INTEGRATED RISK MANAGEMENT FOR WATER RESOURCE SYSTEMS

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ABSTRACT

In New Zealand, our quality of life is closely linked to abundant fresh water. Surprisingly, risk management for water resource systems is poorly developed and has been exposed as wanting in a number of recent events. There was a low inflow crisis for the Upper Waitaki hydro lakes in 1992; water restrictions during inadequate reservoir supplies for the greater Auckland metropolis in 1994; ski-field operations disrupted by central North Island volcanic activity in 1996 and 1997; agricultural drought rated at hundreds of millions of dollars cost in many eastern parts of New Zealand in 1998 and 1999; and widespread flooding and property damage in Northland, Taranaki and Bay of Plenty, also in 1998 and 1999. Such risks should be managed to avoid, as much as possible, untimely death, unnecessary suffering, undesirable environmental damage and undue financial loss.

Environmental risk management and the risk management concerns of regional and territorial authorities have also not been adequately addressed in New Zealand. Water resource management should include appropriate risk management, both for the obvious events like floods, droughts and contamination spills, and for the more insidious risks due to such factors as climate change effects on crop production, and aquifer water quality deterioration from land use change. Some previously overlooked water-related risks are mentioned in this paper. It is timely to implement risk management for New Zealand water resources in a way that is "integrated" in several senses, which are described, and that treats the water resources as the complex physical, ecological and socio-economic systems that they are.

It is concluded that while there is a need for better, and better integrated, risk management for water resource systems in New Zealand, there are suitable approaches available, and a start has been made on using them.

KEYWORDS

risk management; water resource systems; New Zealand; water supply; natural hazards.

1. INTRODUCTION

Human settlement on floodplains, hydro-electricity generation, irrigation for export-oriented agricultural production, and water-based recreation and tourism □ all these water-related activities are historically and economically important in New Zealand. Municipal water supply from treated, adjacent natural water is the norm. It is surprising therefore that risk management for water resource systems is poorly developed. Even if consideration is limited to this last decade of the millennium, there are examples from all of these contexts where risk management has been exposed as wanting: a low inflow crisis for the Upper Waitaki hydro lakes in 1992; water restrictions during inadequate reservoir supplies for the greater Auckland metropolis in 1994; ski-field operations disrupted by central North Island volcanic activity in 1996 and 1997; agricultural drought rated at hundreds of millions of dollars cost in many eastern parts of New Zealand in 1998 and 1999; widespread flooding and property damage in Northland, Taranaki and Bay of Plenty, also in 1998 and 1999.

What can be done about managing the risks, and what should in fact be done? The first and last words of the title of this paper, "integrated" and "systems", provide two important keys. And in between them, it has to be emphasised that "risk management" is much more than "risk analysis" or "risk assessment", and that "water resources" are complex, in themselves, and in relation to their physical, social, and ecological environments.

"Risk management" in this paper includes many kinds of risk: physical, organisational and financial. "Hazard management" is just one of the kinds of physical risk management. Both refer to potential or actual events or processes. "Emergency management" usually refers to actual physical crises with health and safety implications.

This paper demonstrates that there is a need for better risk management in relation to water resource systems in New Zealand, and that there are integrated risk management approaches available for implementation.

2. NEW ZEALAND CONTEXT

New Zealand, with its steep, island topography located athwart moisture-laden westerly and southerly air flows, has plentiful supplies of fresh water □ bountiful in relation to our population density. A useful approximation is that precipitation provides about a million cubic metres per year for every 10 people in New Zealand (Painter, 1990). Distribution in time and space, and storage above and below ground, are also mostly fortunate. But in the characteristic human "dominion over" nature, dominating "living in harmony with", these distributions are not sufficiently ideal, and we "create, as it were, a second world within the world of nature" (Cicero, 45 BC). This second world: of agriculture, infrastructure and buildings on floodplains; of dependence on electricity and tap water on demand; of built-up expectations of ski fields well-covered in snow and free from volcanic activity; of tourist locations adjacent to lakes and rivers □ these are all at risk of natural events and weather sequences over which we have little or no control. These risks should be managed to avoid as much as possible untimely death, unnecessary suffering, environmental damage and financial loss.

