Ri'ziliəns
Business Resilience Solutions

State Dam Risk Review - Report

Client: State Emergency Management Committee Secretariat

Dated 24th July 2015

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1 Executive Summary

In March 2015, the State Emergency Management Committee (SEMC) Secretariat commissioned a review of the hazard of Dambreak on behalf of the State Emergency Management Committee.

The review took the form of extensive consultation with a SEMC agreed group of key stakeholders and a risk workshop to ensure the risk of Dambreak was thoroughly assessed across all types of dams and geographical regions in Western Australia (WA). The risk assessment process ascertained the risk posed by the hazard of Dambreak to the State and incorporated the assessment of the categories of:

- Public dams; (including reservoirs and storage tanks)
- Tailings dams; (including effluent dams) and
- Privately owned dams (including gully dams).

All participants in the review and assessment process were briefed on the confidential nature of the topic and that discussions and findings would be subject to a confidentiality agreement.

The outcomes from the review are summarized in the Key Findings and Key Recommendations sections below:

1.1 Key Findings

- There are no State level risks from Dambreak in the 'Intolerable' category.
- All risks that related to Public and Tailings Dams were assessed as Low and therefore in the 'Broadly Acceptable' category. This low level of risk for Public/Tailings Dams reflects the low event probability combined with the ongoing dam safety programs that are implemented under self-regulation against Australian National Committee on Large Dams (ANCOLD) Guidelines. As a result there are no urgent treatments required to reduce risk. However, there are some Prevention/Preparedness controls that could be enhanced.
- Gully Dams posed the highest level of risk at the State level mainly due to the likelihood (event probability) of a dam failure. Assessments of the likelihood of failure are complicated by a lack of data or records relating to design and maintenance of these dams.
- The absence of formal legislation and regulation for dam safety in WA is far from best practice when compared to other States and Territories. Certain types of dams follow ANCOLD Guidelines and apply a self-regulated dam safety program but the vast majority of dams in the state are non-regulated.
- The absence of a comprehensive database of private dams limits the ability to fully ascertain the scale of the risk at State level.
- There are multiple examples of large gully dams on the same watercourse in the SW Region of the State. Invariably these dams will have licenses for water use granted by the Department of Water and development planning approval at Local Government level. However, it is unlikely that the potential for a cascade failure of dams will have been considered in the licensing or planning approvals process.

- Design and maintenance of spillways is proven to be a major contributory factor in the failure of Gully Dams due to 'overtopping'. Basic survey from satellite photographs of the Gully Dams used in this risk assessment show that many spillways appear to be overgrown, blocked or non-existent.

- The ANCOLD Guidelines provide effective categorisation methods for all dams based on a 'Consequence' driven hazard assessment process rather than capacity, type of construction or purpose. Although designed for the regulation of large dams these guidelines are used to categorise small dams in other States/Territories.

- WESTPLAN Dambreak (2004) is too narrow in scope as it focuses entirely on Water Corporation dams (covering only 104 of the >4000 dams in WA) and offers no solution to ownership/management responsibilities for non-public dams.

1.2 Key Recommendations

- The 19 'Tolerable subject to ALARP' risks identified in this assessment all relate to Gully Dams on watercourses in the SW of the State and should be referred to District and Local level for further review and assessment.

- Local Governments should be encouraged to develop comprehensive databases of all dams and hazard categories within their boundaries. Despite inconsistencies in requirements for dam building approvals across Local Governments, it would be appropriate for individual Local Governments to identify those dams in their area of responsibility that require dam safety management processes to be implemented based on risk assessment.

- Examine options to address the regulatory gap in dam safety that exists in the absence of applicable State legislation. Following consultation with key stakeholders, the two most practical options to address the absence of legislation and regulation for dam safety in WA are.

    - Option 1 – Apply State Level Legislation and Regulation

        - Follow VIC, QLD, NSW, TAS and ACT in developing dam safety legislation

        - Appoint a State Level Regulator

    - Option 2 – Extend the Self-Regulation Principle (Recommended as the most effective and economical solution in the short to medium term)

        - Encourage the use of ANCOLD Guidelines as Australian 'best practice' for dam safety management.

        - Manage self-regulation at Local (Local Government) level in conjunction with the current planning approvals process for dam construction.

        - Self-regulation against ANCOLD Guidelines is effective in ensuring that the owner has assessed the hazard and downstream threats to Population at Risk (PAR), infrastructure, impact on owners business, health and social impacts and environmental impacts.

        - Apply the Population at Risk (PAR) factor rather than the likelihood factor to determine which dams need to apply specific dam safety measures.

- Incorporate Dambreak flooding consequences into WESTPLAN Flood and thus remove the requirement for WESTPLAN Dambreak. Prevention and Preparedness for Dambreak are the responsibility of, and should be managed by, the dam owner but Response and Recovery efforts will invariably fall to DFES and can effectively be managed under WESTPLAN Flood and other Support WESTPLANs.

- Regulated Dams should give some consideration to improve Prevention/Preparedness controls in the areas of Public Education and Warning Systems for those Populations at Risk downstream of dams.

- Review planning guidelines that allow multiple gully dams to be developed on watercourses.

1.3 Acknowledgements

Ri'ziliens would like to acknowledge the support provided by the SEMC Risk Section.

Thanks also go to the Department of Mines and Petroleum (Jan De Lange, Inspector of Mines, Kalgoorlie), Department of Water (Mick Owen, A/Regional Manager SW Region), Water Corporation (Steve McCarthy, Security Program Manager and Michael Somerford, Principal Engineer, Dams & Dam Safety) and Brian Humphries for their assistance in developing the credible scenarios.

We would also like to acknowledge the contribution of all participants in the Dambreak Risk Assessment Workshop that was conducted on Friday 26 June 2015. A full list of participants is at Annex A.

2 Methodology

In order to undertake the review the risk assessment for Dambreak was conducted in accordance with the Western Australian Emergency Risk Management Guide (Transitional Edition, June 2014). This methodology was applied in the context of:

- The history and scope of WESTPLAN Dambreak.
- An understanding of current Emergency Management Legislation and relevant policy which would allow for the recommendation of achievable and appropriate legislative and / or policy amendments to be made.
- Jurisdictional benchmarking of how other Australian States and Territories manage the risk associated with Public dams, tailings dams and privately owned dams.
- National regulations and guidelines such as Australian National Committee on Large Dams (ANCOLD), and the Australian Government Attorney-General's Department – Manual titled 'Emergency Management Planning for Floods affected by Dams'.

Specific terms or values used in the standard assessment process are further described in this section of the report.

2.1 Controls

Each scenario assessment commenced with a review of existing Behavioural (BHV), Procedural (PRO) or Physical (PHY) controls related to Prevention/Preparedness and Response Recovery as shown in Table 1 below. Ratings were assigned to these controls based on the Control Table in Section 7 of the WA ERM Guide. These levels range from 1 to 3 where 1 is weak and 3 is strong in terms of control measures.

Existing Prevention/Preparedness Control			Existing Response/Recovery Control		
Control	Type	Level	Control	Type	Level
Design/Building Regs	PHY		Emergency Services	PHY	
Maintenance	BHV		Emergency Shelters	PHY	
Public Education	PRO		Evacuation Plans	PHY	
Warning Systems	PHY		Medical Services	PHY	
Emergency Plans	PRO		Emergency Plans	PRO	

Table 1 – Prevention Preparedness/Response Recovery Controls

2.2 Consequence

The Consequence table from Appendix D of the WA ERM Guide was used to assign levels of consequence. These consequence criteria are drawn from the National Emergency Risk Assessment Guidelines (NERAG). For the purpose of this State level risk assessment, values for People and Economy consequences were adjusted to reflect the WA population of 2,589,100 people and a WA Gross State Product figure of $264.5 Billion.

2.3 Likelihood

Event likelihood criteria was determined by the Project Team and SEMC Risk Section prior to the workshop based on an assessment of previous specific risk studies (Public and Tailings Dams), levels of design and maintenance of selected dams and anecdotal evidence from the Department of Water field based staff.

This resulted in the following criteria being applied for event likelihood.

- Public Dams – Almost Incredible – Frequency less than once per million years
- Tailings Dams – Very Rare – Frequency once per hundred thousand years
- Private Dams (Public Works designed and built) – Rare – Frequency once per ten thousand years
- Private Dams (Gully Dams) – Likely – Frequency once per ten years

Likelihood definitions are taken from the Likelihood Level table in Section 7 of the WA ERM Guide.

