Investigation of potential reservoirs

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SYNOPSIS. Following the introduction of the Water Act 2003, the Environment Agency took over the role of enforcement authority for England and Wales for the Reservoirs Act 1975 from 136 local authorities in October 2004.

As part of their responsibility to maintain a national register of large raised reservoirs, the Environment Agency commissioned Halcrow Group Ltd. to undertake a project to find currently unregistered reservoirs that should be subject to the Reservoirs Act 1975.

The project identified 121 large raised reservoirs that should have been registered. The potential risk to the general public from an uncontrolled release of water has been reduced by identifying and registering these reservoirs.

This paper provides an overview of the project to identify these 'potential' reservoirs, by explaining the legal background, the approach used, the results and future considerations.

INTRODUCTION

Currently the Reservoirs Act 1975 applies to some 2100 reservoirs in England and Wales, details of which were transferred from local authorities to the Environment Agency, when it took over its new role of enforcement authority in October 2004 (Hope & Hughes, 2004).

The Environment Agency introduced a comprehensive quality assurance process to make sure data held on the register was accurate. To make sure that this register was complete, they also commissioned a study to investigate 'potential' reservoirs with an escapable volume of more than 25,000 cubic metres above natural ground level that weren't already registered.

Ensuring reservoir safety into the future. Thomas Telford, London, 2008

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LEGAL BACKGROUND

The original Reservoirs (Safety Provisions) Act of 1930 (HMSO 1930) was introduced following the failures of Eigiau, Coedty and Skelmorie dams, which resulted in a number of deaths. Due to the size of these reservoirs, the minimum volume of a 'large reservoir' within the law was set at five million gallons. (Hughes, 2006)

This legislation was later replaced by the Reservoirs Act 1975 (HMSO 1975) and the minimum volume of a 'large reservoir' increased slightly to that containing more than 25,000m^3 of water above the lowest point of the surrounding natural land.

The 1975 Act also introduced the role of the enforcement authority. 136 separate local authorities in England and Wales held this role until the Water Act 2003 (HMSO 2003) was introduced. As a result, this led to the Act being inconsistently applied and a wide difference in the quality of information recorded.

As part of the Water Act 2003, the role of enforcement authority for the Reservoirs Act 1975 was transferred to the Environment Agency (for England and Wales) with effect from 1 October 2004. It is managed by the Reservoir Safety Team based in Exeter as a ‘national once only service’. One of the enforcement authority’s main roles is to maintain a public register and make this information available to the public. This is defined by Section 2 (2) of the Act:

"It shall be the duty of each relevant authority to establish and maintain for their area a register showing the large raised reservoirs situated wholly or partly in the area, and giving the prescribed information about each of them" (Reservoirs Act 1975, Section 2(2))

As part of this responsibility, the Environment Agency compiled a national register of large raised reservoirs based on the existing records held by previous enforcement authorities. After a quality assurance exercise was undertaken, the register comprised some 1924 reservoirs (Environment Agency 2007). They then set about finding unrecorded reservoirs that could 'potentially' be large raised reservoirs under the Act.

LOCATING POTENTIAL RESERVOIRS

In 2004 the Environment Agency commissioned ESRI (UK) Ltd to carry out a geographical information system (GIS) based search of Ordnance Survey MasterMap™ data for England and Wales to identify all inland bodies of water. (Sampson 2004)

In considering the minimum volume limit of the Act, ESRI was asked to report back only on those bodies of water with a surface area greater than 10,000m^2. Flood storage reservoirs were excluded from the project scope.

ESRI searched all the map data for suitably sized polygons on the 'inland water' layer and also within the 'text' layer for the word "reservoirs" and its derivatives. The grid references of the results were compared with those of reservoirs already on the national register, and where these matched, the water bodies were removed from the list. After the checking and validation of the data, this study produced a list of 205 potential reservoirs to investigate further.

