Perspectives on the Scientific Panel Approach to Determining Environmental Flows for South-Eastern Australian Rivers

Proceedings of a workshop held at the Department of Natural Resources and Environment, Melbourne, 3rd December 2001

Peter Cottingham	CRC Freshwater Ecology
Gary Howell	Dept Natural Resources & Environment
Paul Bennett	Dept Natural Resources & Environment
John Boehm	Goulburn Murray Water
Jane Doolan	Dept Natural Resources & Environment
Graeme Hannan	Goulburn Murray Water
John Harris	CRC Freshwater Ecology
Barry Hart	Monash University
John Koehn	Dept Natural Resources & Environment
Leon Metzeling	EPA Victoria
Gerry Quinn	Monash University
Michael Shirley	Sinclair Knight Merz
Michael Stewardson	Melbourne University
Martin Thoms	University of Canberra

Technical Report 2/2002
August 2002

The Cooperative Research Centre for Freshwater Ecology is a national research centre specialising in river and wetland ecology. The CRC for Freshwater Ecology provides the ecological knowledge needed to help manage the rivers in a sustainable way. The CRC was established in 1993 under the Australian Government's Cooperative Research Centre Program and is a joint venture between:

ACTEW Corporation
CSIRO Land and Water
Department of Land and Water Conservation, NSW
Department of Natural Resources and Environment, Victoria
Environment ACT
Environment Protection Authority, NSW
Environment Protection Authority, Victoria
Goulburn-Murray Rural Water Authority
Griffith University
La Trobe University
Lower Murray Water
Melbourne Water
Monash University
Murray-Darling Basin Commission
Natural Resources and Mines, Queensland
Sunraysia Rural Water Authority
Sydney Catchment Authority
University of Adelaide
University of Canberra

Ph: 02 6201 5168
Fax: 02 6201 5038
Email: pa@lake.canberra.edu.au
http://freshwater.canberra.edu.au

ISBN 1 876810 31 9

Contents

page

Workshop participants

Peter Cottingham	CRC for Freshwater Ecology
Paul Bennett	Dept Natural Resources & Environment
John Boehm	Goulburn Murray Water
Jane Doolan	Dept Natural Resources & Environment
Graeme Hannan	Goulburn Murray Water
John Harris	CRC for Freshwater Ecology
Barry Hart	Monash University, CRC for Freshwater Ecology
Gary Howell	Dept Natural Resources & Environment
John Koehn	Dept Natural Resources & Environment, CRC for Freshwater Ecology
Leon Metzeling	EPA Victoria, CRC for Freshwater Ecology
Gerry Quinn	Monash University, CRC for Freshwater Ecology
Michael Shirley	Sinclair Knight Merz
Michael Stewardson	Melbourne University
Martin Thoms	University of Canberra, CRC for Freshwater Ecology

Acknowledgements

Professor Angela Arthington (Griffith University), Professor Gary Jones (University of Canberra) and Dr John Whittington (University of Canberra) provided very useful comments and suggestions and their contribution to this report was greatly appreciated.

Summary

The widespread use of Scientific Panels is testament to the value attached to them by water resources managers in the absence of quantitative data. Panels may be valued for:

- giving independent and credible advice on the ecological implications of water management activities, supported by scientific understanding and extensive experience;
- explaining environmental water needs, based on credible and defensible information and conceptual models, that provide information for debate on the allocation of water;
- integrating hydrological, geomorphological and ecological information from many sources; and
- advising on short and long-term priorities for action.

The tasks of estimating and providing environmental flows are relatively new to both scientists and management agencies in Australia, and in this context the workshop participants felt that the use of Scientific Panels may not have yet reached its full potential.

Clear project terms of reference and ecological objectives are required if Scientific Panels are to operate efficiently and effectively. Terms of reference should clearly state that Scientific Panels are to provide information on environmental water needs and other river management actions to achieve desired conditions in the river. The Panels' task is to provide information for stakeholders who are directly involved in a wider water allocation process. They are not intended as direct environmental advocates in the water allocation process, although it is recognised that stakeholders often ask 'How much water does a river need?'.

The delivery of environmental flows should be considered a river rehabilitation experiment so that the lessons learnt can guide the development of future recommendations (i.e. adaptive management). As in any rehabilitation project, clear ecological objectives are required so that any ecosystem response to environmental flow releases can be measured against the desired outcomes. These objectives are best set by the community (e.g. as visions of a desired future state), supported by advice from scientists who have a good understanding of the ecology of river systems. Ecological objectives should primarily relate to flow conditions but also consider other aspects of river condition and rehabilitation. For example, poor water quality or degraded habitat condition may potentially confound the benefits of an improved flow regime.

Panel members are usually selected to advise on particular parts of the ecosystems that may have been affected by changes to the natural flow regime as a result of regulation and water diversion. The expertise required of a Panel should be explored before it begins work. A number of points should be considered when establishing a Panel:

- The ecological objectives and resource management questions being asked will be key factors in the selection of Panel members.
- Panel members must be prepared to work in a rapid appraisal environment. Diversity of opinion and debate on key issues are to be encouraged, but Panel members must be prepared to work as a team rather than as a collection of disciplinary scientists.
- Panel members need to provide independent scientific evaluations of issues based on data, experience and predictions or hypotheses.
- Panel membership may change, particularly if the panel is to run for a long time or it must deal with complex issues. Changes must be managed carefully to avoid undue disruption to the Panel.
- Availability of resources can affect the number of members, and consequently the range of expertise, in a Panel. The cost of running Panels needs to be evaluated realistically because panels should not be unduly compromised by a lack of resources.
- There is great value in having an expert hydrologist available to provide rapid feedback, advice and hydrological data to the rest of the Panel. The reliability of hydrological and hydraulic data is also critical.
- Panels should include a person with good facilitation skills who is responsible for coordinating the activities and summarising the recommendations of the Panel, creating an

atmosphere conducive to teamwork and ensuring field duties and data collection or provision occur in a timely and efficient manner.
- Panel members are, by definition, scientists or have a science/technical background. They generally do not have the expertise to integrate ecological decisions with socio-economic decisions and outcomes.

Interpersonal and professional relationships between Panel members will play a significant part in both the conduct and the recommendations produced by Scientific Panels. The Royal Society of Canada has developed protocols for the conduct of expert Panels, which are appropriate for the conduct of many Scientific Panels in Australia. The protocols include four important points:
- Expert Panels are scientific and technical inquiries that should be conducted with integrity.
- Panels should strive for a consensus report, but not at the expense of substantially watering down analyses and results.
- Members serve as individual experts, not as members of organisations or interest groups.
- Panels should avoid premature briefings of Panel results.

Panels commonly do the following:
- confirm the extent of the study area and representative reaches to be considered (representative reaches can be defined on the basis of river-system geomorphology and water supply operation);
- integrate knowledge of the historical and current environmental condition of streams in the study area (including the experience and knowledge of the river system held by Panel members);
- consult with relevant management agencies to understand the operation of the system;
- make a field trip to confirm environmental conditions at sites across the study area;
- consult with local community representatives to discover their perspective of the river system;
- analyse hydrological data to identify changes to stream hydrology that have occurred since the regulation and diversion of water for agriculture and urban supply (good quality data are vital as a sound basis for developing environmental flow recommendations);
- make hydraulic models of sites representative of each river reach;
- participate in workshops at which Panel members can develop a common understanding of the river system, important environmental values to be protected and how these values may have been affected by regulation and other catchment activities;
- develop recommendations for a flow regime that will protect or enhance the environmental values identified for the river system.

No single framework or set of methods for developing environmental flow recommendations has been adopted consistently across Australia. The method that a Panel may adopt will depend on the project terms of reference, ecological objectives, available information and resources, and the views of the scientists on the Panel. However, Panels are likely to require a number of key information sources, no matter what environmental flow method is adopted.

Key hydrological information includes:
- daily flow data for present and natural flow regimes, and
- information on the operation of dams, weirs, diversions, etc.

Key hydraulic information includes:
- stream cross-sections,
- longitudinal profiles,
- hydraulic parameters predicted from models for different flow regulation scenarios (e.g. wetted perimeter, wetted area).

Key geomorphological information includes:
- sediment initiation-of-movement data,
- flows governing substrate composition,
- previous geomorphological studies and information on the trajectory of changes in response to past changes in land use, including dams.

