Integrated Models for Environmental Management

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Abstract The past decade has seen a significant increase in integrated approaches to the management of environmental systems. In Australia, this is nowhere more true than in the development of integrated catchment management (ICM). There exists scope for the use of models to enhance the understanding and decision making processes of ICM groups through the ability of models to allow scenario testing of alternative management actions. For those involved in environmental management there are differing scales of focus, and different modelling approaches appropriate to each scale. Many technically detailed models of individual components of environmental systems exist, and are appropriate to the management of individual system components. The problem of managing across many issues is sometimes tackled by putting together a number of individual models. For this approach to work effectively, attention must be paid to both the technical details of the interactions between system components and also to the processes through which these integrated models are developed. This paper explores technical and social aspects of the development of integrated models for environmental management and suggests that strict attention to the social process of modelling, as well as the technical process, will enhance the use, understanding and acceptance of an integrated model.

1. INTRODUCTION

Integrated environmental management (IEM) has come to the fore over recent decades as managers of environmental *systems* endeavour to improve upon earlier vertically, horizontally and functionally fragmented management efforts [Born and Sonzogni, 1995]. In the realms of land and water management in Australia, the movement to IEM has found focus in the development of the Integrated Catchment Management (ICM) approaches adopted within most States. In these approaches the *catchment* has been selected as the fundamental unit for land and water management activities despite, or because of, there traditionally being little recognition of catchment boundaries in the workings of Government.

ICM groups are based largely within the community, with a broad range of stakeholder representation, and varying degrees of input from agency and authority personnel. With 'community consultation' and 'stakeholder representation' being essential to the functioning of everything from monitoring and research to policy formulation, the community based ICM groups are gaining positions of power in the direction of policy and research of land and water management.

One of the needs of many ICM groups is a clearer understanding of how the complex natural catchment system works, and an ability to estimate where it is best to spend the meager resources available for the betterment of the catchment environment.

Simulation modelling of the catchment environment has the potential to provide ICM groups and others involved in catchment management with tools that enhance their understanding of their natural system, and allow "what-if" scenario testing of management policy. For modelling to be of use, however, considerable attention needs to be paid to both the technical and social aspects of model development. These aspects are explored in this paper.

2. CATCHMENTS AND MODELS

Many of the natural processes that occur in the catchment environment have been *modelled*, in that there exist quantifications and computer code that are able to simulate the natural system under a given set of circumstances. These models have generally arisen from research endeavours and are aimed at capturing the general nature of a particular system. Models cover many diverse aspects of the catchment, such as crop growth, farm economics, river flow, water quality, stream and terrestrial habitat, land use and nutrient generation, population dynamics, regional economics, biodiversity analysis, and infrastructure development. These types of models are adequate, and of an appropriate scale, for local, on-ground decision making, in that they provide quantification of the effects of implementing one management action over another, such as planting this crop or that crop, or releasing water from this dam or that dam.

These system component models do not, individually, satisfy the needs of those with a "whole of catchment" focus. At the ICM scale there is a different focus, concentrating more upon all the system components and their interaction, and the modelling that is appropriate to this scale needs to include both individual system components and broad system interactions.

3. PUTTING THE "MANAGEMENT" INTO ICM

Many ICM groups have undergone exhaustive exploration of management issues over the past few years, resulting in plans and strategies the clearly identify the problems facing those involved in catchment management. Difficulties can arise when it comes to prioritising the funding for actions and on-ground management because different actions:

- influence different issues in different ways; and
- have different levels of uncertainty on their physical, economic and social effects on the state of the catchment.

A role exists, therefore, for *integrated* models to clarify some of the alternatives, and also to clarify just where the uncertainties lie, and to what degree they actually alter the outcomes of various actions. At the ICM scale, the need is for integrated models that capture the interconnectedness of the individual system components and attempt to answer "what-if" policy questions such as:

> "if we plant this catchment area to high water-use pasture and trees, what will be the effect on groundwater level, surface water quality, farm profitability, township income, population and the local government rating base; and what will it cost?".

The development of integrated models also provides the opportunity to inject some rigorous science into what has, at times, been an endless circular debate over the pros and cons of various management alternatives. To effectively introduce technical rigour into integrated environmental models, and for models to generally be well formulated, there are a range of technical and social problems that need to be addressed.

4. PROBLEMS IN MODEL FORMULATION

Many of the players involved in the development of integrated models have reservations over some aspect or other of the process. Some of the researchers and scientists involved in the process have concerns for the loss of detail when only the skeleton of their model has been picked up and included in the modelling effort. There also exists the risk that our current knowledge is not sufficient for capturing the relationships between diverse factors, and that the whole modelling exercise will consequently lose credibility.

