Environmental software and management questions - Is the cart before the horse?

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Abstract

Packaged software systems for managing environmental problems are widely available and have a range of capacities for investigating spatially and temporally complex environmental systems. There also exists many authoring software packages that simplify the construction of custom-built models. In developing software systems, either using existing packages or starting from scratch, it is possible that the management questions being asked are lost in the rush. In this paper we explore three examples of our experience in answering the questions of environmental managers, and commend an approach to environmental management software that starts with consideration of the management question and ends with the provision of a software tool.

Keywords

Environment, software, management, integrated watershed management

1 INTRODUCTION

The 1980s and 90s have seen a rapid proliferation of software tools intended to assist with decision making in environmental management. The increasing availability of high resolution spatial data, along with cheap and powerful computers, has made it possible for an extraordinary level of sophistication to be built into 'decision support systems'. But has this revolution in information technology been driven by the needs of environmental managers, or has it

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occurred simply because it can? Are model builders designing for their perception of the manager's needs, or for the actual needs as identified by the managers?

In this paper we present three case studies to illustrate our experiences with the role of software in environmental management. It is our contention that, while software tools can be important components of a decision making process, their role must be carefully considered in light of the overall management objectives and the audience for the exercise. We believe that the overall objectives can, and should, be used to identify, apriori, an appropriate role for software tools.

2 CASE STUDY 1. NORTH JOHNSTONE RIPARIAN RESEARCH

The riparian zones of many Australian rivers have been significantly altered since European settlement. Many of these changes have degraded the environmental integrity of the areas and raised both public and institutional concern. A national research program on riparian lands has been established, with a 5-year budget of over AUD$5.5 million and three main aims, vis:

1. To identify and quantify the effects of riparian lands on channel morphology, bank stability, and the ingress of sediment and nutrients to rivers and water bodies;
2. To identify the key processes by which riparian lands influence in-stream ecosystems and their functioning, and quantify major effects; and
3. To demonstrate practical, cost effective and ecologically sound methods for rehabilitation and management of riparian lands.

Three different research groups are working to meet these aims. As they are working on the same broad issues, it was thought necessary that a level of overall coordination be established between the groups during project initiation. This was needed to ensure that the goal of improved management of the riparian zone was not lost in the detail of the specific experimental projects. It was also thought important that the end users of the research, i.e. catchment managers, were informed of the work at the outset, and so were able to ensure that it was tackling the issues they face 'on the ground'.

To achieve these varied requirements, it was decided to undertake an Adaptive Environmental Assessment and Management (AEAM) exercise involving representatives from the research, funding and management groups. AEAM is a process that has been applied throughout the world since the 1970s (e.g. Holling, 1978; ESSA, 1982; Grayson et al., 1994) to a range of environmental management problems. A major focus of the approach is the production, in a group workshop environment, of a computer simulation model of the system to be managed. A broad stakeholder group defines the scope and output requirements of the model, and provides the information required to represent each of the important system processes, as well as the linkages between these. The involvement of the whole group in model development ensures a product that is consistent with user requirements, and incorporates best available knowledge of the system at an agreed time and space scale.

In the North Johnstone River example, the AEAM approach was attractive since it led to the development of a conceptual systems model of riparian lands. Ultimately, a model of this type may form a part of aim (3) above, but during project initiation there was insufficient detailed information to completely specify the model. A four day workshop was used to develop a model of the riparian zone without the benefit of new research results i.e., the model was based on the participants collective understanding of what they knew at the time. This provided a framework for assessing the importance of each proposed experimental project, and was seen as a means of achieving the following key objectives:

1. To develop strong links across research disciplines and establish an integrated approach for carrying out field investigations and model development;
2. To develop a computer model to predict the impact of riparian land management on stream water quality, stream bank stability, and in-stream and terrestrial ecology;
3. To determine previously unidentified knowledge gaps and research tasks from 'holes' in the model, and assess how these tasks fit into the three main aims of the research program;
4. To identify data requirements and common variables between participants; and
5. To design field experiments and demonstration sites which link the physical and ecological program objectives with practical management options.

