarser scales will not identify river variation within catchments. A tributary in a river basin may be ecologically important (Meyer & Wallace, 2000) but overlooked as a candidate for conservation because ecological value is averaged

Natural discontinuities, such as abrupt changes associated with tributary inflows (Frissell *et al.*, 1986), major waterfalls and lakes, unambiguously delineate boundaries of river segments. They will be unique to a river system. Each segment has a contributing area or sub-catchment, that is the part of the catchment draining directly to the segment, and associated floodplain wetlands, lakes or estuaries (Fig. 3).

2.4.1.4. Data availability

Traditionally, paper maps were the source of spatial information at the finest scale of 1:250,000 for national coverage. This scale is consistent with the scientific guidelines developed for the National Reserve System Program of Australia (Peters & Thackway, 1998). Much of the information on these maps is now available digitally as separate geographical information system (GIS) layers,

across the catchment. For example, there may be distinct assemblages of aquatic fauna within headwater streams (Harding & Winterbourn, 1997). including streamlines (AUSLIG, 1992; Geoscience Australia, 2003b). These data are useful for continental classification and assessment. Catchment or river basin boundaries (Fig. 2b) can be accurately delineated from a topographic map or derived using drainage analysis software and a DEM. There is a set of nested sub-catchments (Hutchinson *et al.*, 2000), delineated for the National Land and Water Resources Audit, with sub-division of river basins (the smallest is about 2.5 km^2) derived from the national DEM. Like the AWRC river basins, their boundaries do not account for distributary drainage structures, and there are problems in areas of low relief (Box 7; Appendix A).

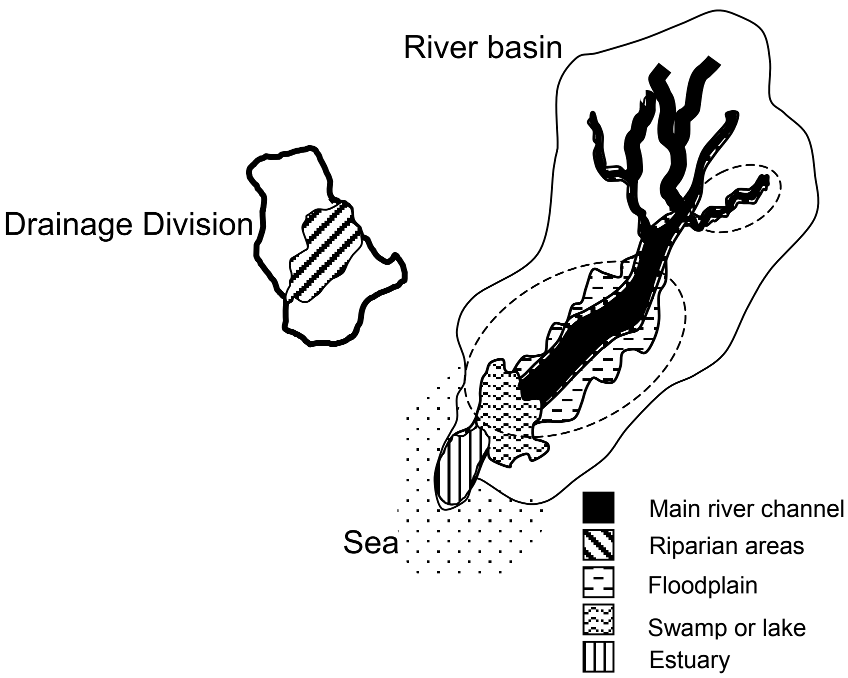


Figure 3. Diagram of theoretical river basin within a drainage division (inset), showing dependent ecosystems (main river channel, riparian areas, floodplains, swamps or lakes and an estuary). Dotted lines indicate potential river segments within this river basin.

Box 8: Catchment reference schemes

1. Various systems can delineate and/or codify topographically defined hydrologic units at continental scales (Appendix A, Table A2).
2. Important characteristics of a scheme chosen include:

i) the ability to automatically delineate and sub-divide hydrological units

ii) a numbering system that enables rapid assessment of tributary–main stem and up–downstream relations within the stream network.

3. The Pfafstetter scheme (Verdin & Verdin, 1999) is one such system that is widely adopted (e.g. Vogt *et al.*, 2003; USGS, 2001). Hydrological units are delineated by successively dividing the catchment into topographically defined basins and inter-basins, as many times as supported by the DEM. The numbering system enables topological relationships in a catchment to be inferred using simple algebraic queries, making it possible to rapidly identify all sections of a river network either up or downstream of any feature of interest (e.g. a dam).

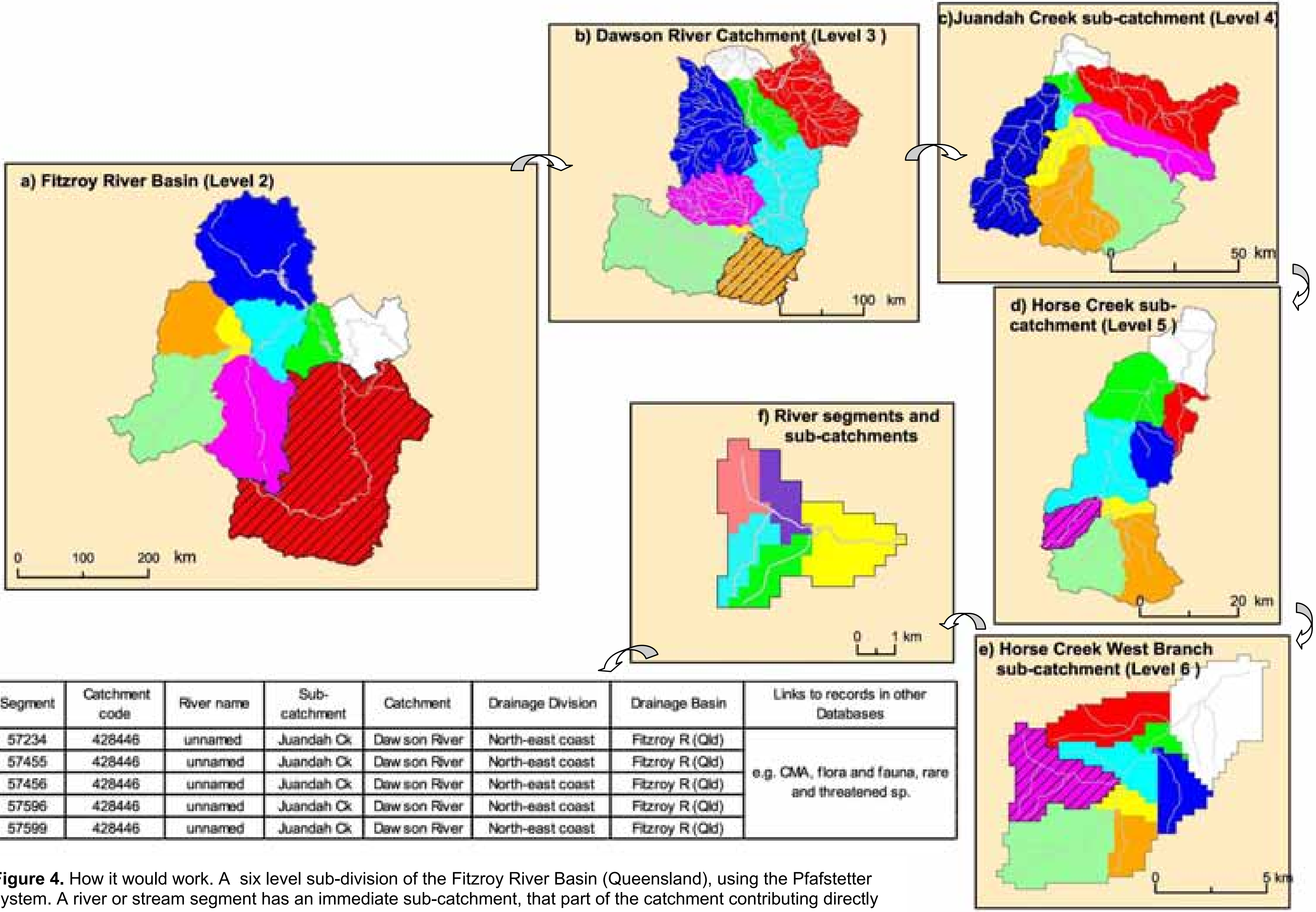
A continental-scale drainage analysis, with an improved DEM (M.F. Hutchinson, J.A. Stein & J.L. Stein, unpublished data) and accommodating distributary drainage patterns, has produced a better set of national catchments, and stream-segment delineation at a map scale of 1:250,000 (Stein, 2003). This new national catchment framework (Stein, 2003; see also Fig. 4) allows individual river segments to be related to their catchments through a spatially nested, hierarchical catchment reference system. Known as the Pfafstetter scheme (Box 8; Verdin & Verdin, 1999), mapping units can be used for conservation assessment (e.g. Burnett River catchment (Phillips *et al.*, 2002)). The Pfafstetter scheme has produced a European-wide database of stream networks and drainage basins (Vogt *et al.*, 2003); and global drainage basin coverage for continental and regional scale modelling and analyses (USGS, 2001). Until there is national agreement on a new set of hierarchically nested catchments (see options in Appendix A, Table A2), potentially using the new national catchment reference system (Stein, 2003), we advocate use of the AWRC drainage divisions and river basins and segments.

Mapping of dependent ecosystems is partly completed. Over 900 of the large Australian estuaries have been identified (Heap *et al.*, 2001) and another 48 moderate-sized estuaries were included in a study of Tasmanian estuaries (Edgar *et al.*, 1999). Estuarine areas were included in coastal wetland mapping in Queensland (Bruinsma, 2001), and a new project to map Western Australian coastal habitats will begin shortly. All wetland areas in New South Wales, including estuaries, and in the Murray–Darling Basin, have been mapped from satellite imagery (Kingsford *et al.*, 2004b) and wetlands, excluding most floodplains, are mapped for Victoria.

2.4.2. Classification system

Classification simplifies complexity by identifying homogeneous groups, according to defined attributes (O'Keefe & Uys, 2000). It enables assessment of rivers and dependent ecosystems, based on ecological values, including representativeness, rarity and diversity (see Box 9). This assessment can then be used to set conservation priorities within class types. Classification and evaluation can identify high-conservation-value rivers at different spatial scales. All classifications are affected by some measure of temporal variability in factors used and so they should allow for updating, or the attributes chosen should be relatively stable over time.

Regionalisation (e.g. bioregionalisation) is a form of spatial classification, with boundaries drawn around areas containing relatively homogeneous features (Bryce & Clarke, 1996). Agreement between State, Territory and Australian government nature conservation agencies to adopt the Interim Biogeographic Regionalisation of Australia (IBRA) classification was a significant breakthrough, enabling comprehensiveness, adequacy and representativeness of the Australian National Reserves system's cooperative program to be assessed and provide the basis for priority setting (Pigram & Sundell, 1997). Nevertheless, such terrestrial-based regionalisation has significant limitations for riverine biota because they are predominantly constrained by catchment processes.



Segment	Catchment code	River name	Sub-catchment	Catchment	Drainage Division	Drainage Basin	Links to records in other Databases
57234	428446	unnamed	Juandah Ck	Daw son River	North-east coast	Fitzroy R (Qld)	e.g. CMA, flora and fauna, rare and threatened sp.
57455	428446	unnamed	Juandah Ck	Daw son River	North-east coast	Fitzroy R (Qld)	
57456	428446	unnamed	Juandah Ck	Daw son River	North-east coast	Fitzroy R (Qld)	
57596	428446	unnamed	Juandah Ck	Daw son River	North-east coast	Fitzroy R (Qld)	
57599	428446	unnamed	Juandah Ck	Daw son River	North-east coast	Fitzroy R (Qld)	

Figure 4. How it would work. A six level sub-division of the Fitzroy River Basin (Queensland), using the Pfafstetter system. A river or stream segment has an immediate sub-catchment, that part of the catchment contributing directly to it, but nested successively within higher level sub-catchments, catchments and basins. Records within databases of conservation value attributes are linked via the river segment but conservation planning and assessment is likely to be undertaken using higher level units, for example a level 5 or 6 sub-catchment unit.

There is a long history of river classification around the world (see Naiman *et al.*, 1992), with many systems being proposed but few that are suitably generic. The more widely recognised classification systems were considered for their suitability for national implementation (Appendix B). While there are useful elements, none provides a universal system for classifying streams, stream habitats or their biotic communities (Jensen *et al.*, 2001b). Australian regional or State-wide classifications exist, but none is nationally consistent (Pressey & Adam, 1995). There are proposals for national classifications of river reaches (Calvert *et al.*, 2001) and wetlands (Semeniuk & Semeniuk, 1995), based on geomorphology, but none has been implemented (see Kingsford *et al.* (2004) for some of the challenges). The National Land and Water Resources Audit classified large estuaries in Australia but did not include the river systems that supplied them. Australian wetlands have often been surveyed and classified separately from flowing waters, usually only at regional scales (Pressey & Adam, 1995). More recently wetlands across all of New South Wales were mapped and classified within river basins (Kingsford *et al.*, 2004b). Although there are some examples of classifications of component freshwater ecosystems (e.g. wetlands in NSW (Kingsford *et al.*, 2004b)) and national classification of large estuaries (Heap *et al.*, 2001), few jurisdictions have a State-wide inventory or classification of rivers. Existing jurisdictional classification systems are not readily compatible in either scale or criteria. Classification will inevitably be required across jurisdictions, reflecting natural geomorphological, hydrological and ecological boundaries of rivers. Boundaries among classification groups should be consistently and transparently derived (Box 9). This requires knowledge of the range of spatial variation within and among river types, information that must transcend jurisdictional borders.

Once the objective of river classification is agreed on, choices need to be made about the river classification system. First, there needs to be a decision on what abiotic or biotic variables will form the basis of the classification. Second, the number of classification groups has to be chosen, as this affects conservation objectives. Too many groups will produce unrealistic conservation targets; too few will not adequately represent aquatic ecosystem variability. *A priori* definition of group boundaries assumes knowledge of all possible rivers and relies on expert knowledge (Phillips *et al.*, 2002). Numerical procedures (multivariate clustering, ordination) rely on the data and are less affected by biases or conspicuous features (Phillips *et al.*, 2002), even though there are subjective choices for groups (Nix, 1992). Numerical methods also integrate attributes consistently and are repeatable, allowing quantification of relationships among groups. They can reflect the continuum of river character and behaviour, and the clear demarcations of tributary–trunk confluences. By definition, numerical procedures are dependent on data, which may not be immediately available. There are essential elements for implementation of classification across the landscape (Box 9; Thackway (1992)). There are two main types of classification that may be attempted:

- biological classification, using the biota of rivers to define different bioregional types
- biophysical classification (includes geomorphic, hydrological and landscape classifications), which uses surrogate variables to define different types of aquatic systems.

Box 9: Essential elements for river classification

Scale—Classification requires hierarchical scales (Jensen *et al*., 2001a; O'Keefe & Uys, 2000), recognising spatial and temporal scales for stream ecosystem processes (Frissell *et al*., 1986), biotic processes and protection and management mechanisms. Our proposed national framework of drainage divisions, river basins and river segments is a suitable hierarchical spatial framework.

Attributes—Attributes should be temporally stable or integrate temporal variation (Bennett *et al*., 2002) and reflect ecosystem processes and distribution patterns of aquatic biota (Phillips *et al*., 2002). Data availability and practicality of measurement influence choice of attributes. The requirements for data or specialist knowledge must be commensurate with the scale and objectives of the classification.

Consistent methodology—Methods need to be clear and repeatable. The boundaries between groups should be consistently and transparently derived. They may be the outer limits of characteristic features (O'Keefe & Uys, 2000) or emergent properties of the primary data.

2.4.2.1. Biological classifications

Biological surrogates can be used to classify areas for terrestrial conservation (Margules *et al.*, 2002) but few national classifications of Australian rivers exist. National classifications have generally not been adopted because of lack of data and insufficient support by jurisdictions. Broad regions were identified for Victoria (Doeg, 2001), but limited data in the north-west of the State prevented State-wide coverage. Biogeographic regions can share a common evolutionary history, reflected in discontinuities in species distributions. For example, distribution of freshwater fish (obligates) reflects current and historical drainage connectivity across Australia, producing biogeographic provinces (Unmack, 2001) that may apply for other obligate freshwater biota (Tait *et al.*, 2003). Understanding of how biogeographical histories affect taxonomic surrogacy is still developing (Margules & Pressey, 2000). Data- sets for flora and fauna are patchy, although some taxa are sufficiently well-known to provide initial biogeographic regionalisations and identify places of high conservation value based on measures of diversity and endemicity (e.g. waterbirds, reptiles, fish, riparian vegetation, some invertebrates). Data gaps may sometimes be filled using modelling, but taxonomic and distributional knowledge for much of Australian freshwater biodiversity (Georges & Cottingham, 2002) remains poor. Existing data are often biased towards more-permanent streams or easily accessible locations. Except for some limited taxa (i.e. fish), inadequate data at a national scale makes biologically based classifications difficult today, but biological classifications will become increasingly possible with more data (i.e. Unmack, 2001). Even so, periodic updates or revisions will be needed because many biological communities are dynamic (Jensen *et al.*, 2001b). Caution should be exercised that perceived geographic variation is not a response to human activities, which are sometimes difficult to detect (O'Keefe & Uys, 2000).

2.4.2.2. Biophysical classifications

Biophysical classifications based on indirect physical measures of the habitat can be useful (Phillips *et al.,* 2002). For example, channel morphological criteria form the basis of many systems of river classification, including the RiverStyles™ framework (Brierley & Fryirs, 2000, 2002), the most widely used in Australia. Founded on a process-based understanding of river character and behaviour, these classifications provide an effective framework for assessing river condition and response at reach scales. Unfortunately, the time and cost involved in gathering data, and the expertise required (field survey, airphoto interpretation), preclude such classifications from nationwide application at this stage (see Appendix B for further discussion). Also, they may be affected by observer bias, reducing consistency within and among catchments. This scale can also be affected by temporal variability. Finally, the ecological relevance of channel morphological classes is poorly understood and so biotic responses may not reflect channel differences. Nevertheless, information gathered could be used to test the validity of classification at the river-segment scale for a national framework.

Flow is a critical factor in the composition and variation of biota in aquatic systems but there are few Australian examples of classifications based on hydrological indices (Puckridge *et al.*, 1998). Limited numbers of flow gauging stations undoubtedly contribute to the difficulties of using flow. Also, the relationships between ecology and hydrological indices may be complex (Puckridge *et al.*, 1998, 2000; Olden & Poff, 2003). In contrast, generic wetland-classification schemes (e.g. Semeniuk & Semeniuk, 1997) employ just a few broad categories of flow permanency as primary delineation criteria, with secondary criteria including soil, water chemistry or vegetation. Even for these, however, the data demands may be considerable (Kingsford *et al.*, 2004b).

Another basis for an ecological classification is use of landscape variables (e.g. climate, topography, geology). These variables exert primary control on aquatic ecosystem patterns and processes, and produce temporally stable groupings of waterways with similar response potential. Also, the data concerned are widely available and geographically referenced at national scales. Environmental domain analysis is a form of landscape classification that emphasises explicit and repeatable procedures, such as numerical clustering, to define classes as an emergent property of the primary data (Nix, 1992). The environmental domain approach has recently been adapted to classify rivers at State (Tasmania) (Jerie *et al.,* 2001, 2003) and national scales (Stein 2003). Biotic data can be used to verify or provide secondary stratifications of the environmental classifications (O'Keefe & Uys, 2000).

No single classification will suit all purposes, as classification is a tool not an end in itself. We caution against adopting a single classification, especially given the highly variable nature of the available data and expertise for Australian rivers and estuaries. Systematic conservation planning readily employs multiple classifications. We recommend the use of as many biodiversity surrogates for which data are available to maximise the likelihood of representing biodiversity in priority areas. For example, biodiversity priority areas in Papua New Guinea were selected using 608 environmental domains, 564 forest types and 10 species assemblages (Nix *et al.*, 2000). Using more than one classification also recognises the variable mobility and biophysical affinities of freshwater taxa (Tait *et al.*, 2003).

2.4.2.3. Interim classification of rivers and dependent ecosystems

To support the immediate task of identification of nationally important rivers, wetlands and estuaries, we recommend the development of interim national classifications, using available biotic and physical data. Combined landscape and biogeographic classifications would allow preliminary identification of representative conservation priorities for Australian rivers. Options include a river landscape classification (e.g. environmental domains) and biogeographic classifications for a range of aquatic and semi-aquatic taxa. These would complement established classifications—the fish bioregions (Unmack, 2001) and the NLWRA estuary classification (Heap *et al.*, 2001)—and could potentially be considered as the basis for an 'interim freshwater bioregionalisation of Australia' (Tait *et al.*, 2003).

Many of the data necessary to derive environmental domains have been compiled at the best available, nationally consistent scales, and preliminary environmental domain classifications exist (Stein, 2003). Revised classifications could be generated quickly. Broad-scale biogeographic classifications could also be derived using existing distributional data, a range of numerical procedures and expert knowledge. These could produce macro-scale groupings of drainage basins and information on sub- basin and inter-basins associations, potentially using obligate and non-obligate freshwater species (Tait *et al.*, 2003) and functional groups. The Australian Heritage Assessment Tool (AHAT), currently being developed, includes over 14 million survey records for a range of terrestrial and aquatic species, compiled from the Australian Biological Resources Study, the CSIRO Australian National Insect Collection and the major State museums (J. Ambrose, Australian Heritage Commission, pers. comm.). It uses drainage divisions and includes physical data. Analysis of the species data can include identification of endemism, species richness and Gondwanan relict species. AHAT is expected to be completed within the next 6–12 months.

A first task for biogeographic classification would be to use all such available data in addition to that held by jurisdictional agencies, and to review the state of the taxonomy for candidate taxa. For example, riparian tree species, which are important components of riverine ecosystems, are reasonably well known. A division of freshwater biodiversity components according to their vagility (i.e. obligate/non-obligate freshwater species) and associated biogeographic constraints (Tait *et al.*, 2003) may be a useful basis for identifying functional groups that can define biogeographic associations at different scales. In addition, there should be representation of major functional groups, whatever their mobility. For broad- scale conservation planning, wetland ecosystems could be included with the river systems on which they are dependent, or classified independently. Wetland ecosystems often comprise aquatic and terrestrial elements, so both terrestrial and aquatic biogeographic regionalisations and biophysical classifications could be used (Tait *et al.*, 2003). Estuaries probably require independent analysis because they are the interface between freshwater and marine ecosystems. Such an analysis could link the existing NLWRA energy-based classification with the river landscape and biogeographic classifications, and possibly with the Interim Marine and Coastal Regionalisation of Australia (IMCRA) (Interim Marine and Coastal Regionalisation for Australia Technical Group, 1998). These classifications are necessary to support an assessment of the conservation value of river basins and rivers (also possibly river segments).

In the long term, finer-scale classifications based on direct measures of stream ecological and geomorphological characteristics (biota, hydrology, biogeochemistry, physical habitat) should be developed for catchment planning and management, assessment of current condition, and design of appropriate targets for restoration or rehabilitation. Remotely sensed data will increase in importance as a tool for monitoring water properties, connectivity, inundation and flood dynamics (Mertes, 2002), allowing for classification of spatio-temporal variability (Handcock & Csillag, 2002) and habitats (e.g. Bruinsma, 2001; Kingsford *et al.*, 2004b). For the foreseeable future at least, the costs of acquiring these data may be prohibitive at national scales. Matching remotely sensed data to field surveys also remains a challenge (Mertes, 2002). River landscape and biogeographic classifications will also provide the basis for cost-effective biological and river-habitat surveys. Landscape classifications could also be improved with high-resolution biophysical information (e.g. terrain, substrate). Phylogenetic research on aquatic taxa representing key functional groupings can also help better define biogeographic boundaries (Tait *et. al*., 2003).