For ICM policy makers there is often a shift in focus required away from issues and towards management actions, for it is the alternative actions that are tested in a modelling framework, and the outcomes of the exercise determine to what degree various issues are treated. This can be at odds with those strategic planning documents that focus on dealing with a single issues of, say, population decline or loss of habitat, through the performance of a number of actions.

A third group that can have reservations over an integrated modelling exercise are those involved in undertaking on-ground management of individual system components. These people often know to a fine degree of detail what action is right in a specific case and just want to get on with doing it. For them, the broader question of whether the problem they are dealing with is the right problem to be funding at present can be quite challenging and a cause for concern.

There are therefore various social as well as technical issues that need to be dealt with in the development of integrated environmental models, and it is useful to consider the model building process as a social process with technical input rather than a purely technical exercise.

5. IS MODELLING AN ANSWER?

For many involved in the work of catchment management, the aphorism "if modelling is the answer, then it must have been a stupid question" holds true. This is particularly so for individuals who are strong advocates of single management actions, such as installing groundwater pumps to deal with rising water tables. Questions such as "Why is there a need to mess with computers when anyone can see that pumping out groundwater will fix the problem of rising water levels?" can be, on the face of it, difficult to answer. Of course, when there is an equally strong advocate for some other solution, the role for simulation modelling in analysing the alternatives, and mixes of alternatives, becomes clear.

It can be argued that an integrated system model that will allow comparison of the effects (physical, social, economic) of each suggested action, and various combinations of actions, provides a tool not only for option analysis, but also for redirecting debate from a finger pointing approach to constructive dialogue. Modelling can therefore be a useful tool not only for analysis of alternatives, but also for making progress towards consensus on actions to be undertaken.

6. THE NATURE OF THE MODEL

For an integrated model to be adopted and used by management there are, again, both technical and social aspects to be considered. On the technical front, the model needs to be portable, flexible, and easy to use, understand and explain. It should be of sufficient portability that individuals, who may be daunted by the prospect of fiddling with a computer in a public model gaming session, are able to take it home to run on their home computer. It might also be designed for access via the world wide web, so that anyone is free to use it, and it thereby avoids the trap of becoming a tool for a particular clique or interest group.

An integrated model should be flexible enough that it directly answers the major questions of management and also has scope to answer wider questions through manipulation of variables and parameters. This flexibility is a feature of good design, and adoption of a broad and open design process will enhance the opportunities for ensuring that the scope of the model is adequate.

A way towards developing a model that is easily used, understood and explained is to include a wide range of potential users in the model design and development process, and to continually expose them to model formulation. Through this the users will be able to refine their understanding of both the model and their natural system, develop a familiarity with the model, and ensure that the model meets their needs.

Undoubtedly, this approach will result in a model that is technically less detailed than were the task undertaken by a research group. Whether this matters or not depends upon the objective of the exercise. If the objective is to get a wide group of people 'up to speed' to a point where they can make informed decisions, then the loss of technical detail is balanced by the likelihood of the model actually being used.

7. THE PUSH FOR PROCESS

Given that there are benefits to be obtained from the development of integrated models for environmental management, attention turns to the process by which such a model is developed. Traditional approaches to the development of a model have involved a researcher, an office, a computer and some computer code, with maybe a lot of journal papers, a questionnaire, some monitoring, a considerable amount of thought and a dart board thrown in. The resulting software, which produces a technically precise representation of an environmental system, is then presented to an International Congress, at which the elegance of the model formulation and the accuracy of the calibration are admired, and finally published in an international journal for all the world to read.

When a catchment management group tracks down the model ten years later it is found that it is difficult to run, that is set up for a situation that does not occur in their catchment, and that the assumptions do not quite hold for the local conditions. When the model is finally run, the output does not really provide the parameters that are appropriate to the questions facing management.

This is neither the fault of the researcher nor the manager, but rather the fault of the process that tries to use a research model, wherein the fundamentals of the system are captured, in an individual case study where exceptions to the rules abound. It can be argued, therefore, that there is a need for *process* that bridges the gaps between the general rules and fundamental truths of a research model and the multiple exceptions facing the manager. One process is to have the managers and the researchers work together on the model so that it answers the problems that the manager is facing with a level of technical certainty that is acceptable to the researcher. This process of developers and users combining in model formulation has been dubbed "white box" modelling [Bonnicksen, 1985].

In developing integrated models for environmental management, where there are many management questions, and many system components to be modelled, the role for white box modelling becomes even clearer as a process by which all parties gain a clear picture of the technical details, assumptions, guesses and limitations of the resulting model.