Details of the exercise are given in Wilson (1995) but briefly, a particular catchment was chosen for the exercise to focus data collation. The workshop involved representatives from each of the three research groups, as well as catchment managers and government agency representatives. Note that the production of a simulation model alone, satisfies just one of the five objectives. In fact, the model development within the workshop environment was the means by which we met the remaining four objectives. Had we, as consultants, developed a model in isolation, there would have been little chance of meeting all five objectives.

It was found that the act of *building* a model rather than the *availability* of the model was the key. Of course, the resulting simulation tool may be used as the basis for a later decision support system (once the key knowledge gaps are filled), but even if it is thrown away tomorrow, the software has served its purpose. It is clear that this role for software is quite different to most applications where the emphasis is generally on the technical and interactive capabilities of the tool. An 'off the shelf' product would have been unsuitable in this example because of the emphasis on, and need for, a model *building* activity.

3 CASE STUDY 2. TOWNSHIP WATER MANAGEMENT

Bungaree and Wallace are two small rural townships. Water supply to these townships is from a combination of rainwater tanks and open channel reticulation, with wastewater being treated through individual household septic systems, and township stormwater flowing into local grassed paddocks. Under future urban planning schemes, the townships may become commuter towns, with the potential for large population increases. There is thus a large potential for township stormwater and wastewater to impact local waterways, particularly a major downstream storage, Lal Lal Reservoir. In 1994 the local water authority was put under considerable pressure to develop a wastewater treatment strategy for the townships, using either local treatment or wastewater pumping to a nearby city. Either option would have involved significant infrastructure development and expense.

The management problem facing the water authority was to estimate the likely water quality and quantity impacts of both stormwater and wastewater under a number of development and climate scenarios. Significant data were available to assist in this evaluation, including a huge range of stormwater and wastewater nutrient information (none from local sources), a little information on nutrient generation from different local land use types, monthly climate and streamflow information over more than twenty years, and a limited amount of water quality data for inflows to Lal Lal Reservoir.

Possible approaches to estimating the future impacts of township growth were:

1. Improved monitoring of streams, groundwater, and all other system components, to identify the range of conditions and impacts of the existing system, and then to extrapolate the results to the future scenarios;
2. Use of a coupled stormwater, wastewater and groundwater model, with dynamic spatial and temporal flow routing; or
3. Develop a simple rainfall and runoff volume and water quality balance model.

The third approach above was selected as offering the best opportunity for immediate use of the existing data, whilst providing the capacity for including new information arising from current system monitoring. The water balance model was developed on a spreadsheet, with inputs to allow calculation of total catchment runoff and nutrient generation from different land uses, storm and wastewater flow and nutrient loads from the townships, and effects of transport processes on loads and flows.

The input variables for the model included catchment and township parameters, such as area, nutrient generation rates and land use percentages, delivery efficiencies of nutrient loads to the reservoir from the catchment and townships, and climatic and flow data.

The modelling approach derived sediment and nutrient loads from the catchment and the townships as the product of concentration and flow. Given the wide range of values in the available data, maximum and minimum likely concentration values were used, so that the possible range in output total loads was provided. Twenty years of monthly historical climate and flow data were used to provide model flow data. These twenty years included wet and dry extremes. Model output was a graphical and tabular presentation of annual loads of sediment, phosphorus and nitrogen, from the total catchment and the two townships.

Two groups of variables were available to users for system exploration. The first of these reflected changes in the catchment and townships, while the second group were those that could be changed to reflect improvements in available data.

Although simple in nature, the software allowed the water authority managers to examine development scenarios, explore possible changes in catchment land use and test the sensitivity of the results to changes in the delivery efficiency to the reservoir. The managers were able to develop an understanding of the catchment and local urban components within system, including identification of the critical assumptions in pollutant generation and transport. The software used a common spreadsheet application, and so provided a familiar working environment to those who may have otherwise felt intimidated by a system simulation model. This was particularly useful, as the managers only use the software occasionally.