3 Context/Community

3.1 Dambreak Background

There have only been two recorded dam failures that have caused loss of life in Australia. One in the 1920s in Tasmania that caused 14 fatalities and the other in Queensland in 2008 causing 1 fatality. There have been multiple incidents involving private dams such as during the Victorian floods of 2010 and 2011 where spillway outflows of some dams recorded their highest volumes. Over fifty dam safety incidents, mostly associated with small dams, were reported. Most were quickly resolved and third party damage was minimal. Anecdotally there is evidence of small dam failures in the SW of the State although none resulting in injuries or major damage.

While Australia's overall dam safety record is good the record of catastrophic dam failures internationally highlights the importance of maintaining effective controls and safety programs. In the US, as an example, the Federal Emergency Management Agency (FEMA 2009) noted 28 dam failures from 1874 to 1979 that had collectively resulted in 3,424 deaths. More recently, the failure of a private dam in 2006, Kaloko Dam in Hawaii, resulted in seven fatalities and conviction of the dam owner.

Further data from the US National Performance of Dams Program (NPDP) shows that between 1975 and 2001 70% of dam failures occurred as a result of 'Overtopping' and 12% due to 'Seepage/Piping' (internal erosion). Overtopping is typically linked to high rainfall events and poorly designed emergency spillways.

Overtopping of an embankment dam beyond its spillway capacity will cause its eventual failure. The erosion of the dam wall by overtopping runoff will remove material whose weight holds the dam in place and against the hydraulic forces acting to move the dam. The removal of this mass unbalances the forces that stabilize the dam against its reservoir. As the mass of the dam wall erodes, the force exerted by the reservoir begins to move the entire structure. The embankment, having almost no elastic strength, can break allowing the impounded reservoir water to flow, eroding and removing even more material as it passes through.

The vast majority of dams in the State fall into a non-regulated category. The main challenge in this category of dams is a lack of data relating to type, size and ownership of dams.

Planning and approvals for dams is a Local Government responsibility and without a comprehensive database of private dams it is almost impossible at State level to understand the magnitude of the risk exposure presented. The fact that the 19 risk statements that fell into the 'Tolerable subject to ALARP' region in this assessment came from the non-regulated Gully Dam scenarios is testament to the need to conduct further work to determine which of the thousands of non-regulated dams require additional controls.

Five out of eight States/Territories across Australia have existing regulations for dam safety supported by legislation that defines which dams are referable and therefore require dam safety measures to be applied. Without similar legislation or regulation in Western Australia there is a reliance on self-regulation. ANCOLD provides a series of guidelines for self-regulation. These ANCOLD Guidelines have been adopted by the Water Corporation and the Department of Mines and Petroleum (DMP) in the self-regulation of Public Dams and the regulation of mining industry Tailings Dams. ANCOLD guidelines rate the hazard on consequences and Population at Risk (PAR), which in turn places the onus on the dam owner to implement dam safety measures.

3.2 Regulation/Legislation

Dam safety is a State/Territory level responsibility and as such is managed differently across Australia. Western Australia is self-regulating on the whole although Tailings Dams are covered by the Mines Safety and Inspection Act and regulated by the Department of Mines and Petroleum. Details for other States/Territories are summarised in Table 2.

State/Territory	Regulated By
New South Wales	Dams Safety Committee
Queensland	Department of Environment & Resource Management
Victoria	Department of Sustainability & Environment
Tasmania	Department of Primary Industries, Water & Environment
Australian Capital Territory	Department of Urban Services
Western Australia	Self regulated
South Australia	Self regulated
Northern Territory	Self regulated

Table 2 – Australia Wide Dam Safety Regulators

3.3 Definitions of Dams

It became clear during both the preparation and the workshop that the definitions and categorisation of dams is problematic especially in the area of privately owned dams. This is primarily due to a lack of clear definition of what constitutes a dam and furthermore what types of dams pose a threat from Dambreak. The descriptors of dams can also be emotive and although the term 'Farm Dam' is used in various government department publications it does not necessarily provide a suitable definition for the multiple types of private dams across the State.

To complicate definitions further there are dams owned by various government agencies that cannot be considered in the same self-regulated category as the Public Dams managed by the Water Corporation.

To that end, and for the purpose of this risk assessment, the six dam scenarios used in the Risk Assessment Workshop have been divided into two groups. They are Regulated (in the WA context this means self-regulated) and Non-Regulated. All Water Corporation and Tailings Dams are considered Regulated as they are subject to dam safety programs that are aligned to ANCOLD Guidelines. All other dams across the State are considered to be Non-Regulated.

3.4 Planning Approvals

A desktop review of Local Planning Schemes (LPS) from twelve shires in the SW Region identified that not all shires or councils require dam builders to seek development or planning approval for new dams. Of the twelve LPS that were reviewed only seven (58%) required planning approval and in one case this was only for dams that were not on agricultural land.

This inconsistent requirement for planning approvals at the local level means that it is difficult to accurately define the construction standards applied to non-regulated dams, their age or level of maintenance. This disparity in approvals for both legacy and new dams suggests that the most equitable way forward would be to address dam safety issues on risk assessments rather than standards against which the dam may, or may not, have been constructed.

3.5 Number of Dams in WA

It is not possible to accurately assess the total number of dams across WA largely due to the lack of data pertaining to dams that might be categorised as Non-Regulated. Public and Tailings dams are all recorded and monitored through either self-regulation by the Water Corporation or formal regulation by the Department of Mines and Petroleum.

Data available in the public domain gives an approximate indication of the potential numbers of dams across the State:

- Public Dams (Water Corporation) – 72 dams and 32 reservoirs
- Tailings Dams (DMP) – 215 active dams, 220 inactive dams (2010 figures)
- Other Dams (figures taken from SKM produced report for Department of Water 2006) - >3820 'Farm' dams across just seven key catchment areas in the South West Region alone.

Given the geographic limits and age of the aforementioned reports, it is reasonable to expect that the total number of non-regulated dams across the State will undoubtedly be much greater than the quoted figures. It should be noted that the SKM report was focussed on total storage capacity across the catchment areas and only described the dams as 'Farm Dams'. This total number is therefore assumed to include a large percentage of dams that are not situated on a watercourse and may be of such insignificant capacity as to pose little or no hazard.

Other States/Territories across Australia have applied legislation to define those dams that require regulation. Table 5 outlines the defining criteria for dam regulation which has enabled the relevant regulator to clearly identify those dams that present a hazard. Note that terms such as 'Significant, High and Extreme' relate to ANCOLD Guidelines that define a dam's hazard category based on the level of consequence downstream of a dam without linking the consequence to likelihood of failure.

State/Territory	Criteria for Regulation	Number of Regulated Dams
NSW	Low consequence category dams >15m height and all other Significant, High and Extreme consequence category dams	346
QLD	PAR > 2 people Failure impact assessment to determine PAR is required if dam is: 1. Height >8m and capacity >500ML or 2. Height >8m, capacity >20ML and catchment area >3 x surface area of dam when full At Regulator's request	106
VIC	All Public dams with Significant or higher consequence category Private dams on a waterway with Significant or higher consequence category; or Height >5m and capacity >500ML or Height >10m and capacity >20ML or Height >15m regardless of capacity	250 Public 700 Private
TAS	Capacity >1ML or on a waterway	8300
ACT	Scheduled dams	6

Table 3 – Other States/Territories Criteria for Regulation

3.6 WESTPLAN Dambreak

The existing WESTPLAN Dambreak (Sep 2004) deals with dam break events occurring at a dam managed by the Water Corporation. Note that its full title is "State Dam Break Emergency Management Plan for Water Corporation Dams". Under this plan, authority was vested in the Water Corporation as the designated Hazard Management Agency (HMA) under SEMC Policy Statement No. 7. When SEMC Policy Statement No. 7 was superseded by the WA Emergency Management Act 2005, the hazard of Dambreak was not transferred across and therefore is not currently prescribed by legislation.

Given that HMAs are required to develop a WESTPLAN to provide strategic, State-level arrangements for managing particular hazards for which they are responsible, the designation of the Water Corporation as HMA for Dambreak is inappropriate as the organization is only responsible for a small percentage of the dams across WA. Note that there are 104 dams across the State that are managed by the Water Corporation. There are approximately 450 Tailings Dams which are regulated by the Department of Mines and Petroleum and an unknown number of non-regulated dams across the State with a broad range of ownership that are not covered by any legislation or regulation. The existing WESTPLAN Dambreak (2004) is therefore too narrow in focus and does not reflect the State level risks identified in this risk assessment process. The risks posed by non-regulated dams far outnumber those posed by regulated dams covered under WESTPLAN Dambreak.