Key ecological and biological information includes:
- water quality parameters (e.g. temperature (including instances of cold water pollution), dissolved oxygen, turbidity, suspended solids, nutrients, EC, pH);
- macroinvertebrate indicators (e.g. AUSRIVAS scores, number of families, number of disturbance sensitive taxa, SIGNAL scores);
- empirical relationships between macro-invertebrates and environmental condition (Marshall *et al*. 2001);

- fish indicators or metrics (e.g. number of species present, number of native species present, species composition of the fauna, % total abundance comprised of exotic species);
- in-stream barriers to fish migration;
- fish habitat preference criteria;
- basic cues for reproductive biology, spawning and migration;
- aquatic and riparian vegetation indicators, including floristics (e.g. species composition, proportion of natives species) and structure (e.g. groundcover, understorey and overstorey);
- presence of weed species.

Scientific Panel assessments are likely to require between 6 months and 1 year for completion, particularly if the process is dependent on interaction with stakeholders such as bulk entitlement groups and river management committees. Altogether, including modelling and incidental costs such as travel and accommodation and GST, indicative costs of $100,000 are to be expected.

It is important to measure the success of Scientific Panel studies, because management agencies want to know that their investment in the Scientific Panel process is justified and communities want to know that investment in environmental water allocations is well-placed and based on credible information and decisions. Scientists wish to confirm the basis of their recommendations and gain new insights from ecological responses to water allocations (if any). However, at present there are no performance standards for Scientific Panels that are engaged to recommend environmental flows in Australia. Potential measures of success for Scientific Panels include:

- whether or not consensus recommendations are reached and the mechanism by which consensus was reached;
- whether Panel recommendations are adopted by management;
- peer review of the methodology and recommendations developed by Panels.

Reliance on Scientific Panels as a tool for recommending environmental flows is likely to continue for the foreseeable future. There are a number of opportunities, both for improving the efficiency and effectiveness of Scientific Panels and for adding to ecological knowledge, to assist future panel deliberations. For example, Panels need:

- consolidated procedures and guidelines that are widely endorsed by scientists, water agencies and stakeholders to help increase the efficiency of panel processes and activities;
- quantitative and predictive models linking flow changes and ecological response, at various spatial and temporal scales;
- data from monitoring and evaluation to assess if environmental flows have the desired ecological outcomes, so Panels can see if they have been successful and can improve their performance in the future;
- appropriate indicators for monitoring the ecological outcomes of environmental flows.

1. Introduction

In February 1994, the Council of Australian Governments (COAG) outlined a water reform agenda that included a national water resources policy, containing elements such as pricing, water entitlements, consultation and the environment. The policy made provision for defining water rights for the environment, based on the best scientific information available about the amount and timing of water needed to maintain the health and viability of river systems.

Water resources management agencies in each state and territory have responded to the federal water reform agenda by including environmental flow considerations when formalising water entitlements and other river management processes. Many water management agencies have appointed Scientific Panels to give them expert advice on the environmental flow requirements of rivers they manage.

'Expert' opinion is widely used in areas such as medical or health sciences and engineering to establish new industry-wide procedures or protocols, but its application to river management in Australia is relatively new. Panels convened to advise on river management in Australia usually include expertise in river ecology, biology of key species, geomorphology and hydrology, and they advise water resource managers on river health issues and environmental flow requirements, particularly for large regulated rivers.

Scientific or Expert Panels (henceforth called Scientific Panels) have provided information for river management in Australia on numerous occasions over the past decade, in relation to river health assessments, catchment and river management plans, and water allocation or environmental flow studies (Table 1).

The Scientific Panel process, as applied to river management in Australia, has evolved from simple beginnings into various methods in recent years. Scientific Panels have adopted several models for determining the environmental flow requirements of rivers (e.g. Swales *et al.* 1994, Swales and Harris 1995, Thoms *et al.* 1996, Arthington 1998, Arthington and Zalucki 1998). Initially, the Panel approach was developed to decide on the in-channel flows needed by native fish species below dams, and a few other related issues, using assessments resulting from experimental flow releases (Swales and Harris 1995). Since that time, the scope of Scientific Panels has expanded beyond single species to include ecological communities, broader aspects of river ecosystems, and river channel–floodplain interactions (e.g. Thoms *et al.* 2000, Cottingham *et al.* 2001a, b).

One of the main attractions of Scientific Panels is that they can make decisions or develop recommendations in situations when information on flow–ecology relationships is limited. However, the lack of quantitative information — in particular, information on relationships between flow and ecology or geomorphology — is also considered to be a common limitation to the Scientific Panel method and similar 'holistic' frameworks for determining environmental flows (Arthington 1998). Panels generally depend to a significant degree on professional judgement and experience of the river under consideration, or judgement based on similar systems. Decisions that are based on professional judgement must be communicated well to people outside the Panel, so they understand the reasons for decisions and how they were formulated. Otherwise, there can be:

- inconsistencies when applying the Scientific Panel approach to different river systems;
- missed opportunities or insights that would be of value to subsequent Panels;
- reluctance by either the community or management agencies to accept the recommendations.

1.1 Review of the Scientific Panel approach

As there has been no agreement on a standard method for determining environmental flows across Australia, or even within states, a strategic review of the conduct of Scientific Panels is considered necessary for identifying consistent guidelines and tools that can guide Scientific Panels in the future

(Cottingham *et al.* 2002). As part of the review, an assessment of the information and data inputs and the analytical tools that are used by scientists involved in the Panels would be particularly useful. Future Scientific Panels would be helped if the review examined which of these tools are most applicable, and in what circumstances. The assessment, along with the results of previous reviews (e.g. Swales and Harris 1996; Arthington *et al*. 1998), could indicate the type of information needed to augment and refine the Scientific Panel approach.

Therefore, the CRC for Freshwater Ecology hosted a workshop on 3 December 2001 to explore the lessons and limitations that have emerged from the conduct of Scientific Panels when determining environmental flow requirements in south-eastern Australia. The workshop was attended by scientists, management agency staff and consultants who have served on, or interacted with, Scientific Panels investigating flow requirements in both regulated and unregulated river systems. The workshop was part of an ongoing review being conducted by the CRC for Freshwater Ecology, which seeks to produce procedures and guidelines that can instruct Panels involved with water allocations in the future. It is hoped that such procedures and guidelines will help produce a consistency of approach, without prescribing the technical methods to be used to determine environmental flow requirements for the river system under study.

A number of key issues relating to the conduct of Scientific Panels were covered in the workshop and are reported here. Participants discussed the perceived value of Scientific Panels; criteria for the membership of Panels; how Panels and their costs are managed; and how to evaluate the success of a Panel. The workshop also considered challenges associated with the setting of targets for environmental flow volumes; methods for assessing environmental flows; and the information inputs required.

Further discussion will be needed as procedures and guidelines are developed.

Table 1. Examples of various river and water management activities in Australia supported by scientific panels

Activity	Rivers	State
River-health assessments	Bega River, Clarence River, Eucumbene River, Geehi River, Hawkesbury-Nepean, Murrumbidgee River, Namoi River, Shoalhaven River, Snowy River, Tooma River, Tumut River, Williams River	New South Wales
Catchment and river management plans	Broughton River, Gawler River, Light River, Wakefield River	South Australia
Water management plans and environmental flows	Barwon-Darling River, Coxs River, Hawkesbury River, Hunter River, Lachlan River, Macquarie River, Manilla River, Peel River, Snowy River, Tumut River, Woronora River	New South Wales
	Baron River, Border Rivers, Brisbane River, Burnett River, Condamine-Balonne River, Dawson River, Fitzroy River, Logan River, Pioneer River	Queensland
	Broken River, Campaspe River, Ovens River, Thomson-Macalister River	Victoria
	North Dandalup River	Western Australia

2 Value of Scientific Panels

The continued use of Scientific Panels for determining environmental flows (Table 1) is testament to the value attached to them by water resource managers. A key point of discussion at the workshop was: Why do natural resource managers use Scientific Panels or want Scientific Panel opinion? Managers at the workshop identified these values of Scientific Panels:

- Scientific Panels help to explain objectively the potential ecological responses of rivers to changes in flow regime associated with water allocations.
- Managers are expected to use best available science in determining environmental water allocations (i.e. make decisions using the best available scientific knowledge and method). Panels are one mechanism of providing scientifically defensible answers for managers.
- Panels give a level of credibility to water allocation decisions. When a Panel has eminent membership, its ecological recommendations or conclusions are less likely to be challenged on scientific grounds.
- Managers have to make decisions, often within a tight timeframe and budget. Panels provide the flexibility required to fit these constraints.
- Scientific Panels are a good way of integrating information from many sources. This is a big advance on a decade ago, when there was a very low knowledge base. It is valuable to ask panels to integrate available information because they can include opinions supported by extensive experience and available data.
- Panels can advise managers on activities that can take place over short and long time-frames, and help in priority setting.

3 Setting environmental flow objectives

Estimating and providing environmental flows are relatively new tasks for scientists and management agencies in Australia. The delivery of environmental flows can be considered a river rehabilitation experiment, and lessons learnt from it can guide the development of future recommendations via adaptive management.