2.4.3. Evaluation system

Systematic conservation evaluation can be used to identify priorities for conservation by comparing ecological value, through established attributes (e.g. populations, species, assemblages or ecosystems) across the landscape, preferably using consistent data-sets (Pressey & Logan, 1998; Margules & Pressey, 2000). The aim is to identify areas of high conservation value. Conservation assessment ranges from small sub-catchments (e.g. Scientific Panel for Lower North Coast River Management Committee. 1999) to large continents (e.g. Commonwealth of Australia, 1999).

The spatial framework for rivers defines the context for the comparison of values among rivers, wetlands and estuaries at the scale of drainage divisions, river basins or river segments. A river type, determined by classification, might be unique within a river basin but common within a drainage division and, conversely, a river type might be common in one river basin but found nowhere else. These scales for conservation and management form the potential building blocks of a protected-area management system and for the management of threatening processes. Without relative comparisons, conservation importance may be underestimated (Hughes *et al.*, 2000) and catchment- scale threats not adequately considered. Ideally, assessment occurs at the river-segment scale as the finest scale of information, with integration for river- basin or drainage-division-scale assessments. Increasing availability of attribute data over time will support this approach.

2.4.3.1. Ecological values of river systems and dependent wetlands and estuaries

Ecological values within the broad context of 'conservation value' are attributes of river-system ecology that should be protected, maintained or restored for present and future generations. Natural or ecological values include the physical and biotic characteristics of river systems and their essential processes. Physical characteristics include hydrological regime, connectivity and geomorphological processes (e.g. erosion and deposition), while biotic characteristics include aquatic community composition, primary and secondary production, growth, reproduction, recruitment and survival. Healthy ecosystems also provide utilitarian values, as well as the opportunity to increase understanding of the characteristics and evolutionary history of the Australian landscape, and to monitor future change. All river systems have ecological values. It is necessary to rank their attributes to identify the highest conservation value areas, at different scales (e.g. national, State, regional, river segment, river basin, drainage division).

Ecological values require translation into definitional *criteria*, explained and exemplified with attributes. Wherever possible, these *attributes* should be quantitative, allowing comparison with other data, and have clearly defined thresholds. Quantitative attributes should ensure transparency and repeatability. Such an evaluation system can be tiered and iterative, with new information refining the process over time, enabling evaluation at progressively finer scales. Frameworks and projects that have helped us identify places of conservation value in Australia include:

- World Heritage Convention (international)
- Convention on Wetlands (Ramsar Convention) (international)
- Register of the National Estate (national)
- National Heritage List (national)
- Marine Protected Areas Strategy (national)
- Wild Rivers database (now Australia's Rivers and Catchment Condition Database) (national)
- Directory of Important Wetlands in Australia (national)
- Regional Forest Agreements (national and States)
- Heritage Rivers program (Victoria).

The proposed Wild Rivers program (Queensland) and the Conservation of Freshwater Ecosystem Values project (Tasmania) will contribute further to the idenfication of high-conservation-value rivers.

We also considered international frameworks for river protection, including the legislative framework in the United States and Canada, proposed protocols for river assessment (O'Keeffe *et al.,* 1987; Collier, 1993; Boon *et al.*, 1994) and evaluation of the conservation status of rivers in the United States (Abell *et al.*, 2000). At the national scale we also considered assessment of representation of rivers within protected areas using a biogeographic framework and river condition (Tait *et al.*, 2003). Common themes of ecological value occur through these existing frameworks. Different emphases reflect the primary conservation goals of the particular program or strategy.

Some important additional emphases emerge from assessment methodologies of Australian rivers (Bennett *et al.*, 2002), views of Australian river scientists and managers (Dunn, 2000), and current river policy and conservation in some Australian

States (Department of Natural Resources and Environment, 2002; Stressed Rivers Report NSW; Queensland Wild Rivers proposal; Wentworth Report, 2003). Firstly, river geomorphology and hydrology are essential and inherently valued components of river ecosystems. They define the ecology of the river system. Secondly, the importance of connectivity highlights differences between terrestrial and aquatic ecosystems and the nature of potential threats. The notion of connectivity highlights additional river conservation values and generates additional variables to be considered in threat management and protection.

Six criteria (see Box 10) are proposed to define ecological values of rivers. They can be applied at different spatial scales (see above) and for different management purposes, ranging from integrated, comprehensive and systematic conservation planning, to river management planning and environmental assessment. Thresholds can then be applied to these attributes to identify conservation importance at different spatial scales (drainage division, river basin or river segment).

Box 10: Criteria proposed for identifying natural conservation values of rivers or their dependent ecosystems

The river or dependent ecosystem:

- **is largely unaffected by the direct influence of land and water-resource development**

A river with a natural or near-natural flow regime and relatively little catchment disturbance is a large-scale ecosystem, retaining most natural features, processes and biota. Unaltered ecosystems that lie within highly altered river basins, can also retain natural features, processes and biota. Such undisturbed systems provide important reference points for assessing the health of modified systems. Undisturbed rivers from source to outfall are particularly valued, as they are rare, even at a global scale. Relatively few of the world's ecosystems are truly 'natural' because of pervasive threats (e.g. exotic species, climate change). This criterion applies to rivers and component ecosystems (river segments, floodplains, wetlands, estuaries) that are predominantly natural, rather than necessarily pristine.

- **is a good representative example of its type or class.**

Protecting the diversity of ecosystems and species is the cornerstone of most biodiversity conservation strategies. Conservation of representative ecosystems is a strategy to capture the range of biodiversity. Representative systems in good condition provide useful benchmarks for monitoring river management and restoration, and have very high conservation value where other examples of a system type in good condition are rare or non-existent. Note the application of this criterion is dependent upon river classification.

- **is the habitat of rare or threatened species or communities, or the location of rare or threatened geomorphic or geological feature(s).**

Protection of rare and threatened species and communities is essential to biodiversity conservation. Whole communities may be at risk by threats to riverine ecosystems in disturbed or undisturbed rivers. Disturbed systems may be more prone to localised species extinctions, and protection may mitigate threatening processes, though protection of communities in undisturbed rivers usually presents a more viable and cost-effective option. Some rare geomorphic or geological features are threatened by human impacts, with little likelihood of regeneration within human time scales.

- **demonstrates unusual diversity and/or abundance of features, habitats, communities or species.**

'Hot spots' or sites with highly diverse communities or abundance, can provide the most cost-effective way to conserve a large number of species or a significant percentage of a population of a species, feature or habitat.

- **provides evidence of the course or pattern of the evolution of Australia's landscape or biota.**

River form and behaviour and biota are markers of evolution. Taxa that are endemic or have Gondwanan affinities are considered to have particular value. Australia is noted for its unique terrestrial species and has many distinctive aquatic taxa. Some taxa, such as the lungfish (*Neoceratodus forsteri*) and the mountain shrimp (*Anaspides tasmaniae*) are of special phylogenic interest and have a limited natural range.

- **performs important functions within the landscape.**

Rivers and component ecosystems sustain habitats, communities and species at a landscape scale. Rivers and their dependent ecosystems can provide refugia within the landscape, especially during dry periods and, seasonally, in monsoonal Australia. They allow many terrestrial fauna to live in inhospitable environments because of the presence of water and abundant riparian and floodplain vegetation. Rivers and component ecosystems provide resources (e.g. food, habitat) for a range of fauna during different seasons or critical stages in their life history (e.g. breeding, recruitment, migration) and corridors for distribution and re-colonisation.

Chapter 3. Implementation of a national assessment of rivers

3.1. Identifying rivers of high conservation value

Given our broad criteria (Box 10), how could the system work? Once the criteria were agreed, they would require attributes for data collection and assessment of ecological value. Bennett *et al.* (2002) provide a comprehensive discussion and worked examples. For a national assessment, the number of ecological attributes likely to be available will be limited by the paucity of data, but the process has five essential components:

- agreement on the spatial scale for the assessment
- appropriate ecosystem classification for the spatial scale
- selection of relevant attributes for each criterion defining ecological value
- relevant data sets
- an agreed assessment protocol and clear decision rules.

The choices about these components would need to be explicit.

The evaluation process hinges on the scale and objective of this process, as this, with the spatial scale, will influence identification of rivers of high conservation value. We acknowledge that these components may work on scales from the finest (river segment) to the coarsest (continental). As jurisdictions overlap these natural hierarchical scales, the evaluation process needs to be adaptable for application at State, Territory or regional scale. For example, a State or Territory government may want to know which of the rivers (and dependent ecosystems) in its jurisdiction are of international, national or State-wide conservation importance. Similarly, a regional body seeking investment opportunities may want to know which rivers and dependent ecosystems are of regional importance.

While we recognise the potential application of this framework at progressively finer spatial scales, we believe that it is important to consider its applicability at the national scale. So the following process allows for identification of what we term 'rivers or dependent ecosystems of national importance'. A similar process could be used by a State or Territory to drive determination of 'rivers or dependent ecosystems of State-wide importance', as it could by a catchment management group or regional body at its scale of operations. Such a process may be developed for even finer spatial scales if a particular group wished to identify relative importance.

3.1.1. Selection of attributes

The criteria listed in Box 10 can be applied to the identification of rivers, estuaries and associated ecosystems of high ecological value, with high thresholds for nationally important systems. Attributes can include the full suite of abiotic and biotic variables relevant to a river or dependent ecosystem (e.g. hydrology, threatened species). We suggest that the following attributes could be used for the six different criteria for a river, wetland or estuary (see Box 10):

Unaffected by development. The river must have minimal disturbance in its catchment and have little or no regulation or abstraction, with predominantly natural flow regimes. This would be applied at river- segment scale. It would include an assessment of river flows diverted, barriers and catchment disturbance, upstream and downstream of river segments.

Representative. It is representative of its type or class, with demonstrably distinctive features and processes (e.g. biological, geomorphological or hydrological; see classification system) at the national scale. For example, a particular river might be predominantly (greater than 95% of flow) supplied by groundwater, a feature rare at the continental scale. Or the river may be the best remaining unregulated example of a typical river of the inland or of the south-eastern part of Australia.

Threatened species, communities, or ecological communities. It contains habitat of listed threatened species or communities (international (IUCN), national or State listed), or nationally important geomorphic or geological features that could be threatened.

High diversity and/or abundance. It provides habitat for a high abundance of organisms or has high species diversity, based on comparisons with similar habitats on a national scale. For example, abundant waterbird populations could be assessed using the threshold for Ramsar listing (i.e. regularly supporting more than 20,000 waterbirds).

Evolution of landscape or biota. It demonstrates outstanding evolution of Australian riverine and floodplain landscapes. The river geomorphology may demonstrate a style typical of ancient climatic conditions once widespread across the continent, or a landform that demonstrates large-scale past geomorphic processes such as glaciation or ancient sea levels. A candidate river could provide identified habitat for important populations of Australian taxa, especially those endemic at higher taxonomic levels (family and above), or have an unusually high range of related endemic taxa (centre of endemism). It could provide habitat for species endemic to Australia and of particular phylogenetic significance, including families with relationships with key taxa found in other southern lands and indicative of Gondwanan affinities. Some Australian taxa of limited distribution are of special interest for their place as 'living fossils'.

Important functions. Important functions within the landscape may include refugia, or sustenance of associated ecosystems. This may include refuge during extreme dry periods for populations of endemic species, or provision of water resources and a flow regime to sustain important associated ecosystems, including groundwater-dependent ecosystems and karsts of outstanding conservation value. Rivers and associated ecosystems play a critical role in providing resources for particular life-history stages of large populations of species seen as having high socio-ecological significance (feeding grounds or staging places for migratory birds, critical estuarine spawning areas or nesting areas for significant proportions of wetland birds). Australia has international obligations to protect critical habitat for migrating birds (Ramsar, Chinese Australia Migratory Bird Agreement (CAMBA) and Japanese Australia Migratory Bird Agreement (JAMBA)).

3.1.2. How it could work

A national evaluation system could be applied via a hierarchical spatial assessment framework (Fig. 3) across the continent. Ideally, information for conservation value criteria would be linked to individual river segments. Often, the data will not yet support this level of resolution, and so a sub-catchment, aggregating river segments, may be the basic waterway unit for initial conservation assessment. This is also a more effective scale for application of protective management. Dependent ecosystems (estuaries, riparian areas, floodplains, swamps or lakes) could be assessed either collectively with their associated river segment(s) (Fig. 3) or independently. AWRC river basins (i.e. catchment or basin scale) could be evaluated for potential designation as Australian Heritage Rivers on the basis of aggregated sub-catchment conservation values and disturbance.

The criterion of 'largely unaffected by development', where assessed as high for an entire river, specifically defines rivers of national importance that could be considered for nomination as Australian Heritage Rivers. This recognises their importance for ecological and cultural conservation as well as the industries they currently support. Candidates for designation as Australian Heritage Rivers are recommended to have more than 80% of natural mean annual flow, as lower relative flows may increase the risk of environmental degradation (Arthington & Pusey, 2003). Catchments are also recommended to have little intensive disturbance (less than 1% of the catchment area affected by intensive agriculture or urbanisation, deleterious point-source pollution (e.g. mining) or extensive diffuse deleterious impacts). Such thresholds could be determined by an interjurisdictional working group (see below). If a candidate for Australian Heritage River status exhibits some catchment disturbance, then:

i) the disturbance should have minimal impact on the river's present ecological values
and

ii) the river should meet at least one other criterion
or

iii) the river should represent the highest conservation value example of a particular class of river.

Rivers, river segments, wetlands and estuaries of high conservation value at national scales could be identified transparently using attributes, and could be primarily protected through protection-planning mechanisms available within jurisdictions.

High-conservation-value segments/sub-catchments, wetlands and estuaries could be identified and prioritised for protection by systematically assessing the conservation value of all sub-catchments. A catchment reference system that numerically links each river segment through increasingly coarse spatial scales can identify the network linkages. It is particularly useful in ensuring that connectivity between upstream and downstream parts of rivers is recognised (e.g. the Pfafstetter scheme (Verdin & Verdin, 1999); Box 8; see also Appendix A). A national overview of conservation value is provided by drainage-division summaries. The spatial assessment framework for rivers also defines the context for more detailed assessment and management at reach scales.

We illustrate this proposed spatial and assessment framework using the Fitzroy River Basin in Queensland (Fig. 4), but stress that a national assessment can be done only by comparing the relative value of all rivers across the continent, using consistent methods.

3.1.3. Case study—the Fitzroy River Basin

The spatial framework is built upon spatially referenced, uniquely numbered river segments and their associated catchment areas. Each river segment is nested within successively larger sub-catchments, the river basin and its drainage division. The spatial framework includes an associated database that labels each river segment with the AWRC drainage division and river basin number and the equivalent State or Territory waterway or catchment identifier (Fig. 4). This allows linkages within and potentially among existing jurisdictional databases.

The first stage is to access the river segments, sub-catchment and river basin boundary spatial layers (<http://data.brs.gov.au/asdd/index.php>, accessed 18/8/2004 for nested catchments; <http://www.ga.gov.au/>, accessed 18/8/2004 for AWRC basin boundaries) for the Fitzroy River Basin. This is the precursor to evaluation of each river segment in the basin. Spatial data layers for river segments could probably be accessed in the future. Assessment of river segments requires use of GIS commonly employed by all jurisdictions, already credibly demonstrated for the Burnett River Catchment (Phillips, 2001; Phillips *et al.,* 2002) and used in Tasmania in the project on Conservation of Freshwater Ecosystem Values.

Using the agreed criteria (Box 10), attributes are selected for assessment (see "Evaluation system") from potential candidates listed in Bennett *et al.* (2002) that could be applied consistently at a national scale. For the Fitzroy River Basin, this means collecting and reviewing all available data in national and jurisdictional databases and applying them to the appropriate spatial scale. Measures of catchment land use for each segment in the Fitzroy River Basin (e.g. National Land and Water Resources Audit, Bureau of Rural Science, wildlife atlases, fish databases, hydrological data) could be derived, but information on flow diversion may be available only for aggregated river segments (e.g. Juandah Creek catchment, Fig. 4c). As flow regulation affects all downstream river segments, these would need to be attributed as affected by flow regulation, depending on the degree.

Additionally, the natural integrity of population processes (dispersal, migration) might be denoted as disrupted upstream of major in-stream barriers.

Assessment could occur at coarse spatial scales, but all data should be attributed at river-segment scale so refinement with future data can occur easily at the finest resolution.

Qualitative information (e.g. the river is important for the maintenance of karst features) would be coded and spatially referenced to river segments within the Fitzroy River Basin. Linkages between river segments and the survey sites or mapping units of the attribute data are established by the GIS spatial overlay. This process may identify all river segments where the vulnerable Fitzroy River tortoise *Rheodytes leukops* has been recorded or is predicted to occur. Once a conservation value rating is derived for a river segment or the smallest unit resolvable for the particular attribute data (e.g. a sub-catchment), results can be aggregated into successively coarser scales. This produces a consistent rating of conservation value for sub-catchments (Fig. 4d), the major river catchments (Fig. 4b), the entire Fitzroy River Basin (Fig. 4a), or the North-east Coast Drainage Division. Once the conservation value is established, river segments can be ranked according to conservation value and managed for their different threats in a protection framework (see "Conservation planning and protection"). Because the information base covers all waterways, it will also support development of representative protected river systems and inform an integrated approach to river management.

3.2. National assessment

There are several different approaches to the selection of places for conservation action. The choice of an approach depends on the objective of the assessment. Four approaches, some of which may work together, are suggested as potentially applicable to river systems.

3.2.1. 'Comprehensive, adequate and representative' (CAR) principles

The application of comprehensive, adequate and representative (CAR) design principles (ANZECC/MCFFA, 1997) to selecting areas for conservation is well-established for terrestrial systems, especially forests, and for marine reserves (National Reserve System Marine Protected Areas, <http://www.deh.gov.au/coasts/mpa/nrsmpa>, accessed 18/8/2004; Great Barrier Reef Marine Park Authority Representative Areas Program, <http://www.reefed.edu.au/rap/>, accessed 18/8/

2004). It also forms the strategic foundation for targeting efforts to consolidate the National Reserve System (NLWRA, 2002b). More recently, CAR principles have been used to identify priority areas for freshwater conservation actions in the south- eastern United States (Smith *et al.*, 2002; Weitzell *et al.*, 2003). Identifying and protecting representative ecosystems is a key conservation priority, particularly for biodiversity conservation. Other values may be incorporated within or outside such representative areas, until all targeted conservation values are protected. It follows from the CAR principles that places with values not already captured within a protective management framework are rated at a high priority for identification and protection. Classification is a prerequisite for the assessment of representativeness. Algorithms based on complementarity ensure efficient representation of targets in priority areas and can be adapted to minimise opportunity costs (e.g. foregone timber production (Nix *et al.*, 2000)) and integrate the knowledge of local and technical experts to overcome limitations of available spatial data (Balram *et al.*, 2004).

The identification and protection of representative ecosystems is a strategic foundation to ecosystem conservation but, as yet, there have been limited attempts to apply such an approach to freshwater ecosystems in Australia or other parts of the world. Recent assessment of wetland classification and protection in New South Wales (Kingsford *et al.*, 2004b) provides baseline information on which a CAR-based wetland-conservation strategy could be developed for that State. Tait *et al*. (2003) assessed the representativeness of existing protected areas that include rivers, on the basis of fish biogeographic provinces (Unmack, 2001). In Tasmania, the Conservation of Freshwater Ecosystem Values project is working towards a strategic management system for conservation based on CAR principles. Measures for protection will not be limited to formal reserves but will also include informal reserves, covenants on private property, implementation under water-management protocols, and codes of practice, all of which can be delivered by a CAR model. CAR should not be seen as an opportunity for development where only high-conservation-value areas are protected. Most ecological processes, including those in rivers, require networks of sometimes insignificant habitats to support organisms and functions.

3.2.2. Categorisation

The US Wild and Scenic Rivers scheme is a classificatory system for identifying rivers of particular conservation value. Descriptive classifications are first established with agreed thresholds for various key criteria. Rivers (or river sections) demonstrated to fall above the agreed thresholds may be classed as 'wild', scenic' or 'recreational'. (Note that other procedures would be included before such a river was to be listed under the *Wild and Scenic Rivers Act 1968.*) Such a process enables a transparent process to identify rivers by degree of disturbance. It does not take account of other conservation values. There are at least two Australian examples of a classificatory approach: the Stressed Rivers program and the Statement of Intent for coastal lakes, both in New South Wales. In the Stressed Rivers program, rivers are classed on two key dimensions (hydrological stress and conservation value) and the resulting matrix interpreted to identify the broad management category for each river type. For the coastal lakes, all coastal lakes are classified into management categories: comprehensive protection, significant protection, healthy modified conditions and targeted for repair. Classification is based on natural sensitivity, current condition of lake and catchment, ecosystem and conservation values, and socio-economic factors.

3.2.3. Criterion-based approaches

International programs or frameworks for identification of places of conservation value often adopt a criterion-based approach. The World Heritage Convention and Ramsar Convention each set out several criteria and, for some values, recommend specific thresholds that a place must meet to be listed. Decision rules are specified, including the requirement for only one criterion to be met, and matters regarding the ecological condition of the candidate site are detailed. There is no limit to the number of places of particular kinds, nor a requirement to rate values of places against each other, although some comparison is implicit in order to identify outstanding places of a particular type.

In Australia, a criterion-based approach to sites of significance has been applied through the Register of the National Estate. Criteria and descriptive thresholds to assess significance are used to consider nominations for the National Heritage List established under the EPBC Act. Only places that meet criteria of outstanding heritage value to the nation are considered for listing, using comparative analyses.

Criterion-based approaches allow for common conservation themes (criteria) to be promoted while allowing for flexibility in the range of evidence provided. No comparisons are therefore required between, say, the relative importance of a rare bird taxon from northern Australia and an endemic crustacean of phylogenetic significance from the Tasmanian highlands. Once the criterion has been met at an agreed standard, then the place may be considered eligible for listing.

The key feature of a criterion-based system is that the values of the place are tested against the criteria, not against another place of the same type.

3.2.4. Scoring and ranking

Relative assessment is an essential part of criterion-based approaches, and scoring can be used to underpin comparisons. Some attempts to summarise the values of rivers by a system of scoring and ranking have been developed (O'Keefe *et al.*, 1987; Collier, 1993; Boon *et al.*, 1994, 1997; Bennett *et al.*, 2002), although not widely applied. A numeric index of ecological value has appeal as a simple means to convey an order of importance or significance. This can be done objectively by comparing variables (or measures) that describe each criterion's attribute (or indicator) among all rivers and dependent ecosystems (see methods in Bennett *et al.* (2002)). This method assigns a rating (1–5) to a series of measures (variables) that describe attributes (indicators) that produce an evaluation. To apply it consistently, explicit choices need to be made.

Benchmarks need to be defined for most attributes, but there are few established precedents that derive scientifically credible values. For quantitative measures such as the percentage of natural cover, a continuous scale could be employed, with the highest possible measures (100%) assigned a 5, the lowest (0%) a 1, and others scaled. The scale need not be linear; a step function might be appropriate. For example, effects of diversions on ecological functions in dryland rivers may be similar across a range of offtakes, until they drop flow below a flow level that has ecological significance (Thoms & Sheldon, 2002). Where the possible range of values cannot be set theoretically (common for measures of diversity and rarity), benchmarks could be defined from the distribution of measured values across all rivers, using natural breaks or percentiles. Rating diversity, rarity and naturalness requires standardisation to account for natural variation across river types. This could be done by comparing measured values to a reference condition (Bennett *et al.*, 2002) or expected classification (Chessman, 2002), or by comparing similar classes of river types.