Manual 23 of the Australian Emergency Manuals Series – Emergency Management Planning for Floods advises that 'floods can be caused or exacerbated by dams' and recommends strong coordination between dam owners and local emergency managers. In WA, hazard planning for Flood is vested in DFES although the current 2010 version WESTPLAN Flood specifically excludes floods caused by 'dam breaks and infrastructure failures'. However, under the hazard definition section of WESTPLAN Flood the linkage to 'floods caused by heavy rainfall and failure of engineered structures' is clear.

In Victoria the State Flood Emergency Plan (2012) assigns responsibility for floods to VICSES. Dambreak is covered by an attachment to the Victoria State Flood Emergency Plan – 'Management of flooding downstream of dams'. This attachment assigns Control Agency responsibility to the Department of Environment and Primary Industry (DEPI) for safety incidents at the dam site and clarifies Control Agency status for VICSES for response to the flood consequences of a Dambreak.

A similar model to the Victorian model could be adopted in WA with DFES assuming HMA responsibility for response to floods caused by Dambreak. However, in the absence of an overarching regulatory body across all State dams it may be necessary to nominate a range of Controlling Agencies to assume responsibility for safety incidents at a dam site. In effect this structure already exists for Public Dams and Tailings Dams through the Water Corporation and DMP. The solution for other dams is not easily defined but could be designed to rest with relevant Local Government/LEMC in coordination with the dam owner.

This State-wide macro level risk assessment of Dambreak identified no 'Intolerable' risks from a State perspective. Those risks identified as 'Tolerable subject to ALARP' all relate to the scenarios that involved non-regulated gully dams whose risk ratings are elevated by their likelihood of failure rather than their consequences at a State level. As a result it is recommended that the response and recovery aspects of Dambreak can be more appropriately managed under WESTPLAN Flood and other relevant Support WESTPLANs.

3.7 Hazards Assessed

The purpose of the Dambreak Risk Assessment was to ascertain the risks presented by a Dambreak hazard to the State of Western Australia. The scope included the following categories of dams:

- public dams; (including reservoirs and storage tanks)
- tailings dams; (including effluent dams) and
- privately owned dams (including gully dams).

Given the broad range of geographical and climatic aspects of Western Australia it was decided that the selection of Dambreak scenarios for the Risk Assessment Workshop would need to include more than the typical selection of two worst-case scenarios. To this end, it was decided to use six scenarios spanning the types of dams specified in the project scope. The scenarios used are outlined below:

- Regulated (Public) Dams
    - Harvey Dam – failure due to internal piping/erosion
    - Harding Dam – failure due to internal piping/erosion
- Regulated (Tailings) Dams
    - Fimiston 1 – Kalgoorlie – failure to combined high rainfall/seismic event
- Non-Regulated Dams
    - Gully dams south of Donnybrook in the Capel River catchment – failure due to overtopping following heavy rainfall event
    - Dunham Pilot Dam – Kimberley – failure due to internal piping/erosion
    - Gully dams between Manjimup and Pemberton in the Lefroy Brook catchment – failure due to overtopping following heavy rainfall event

Additional detail on these scenarios can be found at Annex B

4 Risk Register

Separate Risk Registers were developed for each of the six scenarios conducted in the Risk Assessment Workshops. These are provided at Appendix 1 to this report. For the purpose of the analysis and evaluation the scenarios have been grouped into Regulated and Non-Regulated dams. The Regulated Dam grouping includes Public Dams (self-regulated by the water Corporation) and Tailings dams (regulated by the DMP)

The risks identified at the Dambreak Risk Assessment Workshop have been analysed and summarised below.

4.1 Controls

Prior to the assessment of each scenario's risk statements, a basic assessment of Control Levels was conducted to enable the attendees to understand the levels of Behavioural, Procedural and Physical controls that are currently in place from both a Prevention/Preparedness and Response/Recovery perspective.

The summary of cumulative Control Levels is shown in Figures 1 and 2 below. Additional detail is provided at Annex B.

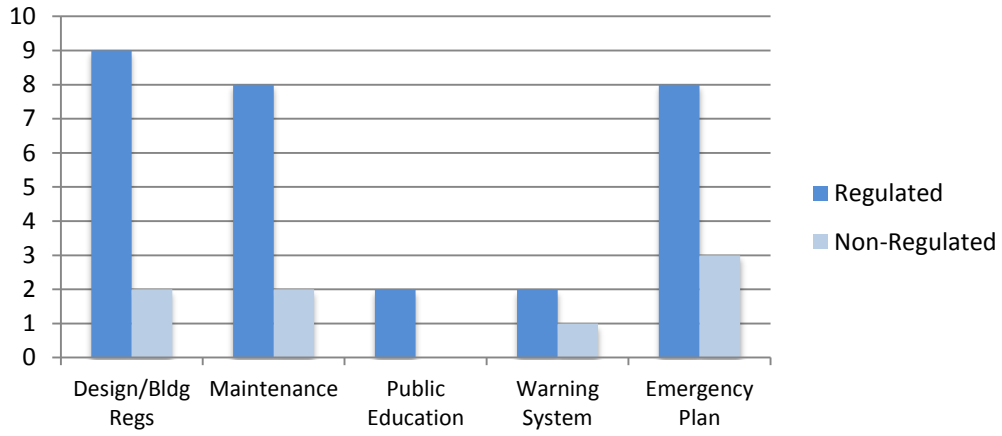


Figure 1 - Summary of Prevention/Preparedness Controls

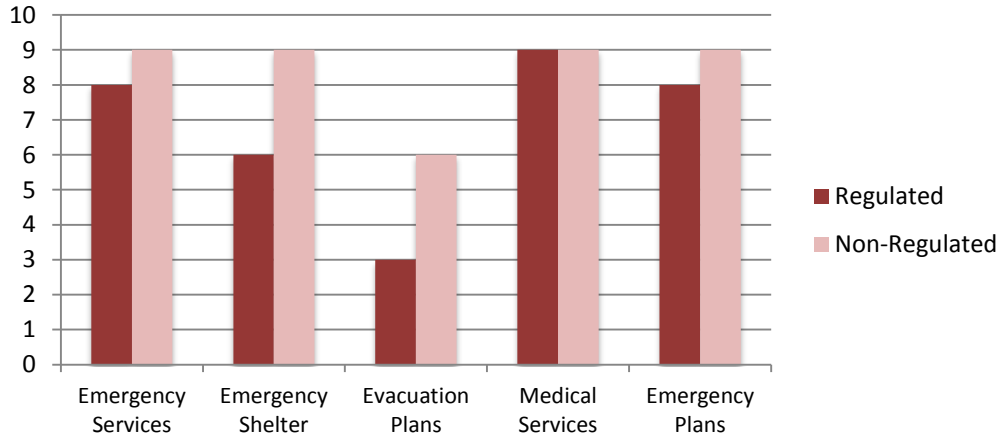


Figure 2 – Summary of Response/Recovery Controls

The data demonstrates that dams from the Regulated group have stronger Prevention/Preparedness controls than the Non-Regulated group which reflects the differences in design and maintenance standards as well as the status of dam specific emergency response plans. Response/Recovery Controls are seen to be stronger in the Non-Regulated group but this mainly reflects the stretch on the capabilities of Emergency Services to cope in the event of the failure of one of the larger Regulated Dams. Response/Recovery controls for both Regulated and Non-Regulated Dams will generally be covered by the application of other State level plans such as WESTPLAN Flood, WESTPLAN Health, WESTPLAN Welfare and WESTPLAN Recovery Coordination.

Regulated Dams should give some consideration to improve Prevention/Preparedness controls in the areas of Public Education and Warning Systems for those Populations at Risk downstream of dams. Although it is unlikely that a warning system for a Sunny Day Failure at the Harvey Dam would benefit the community of Harvey who at best would receive 11 minutes notice; a warning system at the Harding Dam would possibly provide 4-5 hours notice to the town of Roebourne and other communities in the inundation zone.

There was no detailed documented evidence found on Prevention/Preparedness controls for Non-Regulated Dams and the view of the Risk Assessment Workshop participants was that for most Gully Dams these controls do not exist. The lack of recognised design/building regulations and associated maintenance checks was a key factor in using a likelihood rating of 'Likely' to rate dam failure event probability in this assessment. Statistics have identified that overtopping as a result of poor spillway design/maintenance is the main cause of Gully Dam failures.

4.2 Risk Analysis and Evaluation

4.2.1 General

Across the six scenarios addressed in the workshop a total of 96 risk statements were discussed. These risk statements are shown in the Risk Register at Appendix 1. The ratio of risks rated from Low to High are summarised in the chart below. Note that there were no risks rated as 'Extreme' across any of the scenarios.

