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Experiences in an Integrated Assessment of Water Allocation Issues in the Namoi River Catchment, Australia

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Abstract: The Namoi river catchment in northern NSW is an important irrigation region. However water resources in this region are increasingly stressed. Both surface and groundwater supplies are overallocated in many areas of the catchment. Management options to reduce allocations in line with available supply and environmental requirements are expected to have long term social, economic and environmental implications. This paper looks at an integrated assessment model which has been developed to assess long term outcomes of management options for water allocation in the catchment. The development of this tool has been undertaken using an iterative approach with key stakeholders. Feedback on the model and preferred future directions of development arising from discussions with relevant stakeholder groups are discussed. A key aspect of the model framework is that it has been developed to be general enough for reapplication to water allocation issues in other catchments Lessons are drawn from this experience in framework development for the field of integrated assessment.

Keywords: Integrated Assessment, economic modelling, hydrology, stakeholder participation

1. INTRODUCTION

Integrated assessment (IA) of natural resource and management issues is increasingly being adopted by Government agencies internationally. In Australia, the concept of Integrated Catchment Management has been strongly supported at both the national and state level (eg. Cunningham [1986]). However, the development of integrative tools for assessing the trade-offs involved with various policy and regulation options is at an early stage. This paper provides details of an integrated assessment project that was undertaken in the Namoi River Basin in northern NSW, Australia. The project focused on the development of an integrative modelling framework for considering water allocation issues in the catchment. Integration in this project involved both an integration of disciplinary approaches (economics, hydrology) as well as the integration of stakeholders into the model development process. This paper provides background to the framework developed and then discusses feedback from stakeholders on their views of the advantages and limitations of the modelling approach. A number of lessons for integrated assessment arising from this project are also discussed.

2. WATER ALLOCATION IN THE NAMOI CATCHMENT

The Namoi river catchment in northern NSW is an important irrigation region, covering approximately 43,000 km^2. Water resources in this region are increasingly stressed. Both surface and groundwater supplies are overallocated in many areas of the catchment. Management options to reduce allocations in line with available supply and environmental requirements are expected to have long term social, economic and environmental implications. The model discussed in this paper has been developed to consider the management of surface and groundwater supplies throughout the catchment. Further details on the management issue considered by the model can be found in Letcher (2001).

2.1. Modelling framework

The modelling tool that was developed is based on an integrative economic-hydrologic modelling framework. This modelling framework consists of regional scale economic models underlaid by a hydrological flow network. Each region is

modelled as a single profit maximising producer using a nested linear programming-dynamic programming modelling approach. This approach simulates both short and long-run farmer decision making in the region.

Regional scale economic models are linked to the hydrological flow network using policy and extraction models. The policy model mimics State Government policy on commence and cease to pump thresholds, extraction limits and licence volumes in the catchment. The extraction model disaggregates annual extraction volumes derived from the economic models to daily extraction amounts. A more detailed description of the modelling framework is given in Letcher (2001).

2.2. Stakeholder interaction

In the context of this project, the term 'stakeholder' is used to refer to local community members, staff at the various departmental offices within the catchment and members of the various River Management Committees (RMCs) operating in the catchment. RMCs are themselves composed of representatives from Government departments, irrigators and environmentalists. Stakeholders have been utilised in several ways in the development of this model framework:

- **Issue Framing.** Initial choice and focusing of the model issue, and the alternative management options available, were determined using stakeholder views and concerns expressed in different fora. Nancarrow *et al.* [1998a, 1998b] surveyed stakeholders in the catchment regarding re-allocation of groundwater and the development of environmental flows in the catchment. These surveys demonstrated many of the allocation concerns of various stakeholders in the catchment, as well as identifying their priorities and preferences with regard to re-allocation policies. These surveys provided important background information for scoping management issues in the catchment, the complexity of the water allocation issues in the catchment and possible solutions seen by stakeholders to these problems. A meeting of the Unregulated, Regulated and Groundwater River Management Committees was also held in the Namoi catchment in August 1999. This meeting brought together members of all these committees for a facilitated discussion of management issues and priorities in the catchment. Attendees were required to identify the needs and immediate concerns of each of these committees as well as the community as a whole, to identify areas of overlap between these needs and issues, and to identify alternative options to address these requirements. The outcomes and discussion that took place during this meeting were observed and documented and used to focus attention on management issues in the catchment, in particular water allocation, and the alternative options available to the catchment managers. Of particular interest (and concern) was the fact that off-allocation access was identified by all three committees as a possible solution to their management issues. The focus of this project and initial ideas for alternative management scenarios arose from attendance at this meeting.