Rehabilitation projects are unlikely to succeed if the underlying causes of ecosystem decline are not addressed (Hobbs and Norton 1996). River systems that require environmental flows as part of efforts to rehabilitate them are usually affected by multiple stressors, such as runoff from agricultural and urban land, clearance of riparian vegetation or access by livestock, as well as changed hydrology and altered in-stream structure. The ultimate success of environmental flows will depend in part on how non-flow stressors are managed. Scientific Panels should identify and recommend actions to manage the stressors that cause ecosystem decline and potentially compromise the effectiveness of environmental flows.

As in any rehabilitation project, clear objectives are required for the environmental flows, so that any ecosystem response to environmental flow releases can be measured against the desired outcomes (Hobbs and Norton 1996, Kirshner 1997, Lockwood and Pimm 1999). In a review of 87 restoration or rehabilitation projects across a range of habitats, Lockwood and Pimm (1999) found that most projects reviewed were only partially successful in terms of their stated goals. As the success of many of the projects assessed was only followed for a relatively short time, their long-term success was unclear. Unambiguous and agreed rehabilitation objectives, long-term commitment, and monitoring of the effectiveness of management actions are integral components of successful projects.

It can be a significant challenge to set realistic environmental objectives to be met by environmental flows.

- While communities and river management groups may be enthusiastic about improving river health, they may not be aware of the

underlying causes of ecological degradation. They may not be sure that delivering environmental flows will achieve the desired rehabilitation objectives.
- Projects that involve federal, state and local community action present challenges in funding, cost sharing and potentially conflicting objectives between funding programs.
- It can be difficult to get agreement on what is good, bad or acceptable change in response to environmental flows. For example, local communities may be enthusiastic about reinstating environmental flows, so long as the risk of flooding is not increased or their allocation of water is not reduced.
- It is difficult to identify the environmental outcomes that demonstrate that rehabilitation has been successful as a result of implementing an environmental flow regime.

Clear and agreed objectives are, therefore, critical to the success of a Scientific Panel. Objectives that have a broad conceptual basis allow a Panel the freedom to take a wide, holistic view of the system, but increase the risk that the Panel's output may not meet the expectations of clients or stakeholders. Conversely, client expectations will be easier to meet if objectives are narrowly defined, but this approach may lessen the potential for gaining insights about ecological processes. Narrowly defined objectives also may not acknowledge underlying causes of degradation that can override the benefits of an improved flow regime.

3.1 Project terms of reference

The workshop discussed the differences between ecological objectives and project terms of reference or constraints. Most terms of reference constrain Scientific Panels to the consideration of ecological issues. Here are three examples of the terms of reference or constraints used in specific projects.

For the Campaspe Scientific Panel (Marchant *et al*. 1997):

- identify the current environmental values and threats affecting the Campaspe and Coliban Rivers;
- recommend preferred environmental flows to maximise the environmental values of the rivers;
- identify changes in system operations that should result in general improvements in the environmental condition of these river reaches whilst considering the current needs of existing water users.

For the Snowy Scientific Panel (Bevitt *et al.* 1998):

- undertake a rapid appraisal of the environmental condition of rivers affected by the Snowy Mountains Scheme, using the best information available;
- make an informed, qualitative field assessment of the impacts of flow regulation on the geomorphology, fish, macroinvertebrates and amphibians of the affected rivers and river reaches;
- define the important components of an environmental flow regime for each reach;
- develop recommendations for an environmental flow regime for each river and/or other management recommendation options, where suitable hydrologic and/or other information is available.

For the Broken and Ovens Panels (Cottingham *et al.* 2001a and b):

- specify a flow regime that will sustain and where possible improve current environmental values, dependent on water flows in the river basin; and
- provide advice to the project group on the environmental benefits of a variety of management options and operational scenarios.

These terms of reference were developed by steering committees comprising relevant stakeholders. While they allowed the respective Scientific Panels the freedom to identify the environmental values considered most at risk from flow regulation and to recommend environmental flows to address these risks, they gave no clear direction on a vision or rehabilitation end-point that might be acceptable to stakeholders or the wider community.

Agencies are not always sure about the scope of issues they expect the Panels to consider. For example, DNRE has asked Panels to identify:

- current environmental or ecological values and how to protect them; or
- how to maximise existing environmental values; or
- how to maximise existing environmental values and how to improve the system further.

Other Panels have been asked to assess 'river health' as well as flow requirements. These expected outcomes are inconsistent with each other (for instance, is the objective to maintain the existing condition or to improve the system towards a natural state?). The inconsistency makes it likely that Panel members and other stakeholders will have differing expectations. Panels should report clearly the ecological values that are to be protected or restored as the rationale for environmental flow recommendations.

Terms of reference should clearly state that Scientific Panels are to provide information on environmental water needs and other complementary river management actions to achieve desired conditions in the river. In turn, the Panels should guide the stakeholders who are directly involved in a wider water allocation process. Panels are not intended to be direct environmental advocates in the water allocation process, even though stakeholders often ask 'How much water does a river need?'.

3.2 Ecological objectives

A number of key issues related to the setting of ecological objectives were considered at the workshop, including these four.

- Clear rehabilitation or conservation objectives that have been agreed to by relevant stakeholders are needed. The objectives should be based on statements of desired future states or ecological principles that will protect or enhance the environmental values of the river system.
- When objectives are being set, not only should environmental values and threats be considered but also there should be assessment of the differences between present values and the natural condition.
- Environmental flow recommendations should be couched in terms of the rehabilitation objectives they are designed to achieve. This will clarify the rehabilitation end-points and guide the design of programs to monitor performance.
- Scientific Panel recommendations are generally based on a rapid assessment of present river condition and how it has been affected by river regulation and the diversion of water for consumptive use. Stakeholders should understand that recommendations are usually based on limited information, but the best available.

It was agreed at the workshop that ecological objectives should relate primarily to flow conditions but also consider other aspects of river condition and rehabilitation such as water quality and habitat condition. Poor water quality or degraded habitat condition can potentially confound the benefits of an improved flow regime.

Early Panels (e.g. Swales and Harris 1995) aimed to meet 'directional' objectives when considering environmental flow requirements (e.g. 'towards natural'). However, now it is expected that ecological objectives will be more specific (e.g. Arthington and Long 1997, Arthington and Lloyd 1998, Arthington *et al*. 2000, SKM *et al*. 2001). Vision statements and an indication of 'desired future state' provide useful generic objectives, but such goals have to be more specific when applied to reaches of a river. Recent Panels have also considered the ecological outcomes anticipated once pre-defined flow or management options or scenarios have been implemented (Jones and Cartwright 2002).

The Logan River Scientific Panel (Arthington and Lloyd 1998) developed a draft statement of Desired Future State (DFS) through a workshop process, to help guide the trial application of the Building Block Methodology (King and Louw 1996) for determining environmental flow requirements:

> The Desired Future State for the Logan River and its estuary is a riverine ecosystem characterised as far as is possible by natural geomorphological and ecological processes and natural biodiversity, ecological and cultural values. Water resources from the river are presently used for irrigation, industrial and domestic consumption. The DFS includes the sustainable utilisation of these resources. The degraded condition of the channel and riparian vegetation in the lower Logan River catchment is recognised and the in-stream flow requirement should be designed to promote a return to natural processes of erosion, deposition and channel maintenance, water of high quality, diverse riparian and aquatic communities, and natural ecological processes.

This draft statement of DFS was applied to each site or representative reach of the Logan River. It allowed the present conservation status to be compared with the DFS, and provided direction for the Scientific Panel as they developed environmental flow recommendations to meet specific objectives (the reinstatement of flows necessary to support the biota or ecological processes that are included in the DFS). The Logan Scientific Panel considered that DFSs are best determined by stakeholders, including the relevant catchment communities and management agencies, supported by advice from scientists who know the river system well.

Similarly, a vision to guide the development of a rehabilitation plan for the 'flow-stressed' Thomson-Macalister River system in Victoria was developed through a workshop process using stakeholder input (Cottingham *et al*. 2001c). The vision for the Thomson-Macalister system was to:

> Provide a healthy ecosystem with diverse habitats (aquatic and terrestrial), communities and species, and an environmental flow regime that will sustain native flora and fauna. The river system will be one that people can access and enjoy, that supports a diverse landscape with multiple uses and values, and is consistent with community values and expectations.

