

## **A pragmatic approach to Portfolio Risk Assessment at Severn Trent Water**

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**SYNOPSIS** Severn Trent Water Ltd (STW) sought an updated approach to reservoir portfolio risk and undertook a Portfolio-wide Risk Assessment (PRA) during 2010 and 2011.

The PRA was planned in two phases. Phase 1 encompassed data-gathering, interviews and screening, while Phase 2 was to include a more in-depth, quantitative approach. Recognising that the cost of a full quantitative assessment would need to be justified, a pragmatic approach was utilised, and quantitative assessment only considered necessary where it would add value.

The PRA revealed a strong awareness of risk within STW with a proactive approach to dealing with reservoir safety concerns. While the reservoir portfolio contains some older and inherently more risky structures, the review demonstrated that portfolio risk is being well managed. As a result, the outputs from Phase 1 were sufficient for determining asset risk rankings to allow for investment prioritisation.

STW plans for the PRA to be an ongoing process. Recommendations included methodology development with actions implemented to prepare for periodic PRAs appreciating that they are likely to be increasingly quantitative in the future.

Due to the forthcoming changes in reservoir legislation, the study has been extended to include non-statutory reservoirs and sludge lagoons. This process included: (i) a review of all known STW reservoirs; (ii) site visits by an inspecting engineer; and (iii) preliminary inundation mapping. This will enable planning, investment and risk reduction measures to be implemented before the legislation comes into effect.

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### INTRODUCTION

STW is one of the largest water companies in England and Wales and owns a large and varied portfolio of Statutory Reservoirs. Reservoir failure is one of STW's highest business risks. In 2010, STW was looking to better understand the risks across its reservoir portfolio to ensure that they were properly managed and prioritise AMP5 (2010 to 2015) funding and plan for AMP6 (2015 to 2020) funding. In the latter half of 2010 a portfolio risk assessment (PRA) was undertaken and the results of this assessment are being used to direct the implementation of the £8.1m AMP5 reservoir infrastructure maintenance works program. In addition, the PRA is proving valuable in the ongoing development of STW's reservoir risk management.

STW has approximately 750 reservoirs, of which 58 are 'Statutory Reservoirs' having a volume greater than 25,000m<sup>3</sup> above natural ground level and are regulated by the Reservoirs Act 1975 (the Act). These reservoirs range from iconic masonry structures like the Howden and Derwent Dams constructed 100 years ago, to reservoirs such as Carsington, built approximately 30 years ago, and represent the spread in age and diversity of structures within the portfolio.

The remaining 690 'Non-Statutory' reservoirs each contain a volume less than 25,000m<sup>3</sup> above natural ground level or do not hold "water as such" (e.g. they may hold waste products such as sewage sludge) and are not currently covered by the Act. These reservoirs are, for the most part, small service reservoirs, which pose less risk to the public and, crucially, have not typically had the maintenance and knowledge gathering of the larger, regulated structures.

### PORTFOLIO RISK ASSESSMENT

Owners with a large and diverse number of reservoirs, such as STW, require robust tools to enable them to effectively manage their risk portfolio. A Portfolio Risk Assessment (PRA) assists in decision making across all aspects of reservoir portfolio management.

PRA approaches can generally be split into the following categories:

1. Traditional Standards Based Assessment
2. Qualitative Risk Assessment
3. Quantitative Risk Assessment

The traditional approach typically uses engineering standards, experience and judgment to assess the safety (likelihood of failure) of a reservoir. Typically the safety of the dam, or component of it, is determined by how far its design deviates from the standard. A Section 10 inspection under the Act is an example of this assessment type for a single reservoir.

As risk is a combination of both likelihood of failure and consequence, the traditional approach is not a risk assessment. The standards applied may not

relate directly to consequence and the level of risk may vary between reservoirs and across different failure modes. For example, while the adoption of a Factor of Safety of 1.5 for dam embankment slopes will result in reservoirs with similar likelihoods of failure, risk will vary from site to site depending on the consequence of that failure.

On the other hand, a qualitative approach seeks to address the deficiencies of a standards based approach by taking into account the economic and societal consequences of failure. Qualitative assessments are not probabilistic. They include indexing and ranking schemes, hazard identification and matrix schemes. Some formal techniques have been developed such as Failure Modes and Effects Analysis (FMEA).

