CRC for Freshwater Ecology

Scoping Study ScA1

Development of Options for a Quantitative Lowland River Model

Progress Report

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Summary

- The provision of management models and other quantitative output is a priority for the CRCFE.
- Traditional modelling strategies within the CRCFE have largely failed, and are likely to continue to do so without a fundamental shift in approach.
- The CRCFE is in any case unable and/or unwilling to properly resource large scale modelling studies of this type.
- There is a need for a 'bottom-up' approach to the development of research models.
- For the establishment of a centralized group of modellers with a responsibility to support and direct modelling within the CRC.
- Management requirements should be satisfied collaboratively by researchers and modellers outside the constraints of individual projects.

Introduction

The development of conceptual system models within IPs, while an effective tool for crystallizing and communicating our understanding of these systems, falls short of providing the quantitative answers increasingly demanded by the CRC, stakeholders, and the wider community. Mathematical models have been identified as a convenient way of communicating research findings to researchers and managers alike. This scoping study evolved out of the Combined Projects Workshop (IPs 1, 2, and 8) held at Monash in August last year, where the possibility of linking projects through such a model was discussed.

This study's purpose is to look at the options for developing a mathematical model of lowland river systems. The CRCFE currently has virtually no skill base in quantitative modelling, and recent modelling based projects (*e.g.* IP2) have not been resounding successes. This report therefore starts with an examination of past failures and attempts to map out a viable alternative strategy. Key requirements for the implementation of this strategy are discussed, and finally a number of recommendations made.

While the brief of this study specifies 'models', these are but one method of packaging and delivering quantitative information that emerges from research activities. Other methods, such as decision support trees, expert systems, or empirical (as opposed to mechanistic) models, will prove more appropriate in some instances. While it is outside the scope of this report to discuss their relative merits, the term model as used here encompasses all such meanings.

Modelling is simply a means to an end. Within the CRC, two uses for models can be identified: research-oriented models and management-oriented models. Research models (*e.g.* mechanistic type models) are intended to assist in formulating and testing research hypotheses, as a framework for the interpretation of data, and furthering our understanding of how complex systems work. Management models deliver quantitative answers to specific management questions. This is more than an arbitrary distinction, as is discussed below.

Lessons from IP2

It is the opinion of the team (Harper, Burden, Lawrence) that 'traditional' modelling strategies within the CRC have failed, and are likely to do so in the future. This has been highlighted by IP2, which was intended to develop a research-type model of sediment nutrient processes, and ultimately to distill this into a simpler but more robust management model capable of predicting sediment-water nutrient fluxes. The failure to properly implement the former has jeopardized the latter.

Originally sold as the unifying theme, the modelling within IP2 conspicuously failed to deliver. The modelling team, though having only a poor understanding of early diagenetic processes, made no effort to draw on the expertise of the experimentalists. For their part experimentalists apparently viewed the model as irrelevant to their work and considered their commitment to end with the delivery of data. Researchers had no confidence in, understanding of, or even opportunity to use, the model produced. For these reasons a derived management model would be worthless.

IP2 exemplifies large-scale modelling exercises we may characterize as 'top-down'. A project brief has stated the requirement for a management model, and researchers have been instructed to furnish data. However, all too frequently the essential co-operation taken for granted at the higher level may never materialize, and the project is effectively (if not officially) a failure.

An Alternative Strategy for Research Models

For the foreseeable future the CRC will possess neither the skill base, nor the resources to make this approach work, and must consider other modelling strategies. What the team has proposed is a more flexible 'bottom-up' strategy. Here researchers decide, based upon their expert knowledge of the system, what aspects would benefit from the development of small-scale research models. The models evolved by workers in similar projects would overlap and point the way towards larger integrated models. Again, these would only be developed if researchers perceived the need. This strategy has a number of advantages. Researchers have ownership of the models, and control directly their evolution. Feedback between experiment and model is maximized and the communication barrier between modeller and researcher removed. Models come to be viewed as an aid, rather than an impediment, to research.