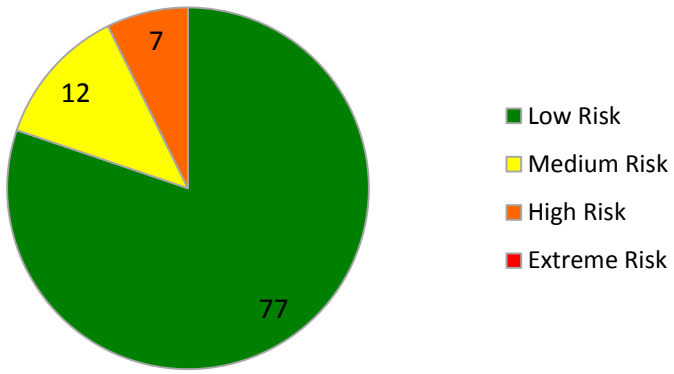


Figure 3 – Ratio of Risks

4.2.2 Risk Distribution Across Scenarios

The distribution of rated risks across the six scenarios is shown in Figure 4. It can be seen from this chart that all of the risks rated as 'Medium' and 'High' are related to the two scenarios that featured the failure of Non-Regulated Gully Dams. There were seven risk statements in the 'High' category and twelve risk statements in the 'Medium' risk category. All nineteen of these risks fall into the category of 'Tolerable subject to ALARP'.

The other seventy-seven 'Low' risk statements are categorised as 'Broadly Acceptable' from a tolerability perspective at State level.

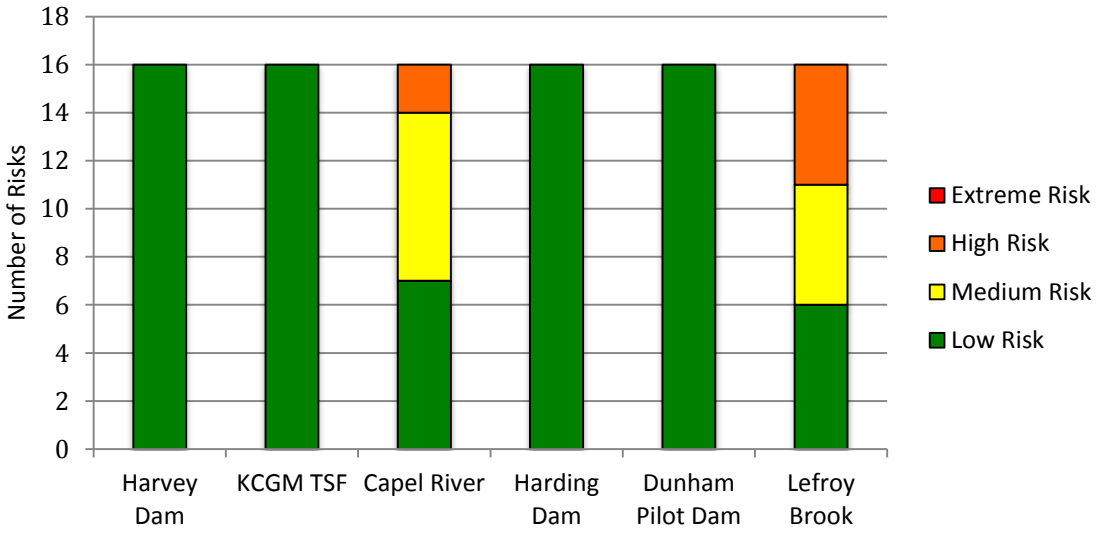


Figure 4 – Risk Distribution

4.2.3 Regulated Versus Non-Regulated Dams

When the scenarios and types of dam are grouped into Regulated and Non-Regulated Dams the proportion of 'Low' risk statements to 'Medium' and 'High' risk statements gives focus to those risks that require further action. The chart below shows that 100% of the risk statements that were considered for Regulated Dams were rated 'Low'. For Non-Regulated Dams, 59% were rated 'Low', 26% were rated 'Medium' and 15% were rated 'High'.

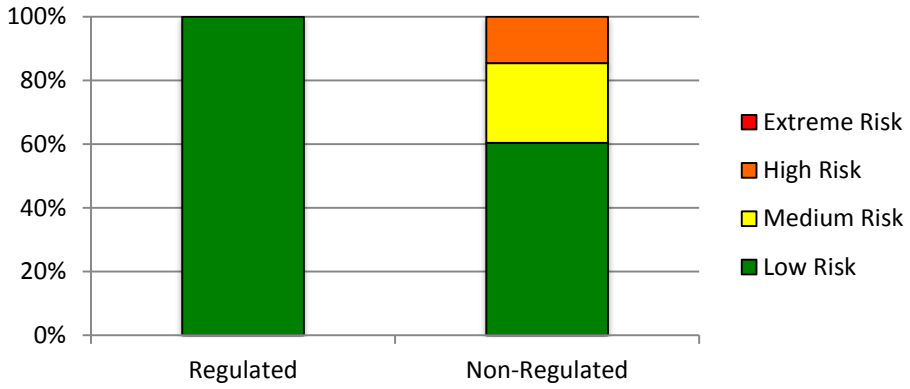


Figure 5 – Regulated/Non-Regulated Dam Risks

4.2.4 Risks Grouped by State Core Objectives

Each scenario examined the same 16 risk statements. Those in the Medium and High category for both Regulated and Non-Regulated dams are summarised in the chart below to indicate where the risks were identified against the six State Core Objectives of the community environment – People; Environment; Economy; Social Setting; Public Administration; and Infrastructure. More detail on State Core Objectives can be found in the WA ERM Guide.

Figure 6 – Risks Grouped by State Core Objectives

4.3 Consequence Comparisons

4.3.1 Regulated Dams Consequence Ratings

Figure 7 shows the maximal consequence rating per risk statement before the Likelihood is factored in for Regulated Dams. Although there are ten risk statements with a 'Major' consequence rating the final risk rating is 'Low' when the Likelihood rating of 'Almost Incredible' or 'Very Rare' is incorporated.

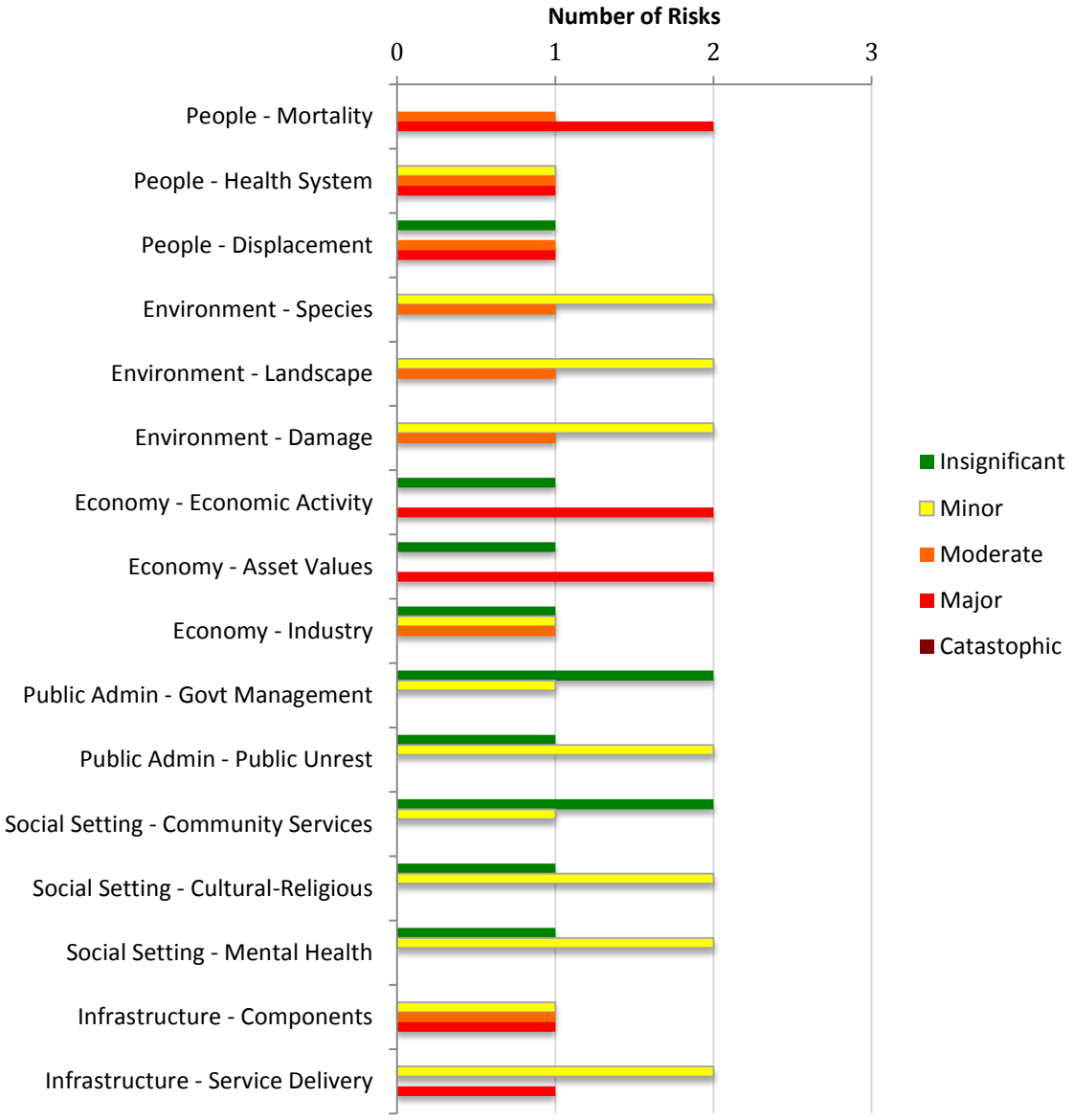


Figure 7 – Consequence Ratings for 'Regulated Dams'

Of note from this data is that the 'Major' consequence risk statements affect three of the State Core Objectives – People (4), Economy (4) and 'Infrastructure' (2).