Finally, quantitative risk analysis builds on both the traditional and qualitative approaches. The analysis seeks to determine the level of the risk given numerical values assigned to both the likelihood and consequences of failure. Formal quantitative assessment methods include event and fault tree analyses where probabilities are assigned to every step leading to failure. However, quantitative analysis is still limited for many aspects of dam safety such as internal erosion. In these areas experienced engineering judgement is also needed to determine the probabilities. This leads many to criticise overdependence on quantitative analysis and question both the reliability of its output and the value added for the significant investment required.

In summary, traditional approaches may generally be perceived to be inadequate and the information insufficient for a full quantitative approach. However, valuable information can be gathered from aspects of all three approaches with an understanding of their limitations.

Public expectations for information on risk are increasingly growing and as a result there is a general shift in engineering practice to meet these needs. This has resulted in the need for more transparency in decision-making with increasing reliance on probabilistic and reliability type analysis in place of engineering judgment to defend investment decisions. Societal factors, such as loss of life and the destruction of property, instead of engineering standards, are becoming more relevant in safety evaluation. This is reflected in ICOLD's Bulletin 130 (ICOLD, 2005).

Internationally, some regulatory authorities prescribe a method to be employed, whilst in the UK this decision rests with the undertaker. However, various risk assessment tools have been developed and used in the UK. These include Defra's Interim Guide to Quantitative Risk Assessment (QRA) (Broiwn & Gosden, 2004), the risk assessment procedure outlined in CIRIA C542 guidelines 'Risk Management for UK Reservoirs' (Hughes *et al*, 2000), and portfolio specific methods developed by individual undertakers.

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The Defra/EA sponsored Risk Assessment in Reservoir Safety Management (Environment Agency, 2012), currently underway, has indicated that a tiered approach will be adopted. The proposed tiers include an initial qualitative assessment and two tiers of quantitative assessment in increasing complexity. This guidance is planned to be available to the industry towards the end of 2012.

Like all UK reservoir owners, STW reservoirs are subject to ongoing reviews and inspections which include traditional assessments of the engineering standards. Despite this, the majority of STW reservoirs have limited as-built data, due to their age, that is required to confidently derive the probabilities of failure required for quantitative analysis.

For STW a pragmatic approach was required that captured the portfolio risk profile in sufficient detail for continued risk reduction and capital allocation. Hence, a qualitative approach was considered more appropriate and feasible.

### THE SEVERN TRENT WATER PRA PROCESS

#### Portfolio Risk Assessment Objectives

Before undertaking a portfolio review, it is important to determine the objectives of the study and the outcomes required.

STW has the following objectives:

1. *“be the best water and waste company in the UK”.*
2. *“to be recognised as the best in Great Britain at managing reservoir safety”.*

In order to proactively achieve these goals, and further increase reservoir safety, the reservoir safety team aims to identify and remedy all reservoir safety concerns before they are raised as ‘matters in the interest of safety’ by an Inspecting Engineer. Whilst risk reduction is paramount, this approach is the most cost effective as safety concerns are dealt with before timeframes or other prescriptions are enforced.

To assist in achieving the goals set out by STW, the following outcomes or deliverables were required from the PRA.

1. Risk ranking of reservoirs.
2. Allocation of investment to minimise risk.
3. Understanding of reservoir portfolio risk.
4. Identification of items that may be required in the interest of safety

#### Assessment Approach

It was agreed that a full quantitative assessment of each reservoir may not be required to achieve these objectives. Instead, a more pragmatic phased approach was proposed and taken forward in which the portfolio would first

be subjected to a screening review followed by selected detailed quantitative assessments where necessary.

#### Phase 1 Assessment

Phase 1 methodology included the following;

1. Data gathering
2. Reservoir Interviews
3. Failure mode discussion
4. Screening Assessment
5. Reservoir Ranking

#### *Data gathering*

To begin the PRA process, a review of the statutory reservoir data available was undertaken. STW's AQUIR database and other spreadsheet databases, which hold all reports and other information for statutory reservoirs, were interrogated. The data reviewed included studies, action plans and Reservoirs Act (1975) Section 10 and 12 documents. This information gave background for the interviews and provided the basis for classification and ranking.

