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Theme Paper *Theme I*

Research and development for management of water resources

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Abstract
Sustainability of fresh water supplies depends on improved management. However, the processes which determine availability of fresh water are poorly understood, too poorly for development of universally applicable theoretical models to analyse water resources situations. Therefore empirical models are used, most of which depend on local observed data for their calibration. To underpin the empirical modelling there is a need for a manyfold increase in monitoring of all water resources variables. To achieve this increase the cost of monitoring and archiving will need to decline by orders of magnitude – a major challenge for researchers! Another area of major need is how to integrate water resources management and socio-political policies. Widespread work in this discipline has had little effect on day-to-day water resources management. Why? Perhaps because socio-political policies change abruptly. Good ideas for improving water resources management are often irrelevent by the time they are developed. The social and economic framework in which they were to operate has moved on to another, quite different set of priorities and objectives. Changes in water resources management usually involve changes in attitudes of the community and in infrastructure, both of which require long timeframes. Therefore it is understandable that by the time "new" ideas are developed they may already be irrelevent. Social policy research on water resources management issues has therefore declined. How can we change this trend and encourage more research of all types to assist in solving the desperate sustainability problems of water shortages, flood damage control and increasing water logging and salinisation?

INTRODUCTION

Water resource use now exceeds local availability in many parts of the world. Clearly there must be doubts concerning the sustainability of such a situation. As population increases and living standards rise worldwide consumption and usage of fresh water will continue to rise. The worlds stock of fresh water is fixed except for possible small increases from desalination. Some countries, and huge numbers of other politically defined regions use far more fresh water than naturally occurs within their boundaries. For example a Table (World Bank 1999) of indigenous water supplies shows that Egypt and Turkmenistan depend on flows from upstream countries for most of the water they use. Many other countries also depend on cooperation and good relations with upstream neighbours for significant proportions of their supplies. Ongoing development of water resources by upstream countries must jeopardise the supplies of those downstream. Similarly much of the "fresh" water has already been used many times. Downstream consumers are therefore dependent on the good practices of those upstream in ensuring that all water returned to streams after use is of good quality. As population density increases the quality of returned water tends to decrease so that the water available from the lower reaches of many of the worlds great rivers continually declines in both quantity and quality.

Increasing populations also increase flood hazards. Rising population densities increase the numbers of inhabitants of flood prone regions, and increase runoff from upland areas due to increased land clearing and a general reduction of infiltration. As floods occur and the magnitude of the flood hazards are realised there are demands for implementation of flood protection and mitigation policies, both structural and non-structural types. However, over time we have learned that very large floods are hazards which, in general, can neither be prevented, nor reduced, so that there is a need to learn to live with them – to extract the benefits of flood plain habitation and development without incurring the costs of flood devastation.

Drought must also be recognised and accepted as a natural phenomenon which cannot be prevented but whose effects can be ameliorated. Irrigation schemes usually provide no drought protection because the benefits of gainfully using all available water as soon as possible are usually so great as to overwhelm the potential, but uncertain benefits of long term saving of water to provide good supplies during drought periods.

