

PRIORITISATION OF DAM SAFETY MANAGEMENT IN A LARGE WATER BUSINESS

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INTRODUCTION

A common issue facing many dam owners across the world is the need to prioritise and fund dam safety upgrading projects. In many cases, the dam safety liabilities which have been identified are extremely large in comparison with the owners' ability to fund or to allocate appropriate resources to undertake these works.

There have been many recent improvements to techniques for assessing the condition and safety of dams, including advances in hydrology, seismic analysis of dams and the understanding of erosion mechanisms in embankment dams. Many organisations are also using dam safety risk management programs to prioritise upgrading works at a single dam or between a number of dams.

An emerging challenge is to prioritise and justify dam safety upgrading projects within the context of the dam owner's business, where there are competing demands for funds and resources.

Goulburn-Murray Water is one of Australia's largest dam owners with a portfolio of 17 dams, up to 130 years old. The portfolio includes Dartmouth Dam, which at 180m high is the highest dam in Australia. Over the past eight years more than AUD 80 million (USD 64 million) has been spent on dam safety upgrading works on these dams. This has been performed within a risk management framework, with relative priorities of works being determined based on quantitative risk assessment techniques.

Goulburn-Murray Water has also developed a whole-of-business risk process which allows all major investments to be prioritised within the overall context of its business. This allows comparison and business justification of investments for all projects including dam safety, environmental management, health and safety programs, technology investments and other infrastructure works.

This paper presents Goulburn-Murray Water's dam safety management program and in particular the techniques used to prioritise individual dam safety projects and to compare these risks and investments to other business priorities.

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GOULBURN-MURRAY WATER

Australia's largest irrigation authority, Goulburn-Murray Rural Water Authority (Goulburn-Murray Water) was established in 1994, and covers an area of 68,000 square kilometres in the State of Victoria (Figure 1). The area includes the catchments of most of the State's north flowing streams that enter the River Murray.

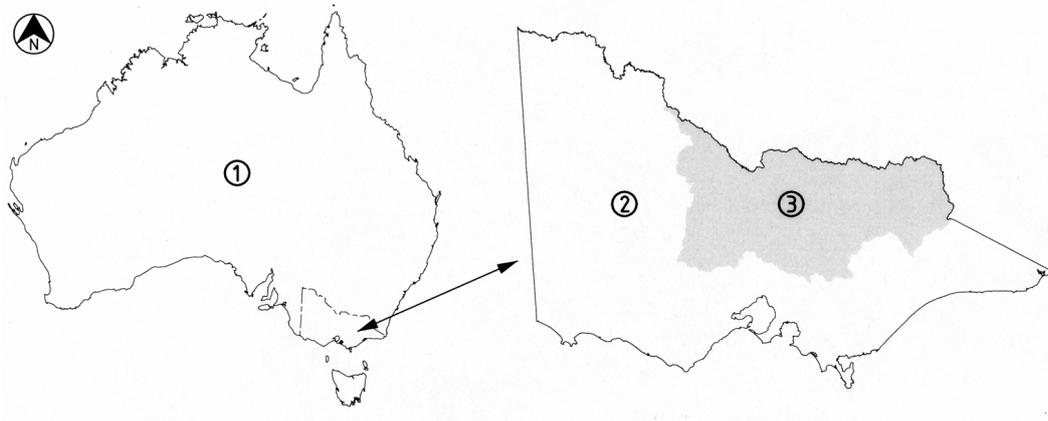


Figure 1

Goulburn-Murray Water Region

1. Australia
2. State of Victoria
3. Goulburn-Murray Water Region

Goulburn-Murray Water's main business is the supply of retail irrigation water to farmers, via a large network of open channels. There is an internal financial separation of the Bulk Water (dam management) Business from the retail business. The Bulk Water Business includes the management of 17 large dams and the delivery of bulk water to groups of irrigation customers and to other authorities that operate urban water supply systems.