This approach raises conceptual and practical difficulties. Conceptual problems include a lack of awareness or a misunderstanding as to the usefulness and limitations of models, and manifest themselves as entrenched skepticism or unrealistically high expectations. Interested researchers should be made aware (*e.g.* through discussions with modellers) of how models might be of relevance to their research, ideally backed up with concrete examples.

Practical difficulties include how to produce and solve a model, skills which researchers generally have neither the time nor the inclination to acquire expertise in. However, over the last few years tools specifically designed for these tasks (*e.g.* ModelMaker, Stella, Simulink) have allowed non-specialists to produce relatively sophisticated models. These tools frequently use a graphically based approach (Figure 1), and facilitate the translation from conceptual to mathematical models. Provision of such tools, and instruction on how they work and how to use them (again with seminars and particularly workshops) forms a crucial part of the strategy.

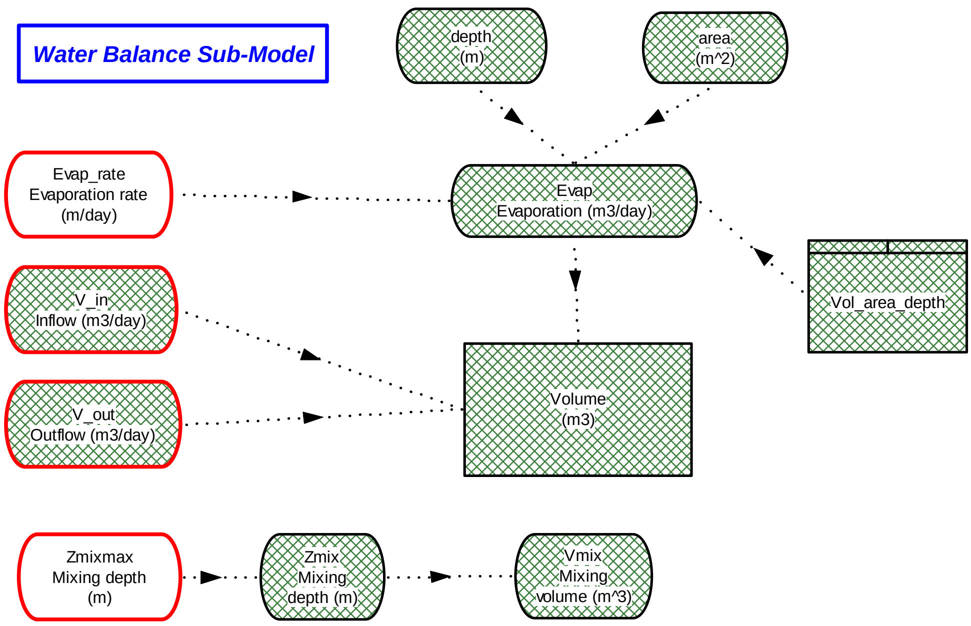

Figure 1. Component of a ModelMaker model for estimating reservoir volume based on inflow, outflow and evaporation rates.

Delivering Management Models

Evolving research models would still have to make the transition to management models. When workers have confidence in and understanding of research models, their packaging as tools usable by managers present much fewer difficulties. However, this approach on its own cannot ensure the development of appropriate management models. Even where management issues drive the research agenda, the nature and scope of research and management models will frequently be fundamentally different.

It is therefore crucial that while drawing on the research program, this activity should not be subsumed within individual projects. Accordingly there is a need for skilled ecological modellers given free rein to identify linkages between research models, and package into management tools quantitative information from across the CRC. While there is clearly a symbiotic relationship with Knowledge Brokers and linkages with the Technology Transfer program, these modellers must be grounded in the research program.

Implementing the Strategy

Implementing these strategies requires two components: a ‘distributed’ and a ‘centralized’ group. The distributed group will contain researchers engaged in building such models as they deem appropriate for themselves or their research groups. In this they will be advised and assisted (on a one-to-one basis or at workshops or seminars) by a centralized group of individuals with ecological modelling expertise.

