Seqwater Portfolio Risk Assessment and Management

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THE WHOLE POINT OF RISK ASSESSMENT

You Don't Know What You Don't Know

But You need a team to find out if it matters....
SEQWATER — DOWN UNDER
WHERE WE OPERATE

- One of Australia’s largest water businesses
- $12B in assets
  - 26 dams, 51 weirs, 2 bore fields
  - 37 water treatment plants
  - 22 pump stations
  - 18 reservoirs
  - 600km pipeline network
  - recycled water scheme
  - desalination plant
Previous dam safety upgrade projects

- 1979 Enoggera
- 1998 Wappa
- 1999 North Pine Saddle Dams
- 2002 Gold Creek
- 2003 Wivenhoe Stage 1
- 2006 Hinze Stage 3
- 2006 Lake Manchester
- 2006 Lake Manchester
- 2007 Borumba Dam
- 2012 Ewen Maddock Stage 1
- 2014 Maroon and Moogerah

Expenditure over $570M
1. PURPOSE, CONTEXT AND SCOPE
1.1 Purpose of the Risk Assessment

Seqwater adopted risk assessment to:

- Use and all hazards approach to assessing and prioritising identified dam safety issues / deficiencies using the same metrics
- Create a baseline assessment of all dams using a consistent methodology
- Identify and target asset “unknowns” for further investigations
- Develop a prioritised capital upgrade program to meet regulator requirements
- Demonstrate a commitment to dam safety
- Provide project justification
1.2 Context for the Risk Assessment

- **2008**: Seqwater formed from assets of 2 water authorities, NRMW and 11 councils.
- **2008-10**: Dam Safety Management Program instigated including surveillance, maintenance and compliance assessment.
- **2008-10**: Compliance assessment focused on flood capacity to meet new AFC guidelines.
- **2008-11**: Surveillance program, safety reviews and AFC studies identify non-flood dam safety issues.
- **2010-11**: Initial capital upgrade program developed to satisfy compliance with dam safety guidelines.
- **2011-13**: Portfolio Risk Assessment project implemented for prioritisation of capital program.

Initial capital program cost estimates were of the order of $500M based on the assessment of flood security upgrades required across Seqwater’s portfolio of dams.
Dam Safety Management Program
Failure impact assessment, safety reviews, flood capacity assessment, comprehensive inspections

Identified issues / deficiencies / failure risks found for individual dams
Key questions: How urgent? What is the risk?

Approval given in 2011 for $1.6M Portfolio Risk Assessment (PRA) of 26 dams and Mt Crosby Weir

PRA is a detailed quantitative risk assessment using ANCOLD Guidelines on Risk Assessment
Supported by 6 expert reviewers
DAM SAFETY ISSUES IDENTIFIED

Dam safety issues

What are the critical risks?

- Probability of failure
  - How can failure occur?
  - What is the chance of failure?
  - Can we intervene?

- Consequences of failure
  - Loss of life?
  - Economic losses?
  - Environmental damage?

- Flood capacity
- Earthquake stability
- Poor design
- Changing standards
- Downstream development
- Anticipated unknowns
QUEENSLAND DAM SAFETY REGULATION

- Water regulation is managed by the State Government with the regulator appointed by state legislation.
- The Queensland Dam Safety Regulator has three key guidelines:
- The Queensland AFC Guidelines provides owners with a fall back standards based upgrade or permits the use of risk assessment.
- Where silent owner are referred to ANCOLD Guidelines.
Queensland Dam Safety Regulation

- The AFC Guidelines:
  - Specify “When relying on risk assessment, dam owners are required to undertake upgrades at least to the tolerable risk line.”
  - Present “a cost-benefit framework for determining whether ALARP upgrade improvements are required below the limit of tolerability” – a minimum standard based on an economic assessment
  - Specify a VOSL—value of a statistical life = $6.2 million AUD (in 2012 dollars)
  - Requires the probable loss of life and property damage due to dam failure to be determined over the life of the dam
QUEENSLAND DAM SAFETY REGULATION

• Reproduces the ANCOLD risk criteria (Risk Assessment Guidelines 2003)
  o for existing dams, an individual risk to the person or group, which is most at risk, that is higher than $10^{-4}$ per annum is unacceptable, except in exceptional circumstances
  o for new dams or major augmentations of existing dams, an individual risk to the person or group, which is most at risk, that is higher than $10^{-5}$ per annum is unacceptable, except in exceptional circumstances
  o for existing dams, a societal risk that is higher than the limit curve, shown on Fig. 7.4 of ANCOLD Guidelines is unacceptable, except in exceptional circumstances
  o for new dams or major augmentations of existing dams, a societal risk that is higher than the limit curve, shown on Fig. 7.5, is unacceptable, except in exceptional circumstances.
AUSTRALIAN CONTEXT

