The first decade of water resource planning in Queensland: What have we learned about environmental flows?

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Abstract

Environmental flow studies for water resource planning in Queensland commenced in the mid 1990s, in response to water management reforms outlined by the Council of Australian Governments, and now fall within a legislative framework defined by the *Water Act 2000*. A new methodology for environmental flow determination specifically tailored to the needs of the water resource planning processes was developed, i.e. the Benchmarking Methodology. This paper outlines seven key points regarding environmental flow determination arising from studies across nine major Queensland basins: 1) the importance of a holistic approach, 2) the use of conceptual models, 3) the relevance of the entire flow regime, 4) surface–groundwater interactions, 5) the significance of how water is taken, 6) "top-down" vs. "bottom-up" approaches, and 7) the role of Government as the decision-maker.

Keywords

Holistic methods, conceptual models, Benchmarking Methodology

Introduction

Environmental flow studies for water resource planning in Queensland commenced in the mid 1990s, in response to water management reforms outlined by the Council of Australian Governments (COAG – see ARMCANZ and ANZECC 1996). The *Water Act 2000* provides a legislative framework for water management in Queensland compatible with COAG requirements. Water Resource Plans (WRPs) are subordinate legislation to the *Water Act 2000* and provide a more detailed basis for water management at the basin scale.

Reviews of existing methodologies for determining environmental flows at the basin scale were undertaken in the early stages of the process, including a full-scale trial of the South African Building Block Methodology in the Logan River catchment (Arthington 1998, Arthington & Long 1997, Arthington and Lloyd 1998, Arthington & Zalucki 1998, Arthington *et al.* 1998). None of the reviewed methodologies was found to be suitable for reconnaissance-level assessments in large catchments, so a new methodology specifically tailored to the needs of the WRP processes – the Benchmarking Methodology – was developed (Brizga *et al.* 2002, Brizga *et al.* in press).

The author has been involved in the development of nine Queensland WRPs, encompassing the Barron (Brizga *et al.* 1999, 2001a), Burdekin (Brizga *et al.* 2006a, b, c), Pioneer (Brizga *et al.* 2001b, c), Fitzroy (Department of Natural Resources 1998, Brizga *et al.* 2004a), Burnett (Brizga *et al.* 2000a, b. c), Mary (Brizga *et al.* 2004b, 2005a, b), Logan (Brizga *et al.* 2006d), Moreton Region (Brizga *et al.* 2006e, f) and Gold Coast (Brizga *et al.* 2006e, f) basins. All these "basins" (some include multiple river catchments and AWRC basins) drain to the east coast of Queensland. Latitudinally they span a broad area, extending from Cairns in the north to the NSW border in the south, encompassing wet tropical, dry tropical and subtropical environments.

This paper reflects on the lessons learned from the above studies, outlining seven key points regarding environmental flow determination. More detailed information can be found in the reports cited in the above, particularly the most recent publications (i.e. Brizga *et al.* 2006a, b, c, d, e, f).

1) Holistic approach

A holistic approach to environmental flow assessment is one that aims to consider all relevant ecosystem components, generally via the use of multidisciplinary scientific panels (Tharme, 2003). The outcomes of the

Queensland WRP environmental flow studies (as cited above) clearly demonstrate that a holistic approach to environmental flow assessment is needed to ensure that all significant issues are identified and considered.

Relevant ecosystems include riverine ecosystems (instream, high flow channel, and floodplain), linked groundwater bodies (particularly alluvial aquifers) and groundwater-dependent ecosystems, estuaries and nearshore marine ecosystems. Riverine ecosystems have generally been the principal focus of traditional environmental flow studies. Freshwater inputs are of key importance for nearshore marine ecosystems in Queensland, via direct inputs (including water, sediment, nutrients and organic matter) and also via biological linkages, such as result from the use of estuaries as nursery habitat.

Abiotic and biotic components of these ecosystems are influenced to various degrees by flows. The scope of environmental flow studies for Queensland WRPs has included geomorphology, hydraulic habitat, estuarine hydrodynamics, hydrogeology, water quality, riparian vegetation, aquatic vegetation, aquatic macroinvertebrates, fish and other water-reliant vertebrates.

Complex response to flow regime change has been noted as a result of interactions between ecosystem components. For example, in the Brisbane River downstream of Wivenhoe Dam, elevated low flows and reduced high flows have converted many riffles to runs and promoted the growth of dense beds of aquatic macrophytes, with implications for the macroinvertebrate and fish faunas (Arthington *et al.*, 2000, Brizga *et al.*, 2006e). The same hydrological changes have also altered riparian vegetation communities via reductions in flood disturbance and elevated water table levels. Differences in timescales of response complicate and extend the adjustment process.

Holistic assessments can be made efficiently and cost-effectively using a staged approach, commencing with a broad scoping study followed by subsequent more detailed targeted investigations.