The age of the dams in Goulburn-Murray Water's portfolio varies from less than ten to over 130 years, with many dams constructed in the 1950s and 1960s. The average annual volume of delivery is $3500 \times 10^6 \text{ m}^3$, 95% of which is for irrigation.

These dams range from Dartmouth Dam, at 180 metres Australia's highest dam and with a storage capacity of $3.9 \times 10^9 \text{ m}^3$, to small reservoirs such as Hepburns Lagoon with a capacity of $3.0 \times 10^6 \text{ m}^3$. The current replacement value of these dams is AUD 1.6 billion (USD 1.3 billion)

Following various reforms and changes across the water industry in Victoria, the contemporary model of dam ownership in Victoria is a greater number of smaller organisations, with much more specific and well defined areas of responsibility and accountability than had previously existed. Major Victorian dam owners (such as Goulburn-Murray Water) are still generally public authorities. Goulburn-Murray Water is actively involved in the Australian National Committee on Large Dams (ANCOLD) activities and uses ANCOLD guidelines in managing the Bulk Water Business.

Institutional reforms have been occurring since the late 1980s and the Victorian Government's Review of Headworks (1995) set the scene for future asset management of dams in the State. The review identified very large potential expenditure required to upgrade dams across the State, and the central thrust of that review was that a risk based approach to decision making should be adopted in the management of dams in Victoria. This includes assessment of all engineering and other factors, in particular business decisions which lead to the adoption of a total business risk based approach to dams management.

GOVERNANCE ARRANGEMENTS

Goulburn-Murray Water is a public authority constituted under the Victorian Water Act and wholly owned by the Victorian Government. It is financially independent of government, subject to government economic regulation under the Essential Services Commission, and required to meet a series of performance standards under a "Statement of Obligations", issued by the Minister for Water to whom it is responsible. Goulburn-Murray Water is one of 20 such water businesses in Victoria, covering rural, urban and waste water systems. It is the largest dam owner in Victoria.

Legislative requirements for dam safety in Victoria are embedded within the Water Act, and the Statement of Obligations which sets out the requirements for management of dams and implementation of a dam safety program. These requirements are expressed in terms of adherence to relevant ANCOLD Guidelines and using a prioritised approach across the full portfolio of dams for safety upgrading projects.

Under its delegated authority by the Minister, Goulburn-Murray Water operates on a full cost recovery basis for services provided to its customer base, and is required to operate as a not-for-profit business. Government invests in the business from time to time by way of equity injection to support specific Government initiatives.

The Authority is governed by a skills based and independent Board of Directors.

It is within this framework that the organisation must make management and investment decisions across its whole business, including maintaining and managing its significant asset base.

A prime tool for prioritising investment and expenditure is the use of a whole of business risk management framework. Dam safety expenditure decisions are made within this framework.

DAM SAFETY RISK MANAGEMENT PROGRAM

Goulburn-Murray Water has developed a strategy to reduce the risk posed by its dams using risk assessment to support a standards based approach to dam safety. The strategy uses varying levels of assessment for the purposes of determining investigation and works priorities.

The strategy uses an initial risk assessment process, commonly referred to as "portfolio risk assessment" to determine dam safety review priorities and to provide a broad indication of potential upgrade works that may be required. Following the completion of dam safety reviews, a detailed quantitative risk assessment is used in conjunction with acceptable risk to life guidelines to:

- Assist in determining the severity of risks, by comparing the calculated risk to indicative “tolerable” risk levels and then deciding an appropriate time frame for reducing risk;
- Assist in devising interim, or short term, risk reduction measures that achieve a level of “tolerable” risk until funds are available to undertake standards based works; and
- Assist in deciding when business risks might be addressed ahead of low risks to life.

