

Potential changes to hazard categorisation and inflow design floods for reservoirs in the United Kingdom

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SYNOPSIS. UK reservoir legislation is in a time of change. With the introduction of the Flood and Water Management Act 2010, the way in which reservoirs are regulated is due to be altered in the near future. This change in legislation provides an opportunity to undertake a review of reservoir categorisation and the corresponding required safety standards such as inflow design floods. It would therefore seem prudent to look at what other countries use for categorisation of large dams and their selection of inflow design floods. This will not only provide a basis for comparison but will also aid further discussion on potential alternatives to categorising our reservoirs.

INTRODUCTION

At present, reservoir safety standards in the UK are defined by the Reservoirs Act 1975 and the Engineering Guide on Floods and Reservoir Safety¹. The latter provides the widely used system of reservoir categorisation and accompanying inflow design floods according to the potential damage downstream in the event of a breach.

However, the Flood and Water Management Act 2010 incorporated amendments to the Reservoirs Act 1975, including the introduction of 'high risk' reservoirs. This provides an opportunity to revise the existing guidance on reservoir categorisation and the approach to inflow design floods. It would therefore seem prudent to discuss potential options for categorisation and to look at what other countries use for inflow design floods to assist in this task.

For the purposes of this paper, only the highest categories of reservoir from other countries are included in order to allow effective comparison with the new 'high risk' categorisation of reservoirs in the UK.

RESERVOIR LEGISLATION AND GUIDANCE

To assist the reader in understanding the impact of the changes introduced by the Flood and Water Management Act 2010, the following section

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includes a brief summary of the existing legislation and guidance in use, along with a description of the recent legislative changes.

Existing categorisation and inflow floods

Prior to the introduction of the Flood and Water Management Act 2010 reservoirs capable of storing more than 25,000m³ above natural ground level were classified as 'large raised reservoirs'.

The Reservoirs Act 1975 did not distinguish between these large raised reservoirs in terms of risk/consequence of failure, nor did it state any requirements for standards of protection. Instead, the UK reservoir industry has relied on 'Floods and Reservoir Safety', a guidance document that sets out a standard approach for consequence categories based on predicted harm to property/people if the dam were to fail catastrophically. This document recommends particular inflow design floods, which are shown in Table 1 for reference.

Table 1. Existing categorisation and inflow design flood¹

Dam category	Potential effect of a dam breach	Reservoir inflow design flood	
		General	If overtopping is tolerable
A	Lives endangered in a community ^b	PMF ^a	10,000 year flood
B	Lives endangered not in a community or extensive property damage	10,000 year flood	1,000 year flood
C	Limited property damage	1000 year flood	150 year flood
D	Very limited additional flood damage	150 year flood	N/A

^aProbable Maximum Flood

^bGenerally accepted as 10 or more lives endangered

It should be noted that the hazard categories shown in Table 1 are based on the consequence of failure and not the risk of failure. Of the four categories shown, only Category A and B reservoirs are deemed to pose a risk to human life in the event of a breach. Category A reservoirs are defined as 'endangering lives in a community', with a community generally accepted to be 10 or more people.

Flood and Water Management Act 2010

The Flood and Water Management Act 2010 makes several changes to the Reservoirs Act 1975. The changes include the possibility of lowering the volumetric limit for large raised reservoirs to 10,000m³ and the introduction of new 'high risk' reservoirs, which are large raised reservoirs where:

- a) the Environment Agency believes that, in the event of an uncontrolled release of water from the reservoir, one or more human lives could be endangered, and
- b) the reservoir does not satisfy the conditions (if any) specified in regulations made by the Minister.

As it stands, the Flood and Water Management Act 2010 effectively deregulates all other large raised reservoirs i.e. 'not high risk' reservoirs. This will mean that key sections of the Reservoirs Act 1975 will no longer apply to 'not high risk' reservoirs, including the requirements for inspection and supervision under Sections 10 and 12 of the Act.