As well as the ESRI study, the Environment Agency reviewed the incomplete data for some 600 reservoirs handed over from the local authorities.

Previous enforcement authorities, All Reservoirs Panel Engineers and Environment Agency area enforcement officers were also contacted for details of any suggested potential reservoirs leading to the identification of a further 100 sites.

Once duplications (e.g. different names for the same reservoir) and previously registered reservoirs had been accounted for, there was an initial total of 302 'potential' reservoirs to investigate.

Throughout the project, assessors, owners, panel engineers and Environment Agency staff identified a further 78 'potential' reservoirs. By the end of the project, a total of 380 'potential' reservoirs had been considered by the Environment Agency and of these, 345 required further assessments.

ASSESSING POTENTIAL RESERVOIRS

Initial approach

Following evaluation of competitive tenders in 2005, Halcrow Group Ltd was commissioned to carry out the physical assessment and investigation of these 'potential' reservoirs.

As the role of enforcement authority is wholly regulatory and administrative, it was important that the assessments were overseen by an independent qualified civil engineer. To this end, the Halcrow Project Director was also an All Reservoirs Panel Engineer. Police and Criminal Evidence Act (PACE)(HMSO 1984) training was provided by the Environment Agency in the event that evidence and site assessment would be required in subsequent legal proceedings.

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The Environment Agency wrote to all owners of 'potential' reservoirs asking for any information (such as construction drawings) that would help estimate the escapable volume. Communications with reservoir owners and operators were sent in order to seek their permission for an assessor to enter their land and carry out an assessment.

Locally based Environment Agency staff were involved in approaching reservoir owners, and arranging and attending site visits.

It was proposed that a pilot study of a small sample of the potential reservoirs should be carried out to develop an approach that would give an acceptable balance between the cost and accuracy of the volume estimate.

Pilot study

The Environment Agency selected a representative sample of 20 'potential' reservoirs in the south of England. These sites ranged from Cornwall to East Anglia and included non-impounding reservoirs and impounding reservoirs.

LIDAR topography data for each site was provided so that a digital terrain model (DTM) could be produced using geographical information systems (GIS) and an estimation of volume made from this.

Each site was visited to measure key parameters, such as embankment height and the amount of freeboard at the spillway. The results of these site assessments were used to estimate the volume to compare with the GIS method.

Coincidentally, bathymetric survey data was available for five of the sites from an earlier project Halcrow Group Ltd carried out on behalf of the Environment Agency's Wessex (South) Flood Risk Management Team. The results of these surveys were useful in comparing the estimates from the two methods to establish how accurate the desk study was and whether the site visits were necessary.

The pilot study concluded that:

- 40% of the reservoirs contained more than 25,000m^3 of water and therefore should have been registered.
- The site visit results (as opposed to the desk study results) offered the best compromise between economy and accuracy - especially for non-impounding reservoirs where the reservoir bed was more likely to be flat and access generally better due to lack of vegetation.
- There was a higher proportion of non-impounding reservoirs than expected among the potential reservoirs to assess. It is suspected that this occurred because the ESRI search identified discrete polygons,

whereas impounding reservoirs, which had long stream lines attached, were sometimes identified as part of a river and not counted.
- The horizontal grid size (5m x 5m) and vertical accuracy (+/-0.5m) some of the LIDAR data provided at the time meant that the estimates of volume using this method were inaccurate.
- The bathymetric survey data most accurately represented the volume of the reservoirs. However, this method was too expensive for assessing over 300 'potential' reservoirs.

As a result of this appraisal, the approach selected for the main project was to visit and assess all the 'potential' reservoirs to enable a 'first pass' volume estimation.

Main project

The project was programmed to run over two years between 2006 and 2008 and included the remaining 325 'potential' reservoirs, 319 of which have been assessed at the time of writing.

Faced with visiting a large number of sites spread over a wide area, it was important to take a cost-effective, risk-based approach.