- **Model Development.** Definitions of relatively homogeneous regions (see Letcher [2001]) were refined using an iterative process with various stakeholders. An initial cut of regional definitions was taken to the stakeholders for comment. Stakeholders were invited to comment on the appropriateness of regional boundaries and the regional structure was progressively refined with the comments of various stakeholders, using local knowledge of production systems and resources in the catchment. In this way stakeholders were encouraged to understand the way in which the model was being constructed and the assumptions behind its construction. This was also important in allowing stakeholders to query and, in many cases, correct modelling assumptions. It is hoped that this process will ensure stakeholders have a better understanding of the assumptions and limitations of the model, as well as having greater appreciation of the strengths and limitations of the model developed and its outputs. Stakeholders were also consulted on alternative management scenarios they wished to be considered by the model. Stakeholders' knowledge of various aspects of the production system was used to determine not just the current characteristics of each region, but also to identify alternative resource use and management scenarios which could be employed by producers in each region. This was to ensure that the model was as useful as possible to catchment stakeholders as well as to help ensure that the model was as accurate as possible.

- **Model testing and communication of results and conclusions.** The model developed in this paper was presented to a variety of stakeholders during a series of public seminars and discussion sessions. Details of model

input assumptions, structure and also advantages and limitations of the approach were presented. Stakeholders were then asked to provide feedback on numerous issues, including whether or not they felt the model would be useful for policy, and what future they would like the model to have (if any). This feedback was both informal with comments during and after these sessions provided informally, as well as formal, with feedback provided in the form of a written questionnaire.

3. STAKEHOLDER FEEDBACK

Final feedback on the 'first pass' model was sought from a large group of stakeholders through a series of public seminars and discussions. This section provides details of some of the responses of stakeholders to the model. Stakeholders were also asked to prioritise their preferences for future developments of the model.

3.1. Advantages of the Model

Stakeholders were asked to list the advantages they saw of the modelling approach presented to them. A number of stakeholders stressed the importance of the integrated approach used in the model, with the combination of economics and hydrology being seen to 'help make better policy decisions'. The modelling approach was widely assessed to be good for clarifying the relative impacts of changes at the large scale because, as summarised in the words of one respondent, it is 'starting to actually quantify in dollars the impact of changes in water allocation'.

Some stakeholders stressed the importance of the ability of the model to be used in extension of information from technical staff to Catchment Management Boards and other management committees. One respondent stated that the model 'allows for a much quicker explanation process for committees, acceptance of scenario outcomes when all parties can participate in model runs' and that the model would be 'good for demonstrating downstream impacts of upstream decision making'. Other stakeholders also mentioned the flexibility and accessibility of the model as strengths of the approach, with one stakeholder stating that it 'should be possible to adapt the model to a wide range of catchments and policy/natural resource issues'.

Finally the open process of model development was considered to be an advantage for some stakeholders. One stakeholder stated that it was important to involve farmers in the model development process. He felt that it was necessary to ensure that the model remained transparent and accessible to irrigators, especially those on the management boards and committees, in order that the model was not a 'black box" to these groups.

3.2. Limitations of the Model

Several limitations of the current model were referred to by stakeholders providing feedback. The emphasis that stakeholders placed on these limitations differed greatly, depending in many cases on the background of the respondent. Most limitations involved the model structure. The main limitations that were mentioned by stakeholders were:

- the lack of a groundwater modelling component, and thus the lack of links between groundwater and surface water systems;
- crop yields and water use not being linked to climate;
- assumptions about pumping flood flows - some stakeholders suggested that irrigators are unlikely to pump the rising stage of a flood flow in many areas of the catchment as they risk losing their pumps. It was suggested that the model should allow for this as otherwise it overestimates the amount of water actually available to irrigators;
- assumptions about the decision making behaviour of farmers. Several stakeholders raised concerns about
  - assuming farmers are profit maximising;
  - assuming each region is controlled by a single farmer;
  - the lack of differentiation between farmers especially with respect to their levels of knowledge and expertise, and their financial ability to invest and change production.
- the simplified representation of Peel River subcatchment - some stakeholders suggested this should be replaced with a more detailed nodal network for this region to allow investigation of trade-offs between the Peel River users and the rest of the Namoi catchment.

Another set of limitations were the assumptions surrounding farmer decision making. These were discussed at a number of the meetings. Stakeholders' opinions on the importance of this assumption to model outcomes differed widely. Some stakeholders raised this as an issue of concern, whilst others were unconcerned or supportive of the approach taken in the model. On the whole, most stakeholders seemed to accept that these simplifying assumptions still allowed relative magnitudes of impacts to be estimated, whilst

keeping the analysis of the impacts relatively simple. Stakeholders were also challenged to consider alternative decision rules that would better represent farmer decision making in the catchment. The flexibility of the framework to allow use of a 'decision tree' approach or other type of decision making formulation was raised. In many cases stakeholders were seen to raise an assumption as an issue, follow their own line of reasoning through the pros and cons of the assumption and then decide in favour of the more simple assumption currently present in the model. Several stakeholders felt that starting simple, and then adding complexity to the model through discussions with stakeholder groups, was a good approach to take. They felt that this would allow them to see the advantages and disadvantages of each additional piece of model complexity, to see whether additional complexity actually had any real impact on the results. They also felt that testing the model at each of these stages of development would allow users to better understand the implications of new assumptions.