The Murray (Thoms *et al*. 2000), Ovens and Broken River Panels adopted guiding principles that were similar in intent to the draft DFS for the Logan River. These principles were based on:

- an understanding of ecosystem health, including important river and floodplain ecosystem components (for instance, fish or vegetation biodiversity or community structure), that may be affected by management decisions;
- assessing river condition and making recommendations to improve river health within a water management context, focusing on three requirements:
  - —that the diversity of natural habitats and biota within the river channel, riparian zone and floodplain should be maintained (and where possible improved);
  - —that the natural linkages between the river and the floodplain should be maintained;
  - —that natural metabolic functioning of aquatic ecosystems, such as primary productivity and respiration, should be maintained;
- assessing the river as a whole and the operation of the river at the largest possible scale;
- retaining, as far as possible, elements of the natural flow regime (particularly seasonality), to provide or maintain a niche for native species and maintain the natural functions of the river system.

It was agreed at the workshop that Scientific Panels can play a very important role in advising or supporting stakeholders or the community during the development of ecological objectives that should help achieve these groups' visions for a river system. A challenge is to identify where in the decision-making process it is most advantageous to employ Scientific Panels.

The Victorian River Health Strategy was presented as one example to illustrate well-timed employment of a Scientific Panel within a resource management framework (DNRE 2002). The Strategy indicates that Victoria seeks to maintain its rivers in a healthy condition, and it identifies the characteristics by which healthy rivers may be identified.

The Strategy also allows the community to help identify environmental values or assets to be protected. Panels could be a useful part of this process by advising on those environmental attributes that are critical components of a 'healthy river', suggesting indicators for their evaluation, and explaining the actions that should protect those assets.

4 Panel membership

Criteria for selecting Panel members, and the skills and expertise required, were considered at the workshop.

The term 'Scientific Panel' implies a level of expertise that will ensure the credibility and independence of advice that is provided. Members should be of an appropriate calibre so that the standing of the Panel remains high and stakeholders in the water entitlement process see the Panel's recommendations as 'best available' ecological advice. Preferably, Panel members should be independent of the agencies that manage the resource.

Panel members are usually selected to provide expertise on particular ecological components that are considered likely to have been affected by changes to the natural flow regime as a result of regulation and water diversion. Before a Panel is established, the expertise it requires should be explored (say, during a review of flow-related issues for a river system, or when environmental flow objectives are being considered). This will provide a clear rationale for selecting specific skills. The organisation commissioning the Panel should understand that the Panel will advise on environmental aspects of river management based on rapid assessment of river condition, but that it will not have the expertise to advise on the wider water allocation process, or on socio-economic matters.

Sometimes, additional skills are required to address unforeseen knowledge gaps once the Panel has commenced its work. A review of flow-related river management issues, before a Scientific Panel is convened, should make these (potentially disruptive) additions less likely. The review should be undertaken with care by the client organisation (the organisation commissioning the Panel assessment).

At the workshop, a number of observations were made about both the environment in which Panel members should expect to work and the skills or expertise required of Panels.

Panel membership

- The ecological objectives and resource management questions being asked will be key factors in the selection of Panel members.
- Panel members must be prepared to work in a rapid appraisal environment. This means that ideas will be explored without fear or favour. Diversity of opinion and debate on key issues are to be encouraged. Panel members must be prepared to work as a team rather than as a collection of disciplinary scientists.
- Panel members need to provide independent scientific evaluations of issues based on data, experience and predictions or hypotheses, and remain independent from the management agencies that convene them or from any other potentially vested interest that they may have. The standing of Panels may be compromised if stakeholders perceive that Panels are not truly independent and objective.
- Some flexibility is required in terms of Panel membership (i.e. Panel membership may change), particularly if Panels are to run for a long time or the issues with which a Panel must deal are complex. Changes must be managed carefully to avoid disruption to the Panel.
- Availability of resources can limit both the number of Panel members (and consequently the range of expertise in the Panel) and their activities.

Skill base

- Panels often include a number of ecologists but only one geomorphologist and one hydrologist. This has probably been due to the 'data poor' nature of riverine ecology compared with hydrology. Also, hydrological data are collected and analysed using relatively standard approaches. Flow data are generally held by agencies, where staff are available to collate and analyse data, given sufficient warning. Therefore it is relatively easy for a single hydrologist in a Panel to present flow data. Panels often include several ecologists (and the opinions they provide) to compensate for a paucity of ecological data and because ecology has a greater level of specialisation than do geomorphology and hydrology.

- There is great value in having an expert hydrologist available to provide rapid feedback, advice and hydrological data to the rest of the Panel. Interruptions in obtaining and interpreting data from other sources can slow down or frustrate Panel deliberations. The reliability of hydrological data is also important.
- Panels should include a person with good facilitation skills who is responsible for coordinating the activities and summarising the recommendations of the Panel, creating an atmosphere conducive to teamwork and ensuring field duties and data collection or provision occur in a timely and efficient manner. However, all Panel members should contribute to the final written products of Panel deliberations.
- The integration of environmental flow recommendations and socio-economic considerations generally occurs in a forum separate from the Scientific Panel process. Panels should recognise the need to integrate the science and the socio-economics of the river system, and should work towards better models for doing that.

5 Management of Scientific Panels

Management of Scientific Panels and the interaction between members was recognised at the workshop as a key to the successful conduct of Panels. Several alternative management approaches were identified.

1. Panels can be led by an independent facilitator, who is a river scientist. The facilitator helps to collate data, organises Panel meetings and takes a lead role in the compilation of a final report (e.g. Broken River Panel).
2. Panels can be led by an agency staff member in the role of project manager (e.g. Campaspe River Panel).
3. A Panel can be run as a self-organising group that collectively undertakes assessments and produces a report (e.g. Barwon-Darling Panel). However, as someone must ultimately take responsibility for reporting, this approach may not be significantly different from the first approach.
4. A small team with appropriate technical skills may work to determine environmental flow requirements and present these to a Scientific Panel for critique.

Workshop participants considered that the first approach had worked well in practice. The fourth approach was considered to have potential benefits in the future as long as procedures for interaction between the technical team and the Scientific Panel, and the technical methods for determining flow requirements, were clear and applied consistently.

Those at the workshop considered the following questions related to the management of Scientific Panels:

- What important lessons have been learnt about the make-up of Panels?
- What guidelines have been adopted to assist Panels in their deliberations?
- What other approaches might be considered for running Panels?

A number of opportunities for improvement were identified, based on experiences with previous Scientific Panels. The workshop noted it would be useful if the Panel manager could:

- provide opportunities for the Panel members to meet before they go on field trip(s). Initial workshops allow Panellists to develop their interactions, assemble essential background understanding of the system in question, review available data and set the ground rules for the remainder of the project.
- prevent undue influence from state agencies or other stakeholders early in the Panel process. It can lead to constraints being applied too early in the work of the Panel (e.g. constraints related to the economic or operational outcomes of potential recommendations), or it can lead to

agencies wishing to change the emphasis or objectives as new information comes to light.

- ensure that the Panel has a capable hydrologist with pre-agreed and relevant hydrological and hydraulic data to hand, and the ability to provide model outputs from such data. This avoids the delays that are possible if the Panel has to contact agency staff for data and model outputs. Agency staff are likely to have other things to do, as well as meeting the needs of the Panel.
- allow time, particularly on field visits, for Panel members to form a cohesive team, to develop shared conceptual models of the river system and to agree on the appropriate method for determining environmental flows. Having to spend time on other matters (e.g. on public relations visits) can make the Panel less effective.
- arrange time for debriefing — very important following field visits so that Panel members can reflect on the lessons learnt, share new insights and identify future information needs.

As well, the workshop noted these points.

- In general, collection of new data during field visits is of little benefit, unless to confirm previous findings or perceptions about the river (e.g. type of sediment, presence of some conspicuous species or vegetation patterns, observations under particular flow conditions).
- One or more designated Panel members should liaise with local communities to explain the Scientific Panel process and hear the community's view of it. This would also be an opportunity to gain community perspectives and information on the ecology of the river. The interaction should best take place early in the Panel process.
- The Panel leader or facilitator is usually called upon to report findings back to steering committees or stakeholder groups.
- Panel members should understand the physical constraints of the system as they develop their recommendations (e.g. how much water can be physically released from a dam). They should also be allowed to suggest innovative alternatives to existing water delivery mechanisms.
- Panel reports should clearly state the logic used to develop recommendations.
- Panels should state the level of uncertainty associated with their recommendations (for instance, whether decisions are based on good ecological data or on the judgement of Panel members). Such statements do not reduce the value of Panel recommendations, and, like other ecological risk assessment processes, can be used to identify subjective components and indicate how strong the levels of evidence may be.
- The use of Scientific Panels is a learning process for all involved. The ecological and resource management questions being asked can change as new insights are gained. This possibility should be recognised explicitly from the start of a project and time and resources should be allowed for it, so that the Panel members and other stakeholders can have similar expectations of outputs.

5.1 Guidelines or protocols for interaction between Panel members

Interpersonal and professional relationships between Panel members will play a significant part in both the conduct and the recommendations produced by Scientific Panels.