Ratings for individual waterways tell a lot about the waterway, but this may not be useful for broad-scale planning or communication. Summary ratings of overall conservation value consisting of aggregations (e.g. summing, Bennett *et al.* (2002)) of individual criteria may produce simple rankings of waterway units. Such scoring approaches can be ambiguous where they combine heterogeneous ratings (Chessman, 2002). A river with medium ratings across all criteria may rate higher than one with outstanding values against one criterion but only poor values against others. These difficulties can be reduced by judicious choice of integration method. For example, integration of all criteria in the multivariate space represented by the values of their components (e.g. using a standardised Euclidean distance (Norris *et al.*, 2001)) may be more indicative of overall status than average measures. For some criteria, an aggregated rating may be the lowest rating of the component measures because this rating overrides other criteria.

While a numeric index offers an objective basis for judgment, misinterpretation of the numeric index is a drawback (Boon *et al.*, 1998). SERCON, a well-established system of rating rivers in the scientific literature, can be seen and used as "a generator of 'magic numbers'", where underlying data of final output scores and indices are hidden (Boon *et al.*, 1998, p. 611). The SERCON team rejected the reduction of the six indices to a single overall 'conservation score', unlike the system proposed for South Africa (O'Keefe *et al., 1*987), which was one of the earliest attempts at a systematic conservation assessment process. Recent developments may apply expert rule systems or advanced statistical techniques to rank sites or make comparisons among sites (O'Keefe & Uys 2000).

Ranking and scoring are generally not applied to assess values of terrestrial systems in isolation of a conservation strategy. A scoring system may be appropriate for site selection where other variables such as size, condition, threats, pressures and land tenure are included.

3.2.5. Deciding on an approach

The decision about which method, or combination of methods, to use should be made by jurisdictions in the knowledge that all methods will have advantages and disadvantages and are not mutually exclusive. A criterion-based approach could be developed with agreed criteria and significance thresholds. Such an approach is compatible with Ramsar, development of a National Rivers Heritage List and World Heritage listing, and will have some criteria in common. It does not guarantee representativeness, which would be delivered by a more inclusive CAR-based approach to identification and protection of river conservation values. The two could be complementary and represent important elements in a comprehensive conservation strategy for Australian rivers (Fig. 1). For example, a criterion-based approach could be used to select conservation priorities within classes of river types, ensuring that conservation efforts are delivered across a representative range of Australian riverine systems. This approach is being developed in Tasmania's Conservation of Freshwater Ecosystem Values project.

We recommend that a two-stage process — immediate and long term —be used to identify nationally important rivers, wetlands and estuaries. These stages are best achieved by following agreed protocols and processes that allow for consistent data collection. The absence of data should not constrain immediate identification of high-conservation-value rivers and component ecosystems, with long-term investment in data allowing revision of the outcomes of the immediate stage. The program should begin by using all available data, focusing on rivers, large wetlands and estuaries and producing a ranking of rivers, wetlands and estuaries, with the highest ranked being identified as nationally important. These stages would be the responsibility of jurisdictions. They would then provide the data and information for assessment at the continental scale. With suitable investment, Stage 1 would take two years, while Stage 2 requires long-term investment in river management and understanding. The second stage will make comparisons across all wetlands, estuaries and rivers. This is likely to be more intensive and require considerably more data, and is consistent with the approach of having an iterative process that can be updated with accumulating data.

Chapter 4. Protection scheme

The assessment process can identify whole rivers, river segments, wetlands and estuaries that are candidates for protection, based on the proposed criteria. Such an assessment would be targeted primarily at the identification of nationally important rivers, river segments, wetlands and estuaries, but could easily apply at finer scales, such as State or catchment. The next stage is to identify what, if any, mechanisms exist for protection planning of these aquatic ecosystems.

4.1. Potential for an Australian Heritage Rivers system

The sheer scale of river basins, sometimes thousands and frequently hundreds of kilometres in length, often makes traditional biodiversity conservation protection approaches, such as reservation, untenable at a whole-of-basin scale. There are outstanding exceptions, such as the inclusion of most of the Prince Regent and Shannon rivers in reserves in Western Australia. Existing approaches to conservation in Australia, such as reservation, play a very important role but need to be included within a broader strategy that reflects the scales involved in river system protection. Increasingly, communities and their governments around the world and in Australia are recognising the need for basin-scale protection (see Appendixes D and E). This is in recognition of the connectivity of the aquatic systems in river basins and the reliance on catchment processes for long-term ecological sustainability.

Models for whole-of-basin protection vary in terms of their degree of regulation and legislative backing. 'Top-down' approaches with nomination and designation by government can occur, but are usually limited in their appeal because of the potential for regulation and the lack of community support. In contrast 'bottom-up' models that are owned by the communities that live on rivers may not have the same legislative protection but can be extremely successful in terms of community ownership and protection against broad pressures (see discussion of national and international models—Appendixes D and E).

Whole river basins identified as largely intact (i.e. unregulated, limited diversions and little catchment development) and ranked highly in a national conservation assessment are potential candidates for protection at whole-of-river-basin scale. These could be called Australian Heritage Rivers (Box 11). For the most part, these would be river basins that are largely unmodified. A national framework could establish a formal, staged process by which a candidate for Australian Heritage River status may eventually be so designated. This process should engage jurisdictional governments and communities, and be voluntary. A system of national protection needs to allow the community, working with government, to take part in supporting the nomination and designation of a potential river system as an Australian Heritage River. Once identified, the community and their jurisdictional government(s) could receive support for nomination and designation, followed by the development and implementation of a management plan that conserves the integrity and natural assets of a river basin. This would not preclude use of currently available mechanisms for protecting parts of the river basin.

This proposed system is clearly differentiated from listing as National Heritage under the *Environment Protection and Biodiversity Conservation Act 1999* (Table 2). The proposed process is intended to be a community-led one with government assistance, allowing large, unregulated and relatively undisturbed river basins (see criteria) to be identified and managed sustainably by the communities and their governments.

The potential candidates for such a system would initially come from the 245 river basins across Australia. We acknowledge that it may be possible to similarly designate sub-basin areas (i.e. whole tributary rivers), but Australian Heritage River designations are primarily designed to allow for multi- use functions at large scales that promote long-term sustainability and do not degrade ecological values.

Box 11: Naming of high-conservation-value rivers unaffected by development

Various terms are used to describe rivers that are of high ecological significance and relatively unaffected by post-European development. These include 'heritage', 'high-conservation-value', 'natural', 'pristine', 'undeveloped', 'unregulated' 'unspoilt' or 'wild'. Few of Australia's rivers are truly 'natural', 'pristine' or 'unspoilt', due to the size of river catchments and the pervasiveness of key threats. Even the most remote rivers are likely to be affected directly or indirectly by human impacts (e.g. grazing, weeds, feral animals, climate change). The term 'wild' evokes images of rivers remote from any human settlement. Terms such as 'pristine', 'natural' or 'wild' fail to recognise the long history of Indigenous land and water management. 'Heritage' incorporates the notion of generational accountability. 'Heritage' applies to both natural and cultural values, considered essential partners in river protection.

The term 'Australian Heritage Rivers' is proposed for rivers that meet criteria for national recognition. The working group believed that this best expresses their continental significance, the role and importance of the community and the essential inheritance value of such protection. The concept of 'Australian Heritage River' best serves the importance of river protection at the basin scale.

A possible complication is the potential confusion with the National Heritage List, under the *Environment Protection and Biodiversity Conservation Act 1999* (Table 2). The working group believed that while this may present some problems in the short term, such differentiation would be resolved over time (Table 2). As evidence of this, it is noted that, at the time the Canadian Heritage River System (CHRS) was proposed, Canada had a system of national heritage listing. During development of the CHRS (Appendix D), Canada opted for the name Canadian Heritage Rivers to identify important rivers that the community wished to protect, recognising the arguments articulated above. In 2004, Canada celebrated 20 years of highly successful operation of the CHRS (Appendix D). Government and community in Canada now clearly differentiate between the CHRS and listed National Heritage Rivers.

Table 2. Differentiation between National Heritage listing under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* and the Australian Heritage Rivers system proposed in this discussion paper (continued next page).

Element	National Heritage listing[a]	Proposed Australian Heritage Rivers system[b]
Legislative policy context	*Environment Protection and Biodiversity Conservation Act 1999*, administered by the Minister for the Environment and Heritage	Non-statutory, sponsored by government program (Australian, State and Territory governments) and policy with incentives.
Identification	Objective continental assessment	Objective continental assessment provides a basis, as in the Canadian Heritage Rivers System, from which the community may nominate potential candidates.
Nomination	Anyone can nominate a river for listing, including the the Minister for the Environment and Heritage and the Australian Heritage Council[c]	Community instigation of the nomination process, including consultation and documentation of ecological and cultural values. Candidate rivers may be identified from an objective assessment of national conservation values. Government funding may be provided for background studies that assist communities in the nomination process. Nomination documentation must show community and jurisdictional support.
Values/criteria	These include natural, Indigenous and historic values of outstanding heritage significance to our nation.	It is proposed that a nominated river must meet criterion 1 (largely unaffected by development) and at least one other criterion (Box 10). Additional criteria for cultural values may also be included.
Assessment	The Australian Heritage Council assesses nominations, supported by the Australian Government. Only nationally outstanding or exceptional values are considered according to set criteria,[d] using thresholds of significance.	An Australian Heritage Rivers Board could be formed from jurisdictions (see Appendix D; Canadian Heritage Rivers System) to assess nominations against criteria (Box 10). Such nominations would have to demonstrate values and integrity (see Appendix D; Canadian Heritage Rivers System).

a Further information available at <http://www.deh.gov.au/heritage/national/index.html>.

b The proposed Australian Heritage Rivers System is primarily based on the Canadian Heritage Rivers System which has successfully operated for 20 years (see Appendix D and <www.chrs.ca>).

c The Minister for the Environment and Heritage appoints the Australian Heritage Council.

d Sites must meet one or more of nine criteria, with assessment against 'significance thresholds' that identify 'outstanding' heritage value.

Element	National Heritage listing[a]	Proposed Australian Heritage Rivers system[b]
Decision on listing	A river may be listed on the National Heritage List if it meets at least one criterion and is recommended by the Australian Heritage Council and the Australian Minister for the Environment and Heritage.	An Australian Heritage Rivers Board would assess the nomination against agreed criteria. It would also need to be convinced that a nomination was strongly supported by the relevant jurisdiction and the community. Designation would be a second step following nomination, and would occur only once a management plan was developed and approved by the responsible jurisdiction (see Appendix D; Canadian Heritage Rivers System). Such plans would need to demonstrate a commitment by the jurisdictional government and concerned stakeholders to conserve the river's values.
Management	After acceptance of nomination, a management plan is prepared based on the National Heritage Management Principles[e] that set out how the natural heritage values of the site will be protected or conserved. Values are protected by the *Environment Protection and Biodiversity Conservation Act 1999*.	The river would be managed by jurisdictions, according to a management plan prepared for designation. The management plan would target the sustainable management of the ecological values for which the nomination is proposed. There would be no overarching statutory basis for this plan although it would need to be embedded within jurisdictional planning and processes and be consistent with prevailing legislation and relevant strategies and policies.
Reporting and monitoring	There is a requirement under the National Heritage Management Principles for regular monitoring, review and reporting to the Australian Government on the conservation of National Heritage values.	Jurisdictions and communities may report to the community on the condition of designated Australian Heritage Rivers at intervals of up to 10 years. Monitoring should target the ecological values for which a river was nominated originally. De-listing would be a result of degradation of the values for which the river was listed.
Obligations	A person or agency must not take an action that has, will have, or is likely to have, a significant impact on the national heritage values of a national heritage place, without approval from the Australian Government Minister for the Environment and Heritage.	Communities and governments using the river and its resources, or operating or living in the river catchment would do so within the provisions of the designated management plan, protecting the ecological goals for river management, and ensuring that the values for which the river is listed are maintained.
Implications	Relatively few rivers may be listed because of high thresholds for significance, an expectation that limited rivers will be listed and the potential strictures of a Australian Government statutory basis for management.	The proposed Australian Heritage Rivers system is designed to better manage those of the nation's rivers that are in the best condition. It recognises that people need water and development within the catchment but that this should be achieved without further loss of aquatic biodiversity and the health of the entire landscape. The community must initiate the process with assistance from governments. In Canada, involvement of the community in the nomination and management processes has produced strong associations with rivers and encouraged community involvement in their management.

e National Heritage Management Principles include: protection for future generations; use of best available knowledge; integration with other government mechanisms; consistency with conservation of natural heritage values; provision for community involvement; active participation of Indigenous communities; and provision for regular monitoring.

4.1.1. Models for basin-wide protection of rivers

There are essentially only two international examples available: the Canadian Heritage Rivers System (CHRS) and the United States Wild and Scenic Rivers legislation (Appendix D). Our recommendations are modelled on the CHRS because this best reflects our system of government and, because it relies primarily on community input, and is less regulatory (Appendix D). While there are obvious differences between Australia and Canada, there are also striking similarities of culture and governance. The CHRS is a highly successful river protection framework that has evolved over 20 years. This successful framework should be recognised and used to inform this suggested scale of river protection in Australia.

Rivers nominated under the CHRS must meet prescribed value and integrity criteria. The Canadian (federal) Government, with the provincial and territorial (second tier) governments, has mapped river values across Canada but neither prepares heritage river nominations. Nominations are prepared by communities, assisted by local (third tier) governments and conservation organisations. Exceptions were the first nominations prepared by federal and provincial governments.

The CHRS has a two-phase process for listing Heritage Rivers: nomination then designation. Designation occurs only after a management plan aimed at protecting the river values and integrity has been developed jointly through government and community processes.

4.1.2. Parts of an Australian Heritage Rivers system

Stages in the process could include:

- scientific assessment of candidate river basins for designation as Australian Heritage Rivers through identification and analyses of value, condition and threat
- clear community interest in participating in the designation, with consultation of owners and stakeholders
- additional background studies and collation of existing information
- completion of nomination documentation showing evidence of jurisdictional and community support
- completion and implementation of an approved management plan for the maintenance of conservation values and integrity of the river
- designation of the river as an Australian Heritage River
- ongoing monitoring, evaluation and investment in designated rivers to ensure conservation values are maintained.

Designation as an Australian Heritage River would not signify a moratorium on development: rather it could encourage sustainable development, such as low-impact industries, and provide opportunities for improving catchment practices. Designation may also provide security for existing sustainable industries, allowing producers and communities to pursue sustainable marketing initiatives and enhanced opportunities with confidence in the long-term future of the resource.

A similar process is established already, through the Lake Eyre Basin Agreement (for the Georgina–Diamantina rivers and Cooper Creek) and the Paroo River Agreement. The Lake Eyre Basin Agreement has supporting legislation; the Paroo River Agreement does not. This Australian Heritage Rivers System element of the proposed national framework and the staged designation process (outlined above) are major features of the CHRS (see Appendix D; Nevill & Phillips, 2004).

4.2. Protection in a national, State, regional or local context: application of current legislative and policy tools

States and Territories have many protection tools, including legislative and non-legislative mechanisms and policies, to protect nationally important rivers or dependent ecosystems (see Appendix C, Table C2). However, these mechanisms are not always consistently applied across or within jurisdictions. In some jurisdictions, the mechanisms available are not applied effectively (Nevill & Phillips, 2004). Also, many mechanisms are applied at spatial scales that are smaller than the river basin and so protection of high-conservation-value rivers or dependent ecosystems is often inadequate even though protection is the goal.

There are four major ways currently in use that could more effectively protect high-conservation-value rivers, reaches and their dependent ecosystems following the principles for protection (see Box 4— Management principles for protection; Box 5— Protection mechanisms).

These four major approaches are:

- identification and management of

environmental flows

- the use of protected areas (as defined by the IUCN)
- natural resource planning and management at a catchment scale
- the use of incentives to rehabilitate systems and encourage sustainable practices.

4.2.1. Environmental flow management

There is an increasing focus on the importance of identifying the share of water in regulated rivers that should be dedicated as an environmental flow. This is usually done during an assessment of other extractive shares of water and then specified in a water-management or water-sharing plan.

This water can potentially be increased by water savings within delivery systems or by acquiring water from existing extractive shares. The Living Murray initiative represents a commitment by governments to increasing the environmental flow through water savings and possibly reductions in extractive shares.

Many of the large river systems that have identified environmental flows store this quantum of water in upstream dams. For example, in the Macquarie River there is a nominal environmental flow of 125,000 ML of general security water held in storage each year. The use of this water is often governed by different release rules that are aimed at producing various environmental outcomes. Increasingly, there is a need to use adaptive management processes for the release of this water, because it can produce quite different environmental outcomes. For example, three different environmental flow management options in the Macquarie River were predicted to produce quite different environmental outcomes for flooding and waterbird breeding in the Macquarie Marshes (Kingsford & Auld, in press).

Future management of environmental flows will inevitably be attempting to target high-conservation-value areas that are dependent on flows. The Living Murray initiative has identified five key sites for management of additional environmental flows. This is a recognition that there is insufficient water in the river to manage for all ecosystems on the river.

4.2.2. Protected areas

All Australian jurisdictions are committed, by the InterGovernmental Agreement on the Environment 1992, to the establishment of comprehensive, adequate and representative networks of protected areas in terrestrial, marine and freshwater environments.

Item 13 of the agreement (Commonwealth of Australia, 1992, p. 40) contains a schedule on nature conservation, which states:

> *The parties agree that a representative system of protected areas encompassing terrestrial, freshwater, estuarine and marine environments is a significant component in maintaining ecological processes and systems. It also provides a valuable basis for environmental education and environmental monitoring. Such a system will be enhanced by the development and application where appropriate of nationally consistent principles for management of reserves.*

Historically, the greatest development of protected areas has occurred in terrestrial ecosystems, with a CAR national reserve program focused through the bioregional framework of IBRA. This has led to bias against representation of aquatic ecosystems in protected areas (Tait *et al.*, 2003). For example in NSW, only about 3% of all wetlands (including estuaries and floodplains) are in reserves (Kingsford *et al*., 2004b), compared with about 7.6% of terrestrial areas. Nationally, mid and lower reaches of river basins (e.g. Murray–Darling, Fitzroy) are poorly represented in existing protected areas (Tait *et al.*, 2003). This problem was recognised in the discussion paper entitled *Directions Statement for the National Reserves System 2004* (NRMMC, 2004), which specifically refers to the need to ensure aquatic ecosystems are adequately represented in the National Reserve System.

All States have endorsed that commitment through policy statements (Nevill & Phillips, 2004), while Victoria and the Australian Capital Territory have funded programs to establish freshwater reserves. All jurisdictions have tools and mechanisms for identification of protected areas (Appendix C, Tables C1 and C2). Special-purpose legislation for the establishment of aquatic protected areas exists in several jurisdictions (Appendix C; Table C2) but, even when such areas are created, controlling catchment-scale processes to maintain the values within the protected areas remains a problem. Indigenous Protected Areas (IPA), under the National Reserve System, provide for Indigenous communities to pass on their traditional culture and knowledge to future generations through the land and aquatic ecosystems. Aquatic sites, principally wetlands, are also identified in the Directory of Important Wetlands in Australia (DIWA) and may be listed under the International Convention of Wetlands of International Importance (Ramsar) (Appendix C, Table C2). The management of these sites can link to jurisdictional planning frameworks, and increasingly regional natural resource management plans. Ramsar-listed wetlands are matters of national environmental significance under the EPBC Act.

4.2.3. Natural resource planning and management

All Australian States and Territories have statutory planning processes and impact-assessment procedures for assessing likely effects of large ('State significance') development proposals (Appendix C, Tables C1 and C2). They also have strategic land-use planning procedures for controlling cumulative effects of small developments, such as housing or small-scale water infrastructure (e.g. farm dams, agricultural drains, levee banks). Under the Natural Resource Management Ministerial Council's National Action Plan for Salinity and Water Quality and CoAG's water-reform agenda, regional natural resource management plans are now being developed and implemented, including issues of river management and integrated catchment management. CoAG has also agreed to the National Water Initiative. The intergovernmental agreement, signed by the Australian Government and the States and Territories (other than Tasmania and Western Australia), contains provisions committing signatories to identify and manage high-conservation-value rivers to protect and enhance those values.

Managing cumulative impacts of land use and development is one of the more urgent and intractable problems facing communities and government. The major threats facing river systems around the world include water extraction, floodplain drainage, diversion and impoundment, catchment disturbance and invasive pest species (Box 5). Even where there are statutory catchment planning frameworks, they seldom have effective mechanisms for managing cumulative effects. However, without a rigorous approach to the management of cumulative effects, and without the necessary information on the value and condition of freshwater ecosystems, environmental assessment of large and small-scale developments will continue to fail to effectively control cumulative, degrading impacts. Protection mechanisms must manage these threats in high-conservation-value rivers and component ecosystems. Currently, the management of different threats may be targeted by separate legislation and policy and is often the responsibility of different government agencies—as a result, integrated management of assets is seldom achieved.

The emergence of region-based, catchment-focused, natural resource management plans has the potential to provide for coordinated mitigation of these threats in ways not achieved with issue-based legislation and policy tools. However, unless regional natural resource management plans are supported by inventories of ecosystem value, condition and threats, their effectiveness in protection of high- conservation-value assets will be limited.

Good environmental assessment of potentially deleterious project proposals underpins sustainable management of all rivers. If a particular river or dependent ecosystem is identified to be of high conservation value, then the environmental assessment and rehabilitation processes implemented should maintain or restore the long-term sustainability of this asset at the relevant scale, which may often be the whole catchment.

4.2.4. Incentives

Opportunities exist for conservation and rehabilitation of degraded rivers and their dependent ecosystems (e.g. the Living Murray initiative). Identification of rivers and dependent ecosystems of high conservation value establishes important priorities for protective management and rehabilitation. Targeted investment is essential for delivery of the best environmental outcomes.

In addition to public initiatives, jurisdictions should act to protect high-conservation-value assets on private, freehold land through incentive programs such as landowner agreements (Appendix C, Table C1). For example, the Trust for Nature (Victoria) is a statutory corporation that operates under the *Victorian Conservation Trust Act 1972*. The Trust purchases land of high conservation value to manage as private conservation reserves, as well as entering into legally binding conservation covenants with private landholders. The Minister or the Trust can then invest in conservation measures identified in an agreed management plan. Other voluntary, non- binding 'Land for Wildlife' programs can also provide mechanisms for investment in aquatic sites. According to Victorian Department of Sustainability and Environment and the Bird Observers Club of Australia figures, more than 5800 private properties were registered at September 2003, covering 156,000 ha. A considerable number of other future opportunities exist for landholder agreements, reinforced by 'payments for ecosystem services', tax breaks, or other forms of environmental funding.

Chapter 5. Operational and institutional arrangements — recommendations

Current operational and institutional arrangements need to be used for delivery of this national framework. Implementation of the national framework would require cooperation between jurisdictions and the Australian Government. To that end, it could be best progressed under the aegis of the Natural Resource Management Ministerial Council and the National Water Initiative.

Protection of natural river assets is clearly a sound financial investment for governments. A national framework for the protection of high-conservation-value rivers and their dependent ecosystems will establish clear strategic direction, ensuring that river protection activities act to secure high-conservation- value assets, achieving the highest possible return on investment. This will also help to minimise major cost burdens for future generations.

This proposed national framework relies on national, State, Territory and regional institutional arrangements and resources for implementation. The framework would provide an institutional process and resources for development of the national classifications and assessment procedures for jurisdictions to identify high-conservation-value rivers and component ecosystems and to prioritise and evaluate protection activities. The program should also support communities that wish to identify and manage Australian Heritage Rivers at the whole-of-basin scale.

We have identified a number of key parts to this framework throughout this discussion paper and we summarise how these could best be implemented.