Other model limitations mentioned by stakeholders concerned the lack of 'individual impacts' from the model, and also validation of the model. Several stakeholders expressed a desire to see further validation and testing of the model, especially before it is widely adopted for policy analysis in the catchment. One stakeholder expressed concerns over the hydrological models, wanting further details of hydrological model validation and testing to be made available. This may indicate that follow-up work, focusing on delivering more detailed information on model validation (or evaluation) may be required in the future to ensure acceptance and adoption of model results and recommendations.

As a part of the presentations made to stakeholders, the appropriate uses of the model were stressed. In particular it was pointed out that the model did not provide information about impacts on individual producers, rather it should be used to consider 'catchment scale' impacts and trade-offs between upstream and downstream users. One stakeholder expressed concern at the lack of 'individual producer' impacts provided by the model. A strategy for including nested scale (farm to catchment) models to stakeholders was discussed.

One final warning was provided by another stakeholder on the use of the model. This concerned the relative ease of grabbing a 'single number' from the model as an outcome, rather than providing relative changes. This may affect the way in which the system should provide output to stakeholders (ie. should it only report percentage changes from some 'base case' scenario?). Also the use of multiple, rather than single, climate scenarios should be considered when providing policy recommendations.

4. DISCUSSION

Integrated models tend to be fairly complex, containing a representation of a number of distinct system features. The broad view of these models generally means that a large number of assumptions are made about interactions between system components, and simplifications of individual system components are required in order to keep the modelling, and analysis of results, tractable.

The large scale issue focus that drives most IAMs means that a number of 'boundaries' have to be placed on the system considered. Results from a very complex or comprehensive model can also become quite difficult to analyse in more than a rudimentary sense. The large number of non-linearities in the system can make it difficult in many cases to see cause and effect within the results. The trade-off between simplicity and complexity in the model should be driven by the issue focus and the identifiability of the model. Often components that are peripheral to the central issue can be ignored or simplified, at least on the 'first pass' of development. Including these more complex details after the simpler model has been tested can allow the user to better understand the internal workings and trade-offs in the model (and the underlying system). Being faced immediately with the results from a model which tries to capture all or most of the system complexity may mean that none of the more basic (and often more meaningful) relationships within the model are able to be seen and understood because they are obscured by the more complex, often peripherally important interactions.

4.1. Ramifications for the Use of Models in IAM

The need to find an appropriate balance between complexity and simplicity in the model means that an adaptive, on-going process of model development is preferable to focusing on a 'final product'. It also means that the limitations and assumptions of the model need to be clearly stated and communicated, especially to stakeholder groups who are likely to use the model for considering policy questions. One of the problems with this is whether or not this message is heard, and used, by stakeholders and policy makers. The tendency to rely heavily on 'one number' in policy, and the desire to use such complex, integrative models for these purposes is problematic.

Integrated assessment models are rarely developed to be capable of finding such precise, 'single number' answers to policy. They are normally developed to allow investigation of the trade-offs of various policies and so are best used to estimate the magnitude and directions of change (at most) rather than for precise prediction. The problem in many cases is the misuse of such information in policy, where model results may be given much greater credence than is often warranted. One positive benefit of an adaptive, on-going process of development, which includes a dialogue between stakeholders and researchers, is that researchers are in a better position to educate on good model practice, in particular on the uses and misuses of integrative models. It also means that stakeholders are able to communicate their changing policy environment to researchers so that the model maintains its relevance to the community it serves.

In the case study model presented in this paper the focus of initial model development was on developing a framework for integration that would be useful for considering water allocation in the short-term, but which was flexible enough to allow for further refinement and development on the basis of stakeholder needs and the continuously changing policy environment in the catchment. This means that the model discussed in this paper is not and should not be seen as a 'final product'. It is the product of a 'first pass' in an adaptive process of model building and integrated assessment that will hopefully continue for many years. In the words of one of the stakeholders surveyed on their views on the current model it is 'best to start simple and then, if needed, add more detail '.

In terms of the case study model described in this paper, this adaptive process of modelling is likely to contain a number of future options. Stakeholders have suggested a number of modifications they would like to see made to the model including:

- development of a groundwater modelling component;
- updates to daily extraction rules once these have been signed off by the Minister;
- inclusion of conceptual/empirical crop modelling components, preferably utilising results from models already in use in the catchment;
- development of a more comprehensive network for the Peel system to better represent this system; and
- development of a graphical user interface able to be accessed at some level by managers in the catchment, possibly housed with regional staff at State Government Agencies in the catchment.