2) Conceptual models

Conceptual models, in the context of environmental flow studies, are representations of how flow affects whole ecosystems or parts of ecosystems, and of how ecosystems respond to flow regime change. They include cartoon diagrams, flow charts and graphs showing the form of particular relationships.

Conceptual models provide a systematic framework for the integration of information and data, which is particularly important in holistic environmental flow studies because of the wide-ranging scope of issues and extensive amount of information that needs to be considered. They can also be used to provide a systematic link to management. Conceptual models assist in identifying and prioritising the issues that are most important from the viewpoint of environmental flow management, rather than the facets of the ecosystem that are best understood. In this context, conceptual models are also important for identifying knowledge gaps and thus focusing further investigations.

3) Entire flow regime

The flow regimes of rivers and streams are directly susceptible to alteration as a result of water resource development (i.e. extraction, supplemented deliveries and interbasin transfers of water). They can also be influenced by other factors such as irrigation returns, point source inputs and catchment land use, particularly urbanisation.

Changes in river/stream flow regimes can have significant implications for associated ecosystems, including instream, riparian zone, riverine wetland, floodplain, estuarine and nearshore marine ecosystems. Linkages between flow regime change and implications for a single ecosystem component may sometimes be direct and simple (for example, reduction in aquatic habitat at a non-tidal site as a result of reduction in flow), but overall ecosystem implications are generally much more complex. In non-tidal rivers and streams, the whole flow regime plays some role in maintaining geomorphological and ecological functions. In estuarine and nearshore marine ecosystems, higher flows appear to be particularly important but the role of low flows is relatively poorly understood.

An understanding of the role of full range of flows, including medium and high flows, is particularly important in determining environmental flow requirements in systems where further development is contemplated (particularly dams or waterharvesting). In systems already considered to be fully developed, a greater focus on low flows may be appropriate, as this is often the only part of the flow regime that can feasibly be significantly altered through environmental flow management.

The WRP studies have used daily time-step hydrologic modelling covering a period of approximately 100 years to quantify flow regimes at networks of nodes throughout each basin. To link the hydrological data with geomorphological and ecological assessments, attributes of the flow regime have been characterised with reference to five functional categories: total flow volumes, no flow, low flows, medium and high flows, and flow regime variability. Environmental flow targets have specified using long-term statistical indicators that relate to each of these categories. It has been recommended that any assessment of flow regime change based on statistical indicators also be accompanied by examination of flow sequences, as any manageably small set of long-term statistical indicators cannot comprehensively cover every ecologically relevant aspect of the flow regime that could potentially be altered by water resource development.

4) Surface–groundwater interactions
Groundwater development can have significant impacts on surface water ecosystems via changes in river/stream baseflows. A stream can be converted from perennial or intermittent to ephemeral by falls in the water tables of associated alluvial aquifers, as reported from the Lockyer Valley in southeast Queensland (Brizga *et al.,* 2006e). Transmission losses for larger flows may also be increased. Surface water resource development may potentially affect groundwater, especially in situations where a significant proportion of recharge occurs via the stream bed and banks or floodplain surface.

5) How water is taken
The way in which water is taken from a river system exerts significant influence on the nature and magnitude of impacts arising from water resource development. Dams and weirs bring a wide array of impacts arising from impoundment and barrier effects, in addition to impacts arising from flow regime change, including:

- Conversion of pre-existing habitats to dam and weir pondages, leading to loss of riverine habitat (dams and weirs) as well as floodplain and upslope habitats (dams only), resulting in significant alterations to flora and fauna communities;
- Changes in water quality resulting from water retention in dam or weir pondages (as a result of water quality changes due physical and biological processes within the pondage and, especially in the case of dams, also as a result of the effect of a dam in capturing flood peak water quality), with implications for ecosystems within the pondage area and downstream water quality regimes; and
- Reduced connectivity between upstream and downstream reaches, with implications for downstream transport of sediment and dissolved and particulate organic matter, and upstream/downstream movement of fauna.

6) Top-down vs. bottom-up approaches
A “top-down” approach to environmental flow assessment uses the natural or existing flow regime as a starting point, and examines the consequences of altering or removing various components of the flow regime. The Benchmarking Methodology (Brizga *et al.* 2002, Brizga *et al.* in press) is a top-down methodology.

A “bottom-up” approach starts with no flows, and builds a flow regime to meet specified requirements. This is exemplified by the South African Building Block Methodology (Arthington & Long 1997, Arthington & Lloyd 1998, King & Louw 1998).

In systems where environmental flow requirements need to be identified in the context of improving the management of a fully allocated system, a bottom-up approach to environmental flow determination is appropriate. However, in systems where further allocations are contemplated, a top-down approach has been found to be more useful.

