The need for private dam safety assurance policy — a demonstrative case study

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Most private dams were constructed more than 20 years ago. As such, their designs could only be based on rainfall frequencies and intensities and standards of risk available at the time. However, many aspects have changed over time such as population distributions, infrastructure patterns, meteorological information, engineering methods and design standards, together with the condition of the dams, raising serious doubts about dam adequacy.

Significant advances made in the fields of meteorology and flood hydrology have modified both maximum possible rainfall, and design flood levels, on which most existing dams were based. (It may be that some dams were built using only 'rule-of-thumb' standards, without any engineering studies or design). Therefore the spillway capacities of many dams do not meet current standards. The issue is not limited to Australia and in fact is of worldwide concern and attention.

This increased recognition of risks associated with the dams, creates an obligation for owners:

- to manage their dams appropriately; in line with current safety standards
- to reduce the risks involved to a level compatible with community expectations
- to provide increased dam safety assurance to downstream communities.

In addition, as it is the role of Government to protect the community, an associated need has also developed for Government to provide appropriate policies which assure the community of owner participation and which protect them from unacceptable dam safety management practices. A case study reported in this paper demonstrates these needs.

Dam safety management in Australia

In Australia, owner obligation exists under common law to take reasonable care of dams according to *current prevailing standards*. Hence, owners should review their dams, and take appropriate action where necessary, in order to avoid liability for possible failure consequences (McKay and Pisaniello, 1995). The status in regards to this in Australia is discussed in the following sections.

Safety assurance policy

Throughout Australia, most Government dam-owning agencies have assumed the responsibility of evaluating public dams in terms of risk in accordance with current guidelines, and subsequently have either undertaken or are in the process of implementing appropriate action to reduce the risks to modern acceptable standards. For example, in NSW works on Pindari Dam to upgrade the spillway and increase the storage capacity of the dam were recently completed at an overall cost of $68.8 million over a period of approximately four years (NSW Dept. of Land and Water Conservation, 1995). This came on top of Burrinjuck, the major upgrading works of which were completed in August 1994 at a cost to the State of $73.8 million over approximately six years (NSW Dept. of Water Resources 1994). The costs of upgrading these two dams alone represent 0.10% and 0.08% of NSW Government revenue over each period respectively (NSW Parliament, *Budget Papers*, 1988–95).

NSW also is taking a responsible approach to the problem of safety of its privately-owned dams (Pisaniello and McKay, 1996). Elsewhere in Australia there is no supervision over the management of these structures. Webster and Wark (1987) report that owners of private dams are wary of any controls which are likely to add significantly to their costs. Consequently, private owners in general are either ignoring, underestimating or simply remain unaware of the risks and hazards associated with their dams and are frequently guilty of not maintaining the structures. Too often, owners look only upon the benefits gained from their dams and not the hazards which the dams could generate. Local Government bodies are unable to rectify the situation as they lack the power to ensure that owners take remedial action. As a consequence, potential hazards to neighbouring residents and properties exist placing people and community infrastructure at unnecessary risk.

For some time, the Australian National Committee on Large Dams (ANCOLD) has been aware of this problem and has continually expressed concern over the matter. ANCOLD believes that there is a need for regulation and supervision and that this is best provided through uniform dam safety legislation. In 1972, ANCOLD prepared guidelines for dam safety legislation, and proposed that each State should implement such legislation together with establishing an independent control authority. In response, virtually all of the State Governments have acknowledged and attempted to act upon these concerns and proposals by drafting and submitting varying forms of dam safety Bills to their respective parliaments. Unfortunately, due to a high level of political ambivalence, attempts to enact these Bills have not been successful in all States.

To date, only three of the six States and two Territories have been successful in establishing sound statutory control over dam management. However, while Queensland and Victoria have incorporated workable dam safety provisions within existing statutes, NSW is the only State to implement a specific dam safety Act under which an independent dam safety enforcement committee is constituted. Therefore, despite ANCOLD recommendations, there is still a need to ensure that communities are protected against dam management practices leading to unreasonable risk. States which fail to establish some form of safety assurance policy on the management of potentially hazardous private dams are, in effect, unconsciously devaluing the lives of people living downstream of these dams compared with the lives of those living downstream of public dams to which attention has or is being given: South Australia is one of these States.

Reservoir flood capability standards

The Australian National Committee on Large Dams sets the standard for modern acceptable practice in dam safety management in Australia. ANCOLD (1986) provides minimum prescriptive standards on appropriate design floods for dams, known as Recommended Design Flood (RDF) standards. ANCOLD relates RDF to dam hazard potential based on a 3-level hazard rating system (*Table 1*). The criteria used by ANCOLD for the three hazard categories can be summarised as follows:

- *high hazard potential*—failure will endanger many lives in a downstream community and cause extensive damage

Incremental Flood Hazard Category	Annual Exceedance Probability
High	PMF to 1 in 10,000
Significant	1 in 10,000 to 1 in 1000
Low	1 in 1000 to 1 in 100

Table 1: ANCOLD (1986) Recommended Design Flood Exceedance Probability Standards

- *significant hazard potential*—failure may endanger some lives and cause extensive damage
- *low hazard potential*—failure poses negligible risk to life and will cause limited damage.