There are risks from too much, too little, and unsuitable quality water. There are risks of the water [including snow and ice] being unavailable, even if it is in the right place at the right time. The very abundance of water in New Zealand can paradoxically lead to greater damage caused by its temporary scarcity, as when irrigated farming is subjected to severe water restrictions. And control to exclude water, as in conventional river stopbanking, can lead to much greater damage when the eventually inevitable overtopping occurs (Ericksen, 1986).

Risk management for water resources includes emergency management. Flooding is the most common natural hazard in New Zealand, with average annual losses estimated at NZ$180 million (Britton, 1999). The New Zealand Government from 1996 started to change its approach in this area. A new ministry, of Emergency Management, came into effect in July 1999. Emergency Management Groups [EMGs] are being set up with the support of regional councils [regional government agencies which have natural resource management responsibilities], territorial local authorities [district and city councils which are local government agencies] and other local emergency services and utilities.

The new approach is said to be a "risk management-based comprehensive emergency management approach" which includes "national coordination of disaster response and recovery" (Britton, 1999).

The Ministry, EMGs and many other organisations will go through a major test of their risk management procedures as the new millennium arrives, with either a bang or a whimper. ["will go" as this March 2000 conference paper is being written in October 1999.] Hydroelectric energy supply, reticulated water supply, irrigation water supply and sewage and wastewater disposal are all aspects of water resource utilisation whose vulnerability to computer and microprocessor related risks will be tested.

3. RISK MANAGEMENT

3.1 RISK MANAGEMENT IN GENERAL

Professor David Elms dates written evidence of systematic risk management back to the Code of Hammurabi, King of Babylon, in the 18th century BC. Both physical risk, such as collapsing buildings, and commercial risk, taking on a share of the cost of a voyage for a share in the profits, were considered alongside other social "rules". Much later, probability theory was developed in the 16th and 17th centuries AD [originally in the context of gambling], and was a necessary prerequisite for development of a rational approach to risk management. Techniques of risk assessment and management now in use developed particularly rapidly in this last half century (Elms, 1998a).

"Risk management simply formalises the process of taking care." (Tweeddale, 1998) The literature suggests that not all involved have formalised "simply", particularly in risk analysis techniques, but "simply" is appropriate for this brief summary.

Risk management comes in different kinds, and is made up of several parts. David Elms (1998a) provides a classification by context [the water resource itself, or the commercial supply], by objective [avoiding flood or drought damage, or reducing income uncertainty], and by usage [contrasting the management *of* risk, which is protection-focussed, and managing *with* risk, which is progress-focussed]. The parts of the risk management process can be thought of as (Elms 1998b, SANZ 1995):

- Understand the problem or threats. [Flood wave, sequence of low flows/snows, contamination, ...]
- Determine the risks. [Involving both probabilities and consequences]
- Decide appropriate strategies. [To avoid, control, or transfer risks]
- Set "controls" in place. [Including "ownership" of these controls throughout the organisation]

- Monitor all of the above. [For change, deterioration, maintenance, new opportunities or threats].

There have been many benefits in a variety of fields for organisations, companies and the public from good risk management (Elms, 1998c). There are lessons which can be applied to risk management for water resource systems from experience with related natural hazards such as earthquakes (Hom and Ellis, 1998), avalanches (Weir, 1998), civil defence and environmental emergencies (Helm, 1998). And in harmony with the remarks earlier about “risk management which draws on the best approaches and techniques from a variety of disciplines and fields of application”, there is also much to be gained from a study of risk management related to a variety of other fields where it has been practised for a long time (Elms, 1998c).

But it is acknowledged in a recent state-of-the-art compendium for New Zealand (Elms, 1998c) that environmental risk management and the risk management concerns of regional and territorial authorities were not well covered (Elms, 1998d) in the various contributions to the book, and the Centre for Advanced Engineering project activities on which it is based. That deficiency is pertinent to a consideration of risk management for water resource systems.

3.2 RISK MANAGEMENT FOR WATER RESOURCE SYSTEMS

Risk management for water resource systems has much of the same justification, and available approaches, as for many other commercial and public good enterprises. The importance of water resources to human health and happiness has already been noted. And water resources also provide a good example of the observation that a natural hazard is just a natural resource behaving unsuitably. “When humans recognise such a system as potentially useful it becomes a natural resource. Similarly, a natural system becomes a natural hazard when it is potentially harmful to humans.” (Davies, 1997a).