7) Government as the decision maker
In addition to benefits for the intrinsic values of ecosystems, environmental flow provisions will often also have benefits for the societal values of ecosystems (including fisheries, scenic and recreational values). However, environmental flow provisions may restrict the availability of water for consumptive uses. In Australia, the Government ultimately makes decisions regarding water resource allocation, and the role of science is to provide the best available information to inform these decisions. The Benchmarking

Methodology has been developed to link directly to the decision-making process by presenting information on the geomorphological and ecological implications of a range of alternative water resource management scenarios, which include imbedded assumptions regarding environmental flow provisions. This enables the decision-making process to be informed and transparent.

Conclusion

The science of environmental flows has evolved significantly over the past decade. A range of methodologies has been developed, in Australia and internationally, to deal with questions of environmental flow determination at a range of scales. In Queensland, information on environmental flow requirements at the basin scale was required for the development of WRPs and this has been provided using the Benchmarking Methodology. A holistic approach was essential to ensure that all relevant issues were covered. Conceptual models were used to structure and integrate large and complex arrays of data and information. Environmental flow requirements were assessed with regard to the whole flow regime, including low, medium and high flows, as well as flow variability. Surface–groundwater interactions were found to be of key importance in some areas, particularly where there has been significant development of alluvial aquifers. While environmental flow assessment is primarily concerned with quantities of water required for the environment, the way in which water is taken can significantly affect environmental outcomes, for example, via the impoundment and barrier effects of dams and weirs. A “top-down” approach to environmental flow assessment was found to be more useful than a “bottom-up” approach from the viewpoint of basin-wide planning. The WRP environmental flow determination process recognised the role of Government as the decision-maker, and focussed on providing the best available information to inform its decisions.

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References

ARMCANZ & ANZECC (1996). *National Principles for the Provision of Water for Ecosystems. Occasional Paper SWR No 3,* Agriculture and Resource Management Council of Australia and New Zealand and Australia and New Zealand Environment and Conservation Council: Canberra.

Arthington A.H. (1998). *Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Holistic Methodologies. LWRRDC Occasional Paper 26/98.* Land and Water Resources Research and Development Corporation (LWRRDC), Canberra.

Arthington, A.H., & Long, G.C. (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 and Department of Natural Resources, Brisbane, Queensland.

Arthington, A.H., & 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 and Department of Natural Resources, Brisbane, Queensland.

Arthington A.H., & Zalucki J.M. (Eds.) (1998). *Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Methods. LWRRDC Occasional Paper 27/98.* Land and Water Resources Research and Development Corporation (LWRRDC), Canberra.

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

Arthington, A.H., Brizga, S.O., Choy, S.C., Kennard, M.J., Mackay, S.J., McCosker, R.O., Ruffini, J.L., & Zalucki, J.M. (2000). *Environmental Flow Requirements of the Brisbane River Downstream From Wivenhoe Dam.* South East Queensland Water Corporation and Centre for Catchment and In-stream Research, Griffith University, Brisbane.

Brizga, S.O., Davis, J., Hogan, A., O'Connor, R., Pearson, R.G., Pusey, B., & Werren, G. (1999). *Environmental Investigations. Barron Basin Water Allocation and Management Plan.* Technical Report No. 4. Department of Natural Resources, Brisbane.

Brizga, S.O., Arthington, A.H., Choy, S., Duivenvoorden, L., Kennard, M., Maynard, R., & Poplawski, W. (2000a). *Burnett Basin Water Allocation and Management Plan: Current Environmental Conditions and Impacts of Existing Water Resource Development.* Department of Natural Resources, Brisbane, 2 volumes.

Brizga, S.O. (2000b). *Burnett Basin Water Allocation and Management Plan: Proposed Environmental Flow Performance Measures.* Department of Natural Resources, Brisbane, 2 volumes.

Brizga, S.O., Arthington, A.H., Choy, S., Duivenvoorden, L., Kennard, M., & Maynard, R. (2000c) Burnett Basin Water Allocation and Management Plan: Ecological Implications of Draft WAMP Scenarios. Department of Natural Resources, Brisbane.

Brizga, S.O., Hogan, A., Pearson, R.G., Pusey, B.J., & Werren, G.L. (2001a). *Barron Basin WRP. Ecological Implications Report.* Department of Natural Resources and Mines, Brisbane.

Brizga, S.O., Arthington, A.H., Choy, S.C., Craigie, N.M., Mackay, S.J., Poplawski, W., Pusey, B.J., & Werren, G.L. (2001b). *Pioneer Valley WRP. Current Condition Report.* Department of Natural Resources and Mines, Brisbane. 2 Volumes.

Brizga, S.O., Arthington, A.H., Choy, S.C., Craigie, N.M., Mackay, S.J., Poplawski, W., Pusey, B.J., & Werren, G.L. (2001c). Pioneer Valley WRP. *Proposed Environmental Flow Performance Measures.* Department of Natural Resources and Mines, Brisbane. 2 Volumes.