The Royal Society of Canada has developed protocols for the conduct of expert Panels. Some important aspects of these protocols are applicable in Australia.

- Expert Panels are scientific and technical inquiries; they require the same standards of integrity and conduct as other scientific and technical studies.
- Panels should strive for a consensus report, but not at the expense of substantially watering down analyses and results; it is much better to report serious disagreements and explain why the disagreement exists than to paper over such problems. Lack of consensus on all points is not a failure of the Panel.
- Members serve as individuals, not as members of organisations or interest groups. Members are expected to contribute their own expertise and good judgement in the conduct of a study.
- Panels should avoid premature briefings of Panel results:
    - —Conclusions may not be sustained when reviewed.

—Panels may want to change their conclusions (hard to do if already circulated).

—Premature conclusions open Panels to charges that stakeholders have unduly influenced its conclusions.

—Other parties may demand reciprocal rights to briefings.

The Ovens and Broken River Panels adopted the following protocols when they were developing recommendations:

- The opinions of each Panel member are important and members should be encouraged to give and receive information in a constructive manner.
- Panel members should base their recommendations on their own area of expertise.
- Panel members should take as many opportunities as possible to discuss their perspective of the river system. Such dialogue is very useful for expanding conceptual models, identifying sources of ecological degradation, and identifying constraints that may apply to environmental flow recommendations.
- Panel members should access and use as many sources of information as possible.
- Panel members should use other sources of expertise when possible, such as local natural historians and knowledge holders.

5.2 Time-scales and resources

Panel members are generally senior scientists with many responsibilities. Organising meetings and field events can be very difficult without sufficient lead-time. Scientific Panel assessments are likely to require between 6 months and 1 year for completion, particularly if the process is dependent on interaction with stakeholders such as bulk entitlement groups and river management committees.

In terms of indicative cost, the following example is provided as a guide:

- indicative cost for 1 expert for 1 day = $1,200;
- thus for a Panel of 8, cost = $9,600 a day;
- if the Panel is required to have a 2-day field visit, 3 days of workshops and 3 days of investigating and writing, the cost for experts is approximately $77,000. Editing and publishing the resulting report costs extra.

By the time modelling and incidental costs such as travel and accommodation and GST are included, then minimum indicative costs of $100,000 are to be expected.

The cost of running Panels needs to be evaluated realistically and Panels should not be unduly compromised by a lack of resources.

5.3 Measuring Scientific Panel outcomes

Measuring the success of Scientific Panel studies is important at a number of levels. Management agencies want to know that their investment in the Scientific Panel process is justified. Communities want to know that investment in environmental water allocations is well-placed and based on credible information and decisions. Scientific Panels in turn hope to confirm the basis of their recommendations and gain new insights from ecological responses to water allocations (if any).

Peer review is important to ensure that the best available science is included when determining and assessing environmental flows. Performance standards do not currently exist for Scientific Panels engaged to assess environmental flows in Australia. Potential measures of success for Scientific Panels include:

- whether or not consensus recommendations are reached and the mechanism by which consensus was reached;
- whether a Panel's recommendations are adopted for management;
- peer review of the Panel's methods and the recommendations it develops.

6 Environmental flow assessment tasks, methods and information inputs

6.1 Tasks undertaken when developing environmental flow recommendations

One of the first challenges confronting Scientific Panels is to establish whether a river system requires more water (e.g. increased annual volume), or better management (e.g. there is sufficient water, but the timing and delivery of water need to be adjusted to meet the ecological needs of the river), or both (i.e. the river needs more water and better management of the flow regime). Determining if a river system needs additional water requires a 'whole-of-systems level' perspective to examine the large-scale implications of any changes to total annual volume, seasonality and river–floodplain connection that may have occurred with regulation (e.g. Thoms *et al*. 2000). This systems-level approach (e.g. Jones *et al*. 2002) will help identify key components of the river system for which specific investigations or environmental flow objectives are necessary. Panels are commonly confronted with systems requiring a combination of more water and better flow management.

Most Panels apply themselves to a set of general tasks when determining environmental flow requirements:

1. Identify and describe current biodiversity values, ecological processes and significant environmental values (assets) associated with the waterway.
2. Assess the major threats, in particular the impact of the changed hydrological regime, to the environmental values described in task 1.
3. Recommend ecological objectives and the environmental flow regime and other management actions that are required to maintain the Basin's environmental values identified in task 1 and protect those that task 2 identified as being under threat.
4. Advise on the environmental implications of a number of flow regime scenarios developed by the project (steering) group.

For example, Sinclair Knight Merz (SKM 2001) have developed a method that is to be applied in two stages.

Stage 1:

- project inception to set the scope of the project,
- data collation on system hydrology, geomorphology and ecology,
- development of a site paper that consolidates collated information,
- field work,
- issues paper that describes the rationale for environmental flow recommendations.

Stage 2:

- analysis (supported by survey and modelling work),
- report of environmental flow recommendations.

Other examples are shown in Figures 1, 2 and 3. Figure 1 illustrates the general process of determining environmental flows to meet river rehabilitation objectives established for the Thomson-Macalister River. Figure 2 illustrates the decision framework adopted by the expert reference panel (ERP) considering environmental flow packages for the River Murray, following an earlier major ERP review (Thoms *et al*. 2000). Figure 3 illustrates a best practice framework proposed by Arthington *et al*. (1998).

The following activities support the tasks described in the examples presented in the three figures:

- confirmation of the spatial extent of the study area and representative reaches to be considered by the Panel. Representative reaches can be defined on the basis of system geomorphology and water supply operation — i.e. geology and points of control in the water supply system.
- integration of knowledge of the historical and current environmental condition of streams in the study area (including the considerable experience and knowledge of the river system held by Panel members);
- consultation with relevant management agencies to understand the operation of the system;
- a field trip, used to assess environmental conditions at sites across the study area;

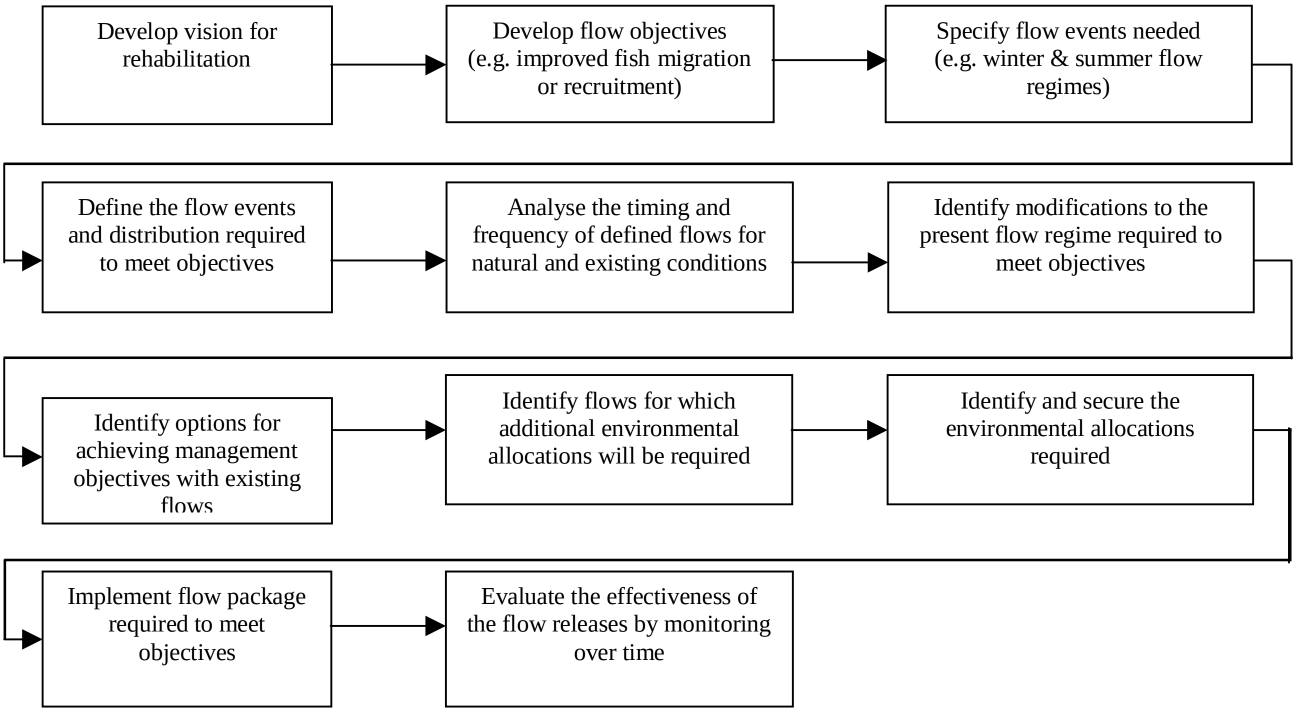

Figure 1. Providing environmental flows to meet river rehabilitation objectives (from Cottingham *et al.* 2001c)

- consultation with local community representatives to gain their perspective of the river system;
- analysis of hydrological data to identify changes to stream hydrology that have occurred since the regulation and diversion of water for agriculture and urban supply;
- hydraulic modelling of sites representative of each river reach;
- a series of workshops so that Panel members can develop a common understanding of the river system, important environmental values to be protected and how these values may have been affected by regulation and other catchment activities;
- the development of recommendations for a flow regime that will protect or enhance the environmental values identified for the river system.