The process of detailed risk assessment and developing a risk reduction program had to meet the following requirements:

- Clearly present the current status of risk and how cost effective measures could be implemented to reduce risk;
- Be subject to review and allow for inputs regarding consequence assessments, by key stakeholders;
- Be to a level of detail that would provide for confidence in decision making and be defensible under scrutiny; and
- Provide risk and consequence information in sufficient detail to support funding submissions to Government.

The risks posed by the five highest priority dams within Goulburn-Murray Water’s portfolio were quantified through a detailed risk analysis process completed in June 2001. The priority dams were Eildon, Waranga Basin, Eppalock, Cairn Curran and Buffalo. The risks are summarised in Figure 2.

The graph shows the tolerable risk boundary from the ANCOLD publication, “Guidelines on Risk Assessment” (2003). The second line is a second risk target, one order of magnitude below the limit of tolerability. ANCOLD 2003 proposed, in the absence of specific legal or regulatory requirements, a limit of tolerability based on emerging international practices.

Dam safety upgrading works across Goulburn-Murray Water’s dams portfolio have been undertaken in a staged and programmed manner to progressively reduce the total risk profile in the most cost efficient manner, with the initial target being to bring all risks below the tolerable risk level. After eight years the current risk profile is as shown on Figure 3 for Five Priority Dams

It can be seen that the program to date will be successful in reducing all risks below the tolerable risk level, with the anticipated completion of a current project at Cairn Curran scheduled for late 2007.

While the formal risk assessment process was only applied in detail to the organisation’s portfolio of dams this process is consistent with management’s approach to evaluation of risks in other business areas and allows the Goulburn-Murray Water Board to consider the priority of dam upgrades in relation to other issues. This is discussed further below.

RISK PROFILE FOR FIVE PRIORITY DAMS

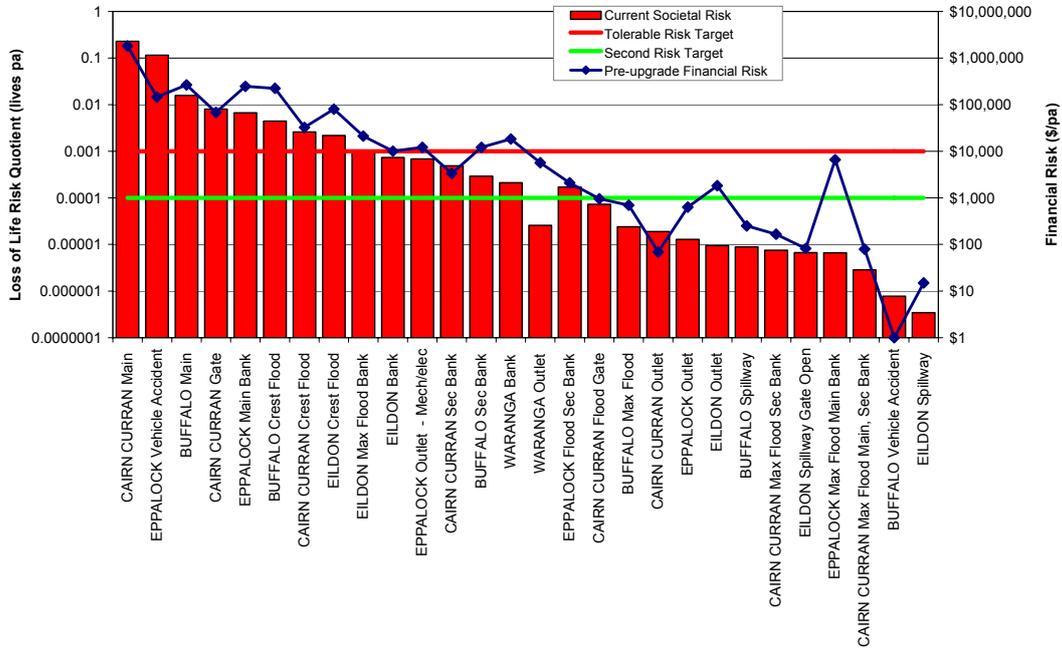
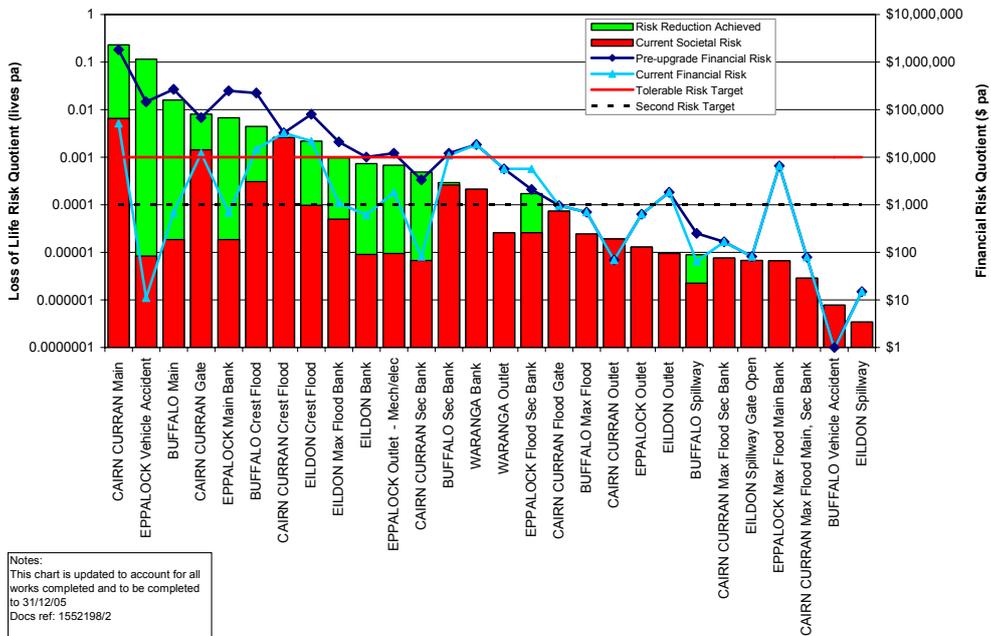