Initially, an engineer examined the 1:50,000 scale map of each site and gave the reservoir a dam category A-D (subsequently reassessed on site) in accordance with Table 1 of Floods and Reservoir Safety (ICE 1996). This categorisation was adopted for all types of reservoir. It was adopted to ensure that a risk based approach was taken to the deployment of resources to resolve any non-compliance that arose. All the potential reservoir sites were then plotted on a map of England and Wales and assigned to some 40 regional groups across the country.

The number of reservoirs in each category for each group was analysed and the groups were ranked according to highest risk. For example, the highest risk group contained nine category A, two category B, one category C and one category D reservoir. The lowest risk group contained only one, remote, category C reservoir.

Grouping the reservoirs by geographical area meant the reservoir assessors could visit several sites in one trip, thus optimising cost. Visiting the groups in order of the highest risk made sure that the risk of dam failure at a site not yet visited was reduced as far as possible.

Written permission was sought from the owner of the reservoir for an engineer (the assessor) to visit the site. The assessor then visited each

reservoir and sought to measure the properties of the reservoir to estimate the volume retained above ground level. In most cases this included measuring:

- maximum embankment/dam height above the level of the lowest point of the surrounding natural ground;
- the minimum freeboard provided above a fixed spillway crest;
- the lengths of the sides of the reservoir;
- the angles of the internal slopes of each side of the reservoir.

Typical problems assessors encountered on site included dense vegetation that prevented accurate measurement of embankment height, no access to some parts of the reservoir, offshore spillways that made freeboard difficult to estimate when the reservoir was drawn down, and estimation of an average internal slope where the slope varies or is hidden by turbid water. Engineering judgement was used in these cases.

Whilst on site, the assessor would note the condition of the dam on a scale of 1 to 5 as shown in Table 1 below. The principles are adapted from the Environment Agency condition assessment manual (Environment Agency 2006). If a dam was considered to be condition 4 or 5, the owner was advised to seek engineering advice, in order to relieve Halcrow or the Environment Agency of any potential liability that could follow.

Table 1 - Dam condition score guidance

Score	**Typical attributes**
1	Excellent condition, no cause for concern
2	Good condition, some minor maintenance issues or early indication of minor seepage.(e.g. unusual reed growth, wet patches on downstream face, a few small animal burrows)
3	Some cause for concern. Wear problems that may get worse if unattended. (e.g. erosion of crest, blocked spillway or major animal burrows)
4	Problems causing immediate concern for safety (e.g. Seepage through downstream face, unstable large trees on dam, inoperable spillway or bottom outlet pipes/valves)
5	Poor condition. Imminent failure possible. (e.g. Major seepage, recent large slips on crest or downstream face, major erosion of dam crest or downstream face)

As the majority of the potential reservoirs were expected to be non-impounding reservoirs, the default volume calculation methodology was to multiply the surface area by the maximum retainable water depth above the

surrounding land, and then subtract the volume of any islands and the internal slopes into the reservoir.

For some cases, including triangular shaped impounding reservoirs, this method was not suitable and so, in these cases, the assessor would carry out separate calculations, taking into account the slope of the valley on the reservoir bed.

For every reservoir visited, the assessor produced a one-page data sheet. This contained a summary of:

- the properties of the reservoir, including owner contact details, location, shape, orientation, dam category, and condition score;
- the dimensions measured on site, including embankment height, freeboard, slope angles, and side lengths;
- comments on the limitations of the site visit, assumptions made during the calculations, justification for the dam category and condition score assigned;
- the current best estimation of the escapable volume and a confidence score in that figure.

The Environment Agency established a monthly panel process to review these data sheets together with any accompanying calculations and to decide whether or not to register the reservoir or to seek further information or clarification. This process ensured that a consistent approach was adopted in deciding whether or not to register a reservoir.

By using the assessed dam category, capacity, confidence score and condition a risk based approach was adopted to prioritise any enforcement activities.