5.1. Major recommendation

Implementation of the national framework would require cooperation between jurisdictions and the Australian Government. To that end, it could be best progressed under the aegis of the Natural Resource Management Ministerial Council and the National Water Initiative.

5.2. Spatial framework

Recommendations

a. Use current drainage divisions, river basins and river segments for initial implementation of this framework. These map layers , and the sub-catchments and catchments they support, should be publicly available.
b. River ecosystem data should be labelled according to resolvable hierarchical scales, allowing for evaluation and future reassessment of classifications.
c. Develop a new hierarchical spatial framework for management of aquatic systems and rivers, based on topography and drainage networks, without many of the problems identified for current spatial layers.

5.3. Evaluation and classification

Recommendations

a. Develop agreed approaches for assessing criteria and use of attributes for rivers, river reaches and dependent ecosystems.
b. Develop agreed national classifications of rivers and dependent ecosystems, with agreed objectives, to support evaluation and assessment.
c. Apply a nationally agreed set of evaluation criteria and significance thresholds, compatible with Ramsar and National Heritage, with nationally available data aggregated to the smallest resolvable scales of assessment (i.e. river segments and their sub-catchments). This could be done to assess all river segments to identify nationally important rivers, wetlands (>200 ha) and large estuaries. Continental data are available in the water body layer (AUSLIG 1:250,000), DIWA and some jurisdictional data sets (e.g. NSW (Kingsford *et al.*, 2004b), OzEstuaries, and National Land and Water Resource Assessments). This initial assessment could be reported at a range of scales, informing a national assessment but also State and regional assessments.

d. Establish long-term collection and storage of nationally consistent data on rivers and their dependent ecosystems that allow for comparison across the country.

5.4. Proposed Australian Heritage Rivers system

While some States have, or will soon have, heritage or wild rivers programs (Appendix E, Table C2), there is currently no clearly defined operational or institutional framework for how 'whole-of-basin level' protection may be implemented at the national level. There are currently some *ad hoc* frameworks for whole of river basin protection, like the Lake Eyre Basin and Paroo River agreements. The Australian Government has primary administrative responsibility for the former, while the latter is administered currently through the Border Catchments Ministerial Agreement between New South Wales and Queensland. Establishment of different models could be explored and possibly implemented under the Natural Resource Management Ministerial Council. These may or may not have a legislative basis (see Appendixes C, D & E, Table C2). Given the voluntary nature of this mechanism, and community involvement, it is likely that this part of the framework may take time but nevertheless may deliver the best environmental outcomes for protection of high-conservation-value rivers in the long term.

Recommendations

a. Identify potential candidate river basins for nomination and designation as Australian Heritage Rivers. This process could be done immediately, using current data. Note that designation would not occur without community support.
b. Identify institutional arrangements that would deliver an Australian Heritage River system, including current models and whether there is a need for legislation. This would have the essential steps for nomination, designation, consultation and administration. The Canadian Heritage Rivers System is a model worthy of consideration.
c. Largely unmodified river basins designated as Australian Heritage Rivers could be priority areas for funding river management plans that protect ecological values, prevent environmental problems, encourage uses compatible with protection of ecological values and promote understanding of ecological values and processes.

5.5. Protecting nationally important rivers and their dependent ecosystems using current mechanisms

State, Territory and Australian governments could protect nationally important rivers, reaches, wetlands and estuaries (identified through a national assessment) through targeted establishment of protective areas, effective implementation of natural resource planning and management, and incentive programs.

No new legislative mechanisms or institutional arrangements are needed to effect protection of nationally important rivers and their dependent ecosystems, except possibly in the control of diffuse cumulative impacts. Existing mechanisms need to be more effectively implemented for ecological outcomes. The specific initiatives that could be implemented include recommendations for environmental flows, protected areas, natural resource management and planning, and incentives.

5.5.1. Environmental flow management

a. Environmental flows for long-term sustainability of rivers and their dependent ecosystems need to be identified at catchment scales.
b. Environmental flows should be managed within an adaptive management framework that ensures the best environmental outcomes.
c. Targets for flow restoration may need to be developed with a focus on better management of flows and access to additional flows if required (e.g. improving water-use efficiency, purchase of water).

5.5.2. Protected areas

The following initiatives could be made for rivers and dependent ecosystems that are nationally of high conservation value.

a. Aquatic ecosystems should be a considered for future acquisition of protected areas (e.g. national parks, nature reserves, conservation areas, or aquatic reserves), or nominations of important wetland areas (e.g. National Heritage, World Heritage and Ramsar sites). This may also include Indigenous protected areas.
b. Policies and management practices and documents for protected areas with rivers and dependent ecosystems should include how the management plans or policies will meet long-term ecological outcomes of sustainability (e.g.

upstream environmental flows, pest control strategies and impacts of catchment disturbance). This could be done under current or developed planning provisions for protected areas that focus on potentially detrimental ecological impacts caused by upstream catchment pressures or downstream barriers. This may include protection of the reserve through catchment-based management of weeds, protection of natural river flows, floodplain and groundwater connectivity, translocation of biota and water quality.

c. These ecosystems could be the focus for the development of cooperative protective arrangements with landholders (e.g. voluntary conservation agreements and other incentive programs).

d. They could be considered for heritage listing under the National Heritage List of the *Environment Protection and Biodiversity Conservation Act 1999*.

e. They coulod be listed under relevant threatened species legislation as endangered or threatened ecological communities if they satisfy appropriate legislative criteria.

5.5.3. Natural resource planning and management

The following improvements to natural resource management and planning could be made for rivers and dependent ecosystems that have high conservation value at a national level.

a. Statutory resource and land-use plans, including river-management plans, should assess and control potentially deleterious impacts on these ecosystems at catchment scales.

b. Environmental objectives in water plans should adequately acknowledge high-conservation-value rivers and their dependent ecosystems and water regimes that maintain their ecological values.

c. River-management planning of these areas needs to explicitly incorporate rivers and their dependent ecosystems within management plans, recognising catchment processes and hydrological connections.

d. For those aquatic ecosystems that cross management borders, river planning should incorporate all of a catchment, taking account of different jurisdictional water legislation.

e. Water-quality policies and management should link to planning, assessment and controls that protect identified aquatic ecosystems. The revised Victorian State Environment Protection Policy (Waters of Victoria) provides a good model for jurisdictions to consider (Nevill and Phillips, 2004).

f. Introduction of exotic species (plants or animals) should be controlled in these aquatic ecosystems and their catchments.

g. River-management planning should involve communities early and involve effective community consultation and communication.

h. Planning should be culturally sensitive (e.g. respect Indigenous decision-making and governance processes) and involve traditional owners for identified ecosystems.

i. For improved management, research and development should focus on that affect conservation values of high conservation rivers, reaches and dependent ecosystems.

5.5.4. Incentives

The following incentive initiatives could be considered for rivers and dependent ecosystems nationally of high-conservation value.

a. Rivers and dependent ecosystems of high conservation value at national, State and catchment scales need to be identified and included in Australian Government, State and regional investment frameworks. This may mean providing priority funding for protection and rehabilitation works (e.g. riparian management, weed management, erosion control, run-off detention, revegetation, land-use change, reinstatement of wetland hydrology, environmental flows and management planning).

b. These aquatic ecosystems could receive priority in monitoring and assessment of ecological values (e.g. Rivercare, Waterwatch, Auditing).

d. These ecosystems could be a focus for tax and rate-relief programs and new incentive schemes for landholders committed to protecting these areas.

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Appendices

Appendix A. Information for the spatial framework

Table A1. Sources of digital information for a national spatial framework for Australian rivers

Data-set	Description	Applicable scales	Spatial coverage	Limitations
GEODATA 250K (Geoscience Australia, 2003b)	Digital (GIS) vector coverage of information from the 1:250,000 scale topographic map series. Includes lakes, reservoirs, swamps, streams and canals.	Segment to drainage basin	Continental	Mapping variability, compatibility with drainage analysis procedures, currency
Nested catchments (Hutchinson *et al.*, 2000)	A network of river links and nested series of drainage basins, catchments and sub-catchments derived from the national 9' DEM version 2. Drainage basins linked to the AWRC drainage basins	Segment to drainage basin	Continental	Does not adequately reflect low drainage density in low relief areas or accommodate distributary channels or anabranching systems
Pfafstetter nested catchments (Stein, 2003)	A network of river links and nested series of drainage basins, catchments and sub-catchments derived from the national 9" DEM version 3 using the Pfafstetter delineation and coding system. First level sub-division based on the AWRC drainage divisions	Segment to drainage basin	Continental	Under development (completion mid 2004), needs evaluation
AWRC Drainage division and river basins (AUSLIG, 1997; Geoscience Australia, 2003a)	Drainage basins for 245 major rivers delineated from topographic maps of various scales. Basins aggregated into 12 drainage divisions.	Drainage basin	Continental	Boundary errors, distributary channels and anabranching systems, confuses basins and catchments; 'basins' also include catchments of adjacent smaller coastal streams
Assessment of River Condition (NLWRA) (Norris *et al.*, 2001)	A network of river links with catchment area >50 km^2 defined from the national 9" DEM (Geoscience Australia, 2001).	Segment to drainage basin	Intensive Landuse Zone	Flow through flat areas, distributary channels and anabranching systems, larger streams only
OZESTUARIES (Heap *et al.*, 2001)	Location and extent of 974 estuaries and other coastal waterways, includes mapping of geomorphic and sedimentary facies (habitat) areas for 405 estuaries.	Segment	Continental	Only larger estuaries

Table A2. Systems for delineation and/or codification of topographically defined hydrologic units at national scales

System	Description	Automated delineation/ coding	Information conveyed by unit coding scheme		
			Membership of higher levels	Tributary/main stem relations	Up/down stream relations
Pfafstetter (Verdin & Verdin, 1999)	Drainage basins successively divided into tributary basins and mainstem inter-basins on the basis of catchment area and drainage network topology	Y	Y	Y	Y
USGS Hydrologic Unit System (HUC) (FGDC, 2002)	Numbers of units and area guide division into smaller watershed (catchments) and sub-watersheds (sub-catchments), downstream boundary decisions made using local knowledge, inter-agency standards and guidelines facilitate consistency	N	Y	N	N
U.S. EPA Reach File 1 (RF1) (U.S. Environmental Protection Agency Office of Science and Technology, 1998)	Stream reach indexing system using a unique reach number for stream reaches and relative position (latitude/longitude), pro-rated against the full computed reach length	Y	N	N	Y
Catchment area thresholds (e.g. Hutchinson *et al.*, 2000)	Unit downstream boundaries located at confluences where the tributary upstream catchment area exceeds specified threshold	Y	Y	N	N
AWRC drainage basins and divisions (AUSLIG, 1997; Geoscience Australia, 2003a)	Based on catchment area of largest rivers, adjacent small catchments merged. Basins numbered sequentially within drainage divisions. First digit indicates drainage division.	N	Y	N	N
Brooks, 2003	Hydrological coding system similar to Pfafstetter using base 64 numbering system requiring less sophisticated operators for up/downstream queries	Y	N	Y	Y

Appendix B. River classification—a review

In the main classification system section, we discussed classification of riverine systems and provided immediate and long term options for identifying representative high conservation rivers and dependent ecosystems at a national scale. The classification options arose from this review of river classification, focused on conservation application. Further information is provided by Australian (Nevill and Phillips, 2004; Pressey & Adam, 1995; Tait *et al.*, 2003) and international reviews (Mosley, 1987; Gordon *et al.*, 1992; Naiman *et al.*, 1992; Downs, 1995; Thorne, 1997; O'Keefe and Uys, 2000; Jensen *et al.*, 2001b; Makaske, 2001; Elliott and McLusky, 2002).

Classification approaches

Classifications may apply to a single scale or, in a hierarchical framework, link rivers explicitly to the surrounding catchment and terrestrial landscape (Jensen *et al.*, 2001b), making them effective at local to continental scales. Stream order, a simple enduring single-scale classification scheme, measures relative position in the drainage network (Strahler, 1957). It can indicate biotic and physical characteristics of a river segment but is less reliable at regional scales (Naiman *et al.*, 1992). Similarly, river zonations using presence of one or more species (Mosley, 1987) seldom apply beyond where they were developed (Naiman *et al.*, 1992). The hierarchical structure in classification may be divisive or agglomerative (Bourgeron *et al.*, 2001a).

Divisive or 'top down' approaches start from large, ecologically heterogeneous areas, successively dividing them into lower more homogenous levels. This widely adopted method (e.g. Blackman *et al.*, 1992; Calvert *et al.*, 2001; Frissell *et al.*, 1986; Maxwell *et al.*, 1995; Snelder & Biggs, 2002) uses ecological units, mapping them progressively and with increasing resolution, data and analysis requirements. Classifications can be produced for entire continents with limited data while providing for finer selected delineations (Cleland *et al.*, 1997). A top down approach accords with theories of the hierarchical organisation of ecological systems (O'Neill *et al.*, 1986). Higher levels functionally constrain lower levels, but because of the asymmetry in the relationships between the levels of ecological hierarchies, emergent properties of higher levels cannot be predicted from the properties of the lower levels (Bourgeron *et al.*, 2001a; Perera *et al.*, 1996; Zonneveld, 1994).

There are drawbacks. The emergent properties of the higher levels may be difficult to characterize when applied to the hierarchical structure of river systems. Classification differentiating criteria are applied using summary values at high levels, although you need to ensure that basin average values are not meaningless for large and heterogeneous basins. Climatic criteria often differentiate high levels of hierarchical classifications (Bailey, 1996; Calvert *et al.*, 2001; Cleland *et al.*, 1997; Snelder and Biggs, 2002) but these are not readily applied to large river basins that include climatic types ranging from montane to tropical lowland (Omernik & Bailey, 1997). Further, this 'top down' approach starting with a grouping of river basins may obscure similarities more closely associated with habitat characteristics than patterns of drainage system connectivity. For example, distinctive montane fish communities span drainage divides (Gehrke & Harris, 2000). Sequential divisive approaches are also sensitive to the order in which classification criteria are specified (Phillips *et al.*, 2002). For example, the particular importance of criteria may vary with valley substrate (Cohen *et al.*, 1998; Heritage *et al.*, 2001).

In contrast, agglomerative or 'bottom up' approaches successively integrate the objects of the classification, according to their shared similarities. As implied, this begins from the lowest levels in the hierarchy, leading to progressively higher levels. The approach follows a view that the character and behaviour of the river reflect the collective characteristics of the tributary sub-catchments (Brierley & Fryirs, 2002). It is inductive and generally independent of spatial constraints (Bourgeron *et al.*, 2001a), except through the spatial dependence of the classificatory variables. However, these approaches depend on data availability at the finest scales of a river to be classified at any level in the hierarchy.

The attributes used to discriminate groups may be direct measures of river ecological characteristics ('response' variables) or the principal factors responsible for the river's characteristics ('driving' or 'controlling' variables) (Bourgeron *et al.*, 2001b; O'Keefe & Uys, 2000). Response variables include descriptors of biotic community structure (taxon distribution and abundance) or of habitat, principally hydrology or geomorphology. Controlling factors operate over a range of spatial and temporal scales (Naiman *et al.,* 1992). Ultimate controls, regional geology, climate and zoogeography, operate across large areas and are stable over long time scales (centuries to millennia). Proximate controls include the local geomorphic processes (e.g. channel migration, sediment transport) and biotic processes (e.g. reproduction, competition, predation) that alter river characteristics over short time periods (decades or less) and are important at small spatial scales.

National classification of rivers and dependent ecosystems

Australia has examples of regional (Riley *et al.*, 1984; Fatchen & Lustig, 1986; Macmillan & Kunert, 1990; Olsen & Skitmore, 1991) or State-wide classifications (Doeg, 2001; Hughes & James, 1989; Jerie *et al.*, 2003; Land Conservation Council, 1989; Kingsford *et al.*, 2004b) but no nationally consistent mapping of river types. A national scheme was developed (Calvert *et al.*, 2001) but has not been implemented. Internationally, there are few examples of river classifications for national scale conservation application (Boon *et al.*, 2000). Two exceptions include classification of British rivers for statutory conservation, based on aquatic plant communities (Holmes *et al.*, 1998; Holmes, 1999), and the freshwater ecoregions developed for conservation assessment in North America (Abell *et al.*, 2000).

Unlike rivers, large Australian estuaries have been classified nationally. Over 700 estuaries in the Australian Estuarine Database (AED, <http://www.ozestuaries.org/> (updated version), accessed 18/8/2004) were classified using a statistical analysis of biologically important physical characteristics (climate and inter-tidal range) (Digby *et al.*, 1999). The classification explained nearly half of the variation in estuary, saltmarsh and mangrove proportions. These estuaries were also classified into six classes according to the relative dominance of the wave, tide and river energies responsible for shaping their form and function (Heap *et al.*, 2001). A geomorphological classification derived from Landsat TM satellite imagery, aerial photographs, and topographic maps confirmed the energy classification. This classification was also applied to an additional 190 estuaries not included in the AED and is now accompanied by conceptual models of the biophysical processes that operate in estuaries and coastal waterways (Ryan *et al.*, 2003). None of these classifications directly considered the regional variation in biologically important catchment inputs such as sediments, nutrients or the seasonal variability of run-off.

Biological classification

Classifications of rivers based on the distribution pattern of biota are often favoured for conservation applications (Olson *et al.*, 2001; Tait *et al.*, 2003). They may use dominant species, indicator species or assemblages of organisms (commonly fish or macro- invertebrates) to discriminate groups (Gordon *et al.*, 1992; Naiman *et al.*, 1992). For example, Gehrke and Harris (2000) identified four broad groups of rivers, Montane, North Coast, South Coast and Murray– Darling, from the fish assemblages recorded in a systematic survey across NSW and Marchant *et al.* (1999) classified Victorian rivers according to macro- invertebrate communities found in edge and riffle habitats (199 sites). Biological survey data are notoriously poor and usually confined to a small number of sites making conservation planning, based on a classification across all rivers difficult. Wider spatial distributions for biota may be predicted from site records by bioclimatic modelling (e.g. Nix, 1986 (BIOCLIM); Fischer *et al.*, 2001; Lindenmayer *et al.*, 2002) or statistical modelling (e.g. Thuiller, 2003). Modelled distributions of terrestrial species and communities can help conservation planning at regional (Margules & Nicholls, 1987; Margules & Stein, 1989; Ferrier *et al.*, 2002a,b; Scott & Drielsma, 2003) and national scales (Faith *et al.*, 2001; Nix *et al.*, 2000). Similar techniques can predict fish distribution (Joy & Death, 2002; Olden & Jackson, 2002). For example, the structure of fish communities in four Queensland rivers was predicted from regional or catchment scale factors (Pusey *et al.,* 2000). Models could be developed for many riverine taxa if suitably representative site data exist, matched to environmental attributes (Mackey *et al.*, 2001).

Achieving the level of sampling in both space and time necessary for modelling the continental distribution of highly dynamic taxa is problematic. For example, variation in macro-invertebrates community structure occurs at fine spatial (Robson & Chester, 1999; Dovciak & Perry, 2002) and temporal (Scarsbrook, 2002) scales, reflecting discharge variability (Humphrey, 1997) or local disturbance (Matthaei & Townsend, 2000). Survey sites are seldom 'representative' of larger spatial units, such as river segments (Downes *et al.*, 2000). Statistical models can predict the expected macro-invertebrate community at a test site (AUSRIVAS bioassessment program, <http://ausrivas.canberra.edu.au/ index.html>) but they require both coarse-scale, map based variables and local scale field measures of water quality and substrate composition (Read, 2001; Smith *et al.*, 1999; Turak *et al.*, 1999). Models of macro-invertebrate community structure using remotely mapped environmental variables alone were less successful with less than half of the regional models for the NLWRA Assessment of River Condition considered satisfactory (Norris *et al.*, 2001).

In lieu of comprehensive data, expert judgement can derive boundaries around broad regions of relatively homogeneous biological assemblages. For example, a regionalisation using macro-invertebrate survey sites and their groupings for Victoria was based on professional judgement (Wells *et al.,* 2002), by positioning boundaries following the method of Newall and Wells (2000). Combined with regional fish distribution maps, the resulting regions underpin selection of representative rivers in Victoria (Victorian Riverine Biological Regions; Doeg 2001). Unfortunately, with limited data State-wide coverage was not possible and "a considerable amount of latitude" was required to reconcile boundaries between component regionalisations (Doeg 2001). A drawback for regionalisation is that geographic proximity may not be the overriding factor driving similarity. For example, complex distribution patterns of macro-invertebrate distribution may reflect the longitudinal gradients and connectivity of rivers (Marchant *et al.*, 1999), rather than geographic proximity (Heino *et al.*, 2003; Turak *et al.*, 1999). Spatial organisation in biological communities is a function of the spatial scale over which data are gathered (Marchant *et al.*, 1999) and the accepted level of within group heterogeneity.

Alternatively, biogeographic methods can delineate region boundaries by identifying concordant taxonomic distributions, rather than community similarity. Biogeographic methods identify constraints, that may be difficult to incorporate into models of species' or communities' distributions using abiotic factors. Boundaries essentially reflect the 'ultimate' controls on rivers (Naiman *et al.*, 1992),such as major geological events, glaciations, and land bridges and can define the highest levels in a hierarchical classification scheme (Naiman *et al.*, 1992; Maxwell *et al.*, 1995; Tait *et al.*, 2003). So, fish provinces exemplify biogeographic regionalisation in Australia (Unmack, 2001). They represent areas with a distinctive recent evolutionary history, reflected by characteristic fish species and subspecies (Unmack, 2001). The provinces were derived from regional groupings of the AWRC drainage basins (see above), guided by concordance among distributions of obligate freshwater fish species. Poor fish data availability for inaccessible regions remains a challenge (Unmack, 2001). Also regionalisation could be improved with better delineations of river basins (Geoscience Australia, 2003a; Hutchinson *et al.*, 2000; see spatial scale). These provinces could delineate 'macro-regions' of an Interim Freshwater Biogeographic Regionalisation for Australia (IFBRA) (Tait et. al., 2003). Lower levels in the proposed IFBRA hierarchy would be based on position in the catchment (Tait et. al., 2003). Biological classifications based on one or two taxonomic groups may inadequately represent other aquatic taxa (Butcher *et al.*, 2001; Paavolo *et al.*, 2003; S. Halse, pers. comm. in Pressey & Adam, 1995). Other faunal groups may also be candidates for bioregionalisation using new phylogeny (e.g. turtles, Georges *et al.,* 2001), that is not confounded by spatial and temporal variability (Tait *et al.*, 2003). Such descriptions may also require separation into ecological subsets of taxonomic groups to account for important patterns and processes (Williams & Hero, 2001). Unfortunately, we know relatively little of how geographical scale and biogeographical histories affect taxonomic surrogacy (Margules & Pressey, 2000).

Fine scale (e.g. river segment, reach) biological classification of rivers is currently not possible because of the lack of comprehensive inventory of Australian rivers and their dependent ecosystems (Nevill & Phillips, 2004) and our poor taxonomic knowledge of freshwater biodiversity (Georges & Cottingham, 2002). Further, comprehensive surveys are rare. Existing survey data are often biased towards easily accessible locations or larger, permanent streams (Williams, 1988; Kingsford, 1995). Even the collections of aquatic macroinvertebrates for the National River Health Program (NRHP) (Read, 2001; Smith *et al.*, 1999; Turak *et al.*, 1999) concentrate on areas of greatest management need and include few temporary streams, especially in arid regions. Low levels of taxonomic resolution (e.g. family) characteristic of many macroinvertebrate data-sets, including the NRHP, may be inadequate for useful generalisations (Hawkins & Vinson, 2000; Tait *et al.*, 2003).