8. WHITE BOX MODELLING IN PRACTICE

It is very easy to talk about open processes, white box modelling and that Holiest of Grails, community consultation, but putting it into practice is difficult, if not impossible, under some circumstances. In its purest form, white box modelling involves bringing players together and taking them all through every step of model development. Steps include selection of input variables, setting the scale of the exercise, component models identification, data analysis, selection of parameter values in the models, and identification of output variables. This type of process is incredibly consuming of both time and money on the parts of all players, but it guarantees that all players have a stake in, and an understanding of, the system simulation program.

Aspects of white box modelling have been used in nutrient modelling of a number of catchments in Australia, through both the Catchment Management Support System, and application of the Adaptive Environmental Assessment and Management (AEA) process [Grayson et al., 1994; Argent et al., 1995]. In the application of the AEA process to the assessment of nutrient sources and loads in the Goulburn River of Victoria, stakeholders were included at various times in the selection of:

- processes to be included in the system simulation;
- the output parameters of the models;
- analysis of nutrient export concentrations from different land uses;
- data collation on nutrient generation by different land use activities; and
- the formulation of algorithms for assessment of risk of blue-green algae blooms.

At the end of the modelling process the stakeholders reached consensus on the major sources of nutrients in the system, and management was given a mandate to undertake more detailed studies to further investigate specific issues.

One of the potential drawbacks in the white box modelling process is that it clearly exposes lacks in data and understanding. For example, in the formulation of a blue-green algae risk index in the Goulburn River, researchers admitted that the causes of blue-green algae blooms were not well understood, and that the best that could be done was to indicate periods of risk when nutrients were high, and the water was clear and warm. This lack of knowledge was accepted by the stakeholders, but in some circumstances it is possible that the level of lack of knowledge is such that it undermines the whole modelling process.

The acknowledgment of lack of detailed understanding of some natural systems can be challenging to researchers, but can be turned into a strength for the process by involving all players in the formulation of the 'best guess' representation of a system component. Overall, the open framework of white box modelling has strengths in taking all players along the same model formulation path so that the technical details, assumptions, guesses and limitations of the resulting model are accepted and understood by all. This therefore increases the likelihood that the model will be used in the assessment of management alternatives, and the outcomes of the modelling process will be acted upon.

9. IS IT RIGHT?

Is white box modelling the right way to go? The degree to which the modelling process should be open and explicit depends upon both the nature of the problem and the nature of the players. Much of the time, people are happy for the knowledge holders to work separately on individual components of the model, provided there is opportunity to review and alter the final model if it does not fairly represent the process in question. Other people or groups, particularly those concerned with highly contentious issues, may want more explicit detail on every step in the process, to ensure that no bias or external influence goes unacknowledged.

The essence of the modelling process comes down to building trust - trust and acceptance that all the essential components of the system and the interactions of those components are integrated in the model, and that the final model fairly represents the way that the system works, at a level of detail required by the decision makers and achievable with present understanding. The level of detail is the *key* part of the model building experience - it determines whether the model represents truth, in the eyes of the users, and whether there is a reasonable chance of the model being used.

10. CONCLUSION

In this paper we have attempted to establish that use of modelling for environmental management is more constrained by the process of model building than by the technical details of the component models.

If model builders genuinely want their creations to be used in integrated environmental management, they must undertake a process that fully involves stakeholders and potential users, that exploits what we know now, and that illustrates the influence of uncertainty in our technical knowledge. In this way the decision makers are in a position to ensure that their 'best guess' decisions make use of the best information available.

11. REFERENCES

Argent, R.M., Ladson, A.R. and Grayson, R.B., Modelling, managing and massaging environmental systems with AEAM, in Hutchinson, W., Metcalf, S., Standing, C. and Williams, M (Eds), *Systems for the Future,* Proceedings of the Australian Systems Conference. Perth, Western Australia, September, 1995, Faculty of Business, Edith Cowan University, 152-159, 1995.

Bonnicksen, T.M., Initial Decision Analysis (IDA): a participatory approach for developing resource policies, *Environmental Management, 9*(5), 379-392, 1985.

Born, S.M. and Sonzogni, W., Towards integrated environmental management: strengthening the conceptualization, *Environmental Management, 19*(2), 167-183, 1995.

Grayson, R.B, Doolan, J.M and Blake, T., Application of AEAM (Adaptive Environmental Assessment and Management) to water quality in the Latrobe River Catchment. *Jour. of Environmental Management, 41*(3), 245-258, 1994.