Where a decision to register the reservoir was taken, the Environment Agency contacted the owner to invite them to either discuss this decision within 28 days or to ask them to appoint both a supervising engineer and an inspecting engineer. If the owner did not agree with the decision to register the reservoir within 28 days, they were contacted again and reminded of their responsibilities under the Act. In some cases where no response was received, enforcement action was initiated.

If owners did not agree with a decision, they were encouraged to provide further information (such as construction drawings, or depth measurements) so that volume estimates could be reviewed and updated as appropriate.

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Difficult decisions

Throughout the course of the project many difficult issues had to be confronted and decisions taken. Most of these were due to the wording of the Reservoirs Act 1975.

For example, the following questions were addressed:

- What size of spillway sill or pipe is required to define top water level in a non-impounding reservoir?
- On a flood storage reservoir with no overflow sill, where should top water level be taken?
- In order for the "designed to hold" statement in the Act (Cl 1(1)a) to apply, what level of proof of design is required?
- Should a reservoir that has been "designed to hold" more than 25,000m^3, but that is now so silted up that it now holds less than 25,000m^3, be within the Act?
- Or the converse argument: should a reservoir designed to hold less than 25,000m^3, but that is actually "capable of holding" more than this amount, be within the Act?

Although the seven reservoir assessors from Halcrow were not qualified civil engineers (QCEs) within the meaning of the Act, the project was undertaken under the direction of an All Reservoirs Panel Engineer. For complex or difficult cases, his review and written opinion was sought. This opinion was provided in an agreed format to enable it to be used in any subsequent litigation. In these difficult cases, the Environment Agency based its decision on whether to register the reservoir, or to carry out further studies, on this advice.

Results

In total, 319 reservoirs were assessed between May 2006 and February 2008. Table 2 shows the proportion of potential reservoirs with estimated escapable volumes above and below the 25,000m^3 threshold of the Act.

Table 2 - Results of the assessment of potential reservoirs

Estimated escapable volume (m^3)	**No. of 'potential' reservoirs**	**Proportion of the total**
>25,000	121	38%
<25,000	141	44%
0	57	18%
Total	319	100%

As a result of the project, 121 previously unregistered and unregulated reservoirs were found to fall within the Act. The relatively high percentage (38%) of this group validates the search criteria of 10,000m^2 surface area, used for the initial GIS search.

The reservoirs in Table 2 that have an escapable volume of zero are those that were found to be not raised above ground level. The initial GIS search identified these as having surface areas greater than 10,000m^2, but the lack of embankment above ground level only became apparent when the site was visited.

Table 3 shows a breakdown of the dam category of the reservoirs now considered to be within the Act.

Table 3 - The risk posed by unregistered reservoirs

Dam category	No. of reservoirs	Proportion of the total
A	16	13%
B	35	29%
C	55	46%
D	15	12%
Total	121	100%

42% of the reservoirs now considered to be within the Act fall within dam categories A (posing risk to life in a community) and B (posing risk to life not in a community). By registering these newly discovered reservoirs and requiring the undertakers to comply with the Act, the Environment Agency has helped to reduce the risk of damage or injury to the general public caused by the uncontrolled release of water from these reservoirs.

Figure 1 shows the distribution of dam category by volume for all 319 reservoirs assessed.

Table 3 and Figure 1 both demonstrate that the majority (46%) of previously unregistered statutory reservoirs fall within category C. This means that a breach in these dams would pose a negligible risk to life and cause limited damage. It could also account for the fact that they had remained undiscovered.

Figure 1 also demonstrates that, of the reservoirs with volumes of between 20-25,000m^3 (that is, just below the threshold of the Act), there is a relatively high proportion (39%) of dam category A and B reservoirs. Goff & Warren 2008 address this issue further.