Figure 2 – 2001 Original Risk Profile

RISK PROFILE FOR 5 PRIORITY DAMS
(Specific Risk - identified)



Notes:
This chart is updated to account for all works completed and to be completed to 31/12/05
Docs ref: 1552198/2

Figure 3 - 2005 Risk Reduction Achieved for Five Priority Dams

RISK ASSESSMENT PROCESS

The risk assessment process comprised the following elements and guiding principles:

- Individual risk assessments of the five priority dams for which dam safety reviews were complete to guide formulation of risk reduction strategy.
- Portfolio risk assessment to prioritise design reviews for the remaining eight dams (a total of 13 state owned dams were considered in this process).
- Use of two consistent measures of risk: societal risk and financial risk.
- Application of a defensible and consistent process.

The overall risk assessment approach was to develop a quantitative understanding of the key contributors to risk at each of the priority dams and to then prioritise the risk events across the entire range of priority dams so that a risk-based risk management strategy could be developed. Specifically, the process for the priority dams risk assessment was as follows:

- Engineering information including detailed design reviews for each dam was reviewed by an expert Engineering Panel to apply event tree analysis to identify the probability of each potential type of failure.
- A broad range of potential consequences was evaluated by an expert Consequences Panel with respect to 1) loss of life and 2) financial cost.
- A measure of risk was derived for each failure type and for each dam; and risk profiles were generated that show the total risk presented by each major dam and the risk for all dam failure types, ranked in order of decreasing risk.
- The event trees and risk profiles were used to develop a prioritised list of risk reduction actions (a risk management strategy) for all failure types applicable to the priority dams.
- The risk reduction benefits and the costs of achieving the benefits were compared and used to develop a schedule of risk management actions.