MODELS AND PROCESSES

In the age of enhanced capabilities for data manipulation and calculation, modelling must have an important role in the quest to improve management of water resources. Modelling skills and computational capabilities have increased so dramatically in recent times that it is now possible to model practically anything. The skills base and computer technology are no longer limiting, as they were before the 1980s. The causes of inadequate modelling are now quite different. They are mainly related to our inability to develop algorithms to describe the processes we attempt to model. In general, water resources management depends on many tried and tested general management principles. However the magnitude of the resource being managed is in a continual state of change depending on amount and timing of precipitation, amount and timing of streamflow, rates of groundwater recharge and discharge, evaporation and transpiration etc. Each of these components of the water resource system depends on numerous other processes, each of which is defined by a number of variables. For example, to describe the movement of a water molecule from its point of impact, as rainfall on a soil or vegetation surface, to its ultimate passage to the sea in river flow would probably require the consideration of more than 20 processes, each of which interacts with, or is dependent upon several other processes. Few if any of these processes are describable by a simple equation and many of them, though observable, can only be defined in qualitative terms or by grossly simplified approximations. How can we model what we do not understand and cannot define? Computational models need algorithms defining all the processes to be modelled. In water resources management there are so many unknown (and perhaps unknowable) processes and variables that all but the simplest of processes must be approximated. Certainly there are not models which can be used with success in different regions without local calibration. For example there are no models, which, without local calibration can provide reliable estimates of how much of a rainfall event will become surface runoff in the local waterways. Estimation of how much will run off from two different storms on the same basin cannot even be estimated accurately without intensive analysis of the local data and many days (or even weeks) of work by a competent hydrologist. There are streams adjacent to each other where all the parameters which are usually considered to govern storm flows are identical (basin size, slope, rainfall, soils, vegetation, geology), but where the observed flows in one are consistently several times larger than those in the other. How can this be? There must be some physical characteristics of basins which, at present, are not considered to influence runoff generation, but which are in fact dominating the hydrology. How can we model this? It has been noticed that in the far west of Australia, peak flood flows of a given frequency are about one order of magnitude smaller than floods from similar storms on similar sized basins on the east coast of Australia. If the Rational Method is used for estimating floods of a given frequency in the two locations, the runoff coefficient in the east will typically be greater than 0.8 but in the west it will be less than 0.2. Why? So if we cannot adequately model single items of the hydrological regime, such as peak flood flows, without heavy reliance on observed data to allow model calibration, it must be impossible, at present, to model the whole breadth of processes which impinge on water resources management.

In summary it can be said that the technology required for developing and running water resources models is already available but the limitation is that the model algorithms are hopelessly inadequate and will continue to be so for the foreseeable future. It is most unlikely that it will ever be possible to describe and define the movement of water through the land phase of the hydrological cycle.

However, this does not mean that hydrological research is a waste of time – far from it, as we shall see in the next section.

An added layer of difficulty in water resources management is imposed by the public nature of water resources. Water is a renewable natural resource, which in one sense, is owned by no-one and yet is owned by everyone. The problem of public resources is that their management is politicised. Hence water resources management does not only have to be undertaken within the constraints of physical laws and processes but also to interact with ever changing social and political expectations.

RESEARCH NEEDS (GENERAL)

Research is needed to increase understanding of the fundamental processes which influence water resources. To an extent the need for understanding of processes is not urgent in that we have learned to function adequately with our current level of understanding. However as demand for water increases and as the community develops greater environmental awareness it is likely that management strategies developed using these inadequate levels of understanding of the processes will gradually be seen to be inadequate. It will be realised by the public at large that the water environment could be much better managed than it is at present. It will gradually be seen that appropriation or allocation strategies, developed over the last century, when water demands were small and the freshwater systems had adequate capacity to provide acceptable dilution of any wastes delivered to the system, are no longer acceptable. Around the world there is a growing expectation that those who remove water from a system will return any residue in a condition similar to what existed for the initially removed water. This means that water users must protect their water from contamination or must treat it to remove all contaminants before it is returned to the river. This philosophy has led to a general, though small, improvement over the last 20 years or so, of the quality of water in many rivers in developed countries. However in most developing countries the quality of river water has continued to decline over this period. There is a need here to raise awareness of the need to reduce contamination of water in developing countries. Research is needed to ascertain the most efficient way to bring about a large change in public thinking, to encourage everyone to realise they contribute to their own environment by their attitude to water, and to protection of water from contamination. Presumably this is not an engineering research area. Rather there is a need for social sciences research on how to educate and change the attitudes of the general population. After all, any benefits of improved quality of environmental water accrue to everyone.

Research is also needed to determine bases for integrating social policies and the management of life-supporting water supplies. Water is widely regarded as a free good, a commodity supplied to everyone by "Nature". Education is needed to convince the public there is a large cost for capture, storage and later delivery of water to every potential user at the time of their need. In many countries the idea that water is a free good has prevented water supply companies charging the real cost of water to consumers. One result of this unwillingness to charge for water has been the decline of existing delivery infrastructure and a lack of interest in delivering water to more residences. It is interesting that electricity, for which consumers are usually billed for total consumption at the real price of delivering the energy, is connected to over 80% of all households world-wide. On the other hand water delivery is often subsidised, and water service providers are forced to depend on government support to survive. As a result good quality water is delivered to less than 50% of dwellings worldwide. This suggests the problem of water availability to all is not a matter of cost or pricing structure, but rather a matter of politics and attitude management skills. Politicians and community leaders apparently believe all are willing to pay for electricity delivery but not for water delivery, and as a result most water companies, particularly in developing countries, do not have the finances to even maintain, let alone provide an expansion, of the delivery infrastructure. How can this inadequacy of water supply services be overcome? It is not just a matter of capital investment. It is more a matter of attitudes, education, community cooperation and leadership in decision making. Research is needed to understand how to deal with this problem, both in general, and in particular cultural settings, so that some moves can be made to begin towards the Mar del Plata World Water Forum aim of providing safe drinking water to all households. Since that 1973 statement of purpose the proportion of worldwide households connected to a piped water supply has actually declined! Why? How can we begin to reverse this trend and head towards achieving the aim, not by 2000 as was the earlier (1973) stated goal, but perhaps by 2050?