The acceptable RDF determined from Table 1 can be compared to the Imminent Failure Flood (IFF) of an existing dam to determine whether its spillway flood capability is adequate. Guidelines for determining the IFF of a dam are provided in ANCOLD (1986). In line with modern acceptable practice, these guidelines must be used in association with both: Australian Rainfall and Runoff (AR&R) (IEAust, 1987), which provides state-of-the-art engineering methods and design criteria for hydrological/hydraulic reservoir flood studies; and modern generalised Probable Maximum Precipitation (PMP) estimates determined by the Bureau of Meteorology as described by Pearce and Kennedy (1993).

Unfortunately, the above engineering processes are highly rigorous and time-consuming in practice and therefore generate high consulting fees. For this reason, owners tend to neglect the need for reviewing their dams and instead develop a sense of complacency, believing that as the dams have not failed up to now, then they will never fail. The result is that dams are deprived of necessary upgrading and downstream communities are placed at risk. The case study reported below, based on the policy-absent State of South Australia, demonstrates the potential seriousness of this problem.

The South Australian case study

In South Australia, concern over the need for private dam safety assurance policy has been expressed by many, for example:

'The construction of farm dams in the flood-prone catchments around Adelaide is a potential cause of concern. It is not known what safety standards have been adopted for their construction, or whether they pose a significant risk of failure. Under current legislation, there is no means of controlling construction or maintenance of farm dams. The lack of power to ensure safety during and after construction has in the past and will in the future, inevitably lead to failures and the exacerbation of flood flows in the river systems. The Flood Warning Consultative Committee through its representatives on the State Disaster Committee, urges the Government to introduce legislation and controls and the establishment of safety standards for the construction and maintenance of farm dams' (Flood Warning Consultative Committee SA, 1990). The seriousness of these concerns has been determined, described below.

Case study procedure

As part of a case study investigating private dam safety management practices in South Australia, the modern flood capabilities were determined of a sample of eleven hazardous private reservoirs located in the Mount Lofty Ranges of South Australia (Pisaniello, 1997). A brief outline of this work is given below.

- The eleven dams were selected on the basis that they be 'referable' in size and rated as either 'significant' or 'high' hazard in accordance with ANCOLD (1986) guidelines.
- The sample dams were all embankment-type structures and had typical spillways that were free flowing and weir-type in nature. The maximum wall heights of the dams ranged from 5.5m to 10.7m; their storage capacities ranged from 50 ML to 250 ML; the size of their catchments ranged from 0.256 km^2 to 5.141 km^2.
- Hydrological/hydraulic models of the dams and their catchments were constructed using the RORB runoff routing package, based on procedures described in Laurenson and Mein (1990).
- Design rainfall information was derived as follows:
  - from AR&R (IEAust, 1987) for storm events in the observed range (i.e. up to 100 year ARI);
  - from Bulletin 53 (Bureau of Meteorology, 1994) for the Probable Maximum Flood (PMF) event
  - using interpolation procedures described in AR&R (IEAust, 1987) for events between the 100 year ARI and the PMF.
- The RORB catchment model parameters, k_c, m and catchment losses, Initial Loss (IL) and Continuing Loss (CL), were determined for each case in accordance with procedures described in AR&R (IEAust, 1987). As each sample catchment was ungauged, k_c and m were determined from regionalised information provided in AR&R. Catchment losses for events in the observed range were transposed from neighbouring gauged catchments of similar size and with similar physical characteristics, while, for events in the extreme domain, IL/CL=0/1 (mm, mm/hr) was consistently adopted in line with AR&R guidelines.
- An Annual Exceedance Probability (AEP) for the Probable Maximum Event (PME) was determined for each sample dam using the procedures outlined in AR&R (IEAust, 1987). For small catchments up to 100 km^2, this is mainly dependent on the value of the following ratio:

  – $\log (X_{PM} / X_{100}) / \log (X_{100} / X_{50})$ (1)

  where:

  X represents the peak event magnitude, for either rainfalls, flows, or flood volumes

  X_{PM} denotes the Probable Maximum event

  X_{100} denotes the 100 year ARI event

  X_{50} denotes the 50 year ARI event.

AR&R divides Australia into two zones and provides limiting AEP of PME criteria for each based on the value of Equation 1. In line with these criteria, 8 sample catchments attracted an AEP of PME of 1 in 10^7 while the remainder attracted 1 in 10^6.

- The RORB model was used to determine peak inflows to the reservoirs for all events necessary up to the PMF. This enabled an inflow flood frequency curve to be established for each dam.
- The RORB model was then used to route all inflow hydrographs through the reservoirs for both an upper bound and lower bound 'start' storage level case:
  - Upper bound case—initial storage level assumed 100% full.
  - Lower bound case—initial storage level assumed 33% full.