Where deemed appropriate by researchers, the centralized group will take on the responsibility of linking these models, while maintaining their usefulness and flexibility as research tools. Eventually it will also fall to them to reconcile the conflicting requirements of research and management agendas by producing and delivering the most appropriate quantitative solutions to managers’ needs. These linkages are identified in Figure 2.

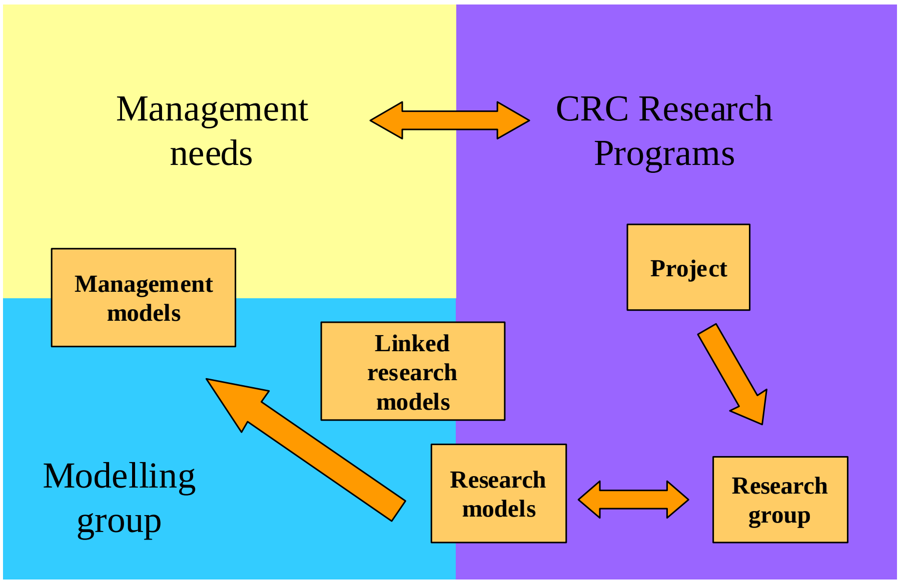

Figure 2. The relationship between research, management and modelling as envisaged in the proposed strategy.

Output

The above argument has formed the basis of the attached two page proposal, “Proposal to Establish a Modelling Support Team”, previously submitted to the Research Committee. The proposal has also been discussed with a number of CRC personnel, who have broadly supported its arguments and conclusions. In order to demonstrate how model development tools can be utilized in an ecological context, a model of phytoplankton dynamics in Cairn Curran reservoir has been implemented with the ModelMaker software, and is currently being evaluated by a research student at the Water Studies Centre. It is anticipated that this will shortly be available as an illustration of the capabilities of this type of software.

Recommendations

- The identification within projects of individuals willing to develop small scale models.
- The provision to these individuals of simple, graphical model development tools.
- The establishment of a central team of experienced modellers with a view to facilitating and advising on model development, and ultimately delivering management models.
- A series of seminars and workshops on models and modelling techniques, by the central group and invited external speakers.

Mike Harper

18/2/00

Proposal to Establish a Modelling Support Team

Background

Large integrated research projects, such as those related to lowland rivers, involve work across a range of disciplines in complex systems where the interaction of a large number of physical, chemical and biological processes determine system response to external forcing. Traditional methodologies seek to isolate a small range of processes identified as controlling behaviour in a particular system. While this approach may be successful, often the same underlying assumptions are justified only locally and the applicability of the research is limited. Moreover, even where only 3 or 4 processes are investigated, quantifying their interaction using conventional techniques becomes a significant obstacle.

Increasingly, process-based numerical models are employed to address these deficiencies: they are applicable across a range of systems, and the effects of adding or removing a process, or altering its importance can immediately be gauged. Ultimately therefore they provide the method for testing the validity of conceptual models and research hypotheses. However the success of previous modelling efforts within the CRC has been limited by a ‘black box’ type approach that restricts flexibility and alienates researchers.

There is a need to integrate the efforts within and between individual research groups working on a range of freshwater systems through the development and use of numerical models. This must be achieved without removing the models from the domain of researchers, for example by coding, and thereby stifling flexibility and ongoing development as new research findings emerge.