It is interesting to note that despite the name, these 'high risk' reservoirs are defined according to consequence of failure as per the existing categorisation and not the risk of failure. This allows a direct comparison between the 'high risk' reservoirs and the existing hazard categories.

Options for categorisation

Current proposals have defined the new 'high risk' reservoirs as those that would lead to a likely loss of life greater than one if the dam were to fail catastrophically. By comparing this with the information in Table 1, it is clear that the 'high risk' reservoirs are defined in a similar manner to Category A and B reservoirs according to 'Floods and Reservoir Safety'.

The introduction of the 2010 Act does not require a change in the existing hazard categorisation of our reservoirs. If the existing categorisation were kept, reservoirs that did not pose a risk to life, i.e. Category C and D reservoirs, would effectively be deregulated, leaving just two regulated categories of reservoir.

However, maintaining the existing categorisation is not necessarily the best long term solution. The 'high risk' reservoirs could be split into many categories, which would allow for a greater range of flood safety requirements for reservoirs with varying degrees of consequence/risk. For example, should reservoirs that endanger 10 lives be subjected to the same flood safety requirements as reservoirs that endanger 100 or 1,000 lives? There is of course no right answer to this and it seems there is a balance to be struck between the simplicity and the effectiveness of the system used, although ultimately this is a political decision.

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CATEGORISATION AND INFLOW DESIGN FLOODS

Whether or not the categorisation of 'high risk' reservoirs is further divided it is still possible to redefine the inflow design floods for the categories of reservoir. To this end, it is prudent to look at what other countries use as design inflows for their high risk/consequence categories to provide a basis for comparison. Table 2 summarises the inflow design flood for the highest category of reservoir in various countries.

Table 2. Dam safety requirements for spillway capacity in other countries^{2,3}

Country	Category	Category description	Inflow design flood ^a
Australia ^b	Extreme Flood Consequence Category	Probable loss of life > 100 with major damage/loss	PMF
Austria	-	H > 15m V > 500,000m ³	1.3 to 1.5 x 5,000 year (~10,000 year)
Finland	Risk class P	Danger to life/health and/or environment	5,000 to 10,000 year
Germany ^c	Large dams	-	10,000 year
Italy	Large dams	H > 15m V > 1,000,000m ³	1,000 year
Norway	High - 3	More than 20 houses affected	PMF
Spain	High - A	-	10,000 year
Sweden	High hazard	Significant risk of human loss of life or injury or considerable damage/economic loss	Swedish Design Flood
Switzerland	-	-	1.5 x 1,000 year flood (~10,000 year flood)
Portugal	High potential hazard	H ≥ 50m (embankment dams) H ≥ 100m (concrete dams)	5,000 to 10,000 year flood

Country	Category	Category description	Inflow design flood ^a
USA ^d	High (risk to more than a few lives or excessive economic loss)	$V > \sim 60,000\text{m}^3$	0.5 x PMF to PMF
		$V > \sim 1.2\text{Mm}^3$	PMF
		$V > \sim 60\text{Mm}^3$	PMF

^aOnly the highest inflow design floods in use are presented

^bAccording to the New South Wales state legislation

^cEach state has separate legislation

^dAccording to USACE (United States Army Corps of Engineers)

Out of 11 countries that appear in Table 2, only three use the PMF for the inflow design flood for their highest category of reservoirs. The majority of the other countries use design floods no greater than the 10,000 year event, with some countries opting for design floods as low as the 1,000 year event.

The majority of the countries also appear to have less onerous requirements for categorising their large dams. For example, the USACE in the USA requires a storage volume of 1.2Mm^3 with a risk to multiple lives before the PMF applies. However, this can be partially attributable to the varying topography in different countries. If a reservoir of a certain volume were to breach, it could have more impact in terrain consisting of narrow valleys with concentrated, ribbon-like developments than in more uniform, flatter terrain.

Reservoir volume or dam height are however not a direct indication of the hazard/risk posed from an uncontrolled release of water. A small reservoir situated directly upstream of a housing development could endanger more lives than a large reservoir with no developments downstream.