6.2 Methods and information needed

It has been estimated that the literature records more than 100 different techniques for advising on environmental flows, and that more than 30 countries now use them as water-resource management tools (J. King and R.Tharme, pers. comm.). Many of the methods are unsuited to Australian conditions because of the unpredictability and large variability of flow regimes in many of our river systems. No single framework or set of methods has been adopted consistently across Australia.

It was recognised at the workshop that the method that a panel may adopt will depend on the terms of reference and the information and resources available. However, there is an expectation that the method adopted by a Panel will be consistent with previous experience in Australia and other countries with highly variable flow regimes, including methods classed as ‘holistic’; for example those described by Arthington *et al.* (1992, 1998). The chosen methods should consider the system at the widest possible spatial scale, and recognise the river–floodplain interactions, rather than just focus on in-channel features.

One key question considered at the workshop was: What are the best available tools and information for linking changes to hydrology with ecosystem changes? The following discussion explores some

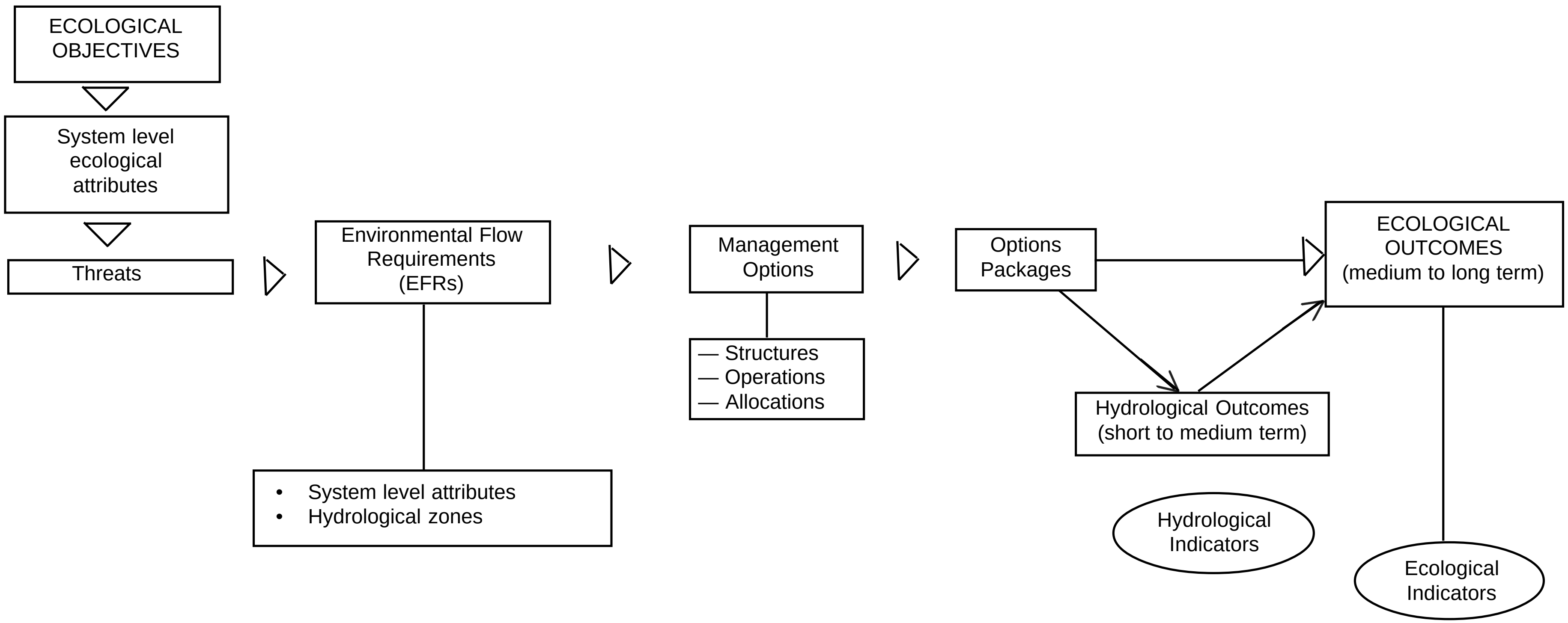

Figure 2. Schematic representation of the deliberation and decision process followed by the Murray expert reference group (Jones *et al*. 2002)

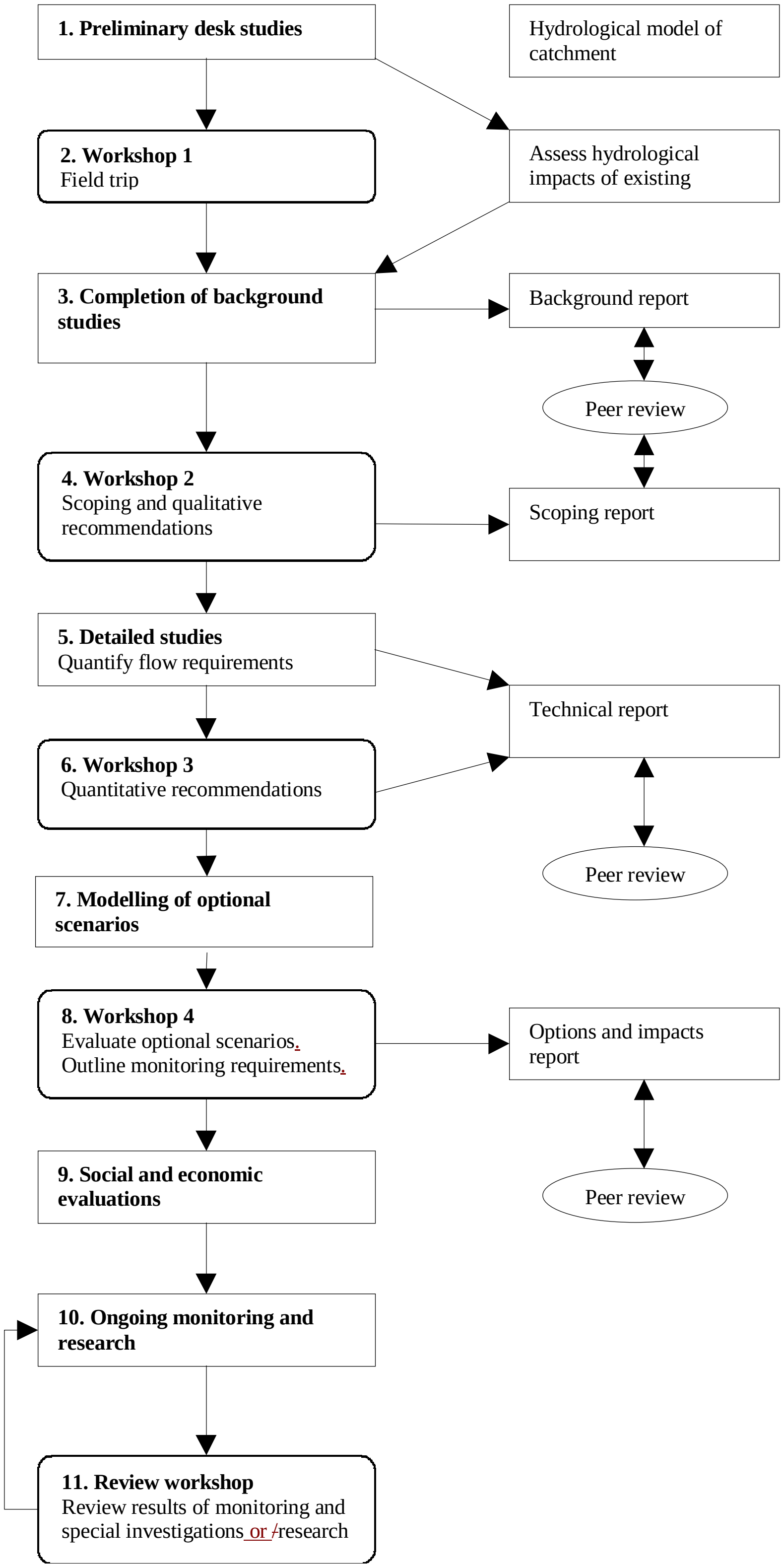

Figure 3. Best practice framework for determining environmental flows in river systems (for more details, see Arthington *et al*. 1998)

of the points raised about the usefulness of the types of information commonly used by Scientific Panels.