Even with a large investment in inventory, two important factors affect biological classifications. Firstly, the distribution patterns of many biota have been modified by anthropogenic activities in ways that are difficult to detect (O'Keefe & Uys, 2000). For example, deliberate (stocking) or accidental (e.g. aquaria, escapees from fish farms) releases of native fish species are widespread (Burrows, 2002) and distributions of native fish species are considerably affected by river regulation (Gehrke *et al.*, 1995; Gehrke & Harris 2001). Similarly waterbird distribution and density is affected by river regulation (Kingsford *et al.*, 2004a; Kingsford & Thomas, 2004). Secondly, population fluctuation can be mistakenly ascribed to geographic variation because there are seldom extended time series (Frissell *et al.*, 2001). Such fluctuations are extreme in many floodplain wetlands with shifting spatio-temporal mosaics of assemblages reflecting complex patterns of connectivity dependent on highly variable flooding (Puckridge *et al.*, 2000; Timms and Boulton, 2001; Reid *et al.*, 2003; Sheldon *et al.*, 2002; Kingsford *et al.*, 2004a). Stochastic processes may structure biotic communities in intermittent or episodic rivers. Two adjacent pools in a temporary river can have entirely different faunal assemblages dependent upon colonisation (Roux *et al.*, 2002). Biological classifications are inherently dynamic snapshots of ecosystems patterns, requiring periodic updating (Jensen *et al.*, 2001b).

Geomorphic and hydrological classifications

There are many geomorphic classifications, using geomorphological characteristics of rivers (Rosgen, 1994; 1996; Montgomery & Buffington, 1997; Brierley & Fryirs, 2000; Heritage *et al.*, 2001; Whittington *et al.*, 2001). They are used to assess river condition (Fryirs & Brierley, 2000), manage rivers and environmental flows (Calvert *et al.*, 2001; Outhet *et al.*, 2001; Thoms & Sheldon, 2002), report on rivers (Whittington *et al.*, 2001), identify targets for river restoration and rehabilitation (Rosgen, 1994) and do ecological inventory (Savery *et al.*, 2001).

River Styles is a generic non-prescriptive approach for evaluating the geomorphic character of rivers (Brierley & Fryirs, 2002), applied State-wide in rivers of New South Wales (Outhet *et al.*, 2001) and catchments in Tasmania, Queensland and South Australia (Brierley & Fryirs, 2002). River Styles are relatively homogenous reaches, identified by river planform, geomorphic unit assemblages and bed material texture—the differentiating criteria depend on the valley setting (Brierley & Fryirs, 2000). Although River Styles recognises a hierarchy of nested spatial scales (catchment, landscape unit, reach, geomorphic unit and hydraulic (habitat) unit), the classification is not a nested hierarchy- a River Style might occur in more than one landscape unit (Thomson *et al.,* 2001; Jerie *et al.*, 2003). Inconsistent interpretation and labelling among catchments occurs with applications of River Styles (Jerie *et al.*, 2003). Accredited training programs, trademarking (Brierley & Fryirs, 2002) and standard rules for categorising reaches and labelling basic styles (Outhet *et al.*, 2001) aim for consistency. With limited time or inexperienced application, River Styles becomes mechanical, predominantly using visual assessment of the river planform and valley confinement with little consideration of the influence of the wider landscape and geomorphic history (Jerie *et al.*, 2003).

The proposed National River Classification System for Australian rivers, designed for environmental flow management, was based on the geomorphology of river reach types (Calvert *et al.*, 2001). The top down hierarchical scheme places channel reaches into 50 *a priori* types, nested within higher levels defined successively by climatic, geomorphic region, flow regulation and valley setting. It covers the full length of rivers from source to the ocean and recognises estuarine and marine reaches. Differentiating criteria are not specified although a list of geomorphic attributes that may form these criteria are given. Establishing uniformly interpreted criteria remains problematic. For example bedrock and alluvial reach types are presented as uniquely nested within associated bedrock and alluvial valley segments (Figure 4, p. 20, Calvert *et al.*, 2001). But, then some of the classified reaches on the Snowy River below Jindabyne Dam, have mixed labelling (e.g. Bedrock Confined Channel within a Bedrock/ Alluvial valley).

In the United States, the Rosgen stream classification system (Rosgen, 1994; 1996) is used for inventories and assessment of streams (Jensen *et al.*, 2001b), particularly by the USDA Forest Service (Savery *et al.*, 2001; USDA Forest Service Stream Systems Technology Center, 2001). It specifies quantitative delineative criteria for measured attributes of channel form (entrenchment, channel planform, width:depth ratio, sinuosity, slope and dominant substrate) to classify reaches. Although quantitative, criteria may not be consistently applied because methods to measure attributes (e.g. bankfull width) vary (Savery *et al.*, 2001) and bias due to unrepresentative field measurements (Myers & Swanson, 1997). The prescriptive classes may be region specific and will not be applicable to unique river forms in Australia (Brierley & Fryirs, 2002; Calvert *et al.*, 2001). Rivers that do not conform to criteria could be assigned a predefined type, with potentially serious consequences for management (G. Brierley, pers. comm. Nov. 2002) or classes must be added or modified (e.g. Savery *et al.*, 2001). The geomorphic significance of the delineative criteria are also questionable (Miller & Ritter, 1996). Channel forms are the end products of a complex dynamic system and may not uniquely reflect controlling factors and processes and so use of fluvial processes or controlling factors for classification may be more productive (Goodwin

1999).

Process based frameworks related to sediment transport on hillslopes and in rivers are reasonably commonly used to classify channel morphology (Nanson & Croke, 1992; Whiting & Bradley, 1993; Nanson & Knighton, 1996; Alabyan & Chalov, 1998; Montgomery & Buffington, 1997). Such classifications may effectively be used to assess channel condition, management response and relationships with ecological processes (Montgomery & Buffington, 1997) but threshold values for geomorphological processes may not be uniform across large areas (Jerie et al., 2003). Functional Process Zones (FPZ) were mapped for the major rivers of the Murray–Darling Basin, as lengths of river with similar discharge and sediment regimes defined by gradient, stream power, valley dimensions and boundary material (Whittington *et al.*, 2001). They are nested within three valley process zones, broadly identified by their sediment transport characteristics (source, transport and deposition). The classification stratifies river valleys for reporting of the Murray–Darling Basin Sustainable Rivers Audit (Whittington et al., 2001) and provides an ecosystem approach for environmental water allocations (Thoms & Sheldon, 2002). Its value is enhanced by accompanying conceptual models of river function, that relate physical factors within each FPZ to ecosystem structures and processes (Thoms et al., 2001).

The mapping of geomorphologic classifications and FPZs, depends on expert interpretation of field data, complemented by remotely sensed imagery, aerial photographs and historical data. Field observations must be sufficiently representative of a reach to ensure unbiased type assignments (Brierley & Fryirs, 2002). For example, a full River Styles assessment may take up to a day per reach (Brierley & Fryirs, 2002). Such requirements restrict the number of streams that are classified. The probability of occurrence of geomorphic types at reach (Young *et al.*, 2001) and geomorphic unit (habitat) scales (Davies *et al.*, 2000; Jeffers, 1998) may be modelled using larger scale landscape variables. Also new techniques for terrain analysis (Wilson & Gallant, 2000; Dowling *et al.*, 2003; Gallant & Dowling, 2004) and sediment modelling (Prosser *et al.*, 2001) offer opportunities for improved representation of critical variables. Modelling geomorphic process types using temporally stable landscape attributes may overcome another difficulty of classifications based on channel form—the low temporal stability of classified forms (< 10 years) (Naiman *et al.*, 1992). Modelling could indicate the types expected and provide a basis for assessing current condition (Davies *et al.*, 2000). Such model development depends on the availability of suitably representative site data, largely unaffected by human activities accompanied by high resolution terrain and substrate spatial data.

The physical features that are the basis of geomorphological classifications also form the habitat of biota and so may be important determinants of biological variation (Maddock, 1999; Newson & Newson, 2000). Geomorphological diversity contributes to the complexity of riverine habitats (Thoms & Sheldon, 2002). However, the geomorphologists' view of river channel types may not equate with those that biota respond to (Karr & Chu, 1999). For example, River Styles did not well represent macro-invertebrate distribution, even within a single bioregion (Thomson *et al.,* 2004). Geomorphic elements are only one of the physico- chemical factors that determine ecological habitat (Thomson *et al.*, 2004). The interaction between geomorphology and hydrology produce a mosaic of hydraulic features (depths, velocities, shear stresses) (Maddock, 1999). Semeniuk and Semeniuk (1995) recognise a high-level interaction between geomorphology and hydrology in the primary delineative criteria they adopt for generic wetland classification (Semeniuk & Semeniuk, 1997). The classification defines 13 primary classes from the combination of five broad landform types (basin, channel, flat, slope, highland) and four classes of water permanence. Vegetation cover (spatial arrangement and internal organisation of vegetation assemblages), salinity and morphology (planform and shape) are secondary classification descriptors for differentiating riverine types. The classification ignores the functional linkages between the river and its floodplain by separating floodplain and channel types at the highest level. Although this separation may be justified for some wetlands on old floodplains controlled by groundwater rather than fluvial processes (Cowardin *et al.*, 1979) this is certainly not the case for most wetlands in Australia (Kingsford *et al.*, 2004a). Semeniuk's (1988) regional classification of wetlands into suites of similar or related types ('consanguineous suites') is more useful for conservation because they probably represent functional ecological units. The classification has been used in regional studies in Western Australia (Nevill & Phillips, 2004) and the Northern Territory (Begg *et al.*, 2001) but it does not provide a workable basis for a national classification of Australian river systems. It is seldom feasible to collect the data for the secondary descriptors over large areas (Kingsford *et al.*, 2004a) and, despite its intended global applicability (Semeniuk &

Semeniuk, 1997), additional types and terminology was required for classification of wetlands in the Daly River Basin (Begg *et al.,* 2001).

Similar criticisms apply to the wetland classification of Blackman *et al.* (1992). Like many wetland classifications, they adopt the broad RAMSAR definition of wetlands (Ramsar Convention Secretariat, 2003), recognising riverine and estuarine as one of five major wetland systems with lacustrine, palustrine, and marine. Riverine systems include only wetlands flowing within an open channel. Secondary criteria of hydroperiod, substrate and dominance (flora or fauna) type subdivide these major systems, with modifiers describing the water regime, soil, water chemistry and anthropogenic influence. The modifying criteria refer to average conditions of dynamic wetland properties and require extended time series of observations. The system uses field description of representative sites from assemblages of wetlands delineated on remotely sensed images. A biogeographic regionalisation and geomorphic land types stratify selection of survey sites. While not providing an exhaustive inventory of all wetlands, the classification produces a framework for systematic regional scale assessment of wetlands (Blackman *et al.*, 1995).

The classification was applied to regions in Queensland (Nevill & Phillips, 2004) and uses a hierarchical wetland classification from the United States (Cowardin *et al.*, 1979). Associations of wetland types and geomorphic land types within wetland aggregations form ‘regional wetland habitats’ that could be useful for protection of wetlands (Blackman *et al.*, 2002). The sensitivity of the classification to the order in which the differentiating criteria are applied may be a problem (Phillips *et al.*, 2002). As with many classifications using prescriptive, *a priori* categories, the system is open-ended and incomplete at lower levels (Blackman *et al.*, 1992). We also have reservations about the ecological significance of the class divisions. For example, the class ‘unconsolidated bottom’ includes all wetlands with at least 25% cover of particles smaller than stones, and a vegetative cover less than 30% (Blackman *et al.*, 1992). These values, derived from the United States system (Cowardin *et al.*, 1979), are unlikely to be universally appropriate. Still, field survey data maintained in a spatially referenced database (Wetland Information System, Blackman *et al.*, 1995) allows flexible access and analysis for alternative classification. The database is also linked to remote sensing and other natural resource, cadastral and cultural information providing a powerful tool to support conservation. The classification is not applicable nationally but the system may be a model for wetland inventory and development of a national wetland information system for *a posteriori* classification, although a primary objective may be first to identify the extent and distribution of wetlands (Kingsford *et al.*, 2004a). Also, like many generic wetland classifications, the classification uses simple, broad categories of hydroperiod to characterise flow. But hydroperiod is just one of the ecologically important components of flow (Hart & Finelli, 1999; Poff *et al.*, 1997) operating over multiple temporal scales (Puckridge *et al.*, 1998; Thoms & Parsons, 2003) used to classify rivers. For example, Puckridge et al (1998) used a set of hydrological measures to describe facets of flow variability that clustered global rivers. A hydrological classification of Victorian river gauges used flow statistics for annual, monthly and low flows and peak (daily) discharges to derive five hydrologically distinct regions (Hughes & James, 1989). Such classifications can only be produced for a small sub- set of gauged streams although methods to extend flow parameters to ungauged streams are developing (see review in Croke & Jakeman, 2001). Also, alteration of flows and catchment disturbance confound detection of natural spatial variation. There is increasing understanding of which hydrological indices may characterise flow (Puckridge *et al.*, 1998; Growns & Marsh, 2000; Pegg and Pierce, 2002) and represent ecologically meaningful variation (Olden & Poff, 2003).

Landscape classifications

Landscape or environment classifications primarily use meso-scale attributes of the physical environment, including geology, climate, topography and vegetation types. Ecoregions are landscape regionalisations, within which the mosaic of ecosystem components (biotic and abiotic, terrestrial and aquatic) are relatively homogeneous and different from adjacent regions (Omernik & Bailey, 1997). Many countries use such classifications to support an ecosystem based approach to natural resource planning and management (Clarke *et al.*, 1991; Warry and Hanau, 1993; Omernik, 1995; Bailey, 1996; Bryce & Clarke, 1996; Uhlig, 1996; Harding & Winterbourn, 1997; Wells & Newall, 1997; Sandin & Johnson, 2000).

The Interim Biogeographical Classification of Australia (IBRA) is a continent-wide regionalisation of landscape patterns, inferred from regional and continental scale data on climate, geomorphology, landform, lithology and expert knowledge of characteristic flora and fauna

(Thackway & Cresswell, 1995). It supports the national reserves system program (Pigram & Sundell, 1997) but it poorly represents biotic patterns of rivers (Marchant *et al.*, 1999; Turak *et al.*, 1999; Wells & Newall, 1997). Similarly, a review of international aquatic studies found that broad landscape regionalisations did not effectively partition biotic composition (algal, invertebrate and fish) among sites (Hawkins *et al.,* 2000). Ecoregions do not seem to adequately represent longitudinal gradients (Snelder & Biggs, 2002) or dispersal barriers between rivers (Tait *et al.*, 2003) or within region variation in local habitats (Hawkins *et al.*, 2000). This may not be universal as benthic invertebrate assemblages showed "remarkably good concordance" with terrestrial ecoregions in Missouri that followed major catchment boundaries and where there was low within-region altitudinal variation (Rabeni and Doisy 2000). So sub-regions of IBRA (Morgan, 2001) that divide major geomorphic units may perform better, particularly if entirely aquatic organisms are separated from those with terrestrial life stages or distributional abilities (Tait *et al.*, 2003). As a national classification, IBRA is inconsistently applied and does not communicate decisions rules for boundary placement well. So there are methodological variations, most marked in the IBRA sub-regions along some state borders (Environment Australia, 2000). For example, Victoria uses detailed vegetation mapping to define particular regions, whereas New South Wales and South Australia use coarser land system mapping and geological or geomorphological mapping to define boundaries. Some IBRA regions also cross several different climatic regions (Hutchinson, M. F., McIntyre, S., Hobbs, R. J., Stein, J. L., Garnett, S. and Kinloch, J., unpubl. data; Landsberg & Kesteven, 2002).

IBRA and the Interim Marine and Coastal Regionalisation of Australia (IMCRA) use several variably applied factors to define individual ecoregions. Like IBRA, IMCRA integrates state and territory regionalisations, adjusting the boundaries as necessary on the basis of commonalities in region descriptions (Interim Marine and Coastal Regionalisation for Australia Technical Group, 1998). As with IBRA, there was no consistent national approach adopted. The individual regionalisations that form IMCRA cover a range of spatial scales, using different combinations of biological and/or physical environmental data and approaches. Some were qualitative expert-driven, others quantitative and analytical. IMCRA provides a broad bioregional context for estuaries but the extent to which these regions reflect intrinsic patterns of estuarine biota remains to be tested.

The River Environment Classification (REC) (Snelder & Biggs, 2002) employs the 'top down' hierarchical controlling factor method of ecoregion definition (Bailey, 1996), recognising particular environmental factors as controlling ecological variation at characteristic scales. REC classifies river segments using six broad classes that characterise the dominant climate of the upstream catchment. These climate classes are successively sub-divided using prescriptive categories of source of flow, geology, land cover, network position and valley landform. The classification differs from other regionalisations because it assigns individual river segments to a class independently using specified criteria, producing classes that may show wide geographic dispersion. It also recognises the river as a network of linked river segments, better representing the longitudinal gradients in aquatic ecosystems. The approach classified all the rivers of New Zealand at a mapping scale of 1:50,000 (Snelder & Biggs, 2002), providing a useful management framework for water allocation (Snelder *et al.*, 2001) and identifying reference and impaired reaches for stream eutrophication (Biggs *et al.*, 2002). There are some concerns about its application to Australian rivers. It uses catchment averages for grouping in the first four system levels which may be meaningless, particularly in large catchments and not representative of the integrated effect of controlling factors. For example, the 'dry' climate class encompasses all rivers with a value of 500 mm or less mean annual effective precipitation, effectively 70% of Australia. The developers acknowledge that different criteria need to be developed for applications outside New Zealand (Snelder and Biggs 2002), but few data are available to set ecologically relevant class boundaries. Furthermore, thresholds in stream ecosystem characteristics will vary because of the complex interaction of environmental variables (Jerie *et al.*, 2003; Omernik, 1995).

Numerical procedures (e.g. clustering) provide an alternative approach to landscape classification. Waterways can be grouped using similarities across a range of attributes. The number of groups may be chosen to suit specific objectives and the relationship between them quantified. Numerical agglomerative classification procedures were preferred over *a priori* intuitive classification to delineate river types ("bioregional aquatic systems") in a trial in the Burnett River catchment (Phillips *et al.*, 2002). Also, field measures of channel form and dominant substrate with derived landscape attributes (mean annual rainfall, slope, catchment area upstream, distance to sea) were required to delineate ecologically meaningful types but, field measures were available for less than one quarter of the sub- catchment units. This may not be a problem for landscape classifications where attributes represent the range of controlling factors that drive stream ecosystem processes (e.g. Jerie *et al.*, 2003) (see below).

The definition of classes numerically, as an emergent property of the primary data, is a feature distinguishing environmental domain analysis from other ecoregion approaches. Environmental domains are spatial units, for which attributes of meso-scale climate, substrate (regolith and soils) and topography are relatively homogenous at a prescribed level of dissimilarity. These attributes integrate effects of primary environmental attributes (e.g. light, mineral nutrients, moisture, temperature) that drive landscape physical and biological processes, defining ecosystem patterns (Mackey *et al.*, 1988, 1989;\, 2001; Nix, 1992, 1997). Environmental domain analysis also differs from ecoregion approaches in two other important respects. Firstly, classes are delineated in environmental rather than geographic space and secondly, hierarchical levels are defined using an agglomerative 'bottom up' approach. Environmental domains can represent patterns of biodiversity (Mackey *et al.*, 1989; Lewis *et al.*, 1991; Belbin, 1993; Kirkpatrick & Brown, 1994; Mackey *et al.*, 2000; Nix *et al.*, 2000; Mackey *et al.*, 2001; Leathwick *et al.*, 2003) and assess representativeness of biological survey data (Richards *et al.*, 1990; Mackey *et al.*, 2001). The classification focuses on collating primary attribute data at highest possible spatial resolutions, rather than producing a single generic classification. By varying the numbers of groups, weightings, or choice of clustering strategy a classification can be produced for different objectives.

Two recent studies adapted the environmental domain approach to address variation in rivers in Tasmania (Jerie *et al.*, 2001; 2003) and across Australia (J.L. Stein, unpubl. data). Variables, numerical procedures and spatial units (grid cells versus river segments and catchments) varied but both studies chose variables that controlled river characteristics and recognised the influence of the broader catchment. The two studies could be usefully compared in the future. Early results from Tasmania suggest environmental domains can describe regional variation in river character and behaviour (Jerie *et al.*, 2003). Continent-wide application is currently limited by the coarse resolution or absence of national coverage for some key data layers, notably geology, soils and landscape history. Other supporting areas for investment include the representation and mapping of the environmental variables that control rivers, identification of regionally appropriate combinations and relative weightings of these variables and the effect of the mapping scales used.

Regardless of approaches, we need to validate the utility and accuracy of all classifications, their usefulness as functions of the variables chosen, the strength of the assumed relationship between variables and ecosystem characteristics, the estimation procedures and spatial data resolution used (Bourgeron *et al.*, 2001b). An iterative process that generates hypotheses, includes exploratory data analysis, and evaluates and modifies hypotheses will probably produce the most robust classifications (Gerritsen *et al.,* 2000).

Conclusions

We reviewed different approaches to river classification for conservation use. There is no universal system for classifying streams, stream habitats or their biotic communities (Jensen *et al.,* 2001b) and none provide a sufficient basis for all of the conservation tasks for which a classification is needed.

Landscape classifications, environmental domains or the River Environment Classification, utilise existing, geographically referenced sources of data and an automated spatial analysis framework making it feasible to classify all rivers. They address the spatial distribution of relatively stable associations of environmental factors that drive the pattern of flow, channel morphology, substratum, temperature and mineral nutrients that collectively define the physical habitat template of rivers. As a result, they produce temporally stable groupings with similar response potential (i.e. range of possible states), regardless of current natural or anthropogenic disturbances (Bailey, 1996). Biogeographic classifications reflect historical effects of processes that limit the pool of species within a river. Together, landscape and biogeographic classifications represent the range of ultimate controls on aquatic ecosystem patterns and processes. They could support conservation applications at regional to national scales, including assessment of ecological value, design of comprehensive surveys, reporting progress towards conservation targets and helping co-operation and co-ordination among jurisdictions. They also provide the landscape scale context for the finer scale classifications, based on direct measures of ecological and geomorphological characteristics of rivers for catchment specific planning and management, assessment of condition and design of appropriate targets for restoration or rehabilitation. These direct measures integrate the proximate factors that control aquatic ecosystems.

The full range of ultimate and proximate controls are necessary for effective river classification

(Naiman *et al.,* 1992). If only limited controls are used to define a stream type, the management tools or prescriptions may be too broad or too specific to be effective. A single integrated classification could be developed, by overlaying individual classifications (landscape, biogeographic, habitat/ species assemblages). It may help with communication and adoption but still need arbitrary decisions on boundaries (e.g. Doeg, 2001) and it will confound a range of spatial and temporal scales. We prefer independent classifications linked via a multi-scaled hierarchical framework. This is exemplified by use of independent classifications (ecoregion, flow and geomorphic units) to identify representative rivers in the Greater Addo Elephant National Park in South Africa (Roux *et al.*, 2002).

This paper recommends the methods and data currently available are used to develop a national landscape classification for Australian rivers. Biogeographic classifications, preferably for functional groupings of aquatic and semi-aquatic taxa, should be developed using existing data and expert knowledge, to complement the existing fish biogeographic provinces (see Unmack 2001). Together, these classifications will support a preliminary national assessment of conservation value. In the long term, we recommend major investment in systematic and comprehensive inventory of rivers and associated ecosystems, using nationally agreed survey protocols, for river classification based on species assemblages and habitats. This depends on the collection and storage of primary attribute data rather than assigning *a priori* categories. Classification must be an emergent property of the data for a range of objectives and should be iterative with updated data and knowledge.