In order to prevent these 'smaller' reservoirs from being excluded from legislation, every reservoir regardless of volume could be categorised according to consequence/risk posed and required safety standards provided. Of course in practice, limited resources necessitate a more pragmatic approach, often achieved by setting a volumetric threshold for inclusion of reservoirs within legislation.

Choice of inflow design flood

The choice of inflow design flood depends on a variety of factors. It could be argued that as embankment dams are more susceptible to overtopping failure than concrete dams, countries with a larger proportion of embankment dams would be justified in more cautious design floods.

Conversely, it can be argued that using a consequence categorisation (effectively assuming a hazard has 100% probability of occurrence) together

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with the PMF (the largest reasonable flood possible) is too conservative and could lead to unnecessary economic investment.

It is not a simple choice to reduce the existing inflow design flood requirement from the PMF to say, the 10,000 year event. Regardless of the conservative nature of the PMF, reducing the requirement on the inflow design flood could be construed as reducing reservoir safety. This could be hard to justify, especially given the quantity of work undertaken thus far to allow reservoirs to pass the PMF.

RISK VERSUS CONSEQUENCE

The Flood and Water Management Act 2010 defines 'high risk' reservoirs using a consequence based approach, including all reservoirs endangering human life as a result of an uncontrolled release of water. However, it does not prevent the use of a risk based approach (using both likelihood and consequence) to define and/or regulate potential sub-categories for these 'high risk' reservoirs.

By using consequence of failure to categorise reservoirs, no account is taken of the likelihood of a particular reservoir failing during a flood (or other) event. This limits our ability to effectively categorise (and hence provide safety requirements for) reservoirs according to the risk they pose, as reservoirs within the same category can (and do) have varying likelihoods of failure for both flood events and 'sunny day' failures.

By including a risk based approach to define and/or regulate the sub-categories, it could be possible to retain the use of the PMF for reservoirs with the highest risk to life (as opposed to consequence), while using the 10,000 or potentially even the 1,000 year floods for reservoirs with a lower risk. Although implementing and managing such a system may seem unwieldy, a similar system is already in use in the state of New South Wales in Australia.

State legislation uses consequence categories based on a combination of probable risk to life and severity of damage. Inflow design floods are assigned based on these categories, with the PMF only being required when the probable loss of life from catastrophic failure of the dam is greater than 100 along with major damage/loss⁴. Owners of the highest categories of dam are then required to demonstrate that the flood risks posed by their dams to community interests are tolerable or will be made tolerable following improvements in safety.

In Scotland, the Reservoirs (Scotland) Act 2011 makes provisions for a fully risk based approach to reservoir categorisation. The Act includes 'high', 'medium' and 'low' risk reservoir categories, to be defined on the basis of potential adverse consequences from an uncontrolled release of water and the probability of such a release. This appears to be a more logical approach

to categorisation as it allows for an appropriate level of legislation to risk posed by a reservoir.

This does not mean that categorisation on a consequence basis is wrong. Using a risk based approach is likely to be complicated, difficult to reach consensus upon and implement. There are advantages to using consequence to categorise dams, and this is evident to a degree in existing UK reservoir legislation.

Consequence can provide a simple and effective method for assigning safety standards to reservoirs. Combined with modern tools and techniques such as inundation mapping, panel engineers can obtain more data than ever before about the potential downstream impact of reservoir failure and should therefore be able to provide more accurate reservoir categorisation.

CONCLUSIONS

The introduction of the Flood and Water Management Act 2010 provides a rare opportunity to revise our current guidance on reservoir categorisation and inflow design floods. By looking at other countries around the world, it is apparent that a large proportion does not share our use of the PMF for the highest category of reservoir and, in general, the definition of a large reservoir is significantly different from our own.

Although the new Act defines 'high risk' reservoirs according to consequence of failure and not risk, it does not prevent the inclusion of a risk based approach within UK legislation and/or guidance. By giving more thought to the approach we use to categorise our reservoirs, we could potentially allow for a less onerous use of extreme event floods such as the PMF.

REFERENCES

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