Brizga, S.O., Arthington, A.H., Choy, S.J., Kennard, M. J., Mackay, S.J., & Pusey, B. J. (2002). *Benchmarking, new a 'top-down' methodology for assessing environmental flows in Australian rivers.* In Proceedings of the International Conference on Environmental Flows for River Systems, incorporating the 4th International Ecohydraulics Symposium. Unpublished proceedings. Cape Town, March 2002.

Brizga, S.O., Craigie, N.M., Condina, P., Capon, S., Lait, R., Long, P., Arthington, A.H., & Bunn, S. (2004a). *Fitzroy Basin WRP: Overland Flow Amendment. Report on Environmental Issues.* Department of Natural Resources and Mines, Brisbane.

Brizga, S.O., Arthington, A.H., Condina, P., Connolly, N., Craigie, N.M., Kennard, M.J., Kenyon, R., Loneragan, N.L., Mackay, S.J., & Werren, G.L. (2004b). *Mary Basin Draft WRP. Environmental Conditions Report. (Includes Mary River, Burrum River and Beelbi Creek Catchments).* Department of Natural Resources and Mines, Brisbane. 2 Volumes.

Brizga, S.O., Balcombe, S., Connolly, N., Craigie, N.M., Mackay, S., Schlacher, T., & Werren, G.L. (2005a). *Mary River Basin Draft WRP: Environmental Conditions Report (Sunshine Coast Catchments).* Report for the Moreton Bay Waterways and Catchments Partnership and the Department of Natural Resources and Mines, Queensland.

Brizga, S.O., Arthington, A.H, Balcombe, S., Condina, P., Connell, M., Connolly, N., Craigie, N.M., Kennard, M., Kenyon, R., Mackay, S., & Schlacher, T. (2005b). *Mary River Basin Draft WRP: Environmental Flow Assessment Framework and Scenario Implications.* Report for the Department of Natural Resources and Mines, Queensland.

Brizga, S.O., Kapitzke, R., Butler, B., Cappo, M., Connolly, N., Lait, R, Pearson, R.J., Pusey, B., Smithers, S., & Werren, G.L. (2006a). *Burdekin Basin Draft WRP. Environmental Assessment Report. Phase 1 – Current Environmental Condition.* Department of Natural Resources and Mines, Queensland.

Brizga, S.O., Kapitzke, R., Brodie, J. Burrows, D., Butler, B., Cappo, M., Dowe, J., Lait, R, Pearson, R.J., Pusey, B., & Werren, G.L. (2006b). *Burdekin Basin Draft WRP. Environmental Assessment Report. Phase II – Environmental Flow Assessment Framework.* Department of Natural Resources and Mines, Queensland.

Brizga, S.O., Kapitzke, R., Brodie, J. Burrows, D., Butler, B., Cappo, M., Dowe, J., Lait, R, Pearson, R.J., Pusey, B., & Werren, G.L. (2006c). *Burdekin Basin Draft WRP. Environmental Assessment Report. Phase III – Environmental Implications of Possible Future Water Resource Management Scenarios.* Department of Natural Resources and Mines, Queensland.

Brizga, S.O., Arthington, A.H., Connolly, R., Kennard, M., MacAlister, A., Mackay, S., McCosker, R., McNeill, V., & Udy, J. (2006d). *Logan Basin Draft WRP. Environmental Investigations Report.* Department of Natural Resources, Mines and Water, Brisbane. 2 Volumes.

Brizga, S.O., Arthington, A.H, Duke, N., Evans, P., Hadwen, W., Kapitzke, R, Kenyon, R., MacAlister, A., McCosker, R., Mackay, S., Smith, M., Udy, J., & Vance, D. (2006e). *Moreton and Gold Coast WRPs: Current Environmental Condition Report.* Moreton Bay Waterways & Catchments Partnership and Department of Natural Resources, Mines and Water, Queensland. 4 Volumes.

Brizga, S.O., Arthington, A.H, Bennett, J., Connolly, R., Duke, N., Hadwen, W., Hunter, H., Kapitzke, R, Kenyon, R., McCosker, R., & Mackay, S. (2006f). *Moreton and Gold Coast WRPs: Environmental Flow Assessment Framework and Scenario Implications*. Moreton Bay Waterways & Catchments Partnership and Department of Natural Resources, Mines and Water, Queensland. 2 Volumes.

Department of Natural Resources (1998). *Fitzroy Basin Water Allocation and Management Planning:* Technical Reports. Department of Natural Resources, Brisbane.

King, J., & Louw, D. (1998). Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. *Aquatic Ecosystem Health and Management* 1: 109-124.

Tharme, R.E. (2003). A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. *River Research and Applications* 19: 397–442.