The dams risk assessment process was reviewed throughout its progress by a Goulburn-Murray Water Board-appointed Stakeholder Reference Panel. The panel included a broad range of local authorities and interest groups.

Figure 4 summarises the links between the Engineering Panel, the Consequences Panel and the risk analysis process, and it shows how the dam risk profiles and the failure type risk profiles were developed.

The method used to perform the priority dams risk assessment followed the process established by the RISQUE method (Bowden et al. 2001). The RISQUE method follows a systematic methodology and is defensible with respect to best practice at the time. It complied with the Australian Standard on Risk Management, the current version of which is AS/NZS 4360:2004. The use of expert panels was fundamental to this quantitative risk assessment because inputs to risk modelling (such as probability of occurrence and magnitude of consequences) based on actuarial information were not available for the identified risk events.

The risk assessment and formulation of the risk management strategy proceeded as a staged process. This process follows AS/NZS 4360:2004, as outlined in Figure 5.

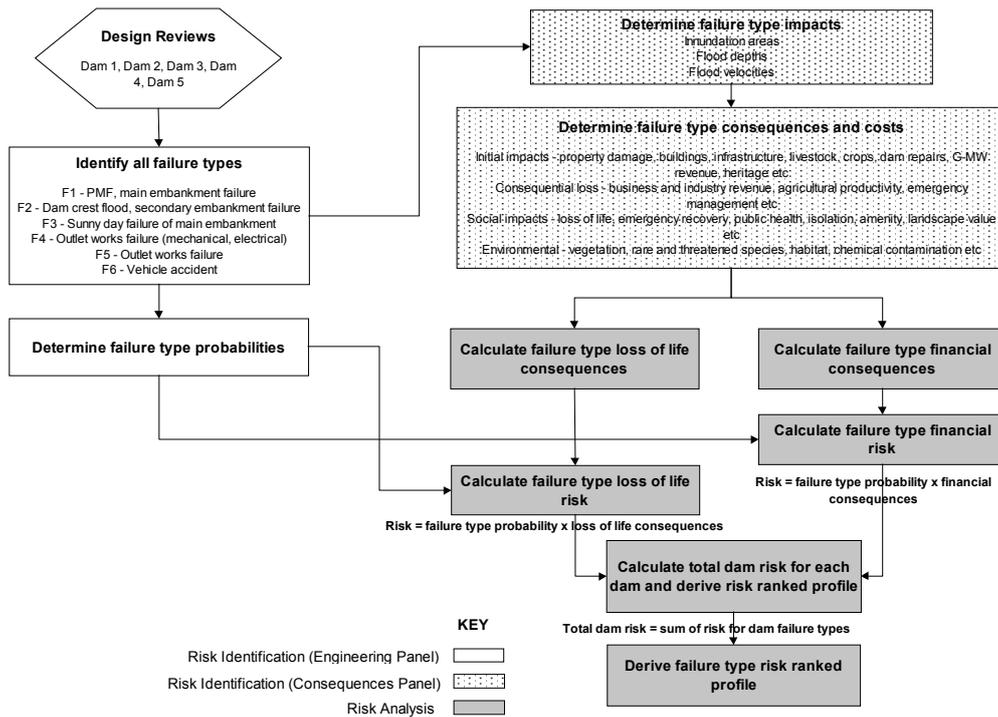


Figure 4 - Risk Assessment Process

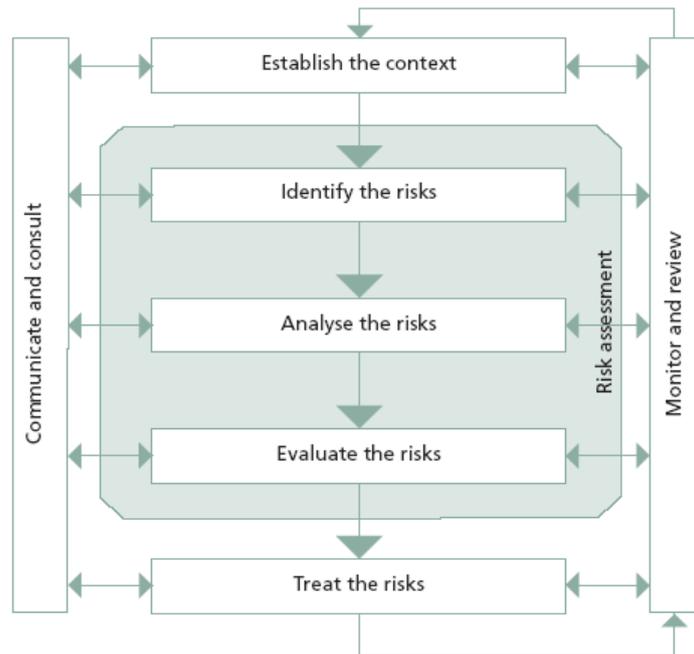


Figure 5 – Risk Management Model (AS/NZ 4360:2004)

Stage 1 Establish the Context. Established the background to the risk management process and determined the required level of detail for the assessment. Stakeholders were identified and the risk management aims and structure were developed.

Stage 2 Risk Identification. Expert panels identified and characterised the key failure scenarios using event trees. For each event, the probability of occurrence and the consequences were assessed. Documentation of the panel's findings was consolidated onto a risk matrix that described each risk event and indicated probabilities and consequences.

Stage 3 Risk Analysis. The probabilities and consequences for each substantive risk event were quantified and modeled. The risk model derived a range of outputs that included risk profiles, exposure profiles and risk maps.

Stage 4 Develop Risk Management Strategy. Formulation of risk management strategy utilised the results of the risk analysis process to evaluate various actions to treat key risk events. The benefits (risk reduction) of implementing the action plan were estimated by modifying and re-running the risk model until the interim risk targets were achieved. The severity of risks was compared to indicative guideline targets in developing a timeframe for implementation.