While of value in itself, this process is also a means to an end. The conservation and restoration of river systems increasingly demands numerical answers to evaluate management scenarios. Traditional research methodologies within the CRCFE lack an effective mechanism for communicating findings to non-specialists and cannot satisfy this requirement. Ultimately therefore research models of sub-systems must evolve to a stage where the findings of integrated projects can be used to answer specific management questions.

Objectives

- Development of process-based numerical models for a range of freshwater systems.
- Integration of modelling techniques into research hypothesis development and testing.
- Provision of tools to assist managers in making resource decisions, investigating scenarios and setting targets.
- Raising the awareness of, and skill base in, quantitative modelling within the CRC.

Project Outline

The project will be implemented at two levels: within individual research groups, and centrally within a group comprising the named project staff. The three successive stages are: -

1. Scoping of opportunities within research projects and programs for quantitative modelling. These will emerge from an assessment of compiled and documented existing

conceptual models developed as part of previous IPs, and from close liaison between project staff and individual research groups.

2. Translation, by individual research groups, of conceptual models into quantitative models of their systems or sub-systems of study. This will be facilitated and supported by the activities of project staff in several areas. Firstly, the provision and demonstration of visually / spreadsheet based modelling packages. These packages allow the rapid development of numerical models using a simple graphical approach without the need for coding. Secondly, by the provision of a suite specifically developed templates and tools covering a range of processes of relevance to several groups (sedimentation, advection and diffusion, nutrient transformations). Thirdly, by the provision where required of more complex models or general advice.

3. Where appropriate the linking of smaller models into integrated process-based models of freshwater systems. These will be documented and returned to research groups for evaluation and feedback. These models will represent our best attempt at quantitative descriptions of freshwater systems, and as such will provide a framework for the development of future research, identification of deficiencies in our understanding, and the basis for the development of management and decision support tools.

Philosophy

The central theme of this approach is to facilitate modelling activity within research groups. This has a number of advantages. By integrating modelling at the research group level, the feedback between models and experimental work is maximised. Relatively simple models constructed using visual tools can be rapidly built, tested, and adapted. This is in contrast to traditional approaches where the modeller is distanced from research groups, inevitably has a poorer understanding of the system, and takes months to produce inflexible coded models impenetrable to end users.

It is of prime importance that every opportunity is taken to encourage researchers to pursue a quantitative modelling approach. Consequently project staff will constitute an accessible, flexible, and responsive group whose goals are concomitant with those of research groups. Before most scientists will consider applying modelling techniques, their well-founded reservations must be addressed by building confidence in, and an understanding of, models. It is therefore envisaged that as an adjunct to model development there is an important role for project staff in educational and technology-transfer activities.

In a wider context, this project will develop a template for the successful implementation of modelling techniques across the CRCFE. Moreover it will ultimately help to establish communication and transfer of knowledge between scientists and external agencies seeking to apply research findings.

Output

- Publication of compiled conceptual models relevant to biogeochemical and ecological processes in freshwater systems.
- Quantitative models of these processes applicable across a range of systems.
- The development of a modelling ‘toolbox’ for a range of common physical, biological and chemical processes.
- The development of a strategy capable of satisfying the CRC’s needs for integrating individual research projects within a larger framework

- An enhancement at all levels within the CRC of its capability to undertake quantitative modelling.

Project Duration

3 year project, with possible extension to 5 years after review.

Project Team

Dr Mike Harper (WSC, Monash University)

Assoc Prof Frank Burden (Monash University)

Ian Lawrence (Univ Canberra, ACT Environment)

Budget (p.a.)

Cash	
Mike Harper (0.5)	
• salary	$25,000
• salary on costs (30%)	$7,500
• Institutional on costs (30%)	$7,500
Computing costs	$15,000
Operating costs	$10,000
Travel, seminars, workshops, consultations	$10,000
Total cash	**$75,000**
In kind	
Frank Burden (0.2)	$44,000
Ian Lawrence (0.2)	$36,000
Total in kind	**$80,000**
Overall total	**$155,000**