- Benchmarking of Australian owners found:
  - All major dam owners in Australia have adopted risk assessment
  - Owners have achieved at least an order of magnitude reduction in life safety risk over 10 years with another order of magnitude in the following 10 to 15 years
  - Still no consistent methodology for ALARP
1.3 **Scope of the Risk Assessment**

- The PRA was undertaken for all 26 referable dams
- Undertaken to assess life safety, economic, financial and environmental risks from dam failure
- To provide the “best estimate” of risk
- Based on the available data for each dam
- Required the development of a risk management strategy
**Risk Assessment Challenges**

**Uncertainty**

- Probability of failure – e.g. for Wivenhoe probability of the flood which would overtop the dam could be as frequent as 1 in 1,000 or as rare as 1 in 10,000,000
- Loss of life estimates – e.g. the estimated loss of life for Leslie Harrison Dam ranges from 78 to HEC – LifeSim maximum value of 2953

**Methodology**

Failure Impact Assessment Guidelines specify:

- Graham (1999) and RCEM – not applicable to large populations at risk on a flood plain
- Breach dimensions and timing – does not accurately reflect the possible failure modes
**RISK ASSESSMENT CHALLENGES**

**Methodology**

Queensland Regulator AFC Guidelines specify:

- The upgrade justification is based only on the incremental benefit beyond the limits of tolerability

- The scaling of options to produce an answer that just meets ALARP for spillways – not applicable to many of the key failure modes - yes or no decision

**New Dam or Major Augmentations**

- Evidencing why a major dam upgrade may not comply with new dam standards?

- ANCOLD and QLD Regulator call out a higher standard for new dams or major augmentations - what constitutes a major augmentation?
Risk Assessment Challenges

Changing Population

- The PAR for coastal dams has increased exponentially and will continue to increase.
- The outcomes of a risk assessment will therefore be only a snapshot in time.

Changing Standards and Load Estimates

- Best practice is evolving and our understanding of flood and earthquake loading changes through new tools, ongoing research, and improved calibration data.
2. Baseline Risk Assessment
### 2.1 Potential Failure Modes Identification

#### Background Data Collation
- Collate all available documentation and review
- Provide key data to staff involved in the inspection

#### Site Inspection
- Undertake a site inspection with operations staff, dam safety, planners, consultants, and expert reviewers and review and discuss list of potential failure modes on site

#### Failure Modes Analysis
- Workshop all conceivable potential failure modes and exclude only where compelling evidence justifies it
2.2 Evaluation against Standards

- Regulatory reviews available for all dams including:
  - Failure impact assessment (dam break inundation mapping)
  - 20 year safety review
  - Detailed design and construction documentation and reporting (not all dams)

- Update loading conditions:
  - Update the design hydrology data
  - Update or adopt the latest seismic loading assessment

- Data mining:
  - Seqwater project team undertook an exhaustive data mining project
  - Previous owners, state libraries, regulators library, consultants libraries, internet
2.3 RISK MODEL FORM

Failure Modes
- Developed by the project team with the owner, expert panel, operators and regulator

Initiating event partitioning
- 5 to 6 flood partitions – design hydrology
- 3 earthquake partitions – available data

Event trees
- Workshop with the greater team to map event trees and conditional probabilities based on available data or judgment – entered into precision tree
2.4 ESTIMATION OF LOAD PROBABILITIES

- Seqwater prior to the PRA had updated the design hydrology – allowed for conversion of a water level to a probability
- Seismic hazard assessments were updated for key dams and used to assess regional risk
2.5 Estimation of System Response Probabilities

- Safety reviews for each dam were used for engineering assessments – stability analysis, design data and basis
- Piping toolbox used – as constructed data used to inform conditional probabilities
- Engineering judgment to make realistically pessimistic assumptions as a last resort
### 2.6 Estimation of Consequences

<table>
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<tr>
<th>GIS layers of existing mapping</th>
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<tbody>
<tr>
<td>Emergency Planning</td>
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<td>Sunny Day</td>
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<td>Dam Crest Flood</td>
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<td>PMF</td>
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#### Site walk over and data collection
- Inspect the inundation area
- Collate publicly available infrastructure and property data

#### Life loss and economic damages
- Graham
- Seqwater financial data
- Government flood damage data
2.7 Existing Dam Risk Estimates and Tolerable Risk Evaluation

- F-N Plots - above the limit of tolerability
- Individual Risk Criteria – above 1 in 10,000
- Minimum upgrade defined by Cost / Benefit Ratio
- ALARP determined from:
  - Good practice
  - Gross consequences
  - Probability of failure
  - Level of residual risk
SOCIETAL RISK

- Cooloolabin
- Maroon
- Wappa
- Bill Gunn
- Little Nerang
- Wyaralong
- North Pine
- Leslie Harrison
- Ewen Maddock
- Lake Macdonald
- Wivenhoe
- Sideling Creek
Risks are unacceptable, except in exceptional circumstances

- Cooloolabin
- Atkinson
- Little Nerang
- Lake Macdonald
- Nindooindbin
- Bill Gunn
- Leslie Harrison
- Ewen Maddock
- Sideling Creek
- Wappa

Practice implemented by our ANCOLD peers = Dam Risks at least one order of magnitude below the limit of tolerability.