6.2.1 Hydrology and hydraulics

Common inputs of hydrological information are generally related to flow (including actual data for existing conditions and modelled natural flow data), information about the potential operation of the water supply system (e.g. points of flow management), and measures of hydrological deviation from natural. This information is used to quantify the frequencies of floods and droughts, undertake spell analysis, identify commence-to-flow levels and develop accession/recession and flow-duration curves.

Panels usually prefer daily (or continuous) flow data instead of weekly or monthly data. Daily flow data are essential if a Panel's terms of reference require small-scale ecological considerations. Monthly flow data often have limited application for developing environmental flow recommendations, but they may be sufficient if they match the scale being considered by the panel (e.g. seasonal, annual patterns of water allocation, or flow in large lowland rivers). Care is needed when interpreting 'natural' or 'reference' modelled flows that have been derived from monthly data, and flows modelled at very low or very high water levels. A review of what can be achieved with monthly flow data would be helpful for identifying the scale at which flow variables can be realistically applied in water allocation plans.

The workshop participants noted that there is still not an agreed set of flow parameters or statistics for describing flow regimes, modifications to flow regimes or environmental flows. A high priority in Australia is to develop such a set, or sets, of parameters or statistics and to show how the statistics relate to ecological or geomorphological responses under different flow scenarios.

Key hydrological information includes:

- daily flow data for present and natural flow regimes,
- information on the operation of dams, weirs, diversions, etc.

It is often hypothesised that ecology and flow are related because of the linkage between hydrology and the structure or availability or suitability of habitat. Many of the hypotheses that form the basis of environmental flow recommendations, particularly those targeted at small scales of resolution (e.g. in-channel), are based on hydraulic processes. Hydraulic models (e.g. HECRAS) are, therefore, useful tools for examining these links and can be used by Scientific Panels to address specific issues, such as:

- the needs of rare and endangered species,
- fish popular for recreational fishing,
- the needs of biota with specific habitat requirements,
- the wetting of features such as river bars, benches and backwaters.

Most of the ecology–flow relationships used when developing environmental flow recommendations are qualitative or at best semi-quantitative. The relationships need to be quantified and modelled, to improve the certainty associated with decision making.

Key hydraulic information includes:

- stream cross-sections,
- longitudinal profiles,
- hydraulic parameters predicted from models for various flow-regulation scenarios (e.g. wetted perimeter, wetted area).

6.2.2 Geomorphology

Geomorphology and sedimentology are usually investigated in environmental flow studies to predict what will happen to habitats for biota. An understanding of geomorphological processes is an important intermediate step when assessing the qualitative and quantitative links between hydrology and ecological processes. For example, large flow events are important for flushing sediments from riffles and pools and therefore maintaining habitat structure, complexity and quality for macroinvertebrates and fish.

Key geomorphological information includes:

- data describing the initiation of sediment movement,
- flows governing substrate composition,
- previous geomorphological studies and information on the trajectory of changes in response to past changes in land use, including dams. Where is the system now and where is it likely to go in the future?

6.2.3 Biology and ecology

Much of the monitoring of river ecosystems in Australia is undertaken to assess water quality and hydrology, with more recent work to determine river health. Scientific Panels try to use this information to develop ecology–flow relationships that serve as the basis for determining the environmental flow requirements of a river. A key feature of this approach is to identify the desired ecological outcomes likely to result from particular environmental flow releases. The outcomes can be assessed by considering if a river system is closer to 'healthy' or not, or by comparing components of a river that receives environmental flows with another 'healthy' system that is used as a reference. 'Benchmarking', as applied in Queensland, uses such comparisons to assess the probability that flow regulation will have a stated range of ecological consequences (Whittington 2000).

Environmental flow studies often use ecological and biological indicators as response variables when assessing changes to a flow regime (i.e. we seek to identify the ecological outcomes of environmental flows as well as using hydrological indicators to assess compliance with a flow management plan). Ecological indicators may include animal population measures (abundance, size structure), aquatic community measures (diversity, species composition, proportion of exotic species) and process measures (productivity, decomposition, P/R ratios, food web structure).

Key ecological information includes:

- water quality parameters (e.g. temperature (including instances of cold water pollution), dissolved oxygen, turbidity, suspended solids, nutrients, EC, pH);
- macroinvertebrate indicators (e.g. AUSRIVAS scores (Coysh *et al*. 2000), number of families, number of disturbance-sensitive taxa, SIGNAL scores (Chessman 1995));
- empirical relationships between macro-invertebrates and environmental condition (Marshall *et al*. 2001);
- fish indicators or metrics (e.g. number of species present, number of native species present, species composition of the fauna, % total abundance comprising exotic species);
- in-stream barriers to fish migration;
- fish habitat preference criteria;
- basic cues for reproductive biology, spawning and migration;
- aquatic and riparian vegetation indicators, including floristics — for example, species composition, proportion of native species — and structure (e.g. groundcover, understorey and overstorey);
- presence of weed species.

7 Future for Scientific Panels

The workshop participants felt that Scientific Panels as a tool might not yet be at their peak in terms of usefulness. The generation of new ecological knowledge is slow (there have been few controlled flow experiments, and ecological responses may occur over long time-frames) but the refinement and complexity of questions being asked of Panels has increased. Monitoring and assessment of environmental flows are essential to let panels see the success of their efforts and to help them improve their performance in the future. To date, this monitoring and evaluation phase has been lacking due to factors such as the difficulty and expense associated with design and implementation, and the priorities of agencies.

Reliance on Scientific Panels as a tool for recommending environmental flows is likely to continue for the foreseeable future. Sound procedures and guidelines that are widely endorsed by scientists, water agencies and stakeholders are needed to help increase the efficiency of panel processes and activities. Areas such as decision theory assessment, ecological risk assessment and environmental ethics may offer valuable insights when developing procedures and guidelines.

The community of freshwater scientists in Australia is relatively small and panel conveners often choose members with previous panel experience. Some scientists serve on many Panels and have developed considerable experience in the conduct of Panels, so that they run very efficiently. This can also mean that different Panels can have considerable overlap in membership, resulting in similar views and interpretations. A potential disadvantage is that this may limit the diversity of recommendations and constrain the development of novel solutions.

7.1 Filling knowledge gaps and other forms of assistance

Key knowledge gaps identified at the workshop included:

- the causal links between hydrological change and ecological response — quantitative and predictive models are required to relate flow changes to ecological changes;
- the temporal and spatial scales at which ecosystems respond to changes in flow regime (and how to scale-up from reach-based assessments, say, to whole-of-river decisions);
- how to deal with data of varied quality and reliability;
- the ecological outcomes of environmental flows already included in the flow regime of some regulated rivers. There have been few instances of environmental flows being delivered as recommended and even fewer instances of monitoring and assessment of these flow changes; and
- confirmation of appropriate indicators for monitoring the ecological outcomes of environmental flows.

Scientific Panels could assist in addressing these knowledge gaps by:

- investigating the causal links between hydrological change and ecological response (e.g. via literature review, current research, new investigations, comparison of generic principles with river-specific data, investigation of potential scale mismatch between hydrological data and ecological responses);
- stating the uncertainty associated with specific recommendations;
- developing specific questions (hypotheses) about flow–ecology relationships that can be tested by short term experiments; and
- stating the temporal scale at which responses to environmental flows are likely to occur.

Other measures that would assist managers dealing with environmental flow issues include:

- providing methods so managers can assess whether they should focus on environmental flows, physical in-stream habitat rehabilitation, riparian restoration, water quality issues, or all of these; and
- presenting flow recommendations as a range related to probabilistic statements of outcomes (cf ecological risk assessment), rather than as single numbers. ‘Benchmarking’ is a risk-assessment approach developed to cope with situations of data scarcity and limited capacity to predict ecological outcomes (Vanderbyl 1998, Whittington 2000).

8 Conclusions

The widespread use of Scientific Panels is testament to their value to water resource managers, in the absence of quantitative data. Panels may be valued for:

- providing independent and credible advice on the ecological implications of water management activities, supported by scientific understanding and extensive experience;
- explaining environmental water needs, based on credible and defensible information and models, that guide debate on the allocation of water;
- integrating hydrological, geomorphological and ecological information from many sources; and
- providing advice on short- and long-term priorities for action.