This level of consequence is captured and managed under ANCOLD Guidelines that require dam owners to implement appropriate levels of dam safety programs. These include specified inspections and engineering reports as well as Dam Emergency Response Plans.

4.3.2 Non-Regulated Dams Consequence Ratings

By comparison to the consequences for Regulated Dams, the same data for Non-Regulated Dams is shown below. There are no 'Catastrophic' or 'Major' consequence ratings but there are eleven 'Moderate' consequence ratings. These 'Moderate' consequence ratings equate to 'High' risk ratings when the Likelihood rating of 'Likely' is factored in.

Figure 8 – Consequence ratings for Non-Regulated Dams

Note that for Non-Regulated Dams the 'Moderate' consequence ratings have a slightly different effect on the State Core Objectives – People (6), Environment (3) and Economy (2).

Although at State level the highest defined consequence level is Moderate it is anticipated that a Local level risk assessment would reach a higher consequence risk rating.

4.4 Summary of Risk Analysis and Evaluation

The data demonstrates that event probability is a key determining factor in the results of this risk assessment.

All of the nineteen Medium and High Risks (Tolerable subject to ALARP) were related to the Non-Regulated Dams that were examined and in particular to the scenarios involving Gully Dams on the Capel River and Lefroy Brook. The event probability of 'Likely' increased their risk levels rather than the consequences at a State level.

The Gully Dam scenarios used in this risk assessment were in many respects generic and selected to represent examples of the hazards presented by Gully Dams on watercourse through the SW of the State. Any measures to reduce the risks into the 'Broadly Acceptable' region must be the responsibility of Local Governments who provide planning approval for the construction of such dams. Accurate details of the numbers and types of dams that pose a threat must be gathered before work can commence to mitigate the risk though detailed risk assessment/dam safety planning.

The ANCOLD approach to risk defines the hazard category against a scale of adverse consequences defined by the size of 'Population at Risk' (PAR) and the severity of damage and loss caused by dam failure. This categorisation is independent of event probability and is used across Australia as 'best practice' for determining appropriate levels of dam safety programs.

As an example under ANCOLD the Hazard Category for the Water Corporation Harvey Dam is 'Extreme' but under the process used for this assessment the Risk category at a State level for the Harvey Dam in 'Low'. Note that the main contributory factor for an 'Extreme' rating under ANCOLD is the Population at Risk factor of >1000 people.

The application of ANCOLD Guidelines to the plethora of Gully Dams across the SW of the State would enable Local authorities to base dam safety programs on downstream threats rather than likelihood of failure.

5 Treatment Strategies

5.1 Regulated Dams (Public Dams and Tailings Dams)

From a State perspective all risks pertaining to Regulated Dams were rated as 'Low' and in the category of 'Broadly Acceptable Tolerability'. As a result there are no urgent treatments required to reduce risk. However, there are some controls that could be enhanced:

- Improve public education
- Consider the need for automated warning systems
- Link the response and recovery aspects of Dambreak to WESTPLAN Flood

Treatment 1	**Improve public education and awareness of the risk of Dambreak**
Benefits	Increased awareness of the hazard presented by regulated dams which are actively managed under a dam safety management program. This should provide reassurance to the public that the overall risk is rated 'Low' based on event probability.
Resources	This can be managed through Water Corporation and DMP interface with respective Local Governments and LEMCs
Responsibilities	Water Corporation and DMP

Treatment 2	**Review the need for automated Warning Systems on Public Dams**
Benefits	Advanced notice to communities and populations down stream will enable evacuation procedures to be activated and thereby reduce the population at risk
Resources	This process could be incorporated into the State Risk Management Project
Responsibilities	Water Corporation

Treatment 3	**Increase the scope of WESTPLAN Flood to incorporate Dambreak as a source of flooding rather than a hazard in itself**
Benefits	This will ensure that the HMA responsibilities for dealing with the effect of a Dambreak can be legislated regardless of dam ownership issues.
Resources	DFES and SEMC
Responsibilities	DFES and SEMC

Table 4 – Proposed Treatment Strategies Public & Tailings Dams

5.2 Non-Regulated Dams

There is a need to provide treatments options for the nineteen 'Tolerable subject to ALARP' risks identified in this State level risk assessment. These all related to private gully dams and were drawn from the two scenario examples used in the Risk Assessment Workshop. These scenarios were selected as generic examples of gully dams on watercourses in the southern part of WA and are indicative of many other similar gully dams across the region. It would therefore be of limited value to drill down into detailed treatment options for these two particular examples when there may be more pressing examples of the same scenario at Local (Local Government) level.

The fundamental challenge to developing detailed treatment options for private dams is understanding the number of dams that present a hazard and therefore the development of an appropriate database is a high priority.

The macro level treatment options required for non-regulated dams are:

- Identify the number of non-regulated dams across the State and develop a comprehensive database
- Extend dam safety self-regulation, as practised by the Water Corporation, to include private dams
- Review planning guidelines that allow multiple gully dams to be developed on watercourses

Treatment 4	**Conduct Dambreak Risk Assessment Workshops at District and Local level to identify the scale of high-risk dams.**
Benefits	DEMCs and LEMCs would develop an increased understanding of the risks associated with Dambreak and data could then be consolidated to provide a State-wide database.
Resources	This process could be incorporated into the State Risk Management Project.
Responsibilities	SEMC, DEMC and LEMCs

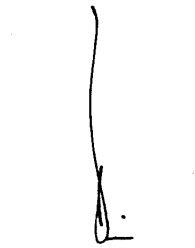
Treatment 5	**Encourage dam owners to adopt a self-regulating process for assessing their dam against the consequence rated categories included in ANCOLD Guidelines.**
Benefits	Dam owners will be more aware of the responsibilities associated with dam ownership and the potential impact downstream in the event of a dam failure.
Resources	Ideally this should be driven at Local Government level although it may be necessary to provide State level 'tool-kits' to describe ANCOLD methodology.
Responsibilities	Local Governments

Treatment 6	**Review planning guidelines that allow multiple gully dams to be developed on watercourses.**
Benefits	The proliferation of gully dams on watercourses presents an additional risk of failure due to the cascade effect of one dam failing upstream. Planning approval process improvements to consider the downstream impact of both new and existing gully dams will help to mitigate this effect.
Resources	Coordination between Department of Water Licensing and Local Government Planning Departments.
Responsibilities	Local Governments, Department of Water, Department of Planning

Table 5 – Proposed Treatment Strategies Private / Non-Regulated Dams

6 Next Steps

The next step is to engage with the Districts, the State Emergency Management Committee and other key stakeholders to review the recommendations detailed in this report and agree on the set of actions required to implement the changes.