Stage 5 Implement Strategy. Implementation of the risk management strategy will be determined by Goulburn-Murray Water's Board and may progressively involve actions such as engineering remedial works, review of dam operations, further investigations, establishment of emergency action plans, installation of detection systems, and community consultation.

TRACK RECORD

Between 1998 and 2006, Goulburn-Murray Water has completed a series of dam-safety risk-reduction projects. The projects were undertaken at Waranga, Eppalock, Cairn Curran, Yarrawonga and Buffalo, Hepburns and Eildon dams, resulting in a substantial risk reduction.

Over this period, as a result of this work the total life safety risk has been reduced by approximately 90% from pre-existing levels. Investment in the program to date has been approximately AUD 82 million (USD 66 million).

CORPORATE RISK MANAGEMENT FRAMEWORK

Goulburn-Murray Water uses risk management as a key tool to achieve business objectives and appropriate standards of governance. Its risk management framework is designed to allow consistent comparison of significant risks across the organisation, and to provide an unbiased and defensible basis for allocation of resources and capital to control risk.

As part of an independent review of Goulburn-Murray Water's dam safety program in 2004, a whole-of-business risk management framework was introduced across the organisation to enable dam safety upgrading expenditure and priorities to be compared to all other corporate issues.

The Framework is consistent with the Australian/New Zealand Standard on Risk Management, AS/NZS 4360:2004 and relates specifically to the management of risk events with adverse consequences and their potential impact on Goulburn-Murray Water.

Goulburn-Murray Water's whole-of-business risk management framework is capable of accepting output from the various risk management programs across the organisation, and standardizing this output to a common measure of risk. There are several risk management programs in place within Goulburn-Murray Water, to identify, assess and mitigate specific sources of risk. These include:

- Occupational Health and Safety Program;
- Environmental Risk Program;
- Dam Safety Program;

- Financial Audit Program;
- Asset Management Program; and
- Critical Infrastructure Security Program

The whole-of-business risk management framework is not intended to replace the various risk management programs functioning successfully at Goulburn-Murray Water. Rather, it is designed to allow consistent comparison of significant risks across these programs. The corporate program operates in parallel with existing risk management programs across the business and provides a method for prioritising risk mitigation actions.