In colonial New Zealand, death by drowning was known as “settlers’ disease”. Short steep rivers with catchments in high rainfall areas gave rise to flood waves, particularly on wide braided river beds, which could sweep away a person on foot or horse all too easily. Drowning is still too common a cause of death in New Zealand. And yet rivers and lakes are the natural resources which provide not only the domestic, irrigation and other industrial water on which New Zealand thrives, but also much of the natural beauty for which the country is renowned.

In between beauty and death related to water resources is a whole spectrum of opportunities and risks which need to be identified and appropriately conserved, used and managed.

4. WATER RESOURCE SYSTEMS

4.1 WATER RESOURCES

Water resources are complex physical entities, in themselves, and in their relationships with ecological and social systems. High quality of water bodies is crucial to quality of human life. These water resources are located in glaciers, snowfields, wetlands, rivers, lakes, reservoirs, aquifers, and networks of pipes and channels. The water is used for human consumption, cleaning and dilution, fire-fighting, electricity generation, agriculture and other industrial uses.

On a global scale, the increasing threat of water shortages for a growing world population is now provoking urgent international action (e.g. Falkenmark and Lundqvist, 1997). In New Zealand, our quality of life is closely linked to abundant fresh water in aesthetic, recreational, biodiversity, energy generation, food and fibre production and other industrial contexts. The time and space distributions of arrival of the water from the atmosphere have always been both variable and uncertain. The uncertainty is being reduced somewhat by better understanding of atmospheric and oceanic processes, but the variability is probably not, and could be increasing at the scale of decades. It also seems likely that the average parameters of the time and space distributions of arrival are changing, and that there are trends linked to global warming and atmospheric composition (Plummer et al., 1999; Salinger, 1999). So water resources, already physically, ecologically and socially complex, are linked in complex ways to national and international policies and behaviour through also complex and changing atmospheric and oceanic processes. This broadens the whole context of their risk management and the threats which should be considered. For example, the future needs of agriculture for water must now be considered to be linked not only to economically-driven and opportunity-driven changes in cropping patterns, but to changes enforced by long-term changes in climate.

4.2 SYSTEMS

“Systems” is an important word in the paper title both because it draws attention to the complexity shown by water resources and the need to deal with them in a holistic manner, and because it suggests that an approach to dealing with them which involves systems thinking might be useful.

Water resource systems engineering as an identified sub-discipline is usually dated from work at Harvard University, USA, in the late 1950s (Maass et al., 1962). Although it has been strongly developed in North America and Europe in the 40 years since, there has always been a gap between academic and research developers of techniques, and the water resource system designers and managers who could use them (Simonovic, 1992). Although uncertainty and reliability are acknowledged aspects of water resource systems engineering and management (e.g. Mays and Tung, 1992), risk management and water resource systems engineering have not yet been integrated in all of the ways advocated here.

A recent conference in the USA (Haimes, 1998), the eighth in a series on risk-based decision making in water resources, claimed a developing "sense of maturity" [proceedings abstract] in dealing with the topic. Some success was also claimed in "developing theory and methodology in risk assessment and management and applying them to water resources problems" but "much more remains to be addressed in future conferences and research." Without underestimating the importance of conferences, and research, it might also be hoped that in New Zealand we can make progress in implementing integrated risk management for water resource systems, even while the research, and the conferences, continue.

4.3 IDENTIFYING RISKS TO WATER RESOURCE SYSTEMS

In recent years, many "flood management plans" have been prepared by regional councils, although not all have received the approval of other interested local authorities (e.g. Canterbury Regional Council, 1993). There have been a few for specific water resource systems (e.g. Barnett et al., 2000). There have been fewer "drought management plans" for either rural or urban areas (e.g. Watercare Services, 1995). The New Zealand Ministry of Health has produced guides (Ministry of Health 1995a,b) to assist health impact assessment and risk assessment relevant to Resource Management Act [1991] requirements. In some other sectors, risk management seems likely to have deteriorated in quality due to organisation restructuring and legislative reform which has not taken risk management adequately into account [e.g. security of supply and greenhouse gas emissions related to hydro and other electricity generation (Orsman, 1998)].

Although there have been no major, chronic network failures in municipal water supply, there are indications in aging infrastructure and deferred capital expenditure that enhanced risk management would be very appropriate. In the last few years a new focus has emerged on water supply infrastructure risk associated with deferred renewal of pipes installed in New Zealand in previous times of rapid expansion (Johnson & Wells, 1999).