Table 1. Severn Trent Reservoir Structures

Structure Type	Statutory Reservoir Category			
	Impounding	Non-Impounding	Service	
Concrete	Buttress	1		
	Masonry	4		
	Reinforced		1	
	Reinforced with Embankment		8	
	Mass Concrete & Embankment		2	11
Earthfill Embankment	Homogenous		1	
	Puddle Clay Core	15	3	
	Rolled Clay Core	4	1	
	Concrete Core	1	1	
Rockfill Embankment	Lined		2	1
	Concrete Core	1		
	Puddle Clay Core	1		
Totals	27	11	20	

Table 1 provides the breakdown of the reservoir portfolio into impounding, non-impounding and service reservoirs. The 3 categories are further split in accordance with the structure types within each category.

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### Reservoir Interviews

The STW Reservoir Safety Team is responsible for the management of the reservoirs under the Act. Each reservoir is assigned to one of the in-house team of five Supervising Engineers. These engineers inspect the reservoir at least annually, as required by the Act, and are closely involved in any work undertaken on each dam. A team of four Reservoir Technicians is responsible for data acquisition and routine monitoring of the Statutory Reservoirs. Finally, an Inspecting Panel Engineer carries out an assessment of each reservoir at least every 10 years as required by the Act, or when otherwise specified by the Inspecting Engineer, or deemed necessary by the Supervising Engineer.

In addition to the monitoring and inspections outlined above, STW has an independent Reservoir Review Panel. The Panel provides review oversight of reservoir related matters and reports to the Director of Water Services.

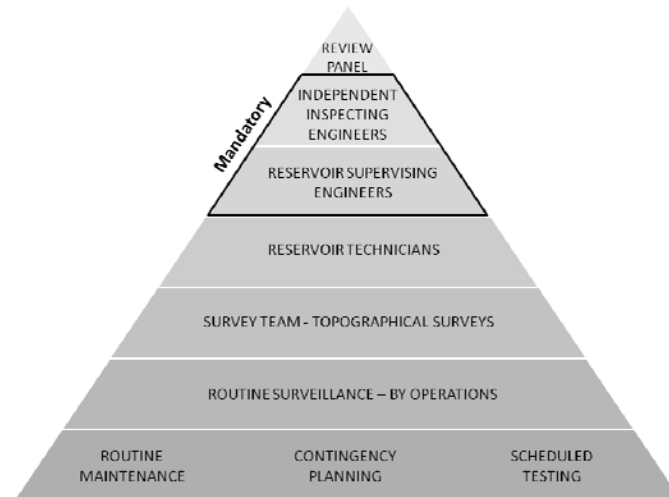


Figure 1. Hierarchy of Inspection Regime and Management (Hope 2012)

Following review of reservoir information, both the Supervising Engineer and Reservoir Technician were interviewed for each reservoir to gain a full perspective and provide any additional information needed. Interviews were conducted by an Inspecting Engineer with additional scrutiny provided by STW's newly-appointed Dams and Reservoirs Manager. Further scrutiny and challenge was provided during the part-time attendance of the chair of STW's Review Panel and various STW staff involved in asset strategy and regulatory reporting.

Each reservoir interview took approximately one hour depending on the reservoir's size, condition and consequence. An agreed standard interview template was filled in during each interview.

The interview process proved to be extremely valuable in determining an overall ranking for the portfolio. The involvement of both Supervising

Engineers and the reservoir technicians, who are closely linked to the operations staff, enabled the interviewers to gain an overall understanding of the condition, operation of and ongoing work being undertaken on each reservoir.

Use of the same interview team for all reservoirs ensured a standard approach, screening and ranking.

#### *Failure mode discussion*

A simple failure mode review was included in each interview. Six common failure categories (as listed below) were developed and reviewed. Their relevance, how they may be initiated and their likelihood were discussed in the interview.

1. Overtopping
2. Internal Erosion
3. External erosion or external feature such as damage during pumping
4. Stability
5. Foundation Failure
6. Hydro-mechanical failure

Operational failure, reputational impact, loss of supply or water resource, and environmental damage were also discussed.

The above was not a formal failure mode analysis (such as that developed by FMEA) but rather an overview to aid in the development of the coarse screening recommendation and to catch any obvious deficiencies that may have escaped previous assessments.

#### *Screening Assessment*

At the conclusion of each interview, the general condition of the reservoir was reviewed by the Inspecting Engineer and a recommendation made to assign the reservoir either a High or Low ranking.

The coarse screening of each reservoir was based on the information brought to light by research and confirmed in the interview including:

1. Age and condition of the reservoir
2. Consequence of failure
3. Known safety concerns or maintenance issues
4. Failure mode discussion
5. Criticality to water supply network

It is important to note that this assessment was intended to inform the ranking and to obtain an early identification of issues. It does not provide definite conclusions regarding the safety or probability of reservoir failure.