The lower bound case was checked simply to eliminate uncertainty.

- The resulting peak outflows and corresponding peak water levels obtained for all recurrence intervals up to the PMF enabled an outflow flood frequency curve and elevation frequency relationship to be established for each dam for both cases of 'start' storage level.
- The Imminent Failure Flood (IFF) capability, being the flood which when routed through the reservoir results in a peak storage level equal to the lowest elevation on the non-overflow crest (as recommended by ANCOLD (1986) for embankment dams), was determined in each case from the associated elevation frequency relationships of the dams.

The case study results are presented in the following Section *(see Table 2)*.

Case study results and analysis

The results of the case study were analysed by comparing them against ANCOLD criteria as illustrated in *Table 2*.

ANCOLD (1986) guidelines recommend that unless normal operating conditions indicate otherwise, a 100% full 'start' storage level should be assumed when assessing spillway flood capability of embankment dams. The comparison in *Table 2* demonstrates that regardless of the 'start' storage level assumed, many hazardous private reservoirs with inadequate spillway capacities do exist in the Mount Lofty Ranges of South Australia. The risk of failure from overtopping is consistently unacceptable for 91% of the total sample and 100% of the High Hazard sample. In particular, the flood capabilities of five of the six High Hazard dams (83%) displayed exceedance probabilities in the order of those required for Low Hazard dams under ANCOLD requirements (ie: 1 in 100 to 1 in 1000 AEP). It is important to note that three of these dams (Dam Numbers 1, 2 and 3) do not even satisfy the required criteria for Low Hazard dams. These disturbing results demonstrate that owners are not taking action in terms of analysis and upgrading of their structures and that the need for some form of private dam safety assurance policy in South Australia is urgent.

Dam no.	Minimum hazard rating (High/Sig.)	IFF if 100% full 1/AEP (years)	IFF if 33% full 1/AEP (years)	ANCOLD guidelines IFF range 1/AEP (years)	Acceptable under ANCOLD guidelines? (Yes/No)
1	High	**40**	800	PMF–10,000	No
2	High	**80**	290	PMF–10,000	No
3	High	**97**	1600	PMF–10,000	No
4	High	**150**	1150	PMF–10,000	No
5	High	**320**	680	PMF–10,000	No
6	High	**2750**	3300	PMF–10,000	No
7	Sig.	**190**	2000	10,000–1000	No
8	Sig.	**130**	570	10,000–1000	No
9	Sig.	**280**	2300	10,000–1000	No
10	Sig.	**500**	2700	10,000–1000	No
11	Sig.	**1400**	6400	10,000–1000	Yes

Table 2: Comparison of flood capability results with ANCOLD Guidelines

Providing appropriate private dam safety assurance policy

In order to provide increased dam safety assurance to downstream communities, it is necessary to educate private dam owners so as they are made to realise their responsibilities and liabilities in accordance with the dictates of common law, and also to establish some form of regulatory control over dam management practices to ensure that owners appropriately manage their dams in line with current standards. A detailed review of international practices conducted by Pisaniello (1997), see also Pisaniello and McKay (1996), indicates that this can be best achieved with the establishment of properly organised, systematic dam safety programs based on dam safety legislation. At the very least, considering that downstream communities ultimately bear the risks associated with dams, they should have the 'right to know' the potential dangers they are living under and be provided with the opportunity for salvation in the event of failure though appropriate Emergency Preparedness Procedures provided for under legislation.

In the USA, affordable public liability flood insurance is offered by the government, and is conditional on a flood mitigation program being in place. The benefits of this approach include:

- raising dam owner and community awareness
- reduction of risk to life
- access to reasonable compensation for victims of dam failure

There is no equivalent program in Australia. Perhaps there should be, but with the further condition that the dams are maintained to an acceptable standard.

Overseas experience together with the experience of NSW, demonstrates that dam safety programs are workable and not too costly (Pisaniello and McKay 1996; Pisaniello 1997); for example, the NSW Dams Safety Committee currently operates on a small annual budget of around $400,000. Elements of best practice can and do exist successfully to control the safety management of private dams and in turn provide increased dam safety assurance to the public and promote the ideals of reducing loss of life as well as environmental and economic losses. Pisaniello (1997) provides detailed guidelines and criteria for determining 'appropriate' safety assurance policy for any jurisdiction, together with a simple and cost-effective flood capability design and review mechanism for the purpose of minimising cost burdens to private owners, see also Pisaniello and Argue (1997) for further details of this.

Conclusion

There is a clear need in States where hazardous private dams exist to ensure that owners review and maintain their dams in line with current acceptable practice and take appropriate remedial action where necessary. Adequate assurance can only be provided through the implentation of appropriate policy that requires the backing of law-makers. The results of the case study here should encourage such backing.

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