There are already hazards from water supplies (Public Health Commission, 1994) which fail to meet New Zealand drinking water standards (Ministry of Health, 1995c). Rapid changes in land use, including conversion of sheep grazing and other rural land to large and intensive dairy farms in many parts of New Zealand in the last few years, have led to actual or potential increases in nitrate pollution of groundwater (Smith et al., 1993). Continuing growth in urban population centres gives rise to increased potential for contamination of surface water and groundwater from both sewage and refuse disposal. Disposal of hazardous wastes in ways which do not contaminate water [or other possible receiving agents] is a currently urgent national priority.

There are also hazards of the low-frequency, high magnitude kind which have hardly been considered. Ocean origin tsunami were highlighted by the 1998 Sissano Lagoon event in Papua New Guinea (Goff et al., 1998). Some of the risks for New Zealand have been illustrated in recent papers (Barnett, 1995, 1998). But the risks of landslides causing damaging water waves on lakes have hardly been considered. A recent engineering student project (Ruddenklau, 1999) made a preliminary study of landslip-prone land adjacent to Lake Wakatipu. Travel time for a possibly damaging wave [e.g. about 5 m high], from likely sites of origin to the tourist restaurants, shops and hotels in downtown Queenstown, was estimated at about 5 minutes! Similar risks undoubtedly exist in other New Zealand inland water bodies.

In 1991 a slope failure in the Tunawaea Stream catchment, just upstream of its confluence with the Waipa River, King Country, North Island, created a dam 70 m high, 80 m long, and impounding approximately 900 000 cubic metres of water. The dam failed after heavy rain approximately 11 months later, by which time the regional council [Environment Waikato] had had time to carry out repeated inspections, commission geotechnical and hydraulic reports, and obtain legal opinions on who "owned" the dam! The dam-break flood wave passed relatively harmlessly down the Waipa River, as had been predicted by numerical hydraulic modelling (Webby & Jennings, 1994).

Another landslide dam in October 1999 blocked the Poerua River above Harihari in Westland, South Island. Several farms and farmhouses were directly threatened. In this case the dam was about 100 m high and 70 m long, about 10 million cubic metres in volume, and impounding 5 to 7 million cubic metres of water (Davies, 1999). Unlike the relatively long-lasting Tunawaea example, this dam failed less than a week after forming, with the resulting surge down the river overtopping 6 m high stopbanks. Although the outbreak flood caused little damage, resulting long-term aggradation might be extremely troublesome, causing flooding and bridge waterway blockage (Davies, 1999).

Mount Ruapehu in central North Island erupted in 1995 and 1996, blocking the former outlet of Crater Lake. It is difficult to predict whether the tephra dam will be eroded slowly, before or after the lake level rises to overtop it, or will fail suddenly with the lake at a level higher than the previous oveflow level (DOC, 1998). There was a disaster in 1953 from the latter scenario, when a lahar travelling down the Whangaehu River destroyed a rail bridge at Tangiwai shortly before a crowded passenger train arrived. Benefits and costs of a possible human intervention to arrange an earlier, safer breach, could be considered, as for a landslide dam. But in this case, there are spiritual and cultural values to be also taken into account, especially for the people of the Ngati Rangi and Ngati Tuwharetoa tribes.

In seismically active New Zealand, with settlement and tourism in alpine areas and alongside rivers and lakes, there are many potential sites for hazards of this kind. Davies (1997b) reports a pre-emptive look at facilities management on the Waiho River alluvial fan, below the Franz Josef glacier. Two of the potential hazards identified are glacier burst and landslide dam failure flood waves. His recommendation is that facilities be progressively moved out of harm's way.

Emphasis has already shifted from "flood protection", implying physical works to contain river floods, to "flood management", implying a mix of works, zoning and warning, or other means of keeping people and flood waters separated. With the availability recently of software suitable for floodplain flow numerical modelling, it is now possible to predict floodplain inundation depth and extent for floods of various magnitudes, in combination with river flow numerical models to also predict likely stopbank overtopping or breakout sites (Connell et al., 1998).