David Borrill

Director
Ri'ziliens Pty Ltd

Annex A – Workshop Participants

Name	Title	Representing
Neil Guise	Regional Director, Regional Leadership & Operations, Southern	Department of Agriculture and Food
Brian Humphries		Private
Saorla Finucane	Pollution Response Officer	Department of Environmental Regulation
Ricki Curtis	Superintendent South West, Country	Department of Fire & Emergency Services
Steve Gray	Manager, Hazard Planning	Department of Fire & Emergency Services
Craig Waters	Superintendent Metropolitan	Department of Fire & Emergency Services
Fiona Rowland	Environmental Impact Assessment Officer	Department of Fisheries
Carol Readshaw	Senior Policy Officer	Department of Health
Kirrillie Caldwell	Policy Adviser - Environment	Chamber of Minerals and Energy WA
Jan De Lange	Inspector of Mines, Geotechnical Mines Safety	Department of Mines & Petroleum
Milan Zaklan	Policy Director	Pastoralists & Graziers Association
Sue Walker	Vice Chair Private Property Rights and Resources Committee	Pastoralists & Graziers Association
Jerome Partridge	Principal Project Officer	Department of Premier & Cabinet
Roland Mau	Manager Riverpark	Swan River Trust
Stuart Vassiliou	A/Senior Sergeant	WA Police
Steve MacCarthy	Security Program Manager	Water Corporation
Michael Somerford	Principal Engineer, Dams & Dam safety	Water Corporation
Tim Katsavounidis	Principal Policy Officer, Strategic Policy Division	Department of Water
Mick Owens	Program Manager, Licensing and Water Use, SW Region	Department of Water
Mal Cronstedt	Executive Director	SEMC Secretariat
Muriel Leclerq	Manager Policy & Legislation	SEMC Secretariat
Vik Cheema	Community Emergency Management Officer, South West	SEMC Secretariat
Lisa Allison	Hazard Researcher, Risk and Mitigation	SEMC Secretariat
David Borrill	Director	Ri'ziliens
Andrew Della-Vedova	Director	Ri'ziliens
Fred Davenport	Director	Galt Geotechnics

Apologies		
Kim Dean		Child Protection & Family Services
Stuart Gunning		SEMC Secretariat
Syed Islam		Bureau of Meteorology
Mel Pexton		WALGA
Simon Rodger		Department of Water
Richard Theobald		WA Health

NB.

1. WA Department of Planning did not attend the Risk Assessment Workshop but did provide advise out of session.
2. WA Department of Local Government and Community recommended that WALGA was the most appropriate body to assist.

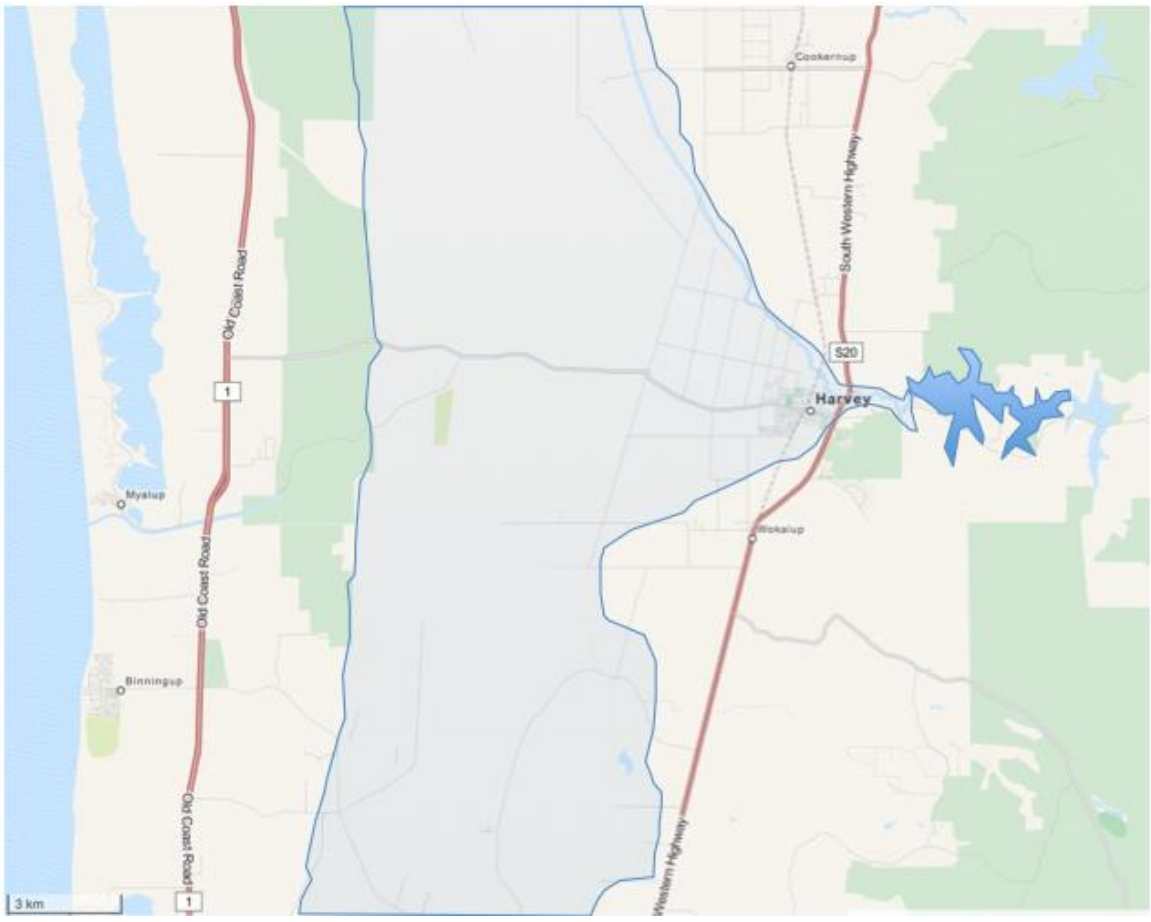
Annex B – Summary of Existing Controls

	Existing Prevention/Preparedness Control			Existing Response/Recovery Control		
	Control	Type	Level	Control	Type	Level
Harding Dam	Design/Building Regs	PHY	3	Emergency Services	PHY	2
	Maintenance	BHV	3	Emergency Shelters	PHY	3
	Public Education	PRO	2	Evacuation Plans	PHY	3
	Warning Systems	PHY	0	Medical Services	PHY	3
	Emergency Plans	PRO	3	Emergency Plans	PRO	2
Fimiston 1 TSF	Design/Building Regs	PHY	3	Emergency Services	PHY	3
	Maintenance	BHV	2	Emergency Shelters	PHY	0
	Public Education	PRO	0	Evacuation Plans	PHY	0
	Warning Systems	PHY	2	Medical Services	PHY	3
	Emergency Plans	PRO	2	Emergency Plans	PRO	3
Capel River	Design/Building Regs	PHY	0	Emergency Services	PHY	3
	Maintenance	BHV	0	Emergency Shelters	PHY	3
	Public Education	PRO	0	Evacuation Plans	PHY	3
	Warning Systems	PHY	0	Medical Services	PHY	3
	Emergency Plans	PRO	0	Emergency Plans	PRO	3
Harding Dam	Design/Building Regs	PHY	3	Emergency Services	PHY	3
	Maintenance	BHV	3	Emergency Shelters	PHY	3
	Public Education	PRO	0	Evacuation Plans	PHY	0
	Warning Systems	PHY	2	Medical Services	PHY	3
	Emergency Plans	PRO	3	Emergency Plans	PRO	3
Dunham Pilot Dam	Design/Building Regs	PHY	2	Emergency Services	PHY	3
	Maintenance	BHV	2	Emergency Shelters	PHY	3
	Public Education	PRO	0	Evacuation Plans	PHY	0
	Warning Systems	PHY	2	Medical Services	PHY	3
	Emergency Plans	PRO	3	Emergency Plans	PRO	3
Lefroy Brook	Design/Building Regs	PHY	0	Emergency Services	PHY	3
	Maintenance	BHV	0	Emergency Shelters	PHY	3
	Public Education	PRO	0	Evacuation Plans	PHY	3
	Warning Systems	PHY	1	Medical Services	PHY	3
	Emergency Plans	PRO	0	Emergency Plans	PRO	3

Annex C – Scenario Outlines

Scenario One – Harvey Dam – Public – Water Corporation

- It is now mid-October
- The dam is checked daily for increased seepage rates and the last check was at 11.00am yesterday.
- Seepage rates were normal and the next check was due later today.
- Overnight seepage rates increased causing major internal piping erosion issues leading to major structural failure at 1000 this morning.
- Capacity on dam at failure was 56GL
- Estimated discharge rate following 'Sunny Day Failure' is 21,500m^3/sec
- Flood waters predicted to reach Harvey town site in 11 minutes
- Depth of inundation 3-5m
- Water moving at 3m/sec (10km/hour)