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### *Reservoir Ranking*

From the data gathering, interviews and screening, the reservoirs and selected pertinent information were ranked accordingly in a spreadsheet.

In addition to the coarse screening, parameters used to rank the reservoirs included the reservoir hazard category, statutory category, structure type and age, the reservoir volume and likely loss of life (LLOL). Each reservoir was evaluated and given a score out of 100 for each parameter based on agreed weightings. The parameter scores were then added and the reservoirs list ranked based on this summed score.

The placing of each reservoir within the final ranking generally conformed to the Reservoir Safety Team's expectations.

### Phase 2 Analysis

Once a portfolio's high risk dams have been identified as a result of a coarse screening exercise, it is typical to conduct a more in-depth risk assessment of these structures to identify the most effective way to reduce the risk posed.

However, it was apparent during the Phase 1 interviews that those reservoirs considered most at risk had already been identified and their deficiencies assessed in considerable detail. All ranking was relative to the STW portfolio. A ranking of "High" did not reflect immediate concerns due to generally good condition of the portfolio but merely relative to its comparators.

Therefore it was found that the objectives set out at the beginning of the PRA had been adequately addressed at the completion of the Phase 1 screening analysis.

As a result, it was not considered necessary for STW to undertake a quantitative risk analysis at this stage. The level of experience and quality of engineering judgment held by STW's staff together with the involvement of the review panel have been adequate in identifying and managing portfolio risk to date.

## APPLICATION OF RESULTS

After completing the Phase 1 assessment, the ranked reservoir list and the data gathered was used to undertake prioritisation of investment needs and identify areas for additional study.

### Prioritisation of Investment Needs

Following the development of the PRA, investment needs related to reservoir safety were collated and ranked. Investment needs were taken from the following sources:



1. Reservoir Category
2. Assessment in 2008 in preparation for AMP5
3. Reservoir Action Plans (works highlighted during S12 inspections)
4. Phase 1 Interviews

To enable a consistent ranking of all reservoir safety items, a simple High, Medium or Low severity rank was assigned to each item by the Supervising Engineer. An estimate of the cost of each item was then made. The investment list was then ranked in bands indicative of reservoir risk, using the severity classification and reservoir ranking.

#### Identification of Further Studies for Statutory Reservoirs

During the review of the STW database, previous investigations and studies were noted along with their completion date with the intent to identify any areas that may require investigation or review across the portfolio. Often, during the periods between Section 10 inspections, accepted practice or understanding develops and analysis of reservoirs may not have been brought up to the latest standards.

Studies related to reservoir risk were identified where it was acknowledged that they may be required to be updated under the next Section 10 inspection. Their identification within the PRA allowed any uncertainty to be brought to light and dealt with, serving to further reduce risk and gain economy by undertaking them in bulk.

Study categories assessed were as follows:

1. Dam Break Analysis / Inundation Mapping
2. QRA: Quantitative Risk Assessments
3. Drawdown Capability Studies
4. Emergency Action Plans (or Flood Plans)
5. Hydro-mechanical Assessment
6. Flood Studies
7. Overflow Spillway Studies
8. Seismic Hazard Assessments
9. Stability Analysis
10. Ventilation and overflow (Service Reservoirs)

#### ONGOING AND FUTURE ASSESSMENTS

While not undertaken to date, some form of Phase 2 (quantitative) portfolio wide risk assessment may benefit STW's decision making process in the future. In particular, it is recognised that both a traditional approach and qualitative ranking assessment do not provide sufficient information to plot the most rapid risk reduction pathway (Bowles 2006). In future reviews additional costs associated with a detailed risk assessment may be justified with more rapid reduction of risk, identification of risks not previously recognised, and identification of other opportunities.

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Recommendations made as a part of the PRA process include the need to maintain the PRA as a live document. The PRA will be reviewed and updated at regular periods, i.e. 5-yearly, and the requirements for a more detailed assessment will be re-evaluated. The need for more in-depth PRAs in the future may be driven by a number of factors such as legislation, insurance or stakeholder requirements, prioritisation, loss of employee experience and succession planning. As such, it is likely that future PRAs will be required with increasing detail.

By undertaking the current PRA, STW has come some way in developing a framework that will encourage the collection and organisation of data for any future portfolio wide or site specific assessment.