Appendix C. Protection tools for Australia's high conservation value rivers

Each of Australia's States and Territories have complex statutory and administrative mechanisms aimed in part at providing 'general' and 'site-specific' protection to natural assets such as soil, water and biodiversity, partly protecting our rivers (Table C1). Jurisdictions can also protect special places. Through these protective processes, it is possible to encourage sustainable activities using incentives, such as funding or tax concessions, or controls on deleterious activities, usually through legislation (Table C1). Different institutional arrangements involving the Australian Government; State and Territory Governments; Local Government or Regional bodies deliver these incentives (Table C1).

Bilateral agreements exist between the Australian Government and the States and Territories providing the heads of authority under which Australian Government funds are allocated. Also, the Australian Government accredits regional natural resource management plans developed by regional bodies established under State legislation. The regional plans are aimed at delivering State and Australian Government natural resource management objectives and are the basis for regional investment by Australian Government, States and Territories or private capital. State agencies, Local Government or the community (e.g. farmers, non-government organisations, contractors or corporations) carry out the activities. Regional bodies can spend and sometimes raise public money but they also have to be accountable and report appropriately.

Table C1. General (G) and site-specific (S) protective mechanisms for rivers that may be applied at national, State, Local Government or regional jurisdictional scales.

Scale	Type	Incentives	Controls
Australian Government	G	Funding programs (e.g. National Action Plan, Natural Heritage Trust) and bilateral agreements for good natural resource management.	*Environment Protection and Biodiversity Conservation Act 1999*. May be used to assess development proposals that affect sustainability of world heritage areas, Ramsar, threatened species and communities and Heritage sites.
	S	Funds may be directed to purchase of protected areas, plans or works. Funding may also be provided to reduce allocation of water (e.g. Living Murray)	For land where the Australian Government has jurisdiction, specific statutory prohibitions may be applied.
States and Territories	G	Jurisdictions have regional Natural Resource Management frameworks for sustainable environmental management. Some are established through policy (e.g. Western Australia) while others have legislation (e.g. South Australia and Tasmania).	A complex array of jurisdictional statutes can be used to control or stop activities. They include: fisheries controls; environmental assessment of major projects; land use planning; pollution control; control of invasive species; native vegetation management; protection of threatened species and communities and water resource management. Controls may include the setting of diversions limits on rivers (e.g. Murray–Darling Basin Cap)
	S	Some States (e.g. Victoria and NSW) have joint management areas, Ramsar sites and voluntary conservation agreements that encourage sustainable activities on privately-owned land. Potential Sustainability Trusts for accessing water for the environment may become established.	All States have statutes enabling the declaration of protected areas (or reserves). Many of these protect rivers and their dependent ecosystems. Some States can designate aquatic protected areas (see Table C2). There are potential applications of environmental flows to particular sites of importance (e.g. Macquarie Marshes, Living Murray, Narran Lakes).
Local Government	G	They can raise money through rates and sometimes environmental levies and offer rates concessions. They can also manage targeted funds from Australian Government and States.	They are often determining authorities on land use planning and developments, influencing threats to rivers and dependent ecosystems. Local government may have delegated responsibilities for pollution control, providing opportunities to influence water quality.
	S	They may provide rate relief in exchange for conservation work or environmental programs on private land.	Local governments can create and manage conservation reserves on municipal land.
Regional bodies	G	They can sponsor or partner programs (e.g. Landcare and Waterwatch) and projects.	In some jurisdictions, regional bodies will take an active role in assessment of vegetation clearing and river management (e.g. NSW).
	S	This is the main mechanisms for delivery of investment programs to individual areas for conservation (e.g. National Action Plan for Salinity and Water Management, Natural Heritage Trust 2).	

Table C2. Legislative and some policy tools for protection of high conservation value rivers and dependent ecosystems, that apply to sites, catchments and water supply (continued next page).

Location	Legislation	Protection of values							Application
		Biodiversity	Geodiversity	Recreation	Cultural	Site specific	Catchment[a]	Water supply[b]	
All States and Territories	Protected Area legislation[c]	✓	✓	✓	✓	✓	✗	✗	Public
Western Australian reserves	Land Administration Act 1997	✓	Unclear	✓	✓	✓	✗	✗	Public
Queensland fish habitat areas	Fisheries Act 1994	Fish only	✗	✗	✗	✓	✗	✗	Public and private
Tasmanian Fauna Reserve	Inland Fisheries Act 1995	✓	✗	✗	✗	✓	✓	✓	Public and private
Victorian Fisheries Reserves	Fisheries Act 1995	✓	✗	✓	✗	✓	✗	✗	Public and private
NSW Aquatic Reserves	Fisheries Management Act 1994	✓	✗	✓	✗	✓	✓	✗	Public and private
Most States and Territories	Threatened Species	✓	✗	✗	✗	✓	✗	✗	Public and private
Australian Government, States and Territories	Directory of important wetlands in Australia[d]	✗	✗	✗	✗	✓	✗	✗	Public and private
Australian Government, States and Territories	Convention on Wetlands of International Importance[e]	✓	✗	✗	✓	✓	✗	✗	Public and private
All States and Territories	Environmental Assessment	✓	✓	✓	✓	✓	✓	✓	Public and private

a Controls relate to specified activities to protect designated site values

b Also includes identification and provision of environmental flows

c Includes designation of national parks and reserves

d Identifies key wetlands in each jurisdiction but generally does not afford any protection value

e Effected through the *Environment Protection and Biodiversity Conservation Act 1999* but limitations exist on applicability

Location	Legislation	Protection of values							Application
		Biodiversity	**Geodiversity**	**Recreation**	**Cultural**	**Site specific**	**Catchment**[a]	**Water supply**[b]	
All States and Territories	Water management[f]	✓	✗	✓	✓	✓	✓	✓	Public and private
All States and Territories	Pollution control	✓	✗	✓	✓	✓	✓	✓	Public and private
Commonwealth	Environment Protection and Biodiversity Conservation Act 1999[g]	✓	✓	✗	✓	✓	✓	✓	Public and private
NSW Wild Rivers	National Parks and Wildlife Act 1974	Application of this section is under review							Public
Queensland Wild Rivers	Legislation developing	✓	✓	?	✓	✓	?	?	Public and private
Victorian Heritage Rivers	Heritage Rivers Act 1992[h]	✓	✓	✓	✗	✓	✓	✓	Public
Canadian Heritage Rivers	No specific enabling legislation[i]	✓	✓	✓	✓	✓	✓	✓	Public and private
USA Wild and Scenic Rivers	Wild and Scenic Rivers Act 1968[h]	✓	✓	✓	✓	✓	✓	✓	Public and private

f Recreational and cultural values have variable coverage in different jurisdictions

g *Environmental Protection and Biodiversity Conservation Act 1999* (Commonwealth)

h Sites and catchments are only partially protected

i Through a management plan

Appendix D. International systems for the protection of heritage or wild rivers

Most countries have similar mechanisms to Australia for the protection of river systems. Some countries have also embarked on national assessments of aquatic ecosystems. For example, New Zealand has initiated a *Waters of National Importance Project* (New Zealand Ministry for Environment 2003) assessing water bodies of national importance against a series of values: tourism; irrigation; energy generation; industrial uses; recreation; natural heritage, and cultural heritage. High conservation value waterways may be protected by the Minister for the Environment under the *Resource Management Act 1991*. In Europe, there was commitment to conservation of the last wild rivers at the IUCN World Congress 2000 in Amman, Jordan. Specific implementation measures are not obviously in place.

We are aware of only two existing systems, the Canadian Heritage Rivers System and United States Wild and Scenic Rivers legislation, that focus on entire river systems. We review main elements of these and their applicability to a national Australian framework.

D1. The Canadian Heritage Rivers System

Overview

We focus on this system because Canada, like Australia, is a Federal jurisdiction (10 Provincial and 3 Territory jurisdictions, and local and city governments) and has broadly similar government structures and responsibilities. The Canadian Heritage Rivers System (CHRS) was created by an agreement between the Federal and Provincial and Territory governments in 1984 and is a good example of a non-statutory model for river conservation. It came into effect with the signing of *Canadian Heritage Rivers System Objectives, Principles and Procedures* by chief ministers from the participating jurisdictions. There is more detail in Nevill and Phillips (2004), and at <www.chrs.ca> (accessed 18/8/2004).

The term 'river' refers to either the entire length or a segment of a river and its immediate environment and includes the lakes, ponds, estuaries, canals or other bodies of water through which it flows. French River in Ontario was the first heritage river nominated in 1986. By January 2003, there were 39 designated heritage rivers, with additional nominations pending. Designated rivers include a wide range from Arctic barrens, southern Ontario's fertile farmlands, Newfoundland's rocky hills, and the mountains and glaciers of the Yukon.

The CHRS creates an administrative structure, based on jurisdictional cooperation rather than legal or funding arrangements, to protect Canada's outstanding rivers. It aims to strengthen existing river legislation and management. The Canadian Heritage Rivers Board (two federal and 13 provincial and territorial representatives) administers CHRS with federal and provincial funding focused (apart from Board expenses) on supporting community involvement in the nomination and designation of heritage rivers. Parks Canada (a federal agency) supplies a secretariat and funds the preparation of some consultancy studies. The constitution of the Board is defined by *Policies and guidelines of the Canadian Heritage Rivers System* (revised January 2000) with three main parts: the charter; policies and principles; and operational guidelines. The charter, signed by Ministers of all provincial and territorial governments in 1997, establishes the importance of rivers to the heritage of Canada and the importance of cooperation. It is to be reviewed in 2006. It also includes a vision, purpose and principles.

> *Canada's outstanding rivers will be nationally recognized and managed through the support and stewardship of local people and provincial, territorial and federal governments to ensure the long-term conservation of the rivers' natural, cultural and recreational values and integrity. (Vision statement).*

The CHRS aims to sustainably protect and manage Canada's important rivers, including their natural heritage, human (cultural/historical) heritage and recreational values (purpose). The objectives of the CHRS are to recognise Canada's outstanding natural and cultural rivers so they may be conserved and interpreted and provide opportunities for recreation and heritage appreciation. Under the principles, the system is voluntary, participants retain jurisdictional powers, and there is respect for original peoples and other stakeholders during the nomination, designation and management of heritage rivers. The CHRS is a cooperative system between Governments and communities. Indigenous communities and other stakeholders must support nominations that are then included on advice of the Canadian Heritage

Rivers Board. Without community support a river cannot be nominated. The CHRS recognises three essential values: natural heritage, cultural heritage and recreation. A river can be included if it satisfies the first two. Consultation between jurisdictions is essential for rivers that cross borders and jurisdictions are responsible for monitoring.

Identification of candidate rivers

Provinces and territories prepare river inventories including information about natural heritage, cultural heritage and recreational river values and condition. Framework documents map the occurrence of the key CHRS values, but these values are not enough to justify listing. A river must also meet integrity criteria. Listed rivers or river reaches must be sufficiently large to encompass surrounding ecosystems and landscapes linked to the river's values, to buffer the river against temporal changes.

Natural values include rivers that

- are outstanding examples demonstrating the major stages and processes in the earth's evolutionary history;
- contain outstanding representations of significant ongoing fluvial, geomorphological and biological processes;
- contain unique, rare or outstanding examples of biotic and abiotic natural phenomena, formations or features; or
- contain habitats of rare or endangered species of plants and animals, including outstanding concentrations.

Cultural values include rivers that

- are of outstanding importance owing to their influence on the historical development of Canada through a major impact upon the region in which they are located or beyond; or
- are strongly associated with persons, events or beliefs of Canadian significance; or
- contain historical or archaeological structures, works or sites which are unique, rare or of great antiquity; or
- contain concentrations of historical or archaeological structures, works or sites which are representative of major themes in Canadian history.

Recreational Values include rivers that have river-related recreational opportunities and related natural values which together providing an outstanding recreational experience.

Rivers may be nominated that have

- recreational opportunities include water-based activities such as canoeing and other forms of boating, swimming and angling, and other activities such as camping, hiking, wildlife viewing, and natural and cultural appreciation which may be part of a river-touring experience;
- Natural values include natural visual aesthetics, and physical assets such as sufficient flow, navigability, rapids, accessibility and suitable shoreline.

To establish river natural integrity, a river must have the following characteristics:

- the nominated area must be of sufficient size and contain all or most of the key interrelated and interdependent elements to demonstrate the key aspects of the natural processes, features, or other phenomena which give the river its outstanding natural value;
- the nominated area must contain those ecosystem components required for the continuity of the species, features or objects to be protected;
- there should be no man-made impoundments within the nominated section;
- all key elements and ecosystem components should be unaffected by impoundments located outside the nominated section;
- natural values for which the river is nominated should not be created by impoundments; and
- natural aesthetic values should not be compromised by human developments.

For cultural integrity values, a river must have the following characteristics:

- the nominated area must be of sufficient size and must contain all or most of the key interrelated and interdependent elements to demonstrate the key aspects of the features, activities or other phenomena which give the river its outstanding cultural value;
- the visual appearance of the nominated section of river should enable an appreciation of at least one of the periods of the river's historical importance;
- the key artefacts and sites comprising the values for which the river is nominated should be unimpaired by impoundments and human land uses; and
- the water quality of the nominated section must not detract from the aesthetic appearance or the cultural experience provided by its cultural values.

For recreational integrity values, a river must

- possess water of a quality suitable for contact recreational activities including those recreational opportunities for which it is nominated;

- have a visual appearance capable of providing river travellers with a continuous natural experience, or a combined natural and cultural experience, without significant interruption by modern human intrusions;
- be capable of supporting increased recreational uses without significant loss of or impact on its natural, cultural or aesthetic values.

Nomination

A heritage river is listed through the two stages of nomination and designation. A river must possess either natural or cultural (or both) values to be nominated. Provincial governments nominated the first heritage rivers but now communities predominantly prepare nominations. A nominated river must be of 'outstanding value' and supported strongly by the community and the provincial government. Even if a river has high natural and cultural values, and can meet integrity criteria, a listing cannot proceed without grass-roots support. This is largely outside government control. If a community group wishes to nominate a river, they check river values and integrity, and compare this to two national framework documents, and the provincial river system plan and the CHRS Board's 10 year strategic plan are examined. For rivers wholly on crown land, the nomination initiative originates and is led by the jurisdiction. A nomination must also be supported by a jurisdiction on the CHRS Board.

A background study must be prepared which comprehensively details the river's natural, cultural, recreational and economic values, its integrity, and suitability as a heritage river. Nomination is granted if the Board considers the river meets the required level of values and integrity criteria, and that plans can be prepared which can effectively protect the river's values and integrity. The Board must be convinced that the nomination is strongly supported by both the jurisdiction and the community.

Designation

The river is not designated until the development and approval of a river management plan by the responsible jurisdiction that protects its nominated values. Provincial and territorial governments may develop these, but now that the CHRS has the maturity of a 20 year history, it is more common that the plans are developed by communities, facilitated by Governments. These plans provide an avenue for both provincial and local governments to provide detailed information to the public and other government agencies and allow for the setting of policies and priorities for heritage rivers. The plan's implementation schedule must demonstrate a commitment by the host government and concerned stakeholders to conserve the river's heritage and recreational values. The approved plan is normally lodged with the Board within 1–3 years after the river's nomination.

Reporting

Provincial governments report on the condition of heritage rivers at one year (short report) and ten year (long report) intervals. Rivers in the System should also have their original nomination values maintained. A river can be de-listed if its nominated values degrade. No special federal funding is provided for the management of heritage rivers.

Benefits

The advantages to the community of heritage river listing are the strengthening of existing river protection frameworks, linked to river tourism and recreation. Limited special federal funding (about 2.75 staff and $Can 160,000 per year) is provided for the management of heritage rivers. Most funding ($Can 80,000) is for joint studies (background and systems studies, nomination documents, management plans and ten year monitoring reports); $Can 25,000 for Board Administration and remaining funding for communications and marketing.

- The system has produced a solid focus on river health and management across Canada, through conferences, awards and music.
- The Canadian Heritage Rivers are a significant catalyst for community action.
- There is a strong sense of identity forged between communities and their rivers.
- Listing of particular rivers has discouraged some inappropriate developments.
- Canadian Heritage Rivers are promoted nationally and internationally as adventure travel destinations. This has had a positive economic spin-off for local communities, particularly in remote areas. A CHRS Economic Impact Study in 1997 concluded that the CHRS contributes $32 million a year to the Canadian economy (D. Gibson, pers comm.).
- There are growing opportunities for stewardship by local communities of parts of rivers.
- There have been considerable successes in rehabilitation efforts, particularly focused on water quality.
- Non-government groups within communities

provide a powerful force in the nomination, designation and ongoing management of rivers.

- The system is effective in uniting different tiers of Government and the community towards common objectives.
- The community is still strongly driving further nominations, after 20 years of the system.

Potential disadvantages

- There is no clear framework on which to judge relative importance of different rivers that may be designated as Canadian Heritage Rivers.
- Some rivers are highly modified with river regulatory structure and poor water quality, as they may meet criteria for cultural importance of natural importance. For example the constructed Rideau Waterway is listed because of its cultural importance. This could redirect scarce funding away from higher conservation value rivers. However, listing of some of these rivers (e.g. The Grand River) has successfully resulted in considerable restoration of water quality.
- Parts of rivers can be designated although this is generally discouraged.
- Monitoring and assessment are generally patchily implemented because of difficulties in obtaining resources and identifying key indicators for measurement.
- Some rivers have not progressed towards designation because community support is lacking.

Summary

According to Don Gibson (National Manager CHRS Program 2003):

> *The Canadian Heritage Rivers Scheme is a model of increased intergovernmental cooperation in conservation. Intergovernmental charters among all jurisdictions are a rare achievement in Canada, especially in heritage conservation, and this charter was a major step forward. The program fosters close cooperation and consensus building between federal and provincial governments which, like Australia, are sometimes conflicting jurisdictions.*
>
> *One of the greatest strengths of the system is the community support it receives from local citizens who want to be proactive in protecting and promoting the heritage values of their community rivers. Significant and diverse support for the System has come from every level of government; national and grassroots non-governmental organisations; Aboriginal organisations, rural and urban communities, and industry including tourism, agriculture, forestry and local businesses.*
>
> *The Canadian Heritage Rivers Scheme is a tool of community revitalisation and increased quality of life for residents. It is a designation which communities can use to market their river as tourism destinations. Communities such as St. Stephen, New Brunswick and Cambridge, Ontario have used the designation as an important component of their long-term economic development strategies. Economic impact studies on the CHRS have been very positive and demonstrate that the program is an excellent investment for governments.*

Potential application to Australia

A system modelled on the Canadian Heritage River System could be implemented within Australia. Australia is a federal system, similar to that found in Canada. Implementation in Australia should address some of the potential disadvantages of the Canadian Heritage Rivers System (see above) while utilising its successful processes. As with the Canadian Heritage Rivers System, it may be important to begin with nominations by jurisdictions and the Commonwealth to develop impetus for the new program.

D2. National Wild and Scenic Rivers System (United States)

Overview

This legislation was enacted in 1968 and is the main law for river conservation in the United States, primarily to balance existing policies for building dams on rivers for water supply, power, and other benefits with new directions protecting free-flowing rivers and other outstanding rivers values. Such rivers and their immediate environments possess remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values. Once designated, these rivers are to be preserved in their free-flowing condition. Eight rivers were designated initially but there are now more than 150 rivers listed, including more than 17,000 km of river. Designation may not include an entire river but it often includes tributary streams.

Designation explicitly prohibits the federal government from licensing or permitting hydroelectric dams or major diversions on these rivers. Similarly, federal agencies cannot assist in any water resource projects on these rivers. Public lands within an average stream corridor of 0.4 km (0.25 miles) are also managed to protect outstanding scenic, recreational, historical/ cultural, fish, wildlife, ecological, geological and hydrological values. There are no mandatory prohibitions on private land or state water resource projects. More detailed information is available (<www.nps.gov/rivers/ information.html>, accessed 18/8/2004).

Designation

There are two mechanisms for designating rivers. Federal Congress designates rivers through legislation or it can direct federal agencies to study the values of rivers and recommend appropriateness of designation. The legislation requires all federal agencies to identify, study and recommend potential Wild and Scenic Rivers in all land, water and resource planning programs. State-designated rivers can be added to the national list, through a request of the state's Governor and approval by the Interior Secretary. For this to occur, a river must meet the same eligibility criteria as Congressionally designated rivers. Small dams, diversion works and other minor structures in existence do not automatically stop proposed designation of a river.

Classification

Three classifications are used for rivers and parts of rivers: wild, scenic and recreational, although all rivers under this classification are usually referred to, as wild and scenic rivers (IWSRCC 1998).

- *Wild river areas* are free of impoundments and generally inaccessible by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of 'primitive America'.
- *Scenic river areas* are free of impoundments and generally inaccessible by trail, with watersheds or shorelines still largely primitive and shorelines largely undeveloped, but accessible in places by roads.
- *Recreational river areas* are readily accessible by road or railroad, with some development along their shorelines, and may have undergone some impoundment or diversion in the past.

Management

Every designated river in the national system has a federal management agency responsible for its protection, unless it was a state-designated river originally. The federal manager cooperates with state agencies and private landholders. There are boundaries established for each designated river but these include no more than about 0.65 ha per river kilometre (IWSRCC 1998). Logging, road building, new mining claims, development of campgrounds and motorised access are usually prohibited from sections of rivers classified as wild. As long as a wild river's free-flowing condition and outstanding values are not affected, grazing, mining of existing claims, hunting and other non-motorised recreation are permitted on public lands. Motorised trails may or may not be allowed in scenic sections, while most other activities are allowed as long as they protect the visual quality, free flowing conditions and outstanding values. All activities usually allowed on public lands can occur on recreational sections of rivers, provided they do not affect the free-flowing condition or outstanding values of the river.

Private land is not affected by designation, as the legislation does not provide for federal jurisdiction of private land use or zoning. Complementary land use and planning are encouraged but are not mandatory. .A state's authority to regulate water rights is unaffected by designation, although reserves of water in designated rivers may need to be managed to give effect to the purposes of the legislation.

Potential application to Australia

The legislation is a 'top-down' approach to river conservation, driven primarily by Federal Congress. It does not require cooperation from the states. Management of designated rivers is also a federal responsibility. The designation tends to emphasise recreational and aesthetic criteria over cultural and natural values. The legal framework is primarily regulatory and may be analogous to National Heritage listing under the EPBC legislation in Australia.

We believe this is an inappropriate model for an Australian national framework because it has minimal involvement of river communities and so ownership of the process can be foregone.

Appendix E. Wild and Heritage Rivers legislation in Australia

Two states have focussed conservation on whole river basins. Victoria was the first state to enact legislation on heritage rivers. Queensland is currently drafting legislation for wild rivers. New South Wales has a provision within the *National Parks and Wildlife Service Act 1974* for the declaration of wild rivers within National Parks. In New South Wales, water sources may also be classified for their conservation value under the *Water Management Act 2000* where their values may be at risk. Western Australia has identified 26 wild rivers, mostly in remote areas, that have not been affected by significant river regulation. The Western Australian government has a commitment to develop a wild rivers strategy. Many rivers or parts of rivers in Tasmania are either within reserves or part of the Regional Forest Agreement. We have reviewed what is accessible for each of these instruments and its applicability for implementation at a national scale.

E1. Victorian Heritage Rivers

Overview

Victoria passed its *Heritage Rivers Act* in 1992, resulting in the declaration of 18 Heritage Rivers, after extensive public investigation by the Land Conservation Council (LCC). This independent State agency appointed above functional agencies had a specific mandate to recommend ‘best use’ of Victoria’s natural resources. Rivers designated under the Act complement rivers and wetlands protected through other reservation and land-use planning mechanisms, within the framework of the Victorian government’s wider system of terrestrial reserves, and its biodiversity and wetlands strategies. The purpose of the Act is to protect parts of rivers and river catchment areas in Victoria with significant nature conservation, recreation, scenic or cultural heritage attributes.