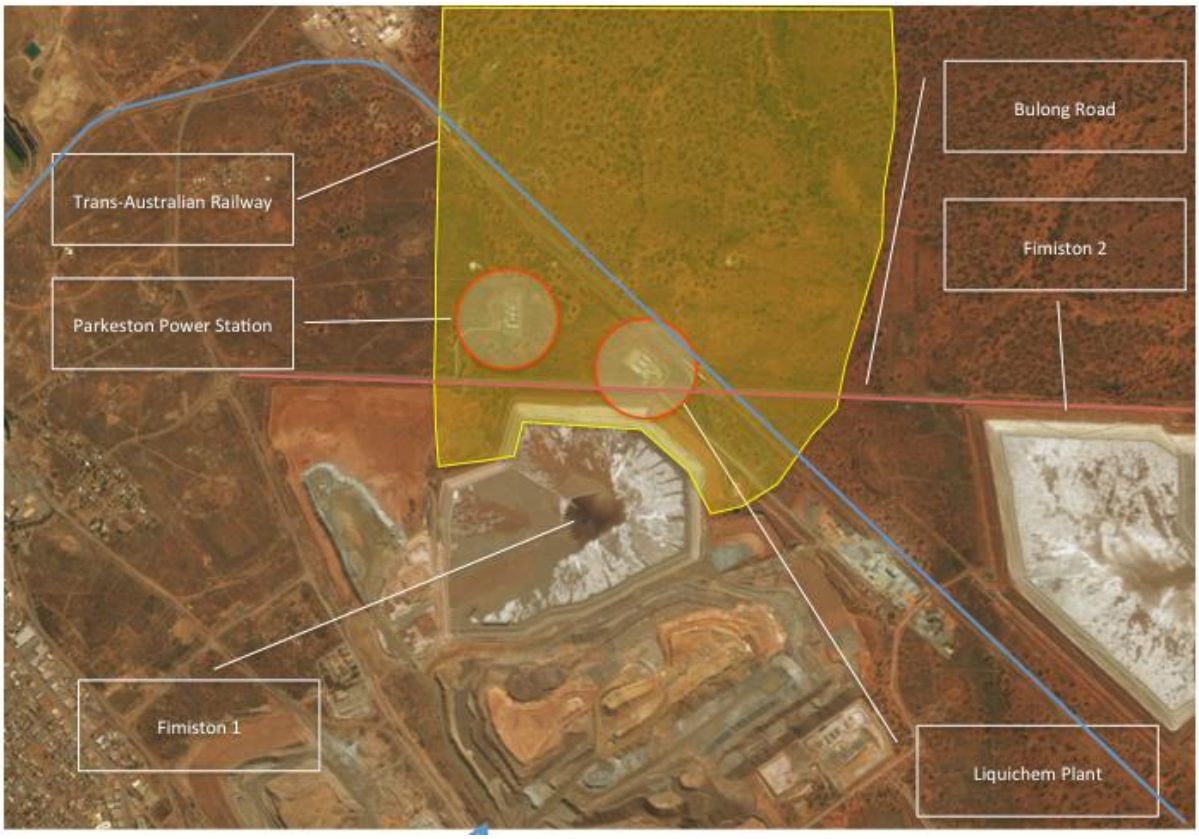


Contributors to scenario development:

Steve MacCarthy – Water Corporation
Michael Somerford – Water Corporation
Fred Davenport – Galt Geotechnics

Scenario Two – Fimiston Tailings Storage Facility (TSF) – Mining – KCGM

- The date is 23rd January - 9 days earlier on the 15th January 50mm of rainfall was recorded at Kalgoorlie in 1 hour, exceeding the 1:100 year event (43.1mm)
- Last night Kalgoorlie experienced more heavy rainfall and up to 10.00am this morning another 86.8mm had fallen in 10 hours
- At 1100 this morning an Earthquake measuring 5.0 on the Richter scale struck the Kalgoolie area
- Geoscience Australia recorded the epicentre 3km East of Kalgoorlie at a depth of 6km
- The combined effects of heavy rainfall and earthquake caused the TSF wall to collapse
- Capacity was ~63m tonnes
- Inundation reaches Trans-Australia Rail line in 2 minutes
- Width of inundation 900m
- Slurry moving at 3-5m/sec (10km/hour) and lasting 10-30 minutes

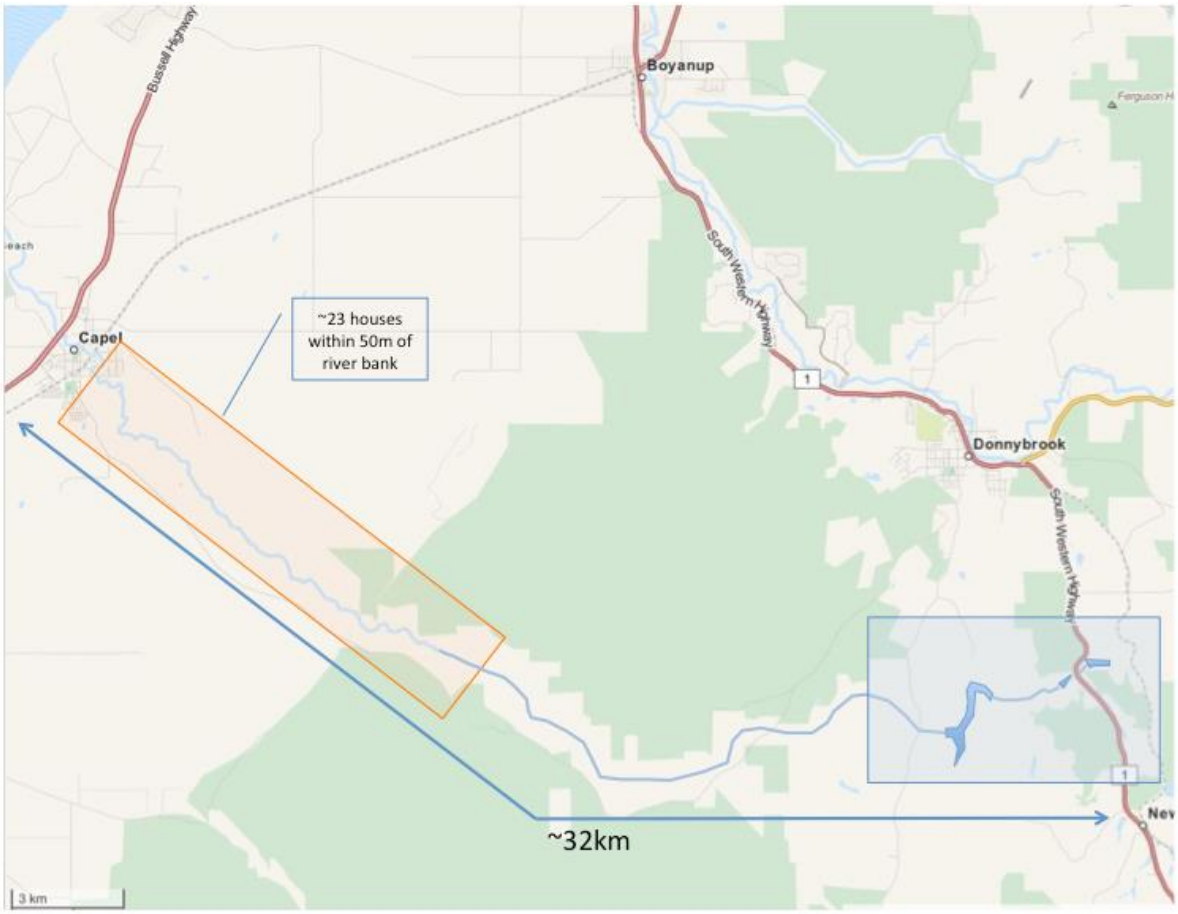


Contributors to scenario development:

Jan De Lange – Department of mines and Petroleum
Fred Davenport – Galt Geotechnics

Scenario Three – Capel River – Private Gully Dams

- The date is late August
- The Donnybrook area has been experiencing heavy rainfall for the past three months – 621mm in 90 days
- So far August has produced 150mm
- All gully dams full and some over topping
- Overtopping of a dam is often a precursor of dam failure.
- American statistics show that overtopping due to inadequate spillway design, debris blockage of spillways, or settlement of the dam crest account for approximately 34% of all U.S. dam failures.
- Incident is triggered by the failure of dam wall on gully dam just east of SW Highway releasing an estimated 210ML