5. INTEGRATED RISK MANAGEMENT FOR WATER RESOURCE SYSTEMS

Risk management for water resource systems should be "integrated" in several senses, some of which have been enumerated in other contexts (Elms 1998a):

- It should be an integral part of the culture of organisations which have responsibility for water resource conservation, development and use ▫ not just an "add-on" bought in and then ignored until there is a crisis.
- It should be connected to and part of other management and governance processes, supported from the policy levels, and understood throughout the operational staff.
- It should be integrated across similar [even commercially competing] organisations when greater good demands it.
- It should be integrated for a whole water resource system, across different responsible organisations.
- It should be risk management which draws on the best approaches and techniques from a variety of disciplines and fields of application.

There are not yet many examples in New Zealand of risk management related to water resources which is integrated in all of these ways. Recently the Wanganui District Council has implemented a comprehensive risk management strategy for all of its activities (Bull & Gilbertson, 1999). This certainly has the intention to address the first two bullet points above, and the potential to do so.

The new emergency management procedures referred to in Section 2 likewise intend to address the third bullet point, and this would include flooding, and possibly earthquake related water hazards. They are not presently intended to address the other water-related risks identified in this paper. A conference of South Island local government leaders in October 1999 "decided to promote combined contingency planning for earthquakes in the South Island" (Christchurch Press, 1999). This is an example of the kind of thinking advocated here.

A major cooperative study of "lifelines in earthquakes" was carried out over the period 1989 to 1991 (CAE, 1991). First based on a Wellington case study, the project has since been continued and extended to other parts of New Zealand (CAE, 1997). This work is a good example, related to earthquakes, of integrated risk management. It is a useful forerunner of what could and should be done in risk management related to water resources.

6. CONCLUSION

As the Conference theme implies, there is crucial self-interest in "Guarding the Global Resource". We guard it for sustainable use by future generations. Water resource systems in New Zealand are inextricably linked to global systems, even if there is not [yet] much direct water resource exchange with other nations. And the management of our water resources is already international in nature, especially as multi-national firms participate in utility ownership and management.

Water resource management should include appropriate risk management, both for obvious events like floods, droughts and contamination, and for more insidious risks due to such things as climate change effects on crop production and aquifer water quality deterioration from land use change.

Even some of the obvious risks, such as landslide induced water waves on lakes, have not been well-considered yet in New Zealand. And very few of the authorities responsible for water resources, and water resource related hazards, have processes in place for integrated water resource risk management.

Approaches are available, and some examples already exist. There are good reasons, involving human safety and welfare in New Zealand, for implementing them.

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Integrated risk management addresses risks across a variety of levels in the organisation, including strategy and tactics, and covering both opportunity and threat. Effective implementation of integrated risk management can produce a number of benefits to the organisation which are not available from the typical limited-scope risk process. This paper explores how to expand risk management to deliver strategic advantage while retaining its use as a tactical tool. Strategy, Tactics and Risk. Integrated Water Resources Management is defined as a systematic process for the sustainable development, allocation and management, of water resource use, aimed at maximizing the social and economical benefits in an equitable manner without compromising the sustainability of vital ecosystems, and having in mind the complex interlinks between water and the surrounding land, ecosystems and socio-economic setting. WMO through Hydrology and Water Resource Programme is contributing to the implementation of Integrated Water Resources Management by promoting water resources assessment and hydrologic Drought Risk Management Scheme -a decision support system. TECHNICAL NOTE Integrated Drought Management Programme. in Central and Eastern Europe. 2.Â The developed decision support system in drought risk management is meant to serve as a common framework for different regional and sectoral specifications. Introducing a common framework in the form of step-by-step process leads to comparability among different systems. The developed framework defines the main principles for drought management that can be applied to various aspects of drought. Furthermore, the recommendations for developing an operational support system in drought risk management concern the application of a number of drought indices in main the part of the risk.

Information systems are needed for resource monitoring, decision making under uncertainty, systems analyses, and hydro-meteorological forecast and warning.Â Water resource management also entails managing water-related risks, including floods, drought, and contamination. The complexity of relationships between water and households, economies, and ecosystems, requires integrated management that accounts for the synergies and tradeoffs of water's great number uses and values.Â The Water Security and Integrated Water Resources Management Global Solutions Group (GSG) supports the Bank's analytical, advisory, and operational engagements to help clients achieve their goals of water security. Integrated Water Resource System Modeling to Support Sustainable Water Management. Submit to Special Issue Review for Water Edit a Special Issue. Journal Menu.Â Addressing the uncertainty in integrated water resource system models. Use of remotely sensed global data sets in integrated modelling. Integrated water resource modeling in practice.