The Victorian *Heritage Rivers Act* attempts to maintain the high natural values of the designated rivers and catchments by (a) requiring management compatible with protection of their values, and (b) prohibiting or controlling threats. No other Australian jurisdiction has been successful in developing similar legislation.

The *Heritage Rivers Act* was underpinned by the *Heritage Rivers Program* which aimed to protect the values of the State’s rivers and wetlands, a commitment of the 1987 State Conservation Strategy *Protecting the Environment*. The Strategy foreshadowed the referral of two freshwater issues to the Land Conservation Council: (a) rivers, and (b) wetlands. The first investigation of rivers started in 1988 and finished in 1991. The second investigation of wetlands never started, due to the replacement of the LCC with the Environment Conservation Council, an agency with similar aims but a new political mandate.

The State Conservation Strategy set out the aims of the Heritage Rivers Program:

- to protect those rivers and streams that essentially remain in their natural condition;
- to ensure that rivers and streams of special scenic, recreational, cultural, and conservation value are maintained in at least their present condition; and
- to ensure that representative examples of stream types in the State are protected.

The *Heritage Rivers Act* identifies 18 Heritage Rivers and 25 Essentially Natural Catchments for protection. The Act does not designate Representative Rivers, which were established by order of Governor in Council following the LCC’s final report (Nevill and Phillips 2004). The Heritage Rivers and Natural Catchments were selected on the basis of natural, landscape and recreational/cultural values, while representative rivers were selected as good examples of the river type (classification) derived largely from hydrological and geomorphological information. Neither Heritage Rivers nor Representative Rivers are protected by specific reservation as they overlay existing land tenures.

Despite the intent of the legislation and the legal designation of heritage rivers and natural catchments, implementation of protective management by state agencies has not been enthusiastic (Nevill and Phillips 2004). The original intent of the Heritage Rivers Program in 1989 saw implementation of protective regimes through management plans on Crown Land and land-use planning controls on private land, sometimes reinforced by formal joint management agreements with landholders. The preparation of final management plans has been delayed for a decade, while controls over private land never systematically started.

The data-set on river values prepared by the LCC in 1989 was by far the most advanced in any Australian State, but the Victorian Government did not incorporate this information into local water assessment and planning processes. There was also no attempt made to update spatial information on values, with the result that the 1987 maps are now somewhat out of date.

Unlike Heritage Rivers and Natural Catchments, the State's representative rivers were not afforded protection under the Heritage Rivers Act. The Victorian State government instructed its agencies in 1992 to prepare plans for the protection of the 15 representative rivers designated by the LCC. However, after over 10 years, four of the fifteen rivers remain without protective arrangements (Nevill and Phillips 2004). Consequently, the system does not currently represent adequate, comprehensive and representative coverage of the State's river ecosystems. The original intention of the 1987 State conservation strategy (*Protecting the Environment)* to protect representative wetland ecosystems as well as rivers has not been realised, because the State's wetland reserves have never been comprehensively assessed against this objective.

Identification of candidate rivers

The selection of rivers was based on an investigation and public inquiry by Victoria's Land Conservation Council (LCC). The LCC examined and mapped rivers according to attributes, including values of nature conservation (highly natural catchments, native fish rarity or diversity, botanical significance, geological or geomorphological significance), landscape (high scenic value, waterfalls) and recreation (whitewater canoeing, car-based camping, recreational fishing for exotics, recreational fishing for natives). The initial report included maps of public land use, water use, aboriginal sites, geomorphic units and hydrological regions, water regulation and in-stream barriers.

From these data, 'river basin values', natural, landscape and recreational values were mapped. This initial identification, selection and management of representative river reserves was based primarily on geomorphological and hydrological assessments, because of paucity of biological data existing at that time (1989) and the strong dependence of freshwater ecosystems on these factors.

Management

A management plan for a heritage river area or natural catchment area must state how the areas will be managed in accordance with the purpose of this Act. Certain land and water activities are not permitted in heritage river areas, such as timber harvesting, dams, and new water diversions that significantly affect the values for which it was designated. In natural catchment areas, certain activities are not permitted: clearing of native vegetation, plantation and harvesting of timber, mineral exploration (except if approved by the State government) and mining, extractive industry, dams and new diversions, waterway management, grazing by livestock, building or upgrading roads, discharging effluent, introducing exotic species, stocking with native species except for conservation, powered water craft.

Potential application as a national system

Some elements in the Victorian Heritage Rivers legislation could be applied at a national scale. The catchment focus of the legislation is particularly important as is the commitment to representativeness. The main detraction is that it is a 'top-down' process and so it is likely to be contentious. Implementation of the legislation in Victoria has been slow. Similarly, implementation in other parts of Australia would probably be difficult if a similar model was applied. Community involvement and ownership are not necessarily incorporated well.

E2. Wild Rivers in Queensland

Overview

A commitment of the Queensland Government before the 2004 election was to "identify and protect our wild rivers for generations to come" (<http:// www.teambeattie.com/10_policies/ policies_index.asp>, accessed 18/8/2004). This would be done through legislation that

- allows limited agricultural, urban and industrial development;
- limits regulated water allocations or extractions;
- does not allow river management (e.g. stream alignment, de-snagging, levee banks);
- no further development of floodplains that would restrict floodplain flows;
- protects associated wetlands;
- does not allow stocking of wild rivers with exotic species;
- does not allow use of exotic plant species in ponded pastures;
- limits the capacity of new off-stream storages, primarily for stock and domestic purposes and;
- does not allow in-stream mining.

Designation

Eighteen 'example' rivers were listed as potential wild rivers under the legislation with final designation dependent on extensive community consultation and introduction of the legislation. Three categories will potentially be established (pristine, natural, heritage) for these rivers.

Potential application as a national system

The main detraction is that it is a 'top-down' process and so it is likely to be contentious in its implementation in some parts of Australia if a similar model was applied. Community involvement and ownership are not necessarily incorporated well.

E3. Wild Rivers in New South Wales

Overview

The purpose of declaring a wild river under the New South Wales National Parks and Wildlife Act 1974 (amended 2002) is:

> *to identify, protect and conserve any water course or water course network, or any connected network of water bodies, or any part of those, of natural origin, exhibiting substantially natural flow (whether perennial, intermittent or episodic) and containing remaining examples, in a condition substantially undisturbed since European occupation of New South Wales, of:*
>
> *(a) the biological, hydrological and geomorphological processes associated with river flow, and*
>
> *(b) the biological, hydrological and geomorphological processes in those parts of the catchment with which the river is intrinsically linked.*

Declaration

Declaration is confined to protected areas. The Government is committed to protect 'wild rivers' in the following protected areas: Colo, Kowmung, Grose, Paroo, Macdonald, Upper Brogo, Upper Hastings and Forbes Rivers and Washpool Creek. The philosophy primarily follows that in the *Wilderness Act 1987* with similar nomination and consultation processes. Declaration of wild rivers must be consistent with the *Water Management Act 2000* and the *Mining Act 1992*, with concurrence of respective Ministers.

Potential application as a national system

Declaration is primarily confined to parts of rivers within protected areas and so it does not necessarily deal with the potential threats to rivers and their values, with limited application to entire river basins. The approach is also a 'top-down' process and so it is likely to be contentious in its implementation in some parts of Australia if a similar model was applied. Community involvement and ownership are not necessarily incorporated well.

Appendix F. Jurisdictional workshops

Workshops and/or presentations were held within jurisdictions and preliminary direction presented for comment. These are summarised according to the major sections of the discussion paper. Italicised comments identify how this paper considered each point.

Overview

1. National approach for protection of high conservation value rivers supported by jurisdictions (*acknowledged and followed).*
2. The most valuable part of a National Framework is to stimulate protection of high conservation value rivers and dependent ecosystems *(acknowledged and followed).*
3. Clear objectives for a national framework are essential if jurisdictions are to participate *(acknowledged and followed).*
4. Cultural values are important but should be considered separately. (e.g. Victorian experience) *(acknowledged and followed).*
5. Some concern that history of national approaches and personnel on working group may bias development of a true national framework *(acknowledged and every effort was made to access as much input into this discussion paper as possible).*
6. A National Framework can resolve interstate cross border issues (e.g. River Murray, Cooper Creek) but it is not a universal problem across jurisdictions *(acknowledged and followed).*
7. Concern that a future national system might not lead anywhere and did not adequately 'move on' from work already done in this area *(acknowledged, hence this attempt).*
8. In eastern States, many developed catchments potentially affected by cumulative impacts while fragmentation affects rivers in Western Australia *(acknowledged).*
9. Sustainable management seldom followed in practice because of poor implementation *(acknowledged).*
10. The role of the Australian Government is to coordinate, ensure consistency and develop strategic processes that guard national interests that jurisdictions cannot deal adequately with *(acknowledged and followed).*

Terminology

1. Definitions in expression are critical because of variable jurisdictional and regional terminology and to avoid misinterpretation *(acknowledged and followed).*
2. The term 'river' must be inclusive of all surface water streams regardless of size or permanence (e.g. ephemeral creeks, 1st and 2nd order streams) *(acknowledged and followed).*
3. Concern that a narrow definition may not include wetland systems on Western Australia's coastal plain *(acknowledged and followed).*
4. Groundwater resources should be included, particularly in the arid zone (groundwater dependent ecosystems) *(acknowledged but the working group believed this outside the terms of reference; there is nothing to stop the application of this framework to assessment of groundwater dependent ecosystems).*

Scale

1. A hierarchical spatial framework is important because it can be integrated and disintegrated, with National, State, Regional, catchment, reach levels *(followed).*
2. Spatial scale is important with water resource planning often conducted at a catchment level, but only addressing regulated reaches *(followed).*

Classification

1. None of the existing classifications are particularly useful and any national classification needs to be purpose-built *(acknowledged and followed)*.
2. The cost-benefit of classification was raised,

given the amount of potential data required to objectively classify aquatic ecosystems across all attributes. A rapid classification could be done and progress identification *(acknowledged and followed—this is an iterative approach)*.

3. Classification was considered not particularly useful at the national scale and should be low priority *(argument is put that classification can be done quickly and is essential for objective assessment)*.
4. Costs and benefits of classification should be considered. It may translate to high effort and cost for low benefit *(data are available to make this process reasonably rapid with high benefit because of objectivity)*.
5. Classification is important for representativeness but may not be for practical application to large scales and community-backed processes (e.g. whole river basins) *(even at large scales, classification may be important but point acknowledged by establishment of whole river basin scale protection for largely natural rivers—this remains the only criteria that needs to be met)*.

Evaluation

1. The main value of a national framework is an agreed listing of criteria that are important, as this does not yet exist *(acknowledged and provided)*.
2. Most rivers have ecological value and a relative measure is important to identify the conservation importance at different scales *(recognised and followed)*.
3. Subjective and informed assessment by the jurisdictions could provide as good (or indeed better) an assessment as the data driven approach because our national databases are so patchy. Systems that are least disturbed are likely to have the least data) *(indirect methods of rapid evaluation that account for poor data, with informed review are recommended)*.
4. To align assessments among jurisdictions, the Australian Government could provide broad assessment guidelines for scoring catchments with outputs cross-checked with Wild Rivers assessment and NLWRA outputs *(recommended with the setting up of an interjurisdictional working group to provide assessment protocols)*.
5. Objective data driven assessment will require high effort which translates to high cost but will produce high benefit. The alternative might be jurisdictional nomination with low effort translating into low cost and high benefit *(combination approach recommended)*.
6. A regionally-based nomination process might be effective for high conservation value identification but jurisdictions and community would need to be aware of the implications *(the scale of regions adopted but assessment needs to be across regions, basins and drainage divisions for objectivity)*.
7. Appropriate scale for assessment and management may vary *(true-according to objectives required for assessment across scales)*.
8. Assessment scale will be driven by data availability *(incorporated in methods)*.
9. Appropriate scale for assessment influenced by the measures of ecological value *(jurisdictional advisory group to provide agreed protocols)*.
10. Consistency between jurisdictions is important *(recognised throughout—jurisdictional advisory group to provide agreed protocols)*.
11. RiverStyles can provide an indication of sensitivity to disturbance that could be refined and possibly target sensitive areas *(note discussion of RiverStyles and appropriateness and cost)*.

12. Identification of threats is critical to management of high conservation value rivers but not necessarily essential for their identification. Establishing triggers to threats is beyond the scope of the project and numbers may be too prescriptive and inflexible. A focus on threats may discount importance of other ecological values. A pressure–response gradient might be a useful alternative to defined trigger values. A technical assessment panel or expert panel approach may be useful for assessing values and threats but it is necessarily subjective *(comments noted and threats treated through assessment process. The framework does provide options for mitigating threats through whole river basin identification, based on river regulation thresholds and catchment disturbance. These rivers are potentially the most cost effective for conservation)*.

Data availability

1. Wild Rivers database (including disturbance index) and the National Land and Water Audit databases are useful *(acknowledged and followed)*.
2. Users need to be cognisant of the data limitations *(acknowledged)*.
3. Queensland has an existing state-wide assessment of change from natural in relation to hydrology, weeds, water quality, floodplain development and aquatic ecology. Data rigour is also considered *(acknowledged and should be used in a national assessment)*.

Protection Planning

1. River protection should start at the largest scale because this is most effective *(acknowledged and followed).*
2. Consideration should be given to a hierarchical approach where river basins attract a general level of protection while iconic sites require more stringent management *(acknowledged and followed).*
3. In Tasmania, whole rivers can be protected by reservation as 40% of the state is in reserves, including two entire bioregions *(acknowledged and followed).*
4. Protected areas over large landscapes is not considered politically possible *(acknowledged and hence establishment of whole of river basin protection level).*
5. 'National' branding will enhance the protection-trigger value and also adds to tourism value *(acknowledged and followed).*
6. Rivers and dependent ecosystems that are not identified as high conservation value still maintain some conservation value and should be managed accordingly *(acknowledged in principles).*
7. Protection of high conservation systems may pressure unprotected systems (e.g. embargos of surface water development in New South Wales resulted in immediate and significant demands on groundwater) *(acknowledged and provided for through identification of natural systems as important).*
8. Some industries supportive of conservation management of rivers (e.g. organic beef industry, fisheries, tourism) *(acknowledged and may be implemented through whole river basin scale of protection).*
9. Trade-offs will occur between protection and the number of high conservation value systems identified. These need to be managed across Governments and communities (*acknowledged*).
1. Listing of areas should involve the community but assessment and identification of potential candidates should be objective to avoid parochial interests (*acknowledged and followed*).

2. Implications of nomination or listing of high conservation value rivers or dependent ecosystems would influence which systems are identified (*acknowledged and hence the importance of an objective assessment process*).
3. The national framework should use existing national frameworks for protection (e.g. national reserve system) (*acknowledged and followed*).
4. Changes to hydrology are currently the main consideration for river protection *(acknowledged in threat section).*
5. An optimal scale of management should be defined, even if protection applies to a range of scales management *(acknowledged that generally River basin scale is the optimum).*
6. There is increasing focus on management and protection of 'icon' sites (e.g. Living Murray, Narran Lakes, Macquarie Marshes) *(acknowledged and incorporated into proposed framework that allows such 'icon' sites to be identified and managed within a catchment context).*
7. Use of existing frameworks such as the National Water Quality Management Scheme and Directory of Important Wetlands in Australia should be utilised to avoid additional frameworks (*acknowledged and recommended for use in assessment as a data source but these systems are not necessarily objective or adequately linked to river management in all jurisdictions*).
8. There was concern in jurisdictions about tying management of high conservation value rivers into regulatory schemes such as the E*nvironment Protection and Biodiversity Conservation Act 1999* (*acknowledged but the aim of national protection legislation is to protect areas of national significance*).
9. There should be discussion of different legislative tools and policies in each jurisdiction. These vary from integrated models (e.g. *Natural Resource Management Act* in South Australia) to theme specific legislation (e.g. conservation, water) *(acknowledged and followed).*
10. Important to also use incentive schemes for delivery of protection *(acknowledged and followed).*
11. A low conservation value for a river may be politically difficult *(acknowledged but important to develop strategic direction for river conservation).*
12. Ramsar listed wetlands have degraded in many areas with lessons for listing processes that are not linked to management. It is essential to link listing to real management processes *(acknowledged and followed).*
13. Sustainable limits of surface water systems should be applied (e.g. Victoria's Sustainable Development Levels) *(acknowledged and followed).*
14. There should be development limits for listed high conservation value catchments, not just for water resource development but also unsustainable land use *(acknowledged as an important issue that would be tackled through catchment planning primarily and linking of sites to environmental assessment processes).*

Operational and Institutional Arrangements

1. River basin scale is the most appropriate scale for river management (*acknowledged and followed*).
2. A national framework should be progressed through the CoAG agenda, the National Water Initiative and/or Natural Resource Management Ministerial Council for implementation and support *(acknowledged and followed).*
3. Investment in rivers will mainly be through Natural Resource Management Regions (*acknowledged and followed*).

4. River conservation investment will compete with other natural resource management within regions and so it is important to direct investment to rivers if appropriate *(acknowledged and identification of important areas will assist with targeting)*
5. Heritage Rivers models (e.g. Victoria) have not generally delivered on promises but national investment and support could assist *(acknowledged).*
6. There should be a national funding program that specifically lists protection as a priority, as current funding criteria are not about protection (*acknowledged and followed*).
7. Any new or additional program needs to have compatible institutional arrangements, crafted around how the States/Regional NRM groups manage rivers (*acknowledged and followed*).
8. Time frames from classification, data collection, planning, consultation, negotiation, listing and active management may be too long. We need to be prepared for a long national process or design a more rapid process. The consultation/negotiation phase often takes most time (*acknowledged and followed*).
9. There is a risk that work will be redone and there will be no equity between jurisdictions in terms of investment in protection (*acknowledged and hence need for objective assessment that also incorporates developed rivers*).
10. Regional River Health Planning is operational in the Victorian CMAs where plans seek to identify assets including ecological, social and economic, identify the threats to those assets and plan for investment in protection and rehabilitation for those assets. They focus first on the high value— high threat assets and monitor the status of the low value assets (*acknowledged and followed*).
11. Tying protection of high conservation value rivers into National Competition Council payments would be a disincentive and fail (*acknowledged and not recommended*).
12. Need to consider the Victorian model (plans, targets, investment strategies, community engagement) in implementation at the regional scale (*acknowledged and followed*).

Appendix G. Feedback from a national forum[a]

The forum was primarily held for jurisdictional people and a presentation given on the direction of the framework, followed by a workshop. The following points represent individual's comments at, before or after the forum about key areas of the discussion paper.

Points are followed by a response comment in italics and parentheses of how the comment has been incorporated or considered within the final discussion paper.

Overview comments

1. There is clearly a pressing need for an Australian Government–State framework but it needs to be reasonably loose and incorporate jurisdictional needs *(agreed).*
2. Overall support for a national framework but detail is critical *(agreed).*
3. Important to have a national framework for the protection of high conservation value rivers because it saves funding in terms of rehabilitation *(agreed).*
4. It is more strategic to look after the healthy river systems *(agreed).*
5. Arguments about maintaining high conservation value rivers rather than investing in restoration are very important and need to be emphasised in a rationale *(agreed and followed).*
6. The framework aims to cover rivers, river reaches and estuaries but 'freshwater' implies that estuaries and primary saline systems which are important in the Australian landscape are not considered *(estuaries specifically included).*
7. The Canadian Heritage Rivers System is mentioned but with no detail (*agreed and provided*).
8. The discussion paper needs to acknowledge the jurisdictional input and extent of consultation, possibly in the form of an appendix (*agreed and followed*).
9. Whole river systems, including their catchments, not bits and pieces need to be identified. (*It is important to encompass the range of different aquatic systems that could be of national importance at different scales, not just whole river systems. These dependent ecosystems are currently where most of the protection effort is concentrated. It is important to have the range of options*).

National River Information System

Forum summary

- It is essential to have national evaluation and assessment criteria that can operate at different spatial scales (hierarchical).
- There is little support for a national database and no need for a new database. Existing systems (e.g. nationally available databases—Wild Rivers, National Land and Water Audit) should be used. There is a need for compatibility in data sets for auditing and management of cross border rivers. There is a need to identify gaps in knowledge.
- Identification of rivers or dependent aquatic ecosystems should depend on systematic scientific input.
- Classification should be applicable to a range of different systems.

The following arguments were based on a preliminary view that there should be a national information system but this has been modified on the basis of the comments below to nationally consistent information.

Numbered points below represent written feedback from the forum.

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a The forum was held at Old Parliament House in Canberra on 1 April 2004.

Advantages

1. Nationally agreed assessment criteria for objective comparisons *(agreed).*
2. Useful to have a national assessment process that could then be carried out by the jurisdictions *(agreed).*
3. Consistent data is the key not a national database *(agreed).*
4. Would allow monitoring and evaluation to provide national reporting *(agreed).*
5. Could guide national investments *(agreed but could do so with nationally consistent information as well).*
6. Consistent with the aims of CoAG agreements on water management *(agreed).*
7. It would be useful to have a spatial system that lists all the protected rivers and their values like the Directory of Important Wetlands in Australia *(agreed—could be further developed).*
8. It would be useful but not essential because regional databases often have more information and are used more *(agreed).*
9. It could enforce jurisdictions to contribute to data collection and updating *(agreed but national program would do the same).*
10. There is a clear need for a consistent data platform among states because data are fragmented, for comparability *(agreed).*
11. Important to be able to share data across jurisdictions *(agreed).*

Disadvantages

1. A national database that requires updating and significant co-ordination, when jurisdictions have constitutional responsibility for land and water management *(agreed).*
2. National spatial framework would serve no purpose *(disagree—a national spatial framework would allow more logical assessment and analysis that recognised real connections between rivers)*.
3. Jurisdictions will resist because of potential loss of control over information and there would be concerns about custodianship of data *(agreed).*
4. Such a database would be too difficult to manage and maintain, need jurisdictional carriage *(agreed).*
5. State databases already exist and do not need to be replicated *(agreed).*
6. There will be issues of compatibility in terms of data collected and methods used as well as among databases held by jurisdictions *(agreed but could develop links and agree to consistent use of criteria).*
7. Need to be sure that current systems are failing *(agreed).*
8. Information is usually required at sub-catchment or catchment scales for decisions and so a national database may be an unnecessary expense *(agreed).*
9. Jurisdictions will have different issues that may not be compatible with a national database *(agreed).*
10. An information system is needed that can be populated by jurisdictions according to nationally agreed processes *(agreed).*
11. One size will not fit all. There needs to be a system of database that targets different spatial scales *(agreed).*
12. Needs to be an information reporting system that allows for updating of databases and data collection (e.g. National Land and Water Audit, Murray–Darling Basin Audit)
13. Access to data and not a new national system is the critical issue *(agreed).*

Scale

1. A national typology is important *(agreed and followed).*

2. Need to be able to operate at various scales, particularly regional implementation scales *(agreed and followed).*
3. Spatial scale needs to be appropriate to threat levels *(agreed but evaluation of ecological value can be independent of threat analysis)*.
4. Catchment scale the most useful for implementation. Drainage divisions not useful and no data exist for river segments (*acknowledged there is a paucity of data but it is important to use the finest scale data available for assessment*).
5. Needs to be relevant to all rivers across Australia *(agreed).*
6. There is an emphasis on whole river systems which is not consistent with the framework working at different scales. (*This is not the case. The framework works at different scales*).
7. There is no reference to the National Estuaries Network (*agreed and rectified*).