Limit of tolerability for existing dams

N, Number of fatalities due to dam failure

F, probability of failure per year with expected loss of life > N
SOCIETAL AND ECONOMIC RISK

The figure above shows a comparison between PLL Risk and Economic Risk for various locations. The x-axis represents different locations, and the y-axis represents the economic risk in dollars per annum. The data indicates a decreasing trend in economic risk as PLL Risk decreases, suggesting a risk-informed decision-making approach for dam safety.
INDIVIDUAL RISK
Third Workshop on Case Histories in Dam Safety Risk-Informed Decision Making
2018 Annual Conference Workshop

Total Annual Failure Probability
2.8 INSIGHTS AND RECOMMENDATIONS

- Data mining and collation – essential
- Data review – detailed data review by the team needs time
- Be very careful excluding low probability extreme events
- Partitioning matters – too coarse unhelpful
- Detailed consequences are invaluable and cost effective
2.8 INSIGHTS AND RECOMMENDATIONS

- No data is no data – assumptions can be very misleading
- Beware of the unknowns – need to have multi disciplinary teams with subject matter experts
- Beware of myths – something is not fact just because it is repeated over and over
- Make sure your team can work together – one dominant voice is not helpful
3. RISK REDUCTION ASSESSMENT
3.1 IDENTIFICATION OF RISK REDUCTION ALTERNATIVES

- Non structural first – operating level, surveillance
- Target key contributors to risk – staged upgrades such as filter buttresses or trenches to address key risk
- Full upgrade options to address all identified deficiencies
3.2 Representation of Risk Reduction Alternatives in Risk Model

- Options evaluated using risk reduction achieved
- The baseline risk models were updated to reflect the impact of each proposed upgrade on the conditional probabilities of failure
- The full upgrade option was incorporated into the risk model to assess ultimate risk reduction achievable
3.3 Risk estimates and tolerable risk evaluation for alternatives

- Following the PRA further engineering assessments and investigations were undertaken.
- The risk model for each failure mode was updated for all options to assess the efficiency of the risk reduction options.
- The level of residual risk was evaluated for partial upgrades and propose upgrade staging.
3.3 **RISK ESTIMATES AND TOLERABLE RISK EVALUATION FOR ALTERNATIVES**

- Proposed upgrades were required to meet the regulator cost benefit criteria.
- The incremental cost to achieve further risk reduction was evaluated.
- Upgrades are targeted at getting to an order of magnitude below the Limit of Tolerability.
- Full standards based upgrades were considered.
3.3 Risk Estimates and Tolerable Risk Evaluation for Alternatives

- Proposed upgrades were required to meet the regulator cost benefit criteria.
- The incremental cost to achieve further risk reduction was evaluated.
- Upgrades are targeted at getting to an order of magnitude below the Limit of Tolerability.
- Full standards based upgrades were considered.
2013 Assessed risk more than halved by upgrades, dam lowering and reassessment of risk – total expenditure approx. $23M
4. LIMITATIONS, DECISIONS, RISK COMMUNICATION AND LESSONS LEARNED
4.1 LIMITATIONS

- The quality of the baseline data available for the risk assessment was highly variable
- Inadequate time for the data review in some cases
- Limited scenarios for the consequences assessment and inundation mapping based on 1D modelling
- Uncertainty clouded the prioritization of the planning and upgrades
4.2 Decision and Risk Management Recommendations

- Future investment prioritised on life safety first, then economic risks and business risk
- Planning investigations initially targeted to reduce uncertainty and confirm risk position
- Risk used to define logical stages to upgrade projects for each dam – the aim is reduce portfolio life safety and economic risk as soon as practicable
- Other decision making considerations include probability of failure, total consequences, and business risks including water security and supply reliability
4.3 Risk Communication

- AEP is meaningless outside of engineering – use risk over the life of the asset
- The F-N curve is invaluable as a pass or fail communication tool
- Clear consistent communication to stakeholders in plain English – how will it go wrong and impacts
- Give management time – the concepts are complex
- Find an advocate on your board or management team
4.4 Lessons Learned

- The use of quantified risk assessment is a powerful tool to understand, prioritise, compare and communicate dam safety issues.
- Management need to come on the journey to understand the message, outputs and changes as they occur.
- You do not know what you do not know – review, research, examine, understand your assets using subject matter experts.
QUESTIONS?