A recent review of those within the water authority revealed that the model is generally unused at present. It was used as part of a presentation to the water authority board to show that the management of wastewater from the townships was not currently an issue worthy of investment and time. The modelling findings, vis. that wastewater was not likely to be a significant problem in the near future under current planning approaches, and that the treatment of stormwater is also an issue that will have to be dealt with carefully under planning approaches, have become institutional knowledge. The managers are comfortable that the model is available and will still be relevant for when the issue of wastewater and stormwater arises again. Given the limited use that has been made of the software, we feel the choice of a spreadsheet approach over more complex modelling software, has been warranted.

4 CASE STUDY 3. ALPINE STREAM MANAGEMENT

Mt Buller village is an alpine resort in the Victorian Alps. It caters primarily for snow sports, with daily peak populations in winter between 11 000 and 15 000. Potable water supply for the village is obtained from the damming and diversion of a local stream. Snowmaking activity is by far the largest water consumer in the resort, with supply from a 75 ML mountain top dam with a small catchment.

To meet future water requirements for both potable water and projected increases in snowmaking area, two possible on-stream storages were planned. In planning for the construction of these dams, the Alpine Resort Commission needed to determine the supply potential from the two streams, whilst maintaining minimum 'environmental' flows in the streams for provision of aquatic habitat, particularly for the endangered stonefly *Thaumatoperla flaveola*.

There were very few data available for the construction and testing of the water management model. These consisted primarily of a few individual flow gaugings, some longer term gauging from one other alpine stream in Victoria, precipitation records from local weather station, and snow depth measurements over three winters (Gippel et al., 1996).

Possible modelling approaches included the use of a simple system model using dynamic simulation software, a spreadsheet input-output model, or the adaptation of an existing spatial and temporal modelling shell. The third approach was selected because it offered great flexibility in model construction, an output that was suited to management use and an internal structure that allowed simple inclusion of spatial processes, like snowmelt, and linear pump/ pipeline systems. The model used a grid-cell based representation, with moisture routing through a bucket water balance, snow fall and snowmelt calculation, runoff routed through a steepest descent approach, and with cell-based storage and pumping information. The model was not a fully calibrated representation of the hydrological response of the catchment, due to a paucity of flow data. The model ran on a weekly time step using climatic data for the three years 1988, 1989 and 1990. These years offered a wide range of snow conditions and winter temperatures.

The intended role of the software was to allow managers to explore water management scenarios. In the end the software was only of minor importance for the managers of the system, as water supply issues were shown to be secondary to geological constraints on the position and size of dams. It is possible that software development was unnecessary in this case, as a simple analysis of the data and the hydrological system would have identified the primary water harvesting constraints. These could have been conveyed to the managers in written form alone, within a report that was prepared on geological, ecological and hydrological considerations. Nevertheless, the clients thought that system software was appropriate, and, indeed, used the software in demonstrations for both internal discussion and media reporting. Thus, the software was able to fulfil a political purpose, whilst possibly being unnecessary for a technical purpose.

5 CONCLUSION

The examples presented highlight the approach we try to take in our treatment of environmental management problems. The role of software over these examples was found to be variable, ranging from politically expedient though technically unnecessary, to an ideal solution to the management problem. For some types of problems, the act of model building can be more useful than the resulting model.

In other cases not reported here we have found the use of software to be inappropriate.

Management questions can change as a project develops, and we have seen enthusiasm for software wane once the primary questions have been answered. This normally requires a focus on an initially simple tool, with more complexity being added if, and when, required. Working closely with clients during development from the simple to complex, enables the final role of the software (if any) to be identified *before* significant time is expended on model development.

There are many packaged environmental management software tools that can be modified to meet the requirements of management in particular problems, as well as a number of authoring software packages that simplify the construction of custom-built models. We commend an approach to environmental management software that starts with consideration of the management question and ends with the provision of a software tool. The art of the modeller is to chose the most appropriate tool or package for the particular problem, rather than force the problem to fit a particular tool. Productive use of environmental management software can occur only when managers have a very clear picture of the role and capability of the software, and the software designers have a very clear picture of the questions the managers wish to answer.

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7 BIOGRAPHY

Drs Robert Argent and Rodger Grayson have a background in environmental modelling. They are currently working upon methods for improving the flow of research information into catchment management processes and activities.