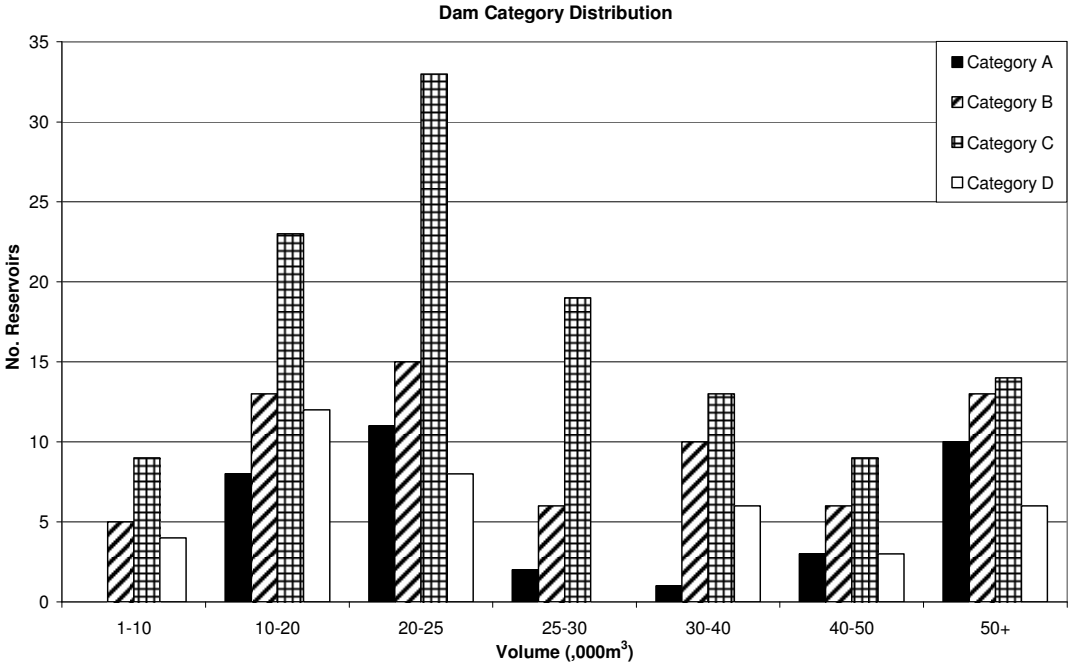

Figure 1 - Distribution of dam category by volume

FUTURE CONSIDERATIONS

During the study, several areas for further investigation were noted.

Firstly, due to limitations in the methods used for estimating the escapable volume, it is recognised that in some borderline cases more detailed analyses may result in a volume immediately above or below the 25,000m^3 threshold. More detailed analyses may include, for example, a detailed bathymetric or topographical survey or the presentation of previously undisclosed construction drawings.

Secondly, the higher than expected proportion of non-impounding reservoirs located by the original GIS search suggested that some impounding potential reservoirs may have gone undetected. The limitations of this original GIS search have been overcome by recent advances in technology and innovative research carried out by Halcrow Group Ltd. A further GIS search of England and Wales is now possible and it is expected this would find further previously unidentified impounding potential reservoirs.

CONCLUSIONS

As a direct result of the Investigation of Potential Reservoirs Project public safety has been improved by the registration of 121 previously unidentified and unknown reservoirs, 42% of which are dam category A or B.

The methodology, risk based approach and proportionate enforcement action that was adopted, ensured the most efficient use of public money. By transparent and open communication with reservoir owners, the project has raised public awareness of the Reservoirs Act 1975, its purpose, and the legal responsibilities on Undertakers imposed by it.

The project has enabled the Environment Agency to carry out its statutory responsibility as enforcement authority under Section 2(2) of the Reservoirs Act 1975. The project has also increased and improved the enforcement authority's understanding and awareness of possible 'grey areas' within the Reservoirs Act 1975, and informed their recommendations for improving the law including the call for the adoption of a risk based approach. The dam condition score and dam category assigned to each reservoir has also highlighted the risk posed by non-statutory reservoirs.

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