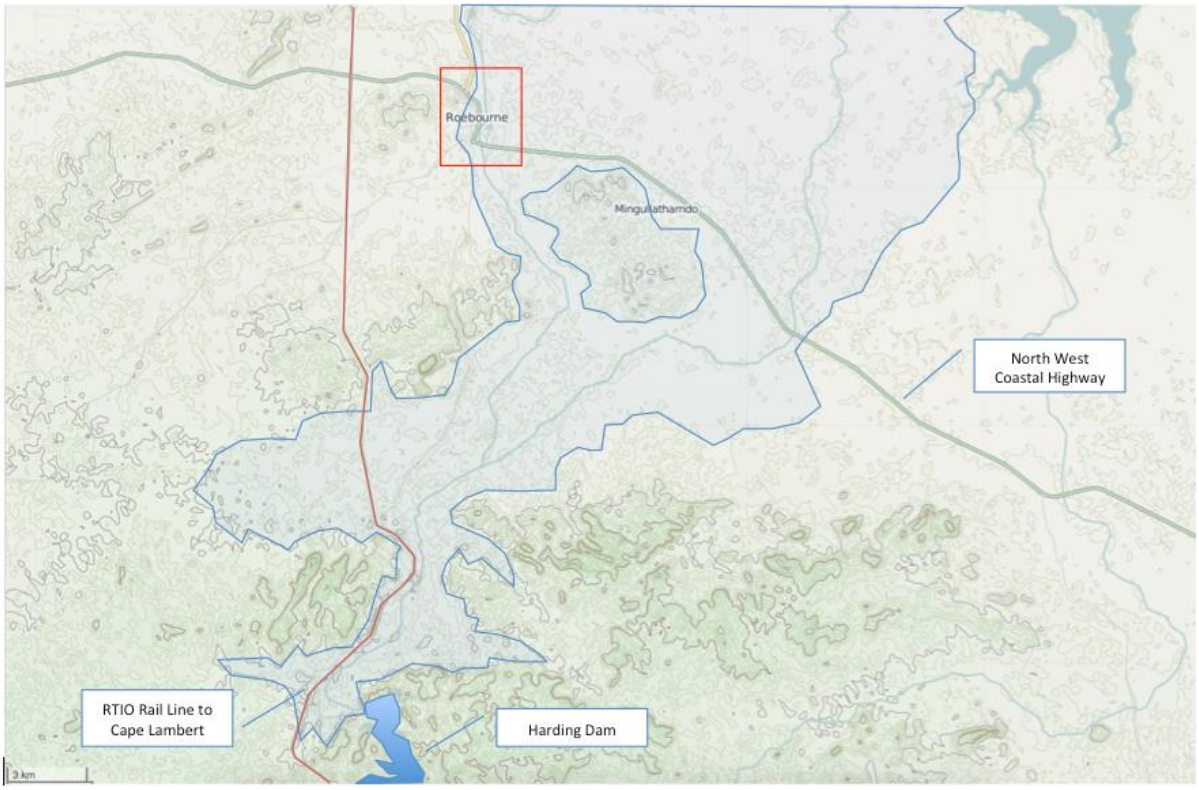


Contributors to scenario development:

Mick Owens – Department of Water
Fred Davenport – Galt Geotechnics

Scenario Four – Harding Dam – Public – Water Corporation

- Internal erosion causes a catastrophic failure of the dam wall at 1300 today
- The Water Corporation will notice an immediate loss of power
- Rio Tinto Rail Control at the Remote Operations Centre in Perth will be alerted to a break in the line near Harding Dam
- Dam maximum capacity 64GL
- Initial depth of inundation 37m
- Flood waters reach Roebourne townsite in 4.9 hours
- Depth of inundation 6m
- Water moving at 2.5m/sec (9km/hour)

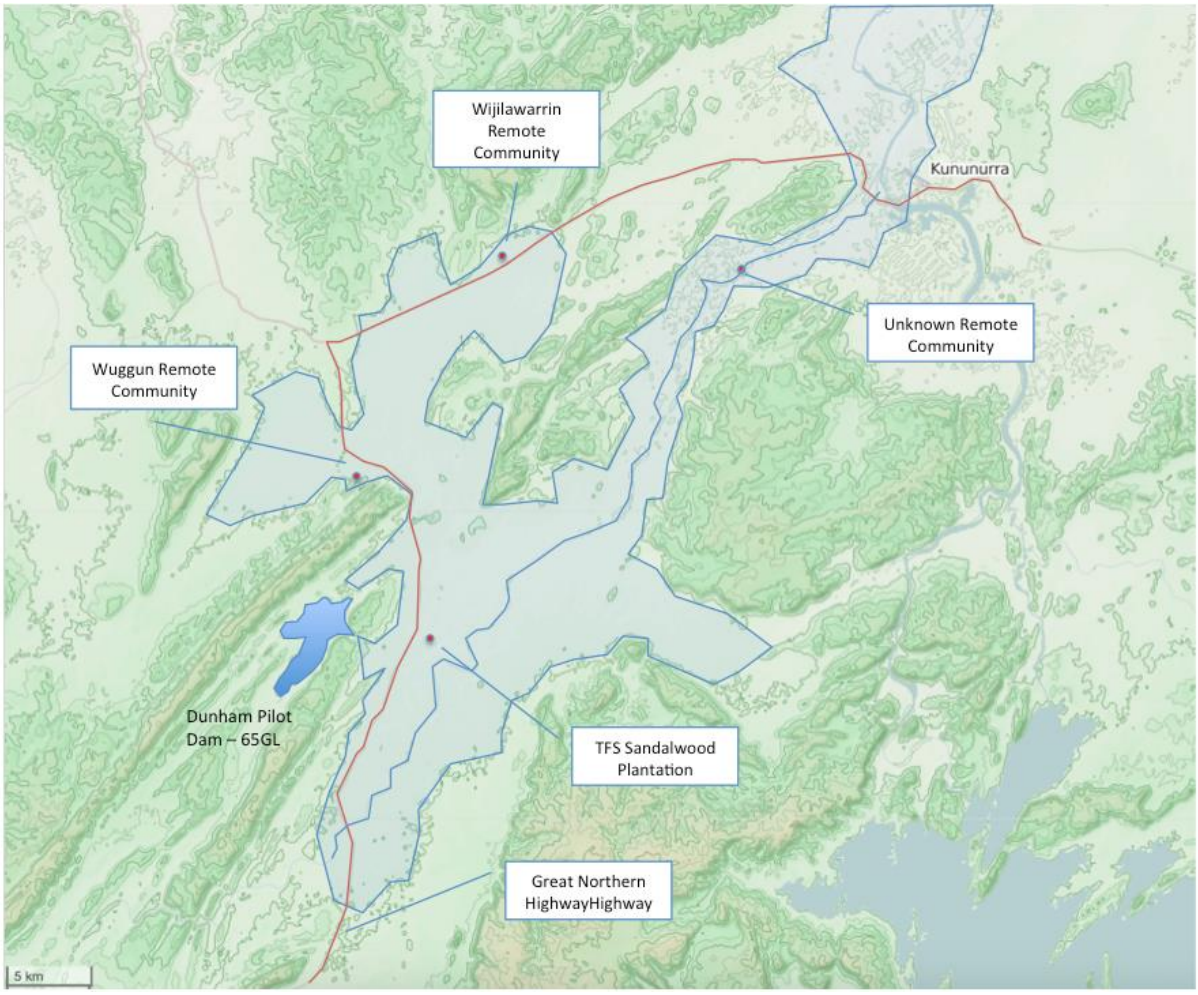


Contributors to scenario development:

Steve MacCarthy – Water Corporation
Michael Somerford – Water Corporation
Fred Davenport – Galt Geotechnics

Scenario Five – Dunham Pilot Dam – Commercial – Tropical Forestry Services

- The dam is owned and operated by the Tropical Forestry Services and provides irrigation for their 2000 hectares of sandalwood plantation which generates about $150m annual revenue
- Original built as the Dunham Pilot Dam in the early 1960s as a pilot project for the Ord irrigation scheme.
- The dam is at 230m elevation.
- The dam sits just above and to the West of the Great Northern Highway.
- Failure of the dam is caused by internal erosion
- Existing seepage around Eastern Abutment increases rapidly this morning
- Dam maximum capacity 65GL
- Flood waters reach Kununurra townsite in 7-8 hours
- Depth of inundation 1-2m
- Water moving at 2.5m/sec (9km/hour)



Contributors to scenario development:

Michael Somerford – Water Corporation
Fred Davenport – Galt Geotechnics

Scenario Six – Lefroy Brook – Private Gully Dams

- It is late August
- Manjimup rainfall over the last four months has been high
  - May 116mm, June 224mm, July 219mm, Aug 205mm
- Water Corporation Manjimup Dam spilling on main spillway
- All gully dams full and some overtopping
- Overtopping causes failure of dam wall on gully dam just below Manjimup Dam which releases an estimated 350ML
- This triggers a cascade failure of the next two dams of Lefroy Brook releasing a surge of another ~1.5GL into existing flow rate of 1.5GL per day
- Flood waters reach Pemberton townsite in 3-4 hours
- Depth of inundation along the watercourse is 3-5m
- Water moving at 3m/sec (10km/hour)

Contributors to scenario development:

Brian Humphries – Private
Mick Owens – Department of water
Fred Davenport – Galt Geotechnics

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