Individual risks are assessed against nine consequence categories and nine likelihood categories and then combined to determine a risk rating for the individual risk event. There are six possible risk rating types that range from insignificant to extreme as defined in the risk matrix in Figure 6. The risk matrix illustrates the combination of consequence and likelihood and the resultant risk rating assigned to a risk event.

Goulburn-Murray Water's also has a third dimension to its risk management framework, which measures how well the risk is being managed given existing controls and improvement opportunities. This is assessed by determining its compliance rating. The compliance rating is a measure of the risk event's control adequacy (as measured against acceptable industry practice or best practice) and its improvement opportunity (opportunity to improve controls and the ease of implementation of these control improvements). While the risk rating details the magnitude of the risk, the compliance rating indicates how well the risk is being managed, given existing controls and improvement opportunities.

The risk and compliance rating for individual risk events are then combined to give a first order evaluation of business priorities for risk reduction. On a quarterly basis the top 25 corporate risks in business priority order are reported to Goulburn-Murray Water's Board of Directors and Financial and Management Audit Committee. The definition of business priorities is shown in Table 1.

The whole of business risk framework has demonstrated that reduction of dam safety risks remains a high priority within Goulburn-Murray Water's complex business.

This risk based approach to prioritizing dam safety upgrades is part of a Dam Safety Management System integrated within the organization's corporate risk management framework, as described by Bowles et al (2007).

Whilst a significant effort has been undertaken to reduce these risks over the past decade using a risk based prioritisation process across the dams portfolio, the ability to be able to use this framework to compare dam safety projects to numerous other issues under a common framework is an extremely useful tool to allow corporate investment decisions to be made.