The workshop participants considered that the Scientific Panel approach was yet to reach its full potential as a tool for determining the environmental flow requirements of river systems. The Panel process should evolve to consider applications to pressing management issues other than flow allocations (e.g. physical habitat rehabilitation, riparian rehabilitation) and could incorporate other disciplines and other ways of thinking (e.g. benchmarking, risk analysis, decision theory, principles of restoration ecology).

Participants considered it important to develop agreed procedures and guidelines, so providing a consistent basis for the conduct of Panels, to maximise the usefulness of the Scientific Panel approach as a tool for determining environmental flows. Procedures should aim to guide the selection process to ensure that the Panels have an appropriate range of expertise, and to facilitate and improve interactions between Panel members.

9 References

Arthington A.H. (1998). Comparative evaluation of environmental flow assessment techniques: review of holistic methodologies. LWRRDC Occasional Paper 26/98, Land & Water Resources Research & Development Corporation, Canberra, ACT.

Arthington A. and Lloyd R., Eds (1998). Logan River trial of the Building Block methodology for assessing environmental flow requirements: workshop report. Centre for Catchment and In-Stream Research, Griffith University, Brisbane.

Arthington A. and Long G., Eds (1997). Logan River trial of the Building Block Methodology for assessing environmental flow requirements: background papers. Centre for Catchment and In-Stream Research, Griffith University, Brisbane.

Arthington A.H. and Zalucki J., Eds (1998). Comparative evaluation of environmental flow assessment techniques: review of methods. LWRRDC Occasional Paper 27/98, Land & Water Resources Research & Development Corporation, Canberra, ACT.

Arthington A., Brizga S. and Kennard M. (1998). Comparative evaluation of environmental flow assessment techniques: best practice framework. LWRRDC Occasional Paper 25/98, Land & Water Resources Research & Development Corporation, Canberra, ACT.

Arthington A.H., King J.M., O'Keeffe J.H., Bunn S.E., Day J.A., Pusey B.J., Bluhdorn D.R. and Tharme R. (1992). Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems. Proceedings of an International Seminar and Workshop on Water Allocation for the Environment. Centre for Water Policy Research, Armidale, pp. 69–76.

Arthington A., Brizga S., Choy S., Kennard M., Mackay S., McCosker R., Ruffini J. and Zalucki J. (2000). Environmental flow requirements of the Brisbane River downstream from Wivenhoe Dam. South East Queensland Water Corporation, Brisbane, and Centre for Catchment and In-stream Research, Griffith University, Brisbane.

Bevitt R., Erskine W., Gillespie G., Harris J., Lake P.S., Miners B. and Varley I. (1998). Expert Panel environmental flow assessment of various rivers affected by the Snowy Mountains scheme. Report to the NSW Department of Land and Water Conservation.

Chessman B.C. (1995). Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat specific sampling, family level identification and a biotic index. *Aust. J. Ecology* **20**, 122–129.

Cottingham P., Thoms M. and Quinn G. (2002). Scientific Panels and their use in environmental flow assessment in Australia. *Aust. J. Water Resources* **5**(1), 103–111.

Cottingham P., Stewardson M., Roberts J., Metzeling L., Humphries P., Hillman T. and Hannan G. (2001a). Report of the Broken River Scientific Panel on the environmental condition and flow in the Broken River and Broken Creek. CRC for Freshwater Ecology Technical report 10/2001 to the Department of Natural Resources and Environment.

Cottingham, P., Hannan G., Hillman T., Koehn J., Metzeling L., Roberts J. and Rutherfurd I. (2001b). Report of the Ovens Scientific Panel on the environmental condition and flows of the Ovens River. CRC for Freshwater Ecology Technical report 9/2001, to the Department of Natural Resources and Environment.

Cottingham, P., Barton J., Finlayson B., Hart B., Quinn G., Raadik T. and Stewardson M. (2001c). Development of a rehabilitation plan for the lower Thomson and Macalister rivers — a scoping study. CRC for Freshwater Ecology technical report 5/2001, to the Department of Natural Resources and Environment.

Coysh J.L., Nichols S.J., Simpson J.C., Norris R.H., Barmuta L.A., Chessman B.C. and Blackman P. (2000). AUStralian RIVer Assessment System (AUSRIVAS) National River Health Program Predictive Model Manual. Cooperative Research Centre for Freshwater Ecology, Building 15, University of Canberra, ACT 2601, <http://ausrivas.canberra.edu.au/ausrivas>.

DNRE (2002). Healthy rivers, healthy communities and regional growth: Victorian river health strategy (draft). Dept of Natural Resources and Environment, Melbourne.

Hobbs R.J. and Norton D.A. (1996). Towards a conceptual framework for restoration ecology. *Restoration Ecology* **4**, 93–110.

Jones G. and Cartwright S. (2002). Future Visions for the River Murray. Murray-Darling Basin Commission and CRC for Freshwater Ecology. <http://www.mdbc.gov.au/naturalresources/e-flows/eflow_picturebook.html>

Jones G., Hillman T., Kingsford R., McMahon T., Walker K., Arthington A., Whittington J. and Cartwright S. (2002). Independent Report of the Expert Reference Panel on Environmental Flows and Water Quality Requirements for the River Murray System. CRC for Freshwater Ecology report for the River Murray Project Board, July 2002.

King J.M. and Louw D. (1996). Development and use of the Building Block Methodology for assessing instream flow requirements in South Africa. In: *Proceedings of LWRRDC and MDBC workshop on instream flow methodologies,* Cooma, ACT, June 1995.

Kirshner J.L. (1997). Setting riparian/aquatic restoration objectives within a watershed context. *Restoration Ecology* **5**(4S), 15–24.

Lockwood J.L. and Pimm S.L. (1999). When does restoration succeed? In: Weiher E. and Keddy P. *Ecological Assembly Rules: Perspectives, Advances, Retreats.* Cambridge University Press, Cambridge, pp. 363–392.

Marchant, R., Frankenberg, J., Humphries, P., Rutherfurd, I. and Smith, G. (1997). Scientific Panel environmental flow assessment of the Coliban River below Malmsbury Reservoir and the Campaspe River below Redesdale. Report to the Campaspe Bulk Water Entitlement Project Group, DNRE.

Marshall J., Negus P., Marshall C., Choy S., Bell D. and Gooda M. (2001). Development of empirical relationships between flow regime and ecological condition in Queensland rivers. Freshwater Biological Monitoring Report No. 29, January 2001, Dept of Natural Resources, Queensland.

Royal Society of Canada. Expert Panels: manual of procedural guidelines. (http://www.rsc.ca/english/expert_manual_intro.html)

SKM (2001). A method for determining environmental water requirements in Victoria. Report to the Department of Natural Resources and Environment.

Swales S. and Harris J.H. (1995). The expert-Panel assessment method (EPAM): A new tool for determining environmental flows in regulated rivers. In: Harper D.M. and Ferguson A.J.D. (Eds) *The Ecological Basis for River Management*. Wiley Press, Oxford, pp. 125–135.

Swales S., Bishop K.A. and Harris J.H. (1994). Assessment of environmental flows for native fish in the Murray-Darling Basin — a comparison of methods. *Proceedings of the AWWA Environmental Flows Seminar*, Canberra 25–26 August 1994.

Thoms M., Sheldon F., Roberts J., Harris J. and Hillman T. (1996). Scientific Panel assessment of environmental flows for the Barwon-Darling River. Report to the Technical Services Division of the NSW Department of Land and Water Conservation. CRC for Freshwater Ecology, Canberra.

Thoms M., Suter P., Roberts J., Koehn J., Jones G., Hillman T. and Close A. (2000). Report of the River Murray Scientific Panel on environmental flows. Murray-Darling Basin Commission, Canberra.

Vanderbyl T. (1998). Assessing environmental flow requirements in the Fitzroy Basin. In: Water for the Environment — recent approaches to assessing and providing environmental flows. *Proceedings of Australian Water and Wastewater Authority Forum*, Brisbane, Queensland, pp.1–10.

Whittington J. (2000). Development of relationships between flow regime and river health. Outcomes of a joint CRC for Freshwater Ecology and Queensland Dept Natural Resources workshop. CRC for Freshwater Ecology technical report 6/2000, University of Canberra, ACT.

Other publications of the CRC for Freshwater Ecology

The Cooperative Research Centre for Freshwater Ecology publishes books, identification guides, guidelines, newsletters, technical reports, magazines, booklets and brochures. All the publications are listed on our web site, <http://freshwater.canberra.edu.au>, which is updated regularly.

A particularly popular product is our free newsletter/magazine, *WaterShed*. Like many others of our products, it is available free of charge, or it can be read on, or downloaded from, our web site, in PDF or HTML format.

To have your name added to the mailing list for *WaterShed*, or to obtain copies of our other publications, please phone 02 6201 5168, or fax 02 6201 5038, or email <pa@lake.canberra.edu.au>.