These suggestions have been made by a fairly broad group of stakeholders, each with a different priority for the future of the model. At the time of writing this paper, the future of the model was still up for discussion with a variety of stakeholders, however it was generally agreed that stakeholders saw its future as a tool available to catchment managers in the region. The focus from these discussions was generally placed on continuing development of the model past the life of this first project, so that a 'consensus' model would be available to managers for the five-year review of current operating rules (~2005). One of the most positive aspects of the model developed mentioned by stakeholders was the openness with which the model was presented for their feedback. Stakeholders were very receptive to the broad consultative, adaptive approach undertaken to developing the model, and felt that this would lead to fewer misunderstandings about the model and its appropriate use. In particular, previous models used to consider management issues in the catchment were seen as being 'black box' approaches. A general feeling of mistrust of the results from such approaches was expressed by members of the Catchment Management Boards. The open, on-going process of model development trialed in the case study of this paper was seen as having the potential to overcome these issues of mistrust.

4.2. Uncertainty

Uncertainty in both individual component models and also in the whole system representation is an important feature of integrated assessment models. Component, disciplinary models may be fairly inaccurate where insufficient data are available to identify model parameters, and to accurately reproduce observed behaviour. This uncertainty is often compounded by linking these inaccurate, uncertain component models together, often in a non-linear way. The level of uncertainty in the final integrative model structure can therefore be large, and also very difficult to measure. Error accumulation in such complex models must be considered.

These uncertainty issues also imply the necessity for an on-going dialogue between researchers and stakeholders in model development. It is necessary that researchers strike a balance in communicating clearly the large levels of uncertainty inherent in such complex, integrative models to stakeholders while retaining a clear view of the useability (or otherwise) of the model for investigating policy questions. Illustrating this issue was the feedback from one stakeholder on the model developed in this thesis, who raised the following concern:

'It is too easy for people to grab a specific figure as the outcome rather than the relative change'.

This type of concern can only be overcome where a close relationship is maintained between model users and developers so that users can develop an appreciation of the uncertainty inherent in the model. The success of this will depend on how honest and open researchers are in discussing the short-comings of their work in a public forum - not necessarily an easy task in an area of research that relies heavily on a client focus and external funds. Stakeholders need to be allowed the opportunity to provide feedback to researchers throughout the development process. In this way both researchers and stakeholders can come to a better understanding of the uncertainties in the model and their importance when considering policy outcomes.

4.3. Issue Focus

Integrated assessment projects are normally focused on one or more management issues in the region of interest. This focus is required to set the boundaries of the system and of the assessment to be undertaken. It is also ideal for ensuring strong, ongoing relationships between researchers and stakeholder groups. However the length of time required to undertake a comprehensive integrated assessment means that the initial focus issue may be unimportant or irrelevant by the time the model is available to consider it (2-3 years is not an unusual length of time for model development). An obvious question then is: Was the effort in developing the model wasted? This problem requires that techniques used for considering IA problems utilise transferable, flexible approaches. It also depends on the broadness of the initial problem focus and model conceptualisation. So long as the problem focus is relatively broad and the conceptualisation is sufficiently flexible to allow future development of additional system components, then it is likely that the integrative model which is developed will be broad enough for reapplication to a number of issues. In this case an issue focus is very useful for fixing the appropriate boundaries of the assessment that is undertaken and for focusing interaction between stakeholders and researchers.

5. CONCLUSIONS

The way forward for Integrated Assessment is to encourage more rigour in integrated modelling and a more 'honest' approach to model building and reporting. It is necessary that the IA community investigates the adoption of results after the completion of projects, and publishes the results of this work for the IA community as a whole to learn from. It is also important that those involved in IA remember that the intention of IA is as a learning process for both researchers and other community members. As such we should hope to improve outcomes, but we must also allow for an investigative mind set. The emphasis of IA should remain on differentiating between outcomes or policies, not on accurate prediction. A second focus for IA should be on educating stakeholders as a whole to have more realistic expectations of the models which they are likely to use and an understanding of the situations in which they are appropriate and inappropriate. Only in this way can wide-scale misuse of model results be reduced and stakeholder concerns about a 'one number' approach to modelling be allayed. An on-going relationship through a series of projects focused around an integrated assessment is a good way to achieve many of these aims. In this way the IAM process can be adaptive to the changing social, economic and political environment of the area being considered.

Additionally, an integration focus should be maintained from the beginning of IA projects, with the development of a conceptual framework for integrating components being a key consideration in the initial phases of the project.

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