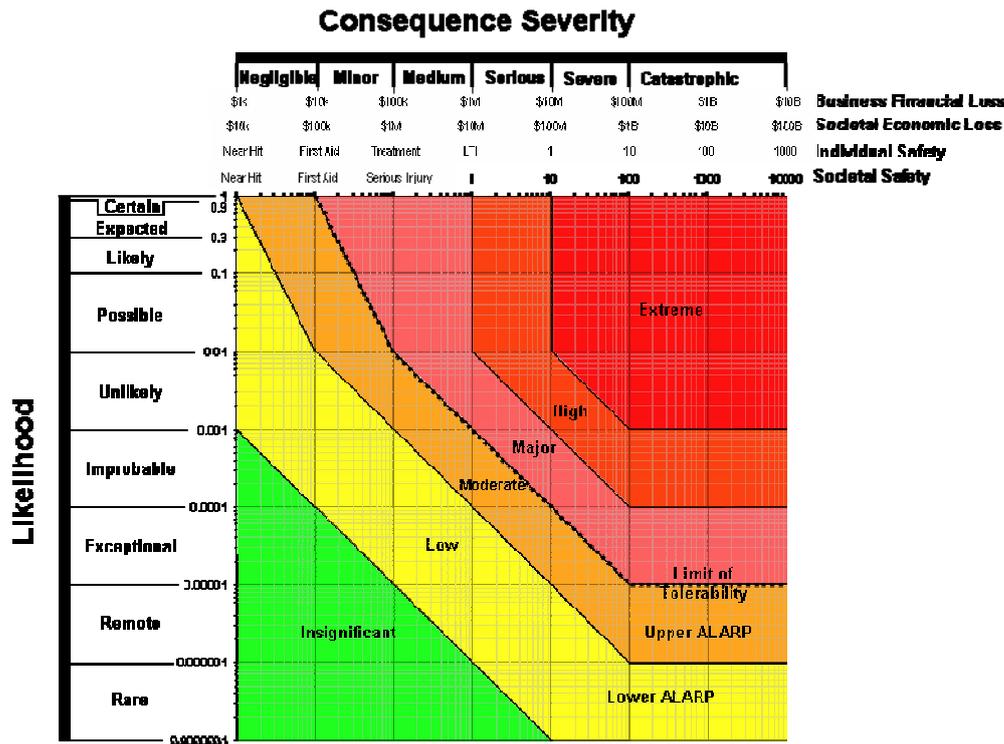


Figure 6 – Risk Management Matrix

PRIORITY RATING	ACTION REQUIRED
1	Action is required to reduce the risk level as a matter of extreme urgency, with dedicated funding and resources. Interim and temporary controls should be implemented immediately if permanent controls are not in place or immediately available.
2	Action is required to reduce the risk level as a matter of urgency. Interim and temporary controls should be implemented as a matter of urgency if permanent controls are not in place or immediately available.
3	Thorough review of existing and potential controls is required. Action is required to reduce the risk level.
4	Risks are to be reviewed to assess treatment options and determine what further action is required. Treatment actions will be based on costs and benefits, and maintained under review.
5	Pursuit of further risk mitigation actions is unjustified. Monitoring should continue to ensure that appropriate controls remain in place. Opportunities for continuous improvement should be sought periodically.

Table 1 – Business Priority Rating

SUMMARY

Goulburn-Murray Water is a large publicly owned water business with responsibility for a significant asset base, including 17 large and potentially hazardous dams.

A carefully managed program of dam safety upgrading has been in place now for ten years, where a risk based tool has been used to prioritise works in the most cost efficient way to maximise risk reduction for both community safety and business needs.

A whole-of-business risk management framework has also been introduced where a number of risk management programs can be compared and assessed to prioritise all major expenditure across the business.

Experience to date indicates that whilst Goulburn-Murray Water runs a diverse and complex business, many of the significant risks to the business and community remain with these large dam assets. The ability to assess dam safety risk reduction programs and present results in a simple and consistent manner across the business is an extremely valuable management tool and assists decision makers at all levels to make informed and justifiable decisions.

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REFERENCES

Australian National Committee on Large Dams (ANCOLD) Bulletin Issue No. 107, December 1997 - "Establishing a Headworks Business Using a Risk Based Approach" by Ian Howley and David Stewart, Goulburn-Murray Water.

Australian National Committee on Large Dams (ANCOLD), "Guidelines on Risk Assessment", October 2003

Australian National Committee on Large Dams (ANCOLD), "Guidelines for Design of Dams for Earthquake", August 1998

Australian National Committee on Large Dams (ANCOLD), "Guidelines for Selection of Acceptable Flood Capacity for Dams", August 2003

Bowden, A.R., Lane, M.R., and Martin, J.H., 2001, "Triple Bottom Line Risk Management – Enhancing Profit, Environmental Performance and Community Benefit", Wiley, New York, 2001.

Bowles, D.S, Giuliani, F.L., Hartford, D.N.D , Janssen, J.P.F.M., McGrath, S.G., Poupart, M., Stewart, D.J.A., Zielinski, P.A., Progress report on the proposed update of the ICOLD Bulletin on Dam Safety Management, International Commission on Large Dams, Symposium on Dam Safety, St Petersburg, 2007

Howley, I.A., McGrath S.G., Stewart, D.J.A., "A Business Risk Approach to Prioritising Dam Safety Upgrading decisions", International Commission on Large Dams, Proceedings of Twentieth Congress on Large Dams, Volume 1, Q.76, R. 17., 2000

Snowy Mountains Engineering Corporation Limited, Australia, internal report for the Victorian Office of Water Reform (Department of Conservation and Natural Resources) "Review of Headworks", 1995.

Standards Australia, AS/NZS 4360:2004, "Risk Management", 2004