RESEARCH NEEDS (SPECIFIC)

Periodically articles appear giving lists of research needs. Sadly the lists are usually personal opinions and they are usually rapidly overtaken by changing circumstances. Having made that criticism here is another (short) list. Some sub-disciplines where intensive attention is required are

- how to change the population's attitudes to the fresh water environment
- a basis for integration of social policy and the management of our life-supporting water resources
- how to encourage more widespread and more detailed observation and archiving of water resources data.

Missing from this list is the ever present need for greater understanding of the fundamental hydrological and hydro-biological processes which govern all water resources. This item is omitted here for two reasons. The first is that this is an ongoing need which curiosity driven research will continue to pursue. Slowly, but inevitably more of the fundamental physical, chemical and biological processes governing water resources will be better understood. However as stated above, the processes will never be sufficiently understood for water resources management practices to be based entirely on theoretical understanding. Secondly there is little urgency for researching of fundamental processes because there is some degree of satisfaction with the current state of knowledge of hydrological processes. We may not have full understanding but our water resources managers have learned to get by in a manner that is acceptable to the wider community. This latter satisfaction is partly supported by the view that most water resources crises arise from extreme, unexpected natural events for which the water managers could not be held responsible. This attitude is probably inappropriate, in that extremes must be expected, but it is widespread and this reduces the demands for greater expertise in management.

Changing Attitudes

Over the last 30 years there has been widespread interest in understanding the integration of social policy issues and water resources management. This development has required large changes in attitudes, not only in the population at large but among the professionals of the several disciplines involved. Some superficial examples will illustrate the types of issues.

Flood protection was a major issue of the 1960s and 1970s. As funds were committed for both structural and non structural measures it was realised that flood damages continued to rise. It is neither economically possible, nor environmentally desirable to eliminate flood risks. Rather the need is to learn to live with the floods that inevitably occur and to ensure that the benefits of our lifestyles on flood prone land exceed the costs exacted by the occasional (but traumatic) floods, and to ensure no sections of the community are disadvantaged while others gain significant benefits.

Similar issues occur when water shortages or droughts are considered. For example some water resources projects originally planned to provide drought protection actually exacerbate drought conditions for the unprepared. A reservoir may be designed to provide irrigation water every season, whether there is drought or not. However, it may make more economic sense to consume all the available water in the current year, rather than store part of it against the possibility of drought in the next year. This "use it now" policy can provide great benefits to the well educated farmer. However the less educated, who may depend on a water supply every year, and have not the opportunity, or flexibility or intellectual capability to revise their practices so as to double or triple their income when water is abundant, may be ruined in a single no-water year.

Water logging and salinity alleviation are also undergoing changes of perception and ideas on needs for community-wide involvement. But how can equitable solutions be found when current thinking suggests that improvements can only be achieved by encouraging the making of costly land use and irrigation practice changes by those who are unlikely to gain any benefits. These problems are magnified by the presence of political boundaries and private land ownership. In these circumstances a farmer whose land is being destroyed by salinisation may be totally dependent on the good-will of neighbouring property holders or on policies pursued in other political jurisdictions. Even community wide schemes such as levying taxes on the introduction of salt to rivers depend on political agreements which may change at any time at the whim of governments or political parties.

In many places the introduction of (often state subsidised) irrigation benefits a few at the great cost of others. For example in Australia, earths driest inhabited continent, irrigated rice is grown, mainly for export, in areas where irrigation induced water logging and salinisation are very serious problems. Rice production gives the lowest return per unit of water use (Aust. Bureau of Statistics, 2000) of any irrigated agricultural activity in Australia, and imposes major, widespread, and perhaps irreversible environmental damage. Why does rice growing continue under these circumstances? Political influence must be involved, possibly motivated by the (fairly small) employment opportunities provided by the rice growing industry in a few electorates.