Classification

1. Better definition of type and class needed (*type or class would be defined empirically by the data).*
2. Class and types should include hydrology, geomorphology and physical and biological *(agreed and followed).*
3. Classification needs to be kept as simple as possible to begin with, restricting it initially to drainage divisions *(believe more sophisticated classifications are possible using available data with better outcomes).*
4. A national classification systems allows legitimate comparisons to be made and is critical for guiding funding and management *(agreed).*
5. Classification should be based on geomorphic and biotic combinations with an IBRA like process *(see Appendix B in relation to problems associated with such an approach).*
6. There are insufficient data to adequately classify rivers meaningfully (*this can be attempted with current data and will provide useful information for the first step*).
7. Needs to accommodate different types of rivers such as spring-fed rivers compared with catchment fed rivers *(agreed).*
8. Classification systems are always challenging and may not be useful for everyone *(acknowledged but dependent on the objective).*
9. The framework needs to define river types (i.e. Alpine, coastal, arid, estuary, floodplain etc.) (*the framework allows classification to be done using different methodologies that depend on the objective but allow the data to produce the classification*).
10. Data availability is a major problem for classification. For example, macroinvertebrate data are problematic for defining bioregions, mainly because of low sampling effort and low taxonomic resolution *(agreed).*
11. It is important and urgent that a national-scale river classification system be developed to allow representativeness to be assessed *(agreed).*

Conservation criteria
There were originally 7 criteria but criteria 6 and 7 were combined.

1. Criteria should only concentrate on ecological values as other criteria (aesthetic and recreational) are identified in other regional processes *(agreed).*
2. It would be useful to have nationally agreed assessment criteria *(agreed and followed).*
3. There was support for tightening up or collapsing of some criteria (*for consideration*).
4. Criteria needs to cater for needs of all jurisdictions *(agreed and followed).*
5. Criteria based on providing important resources

for particular life-history stages of biota or important functions within the landscape could apply to all Australian rivers so are pointless (*the criteria allow relative assessment which reflects the reality of these systems and so the highest ranked systems will be of national importance. This also allows recognition that all systems have value*.)

6. Criteria need to be measurable and quantifiable *(agreed—see discussion of attributes and rating).*
7. Criteria comparable to widely used criteria (e.g. Ramsar) *(agreed, that is why they were chosen).*
8. Criteria 2–7 are reductionist. High conservation value should be about protecting whole relatively intact landscapes not protecting species. We already have ways of protecting rare species *(we believed some merit for large river basins but would preclude important parts of rivers in potentially degraded systems).*
9. Criteria 5–7 could be combined possibly *(we believed that there was value in having some further discrimination power but this could be further investigated by the interjurisdictional group)*.
10. Criterion 6 could be combined with 3 and criterion 7 combined with 3 and then separate criterion 3 into two biological and geomorphic criteria. *(we believed that there was value in having these separate but this could be further investigated by the interjurisdictional group)*.
11. It is impossible to get the communities to agree on values, even at a regional or local scale (*agreed, hence the need to have agreed criteria that may be objectively assessed at a national scale*).
12. Cultural values are important *(agreed but outside terms of reference and require different expertise but believe that if this framework is adopted they can be included relatively easily).*
13. There should also be indigenous values not just western scientific conservation values *(agreed but outside terms of reference and require different expertise).*
14. Agree strongly with inclusion of geomorphic *(agreed and followed).*
15. Rare and threatened species should be managed under different regime not protection *(this group of organisms are acknowledged as a conservation priority, so are included in criteria).*
16. The broad criteria will be met by any river in Australia (*disagree when thresholds are applied this should allow the selection of the best of the best*).
17. Rare and threatened species can be identified at state and national levels (*agreed but this framework is meant to be a national one and so the national threatened species would be used but note assessment of high conservation rivers at state level may use state identified threatened species).*
18. Need to quantify a word such as 'unusual' in criterion 4 *(agreed but this would be done during assessment as a relative assessment).*
19. Not support nomination based on unusual diversity or abundance of features—this is relevant to National Parks and should be managed under that regime (*only a small portion of high conservation value areas are within National Parks and others may not be in the future. Unusual diversity allows for relative identification of important areas*).
20. Unsure that criterion 5 should be included *(believed that this was important in terms of Australia's evolutionary history).*
21. It is important to convince regional bodies of reasoning behind selection of criteria *(we drew on a number of widely accepted criteria—see discussion paper).*

22. Can the framework use or modify the Ramsar criteria? *(we believed that these needed to be extended to other areas in recognition of Australia's rivers).*
23. There should be spiritual criteria considered *(we believed that this was outside the terms of reference but acknowledge its importance for consideration under cultural values).*
24. A further eighth criterion should be added—imminent threatening processes *(we believed that this is primarily part of the management response once high conservation value rivers are identified).*
25. Rivers or dependent ecosystems need to meet more than one criterion, other than the first *(we believed at least one was important but such rules could be determined by the data and ranking).*
26. The criteria are not sufficiently discriminatory. For example a highly modified system could qualify just as easily as an undisturbed system (*a high conservation value river or dependent ecosystem could occur in a highly modified system*).
27. Criteria need to build on threat level at different scales (*the criteria are primarily centred on ecological value, not threats*).
28. Identification of high conservation value rivers should not hinge on simply meeting one of the criteria. This could overemphasise the importance of threatened species (*agreed*.)
29. National significance is essential if the framework is to be non-threatening to state/territory jurisdictions, who are responsible for their own river protection programs, policies and legislation. They are more likely to contribute to a Australian Government-funded national program than to accept a nationally-derived set of criteria to drive their own river protection programs (a *nationally derived set of conservation criteria should cater for all jurisdictions but it is an essential step in deriving a nationally consistent and objective assessment. An interjurisdictional group may decide on the final format of these*).

Evaluation

Forum summary

- There should be a focus on compiling existing knowledge about conservation values, representativeness, and threatening processes to identify candidates for high conservation value.
- This will identify knowledge gaps that can be filled.

1. An assessment of nationally significant rivers could be relatively easily done with an expert panel (Delphi method) *(may warrant further consideration).*
2. There is a clear need to identify rare and relatively undisturbed rivers across Australia, without becoming slowed down by an involved process of data collection *(agreed but we require objective processes for identification. An immediate stage is identified*).
3. First priority should be to identify intact catchments, rather than reaches *(agreed in first stage but need to use the data available at the finest scale).*
4. National assessment important because it allows for objective comparisons *(agreed).*
5. Need investment to provide required supporting data *(agreed and followed).*
6. Absence of data should not prejudice assessment of a river or dependent ecosystem (a*greed and covered by surrogates. Also rivers likely to be considered important can be targeted for data collection*).
7. Identify gaps in information and invest in further data collection if required (*agreed but need to begin with existing data otherwise*

there will be paralysis in progress).

8. Use expert opinion and data for assessment *(agreed but believe that data is preferred for objectivity, expert opinion to test validity).*
9. Use existing databases of information *(agreed and followed*).
10. It is important to examine how well a river meets each criterion and then weight *(agreed but there is a need for transparency and objectivity).*
11. Assessment needs to build on existing work in jurisdictions that has tested application of criteria (e.g. Directory of Important Wetlands in Australia) *(agreed and to be followed).*
12. Strengths and weaknesses of criteria need to be tested *(agreed and should be the focus of future work).*
13. Criteria need to be tightly defined and establish how each criterion will be applied *(agreed, but some further work needed to determine the exact guidelines)*.
14. During assessment any criteria should be met for a river qualifying as high conservation value, not all criteria *(agreed).*
15. Many of the criteria are point locations and so their identification could be driven too much by threatened species *(agreed but other criteria should balance out the effects of threatened species).*
16. We do not necessarily know that much about threatened species *(agreed—data sets will be poor but this group of organisms are acknowledged as a conservation priority, note the comments about data in discussion paper).*
17. We should not worry much about the rules by which agencies apply criteria; different states will have different priorities (weightings) *(agreed, but further work needed to determine guidelines to ensure comparability for a national assessment)*.
18. There is a need for a scoring system or weightings for a number of the criteria (*see discussion about different assessment methodologies).*
19. Measurable thresholds are needed against which each criterion can be assessed *(agreed and preliminary discussion of this presented but necessary for interjurisdictional steering group to determine appropriate thresholds).*
20. Criteria of representativeness and criteria for particular life history stages need well defined guidelines to ensure that the highest conservation value rivers are identified *(detailed agreement by inter jurisdictional steering committee required).*
21. Rivers or dependent ecosystems should meet at least two criteria but it is not important which two *(we believed at least one was important but such rules could be determined by the data).*
22. Rivers or dependent ecosystems should meet criteria 1 (naturalness) and one other *(we believed some merit for large river basins but would preclude important parts of rivers in potentially degraded systems)*.
23. Use separate data layers so information can be analysed separately and then use GIS to combine for scoring *(agreed depending on the final methodology used for assessments).*
24. Natural Resource Monitoring and Evaluation can inform the use of criteria *(recognised through the importance of using all existing databases).*
25. High conservation value river seems to imply systems that are not heavily utilised but mention is made of the River Murray which preempts prioritisation (*agreed—the framework incorporates whole rivers as well as dependent ecosystems wherever they may be because they may still be of high conservation value in a heavily utilised system. The River Murray reference was supposed to be by way of example but has been removed).*

Protection Planning
Whole river protection

Forum summary

The concept has merit at whole river or sub-catchment scale for iconic undeveloped catchments (some cross border rivers) of high conservation value. Majority of river protection needs to apply at the sub- catchment or river segment scale, relevant to the community and regional management. Whole river protection is not applicable to all high conservation value rivers. Management depends on the scale and source of threats.

Whole basin protection requires integrated suite of statutory and non statutory tools covering

- protective legislation (protective areas useful within whole basins)
- water planning and legislation
- catchment and land use planning
- information and incentives
- Delegates to the forum commented on advantages and disadvantages of whole river basin protection.

Advantages

1. This is a useful and optimum concept particularly applied to areas not yet developed with wide-scale benefits *(agreed).*
2. Could work for a small number of river basins but other mechanisms also required *(agreed).*
3. Need to set objectives at the basin scale *(agreed).*
4. Usefulness will depend on what threat the river needs to be protected from *(agreed).*
5. Basin wide is the logical starting point but may need to use catchment scale as the largest scale for implementation *(agreed).*
6. Community support is essential and the system could work at sub-catchment scale *(agreed).*
7. It usefully incorporates a sense of upstream and downstream connectivity between ecosystem types and processes *(agreed).*
8. It potentially accounts for whole of catchment processes and issues *(agreed).*
9. It would be easier to achieve in high conservation value rivers without many development threats *(agreed).*
10. Queensland is currently looking at a number of river basins for catchment/ basin scale protection (*acknowledged*).
11. It could be tailored to suit community aspirations *(agreed).*
12. This has the advantage in that it could incorporate notions of wise use and stewardship *(agreed).*
13. Success or otherwise will depend on trade-offs in the community *(agreed).*
14. There could be educational and industry advantages with such a designation *(agreed).*

Disadvantages

1. Unlikely to occur in highly developed river systems *(agreed).*
2. Land tenure issues likely to be important *(recognised hence the need for broad river planning framework, supported by the community).*
3. Would need to break it down into catchments and reaches for management *(agreed but an overall protection plan for the river would guide such management).*
4. Reference to the Canadian Heritage Rivers System is unhelpful as the Canadian culture and their attitude to rivers is vastly different to Australia's, making comparison a nonsense (*the broad framework provided by the Canadian Heritage Rivers System could be applied within Australia, as discussed. The criteria used for evaluation will vary reflecting the different nation's rivers and culture*).
5. It will depend on the aim of protection and political and community support *(agreed).*
6. Development of community support processes essential so there is clarity *(agreed).*

7. Catchment scale may be too large because too many communities involved with different objectives and aspirations as well as different components of condition from degraded to pristine *(agreed but still believe some communities may see advantages that overcome these drawbacks).*
8. There is a lack of relevance at this scale to current natural resource planning and management so jurisdictional support will be poor *(this is not necessarily true—e.g. Lake Eyre Basin where catchment and natural resource planning processes are built around whole of river protection of river flows. It is a new concept that may require time to develop).*
9. The scale may be too broad to adequately address specific threats *(agreed but it could provide an overarching framework).*
10. Data at large scales may not be consistent and rigorous (*this is a problem associated with all scales*).
11. It may require a single legislative tool to declare areas (*this is not necessarily true—see Canadian system of Heritage Rivers).*
12. Whole of river basin should require development of protection mechanisms to be successful *(agreed—would be carried out with a river management plan).*
13. Requires community ownership and backing *(agreed).*
14. Not appropriate in all cases, it should reflect the nature and scale of the threat. So some threats may be site specific and managed through protection mechanisms *(agreed).*
15. Need to be clear about what a basin is where it moves over biophysical and institutional boundaries *(agreed—need to reflect topography).*

Application of current policy and legislative tools

Forum summary

There is a need to manage cumulative impacts using appropriate mechanisms. After developing overarching policy and directions, a representative system of freshwater dependent ecosystems (also estuaries) is best identified and then protected via a nested approach to

- scales of planning and protection and
- appropriate protection mechanisms

Delegates to the forum gave advantages and disadvantages of using current legislative and policy tools.

Advantages

1. They are cost effective and there is familiarity with implementation of current processes *(agreed).*
2. Current catchment scale processes for planning are an appropriate scale for implementation *(agreed).*
3. Need to be able to apply a suite of tools and mechanisms for protection from formal and informal reserves to planning at landscape scales *(agreed).*

Disadvantages

1. They are not always adequate because of lack of linkages between catchment-based planning and the controls *(agreed and addressed).*
2. Protective tools are often not able to manage increasing threats *(agreed).*
3. Threat management tools are inadequate. They currently focus on sites and not on integrated processes *(agreed).*
4. There is a lack of enforcement with many current legislative and policy tools *(agreed and partly addressed).*

Numbered points below represent comments about protection of rivers and dependent ecosystems.

5. There should be a hierarchy of rivers

established for protection *(the assessment can establish relative conservation value of different rivers and dependent ecosystems).*

6. Formal listing of rivers is not proposed and yet this was a useful mechanism for the Directory of Important Wetlands in Australia (*this could be an outcome*).
7. It is important to articulate the range of management options *(agreed and presented)*.
8. Threats to values need to be considered in priority action planning *(agreed and followed)*.
9. Should focus on whole catchments or sub-catchments as anything smaller is difficult to protect and manage *(agreed for management but for assessment it is important to use the finest data available)*.
10. Recognise social and economic impacts of conservation *(agreed—this will be clearer through potential delivery of incentives and providing communities with the option of recommending whole river basins protection).*
11. Should examine the vulnerability and irreplaceability of the area and prioritise management *(agreed as an important test for prioritising action, requires further development for implementation)*.
12. It is important to ensure appropriate legislative enforcement is available to support protection *(agreed—this is why most of the recommendations refer to currently available legislative and policy tools).*
13. Success of the framework will depend on institutional and high level political commitment. *(agreed—that is why we recommend that subsequent actions involve all the states and the Australian Government, through the Natural Resource Management Ministerial Council).*
14. It is important to have community support *(recognised particularly in relation to whole of river basin protection requiring community involvement and support).*
15. The framework must build on jurisdictional investments *(agreed and wherever possible we have tried to recognise this).*
16. Protection of whole river basins would require statutory primacy over water sharing and allocation plans *(not necessarily just compatibility—e.g. Lake Eyre Basin Agreement, Paroo River Agreement)*.
17. Protection of river basins implies ‘locking up’ rivers which is inappropriate *(this is not the case, it is only a broad commitment to maintaining the values of the river, e.g. Lake Eyre Basin Agreement).*
18. Incentive opportunities need to be explored for protecting high conservation value rivers (e.g. tax, lease arrangements, stewardship) *(agreed).*
19. Need to be able to integrate the tools for protection. Too much emphasis is placed on individual tools and not the overall protection *(agreed).*
20. A table of advantages and disadvantages of various protective tools would be useful with some case studies exemplified *(we did not take this approach because most jurisdictions have similar tools and mechanisms which may not have been adequately used. We focused on better implementation of tools.)*
21. First high conservation value rivers must be identified and then assessed to see if current management objectives maintain these values *(agreed—but also possible to be proactive in management).*
22. Need to recognise current tools such as Ramsar and Heritage amendments to the *Environment Protection and Biodiversity Conservation Act 1999* that may be used *(agreed).*
23. Essential that protection is linked to land and water use planning *(agreed).*
24. Nominations of whole river basins should be by the jurisdiction and supported by data (*the*

Canadian Heritage River system allows communities to nominate with jurisdictional support and data that show high value).

25. Identification of high conservation value rivers is dependent on the implications of this identification *(it is important to make the identification independent of management so there is transparency and objectivity)*.
26. Is the suite of tools available the right type or do we need new ones? (*we believed there were sufficient tools and wished to work within current legislative and policy frameworks in jurisdictions. Better implementation of current tools could achieve protection*).
27. Whole of river basin protection needs to involve industry, particularly agriculture *(agreed).*
28. The framework does not have to address cross-border issues. We already have mechanisms such as agreements to deal with these (e.g. Murray– Darling, Lake Eyre, Paroo) (*a comprehensive national framework should allow for all protective mechanisms to be incorporated as does the one proposed as we cannot predict the future. Currently the Lake Eyre Basin Agreement and Paroo River Agreement do not fit well into any type of framework. A cross-border framework provides for better recognition of the ecological connectivity of rivers*).
29. Investment should focus on protection of high conservation value rivers with additional funding for monitoring *(agreed).*
30. Important to reward people for good stewardship of rivers *(agreed).*
31. There may be a need to collaboratively establish formal duty of care responsibilities for private landholders or leaseholders *(agreed).*
32. The framework should be operationalised (needs to assist managers) and not just be conceptual *(agreed. It needs to have sufficient high level structure so that all elements of protecting high conservation rivers can be identified but also provide sufficient detail that the programs can be put into effect).*
33. Reliance on communities to drive a nomination process for whole river systems is flawed. Many communities do not have the resources especially in remote areas (*acknowledged and Governments will need to resource the community, as in the Canadian Heritage River system for this process*).
34. It is important to recognise the role of stream buffers for ensuring river health and riparian condition and this may be a good way of protecting conservation values *(agreed and included).*
35. Rivers identified for whole basin river protection should also be candidates for higher levels of protection for key sites *(agreed and followed).*
36. The framework should primarily use existing Directory of Important Wetlands in Australia and Ramsar mechanisms for protection (*there is variable uptake and effectiveness of these processes among jurisdictions. Also there are many other ways of effecting protection*).
37. Not all ‘pristine’ river systems need to be ‘locked up’ against development as this will put future development pressure on remaining systems, possibly to the point of extinction. (*agreed—the discussion paper identifies a number of different protection mechanisms that encourage sustainable development, if supported by communities and Governments*).
38. Managing parts of a river system for high conservation values is problematic due to upstream and downstream influences. These values will constantly be under threat unless the whole catchment and river system is managed as a unit—hence a preference for only declaring whole systems (*agreed about pressures and management but not all dependent ecosystems depend on the whole*

catchment and increasingly communities are focussing on key assets).

Operational and institutional arrangements

Forum summary

- Need for coordination of a National framework by the Australian Government.
- Recognition of constitutional realities is essential.
- States need flexibility matched to national interests.
- Need to use the framework to improve existing mechanisms and strategies (e.g. National Action Plan for Salinity and Water Management, Natural Heritage Trust.
- Different elements of a national framework may require different institutional arrangements.
- Involvement of the Natural Resource Management Ministerial Council is important for ownership.
- Identification in the National Water Initiative is important.

Numbered points below represent comments by delegates on institutional and operational arrangements and challenges for implementing a national framework for the protection of high conservation value rivers.

1. The institutional arrangements need to recognise constitutional realities, avoid duplication and accommodate social and environmental values *(agreed).*
2. The framework needs to link in with the National Water Initiative and the funding arrangements through the National Action Plan and Natural Heritage Trust *(agreed).*
3. The framework needs to be simple and clear but not prescriptive (e.g. Lake Eyre Basin Agreement) *(acknowledged for whole of basin protection, but other tools may be prescriptive within a jurisdictions legislative and policy context).*
4. The framework should complement existing arrangements and only augment where there is a clear need. It needs to be owned and supported by all jurisdictions *(agreed).*
5. The framework requires political commitment to ensure resourcing and jurisdictional commitment *(agreed).*
6. There needs to be opportunity to build in community support and involvement (*agreed, see comments about whole of river protection and delivery through regional frameworks)*.
7. Such a framework could benefit from evaluation of National Reserve system applied to terrestrial landscapes *(agreed—attempted to draw on this experience but also recognised that water transcends many boundaries)*.
8. The Australian Government can provide some funding and a national model. The states and territories can also provide funding but contribute to policies and priorities while regional bodies can implement and integrate protection *(agreed).*
9. The framework needs to be robust enough to outlive this present project and engage and influence the future *(agreed).*
10. There are existing arrangements but these are not used due to lack of political will, poor marketing and poor awareness *(agreed).*
11. National framework important to jurisdictions for funding opportunities and through application of further protection tools from elsewhere *(agreed).*
12. A national framework would allow for a consistent approach to protecting ecological assets throughout Australia *(agreed).*
13. Needs to take into account the evolving regional arrangements for natural resource management *(agreed).*
14. National Reserve Scheme should provide a

process for implementation *(agreed).*

15. Australia is a federal system and so funding should be provided by the Australian Government with jurisdictions providing expertise and input data (*all governments provide funding for natural resource management*).
16. Socio-economic values as well as conservation values need to also be assessed in the framework (*this is not necessary to establish ecological value but it is important for management actions*).
17. Important that the framework is engaged by key stakeholders *(agreed).*
18. Federal–State and regional arrangements allow for accountability and setting of standards in relation to protection of high conservation value rivers *(agreed).*
19. Need for a communication program that advertises the main elements and advantages of the framework (*for future consideration*).
20. There is a need to engage key stakeholders early in the process *(agreed).*
21. The National Framework could be broken down into its elements to allow for iterative discussion and agreement at interjurisdictional and Australian Government level *(agreed and followed).*
22. Consider the model of developing the process and then allow implementation by jurisdictions (e.g. National Reserve System) *(agreed and followed).*
23. Resourcing will be essential for such a system to be implemented and major players to engage *(agreed).*
24. Important to strengthen existing partnerships and possibly develop new partnerships but not new institutions *(agreed and followed).*
25. There is a need for strategic decisions on protection of high conservation value systems which may be difficult from an equity standpoint *(agreed and could follow once high conservation value rivers are identified).*
26. Need to develop national standards for information systems *(agreed and followed).*
27. Need to develop a national program of information collection *(agreed and followed).*
28. Need to scope investment in National Reserve System in relation to rivers and dependent ecosystems *(agreed and followed).*
29. Important to sign formal links between National Water Initiative, water plans and land use and land planning *(agreed and followed).*
30. Need agreement on Australian Government and State funding arrangements in relation to protection of high conservation value rivers *(agreed and followed)*
31. Timelines need to be developed for implementation *(agreed and could be considered by interjurisdictional steering committee).*
32. Accountability of Australian Government and State is important for implementation of a national framework *(agreed and followed).*
33. There is currently sufficient information to implement a national framework even if it is fragmented and not easy to access data *(agreed and followed).*
34. Need scientific based objective assessment with community endorsement and support for whole river basin protection (*agreed and followed*).
35. Important to ensure that there is jurisdictional commitment to accessing all available databases *(agreed and followed).*

36. There is general consensus that Wild Rivers was not effective in protecting high conservation value rivers but no analysis of why it and other attempts have not worked *(this issue is difficult because of the large scales, inter and intra- jurisdictional responsibilities and potential impacts on users. We believed we had sufficient experience to provide a way forward in protection of high conservation rivers)*.
37. There is no explanation of how the national framework will foster involvement, understanding and commitment and yet this is an important element *(agreed—this has been done through recognition of jurisdictional investments and using incentives as well as controls for protection).*
38. It would be of value for pilot assessments to be done with rivers considered to be of low conservation value and high conservation value in different regions of Australia *(agreed).*
39. Nomination of protected river systems will be political decisions rather than technical ones (*agreed but we need to allow for objective analysis of likely candidates*).