It is also recognised that risk assessment lies on a continuum of increasing detail and cost. The requirements for each undertaker will be different, reflecting the objectives, varied portfolios and available data.

Should future assessments be to a greater depth, a staged approach similar to that recommended by ANCOLD (2003), Figure 7.2 could be undertaken. The current PRA would form the basis of this and the assessment taken to a level necessary to produce the information required to inform the decision making process.

### INFORMING RISK MANAGEMENT

The PRA and its ongoing review set the scene for STW's risk management strategy in the current AMP period and into the next. The PRA results and the understanding of the portfolio they have given provide a basis for estimating future reservoir requirements. As such, STW intends to undertake future casting exercises into both AMP 6 and 7 and to identify items that may be included in the risk management strategy.

### WIDENING THE NET – NON-STATUTORY RESERVOIRS

The risks following reservoir failure are not necessarily be restricted to the larger statutory reservoirs (>25,000m<sup>3</sup>) that come under the remit of the existing legislation. The risk posed by a reservoir is dependent upon many factors and not just its volume. It is widely acknowledged that a small body of water in a highly urbanised area may represent a far greater risk than a large reservoir that is located in a remote, unoccupied area. Hence it was decided that the PRA process would be extended to smaller (non-statutory) reservoirs and other bodies of water, including sludge lagoons that are owned and/or operated by STW. Principal drivers for the inclusion of the smaller reservoirs in the PRA process were as follows:-

1. Regulatory Change: Revised reservoir safety legislation to replace the Reservoirs Act 1975 and which will reduce the volumetric threshold for reservoirs to be included from 25,000m<sup>3</sup> to 10,000m<sup>3</sup>.

2. Introduction of a risk based approach to reservoir safety management across the industry
3. Concerns over the lack of knowledge, construction details and reporting/surveillance regimes for many of the smaller reservoirs.
4. Historic problems with sludge lagoons at two of STW waste water treatment works.

#### Assessment Objectives

The objective was to give an overview of the level of risk exposed to STW that may arise from their stock of small reservoirs and lagoons that are not currently regulated by statutory legislation.

Findings of the assessment would assist STW in (i) identifying and understanding the works that might be needed to mitigate the risks and (ii) prioritising these works so that necessary funding can be included in future capital spending plans.

The study provided specific recommendations to reduce potential environmental risks that could lead to reputational and economic damage / losses for STW. Where seeking to eliminate risk, the study has also identified specific recommendations for reservoir decommissioning where appropriate.

The final outcome of the Phase 1 process would be to identify which (if any) of the small reservoir sites would require further studies and investigations as part of a more focused and detailed risk assessment (Phase 2).

#### Small Reservoirs Phase 1 Assessment

The first part of the assessment was to carry out a very broad brush screening exercise to determine which of these reservoirs would need to be examined in greater detail. This was a desk based study only and involved an examination of the database of all small reservoirs primarily to evaluate which reservoirs posed negligible risk and could therefore be eliminated from further investigation. From this screening process a select number of non-statutory reservoirs and sludge lagoons were identified to be within the 10,000m<sup>3</sup> to 25,000m<sup>3</sup> band. In addition, some reservoirs and sludge lagoons below 10,000m<sup>3</sup>, but which may constitute a potential risk, were also identified. In total it was estimated that 50 to 60 small reservoirs would need to be considered in this way, of which approximately half were raw water reservoirs together with a further 33 sites with sludge lagoons.

The following methodology was employed to assess those reservoirs selected during the screening assessment:

1. Research each of the sites identified and prepare a visit template

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2. Visit each site, assemble photographs and other information in order to complete the visit template
3. Identify and confirm the works that are required at each site; prioritise these works into those which might be needed to improve safety and other works that might be needed for general maintenance and upkeep
4. Provide a preliminary cost estimate of the identified works
5. Produce risk rankings for the small reservoir sites.

Two separate rankings have been completed for the raw water reservoirs and for the lagoons. Although in line with the wider objectives of portfolio risk, it is envisaged that these rankings can be combined at a later date in order to prioritise the works and the expenditure.

## CONCLUSIONS

The Portfolio Risk Assessment undertaken has given STW a broader understanding of the portfolio and its risks. It has assisted the company in their approach to risk reduction and capital allocation. The PRA has set the scene for risk management of STW's reservoir structures both in the current funding period and those following.

Finally, the selection of a more pragmatic and staged approach to portfolio assessment has delivered STW the benefits of a PRA without the level of investment required for quantitative assessments.

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