Research is needed to examine equitable means of bringing about changes, mainly of attitudes, which will allow new thinking and the welcoming of new ideas for the management of these sustainability threatening issues.

Social Policy

Gradually, some sensible approaches for setting up policy frameworks for solution, or alleviation of some of the above issues have emerged. However in recent times the interest of social policy researchers in these issues has diminished greatly. As ideas for solutions have emerged the political and economic frameworks within which these policy ideas must operate have suddenly undergone a large change, or have remained rigidly fixed, and unwelcoming to new ideas. The frustration of seeing hard fought development and acceptance of new ideas being undermined by either instability, or total rigidity of the socio-political environment has turned researchers away from such fields. However the need is still as great. New ideas are needed to deal with equity issues concerning living with floods, coping with gradual salinisation of large areas of productive land and the inevitable salinisation of rivers downstream of some irrigation districts, etc. However, while political and institutional policies are in a state of uncertainty concerning water ownership and allocation, water pricing and the effects of water projects on the environment, research to improve water resources management is difficult and can be very dispiriting.

Monitoring of Water Resources Processes

As discussed above, there is a huge need for improvement in the monitoring and archiving of data on all water resources processes. Monitoring and archiving activities are expensive and produce very little immediate benefit. In these days of (artificial) requirement for immediate returns from investments there is a need to lower the costs of data monitoring. Long term data collection will always be a public or government activity but it is only sustainable if it produces significant benefits or it costs very little. Census data is seen by governments as important in providing inputs to development of social policy and broadscale economic management. However, water resources data, which has been shown to provide greater public benefits than census data (Cordery and Cloke, 1992) does not have the same beneficial image with the public or politicians, who are concerned only with spending which will result in observable benefits before the next election. So the only way to increase monitoring and archiving of water resources data must be to reduce the cost of these activities. Here is a major research challenge! Rainfall data can now be collected and archived at low cost with tipping bucket rain gauges and inexpensive computer readable data loggers. However for most other variables the costs of observation and archiving are still very high because considerable labour is required somewhere in the recording or archiving process. For example routine streamflow monitoring has remained almost unchanged for the last 60 years. There have been changes from recording on paper charts to recording on data loggers, but instantaneous discharge observations and development and maintenance of stage-discharge relations, which are labour intensive activities, have changed very little. Observation of most water quality variables is very labour intensive and monitoring of most biological variables can only be undertaken when large resources can be gathered. For example to determine what species may be present in a water body, or determine the populations of various species at some location currently requires the mounting of special expeditions involving sizeable teams of observers and assistants.

Research is desperately needed to develop monitoring techniques to bring down the costs of knowing the state of our water resources. Unfortunately many of our resources have changed so much from their "natural" state before we have been able to undertake any monitoring that we will never be able to determine what the "natural" state was. Unless we move soon to increase monitoring activity, there will be no "natural" water resources in existence, and moves to preserve some of our streams and lakes in their "natural" state will be forlorn, because we do not know what those natural states were.

Water resources processes are location specific due to the interacting variability of climatic, geomorphological, geological and biological processes from place to place. Monitoring of processes in a few locations will not help the world community. Data collected in one country is unlikely to have much relevance in another country, even a neighbour. There is a great need, for the sustainability of our life supporting water resources, for all nations to undertake some monitoring of their water resources.

CONCLUSION

What are the research needs for water resources management? Opinions differ. Here two major needs have been suggested – firstly the need for integration of social policy issues, such as equity and social responsibility into water resources management. Interest in research topics in this discipline is in decline because the political and institutional frameworks they seek to influence are proving to be either so unstable, or so rigid, that much of the research undertaken to date has become irrelevant before, or soon after any new ideas have been developed. The second area is that of monitoring of water resources. If we are to manage better, we need to improve our understanding of the resource. To do this we need to observe more variables, more often, and for longer periods. Increased monitoring will only occur when the cost of monitoring and archiving declines by orders of magnitude. Little real change has occurred in monitoring techniques and equipment for 60 years. Research in this neglected field is desperately needed.

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