Research Contract: Reservoir Safety Advice

Supplement No 1
to
Interim Guide to Quantitative risk assessment for UK Reservoirs

Draft to accompany public consultation on Draft of Guide to Emergency Planning

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PREFACE

This document comprises Supplement No 1 to the Interim Guide to Quantitative Risk Assessment (Brown & Gosden, 2004). It represents extended guidance on assessment of the likely consequences of dam failure, developed as part of preparation of the Guide to Emergency planning.

The numbering of sections follows that in the Interim Guide, and it is intended that this supplement would be incorporated in the final Guide to Quantitative risk assessment for UK reservoirs.

A number of refinements have also been made to the workbook accompanying the Interim Guide. These are presented in the example consequence assessments spreadsheet, included as part of Appendix E of the Guide to Emergency planning.

The authors of this report are employed by Jacobs Babtie. The work reported herein was carried out under a Contract placed on 6th September 2002 by the Secretary of State for the Environment, Food and Rural Affairs. Any views expressed are not necessarily those of the Secretary of State for the Environment, Food and Rural Affairs.

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8 DAMBREAK ANALYSIS

8.2.4 Breach hydrograph in cascade failure

In some cases the peak inflow from failure of an upstream reservoir is significantly greater than that from the lower reservoir calculated using the lower dam height and reservoir volume of the whole cascade. In this situation it is suggested that the peak breach discharge from the lower reservoir should be taken as equal to the inflow.

8.3.3 Valley cross section

Some care and thought is required in setting up the trapezoidal cross section used in the analysis, as this should be an average representing the length of river within each zone. Issues which need consideration are

a) the width of inundation should be consistent with the depth of inundation; it has been found helpful to measure the width between contours at say 5 and 10m above the valley floor, as a test of the geometry specified
b) the length of the river bed should be consistent with the magnitude of flows; where high a straight line down the valley is reasonable; where the flows are more moderate the length should follow more closely the meandering path of the channel. This is important in terms of effective longitudinal slope.
c) Where dam break flows approach the magnitude of the fluvial 1000 year flood the published 1000 year flood outline on the Environment Agency website can provide a useful check to the output from the rapid analysis.

8.3.4 Transportation embankments

Attention is drawn to the methodology for the standard hydraulic analysis. It is suggested that a similar approach is adopted here, albeit adjusted to be suitable for incorporation within an Excel workbook.

8.5 Routing

The attenuation length factor La represents the distance over which the initial breach discharge reduces to 37% of its initial value. Application of the theoretical derivation given in RMUKR results, in some cases, in values of La which appear excessive, in that they exceed values typically obtained from standard analysis.

As an interim measure it is suggested that the factor k is adjusted to ensure that the attenuation length factor La remains within the range of say generally 5 to 100km.

This approach is suggested as an interim solution until further research is carried out to provide an improved methodology. The suggested range of La is that obtained from detailed dam break analysis.

9 LIKELY LOSS OF LIFE

9.2.2 Estimating population at risk

General

The purpose of this assessment is to provide an estimate of the number of people likely to be present in the inundation area when the dam break arrives, on average (i.e. over 24 hours/ 365 days). It is noted that this is not intended to be a detailed analysis for each property, but a broad assessment of the overall number of people likely to be in the inundated area, on average.

Principle of Base Population at Risk

There are a large number of possible scenarios which might be considered when assessing the impacts on people, as noted in Table 9.1. The principal issue is the number of lives at risk at the time the dam breach occurs. If the breach can occur at any time of year or day with equal probability, the population at risk may be taken as the time-averaged population, namely:

> "the population associated with each possible location for each scenario" times the "proportion of time that each scenario represents, as a percentage of the time in a year"

An example of this is a mid-range Premiership stadium might expect to be used on 25 occasions in a year for about four hours each time with an average attendance of 35,000. The probability of the stadium being occupied at any time through the year is

(4/24) x (25/365) = 0.0114 (1.1%)

The average population at risk, could thus be said to be

35,000 x 0.0114 = 399

Because the car parking area is in the stadium grounds and the crowd has come and gone from the vicinity of the stadium within the four hour window on each occasion, they do not need to be taken into account separately while in the car park.

In addition there may be say 20 persons who normally work at the grounds, giving a further PAR of

20 x 8 hours x 5 days/ (24 hours x 7 days) = 4.8 average

The total population at risk would therefore be taken as 404.

Population present in non-residential property

The base, or average, population at risk used in evaluating consequence class is obtained on the same basis as above, namely: (definitions of the various terms are given in Section 7.2 of the Guide to Emergency Planning)

> Base PAR = "Building area" x "Occupancy factor"/ "Occupant area"

The occupant area and factor will depend on the type of establishment, with suggested normal values given in Table 9.4. For a small number of properties at risk property specific assessment may be appropriate. However, where a larger number of properties is at risk, considering average values is likely to be reasonably representative.

A check on the number present may be made by using the area of car parking as an independent check on building occupancy; where the area of car parking, including access lanes to bays, is typically about 25m^2/ car. Where most occupants will have traveled there by car the number of occupants is likely to be broadly equal to the number of car spaces; this being reduced where car sharing, walking to the property and public transport are used to travel to the building.

Table 9.4 : Values of occupant area and occupancy factor in non-residential properties

MCM Code	Type of property	Typical area for internal circulation and activity (Pickard, 2002)		Occupant area (m^2 per person) in Table 4.1 of Fire Engineering, CIBS, 2003, 2nd Edition, Chartered Institution of Building Services Engineers Guide E		Suggested normal value	
		m^2 per person	Page	UK	US	Occupant area[1] m^2/ person	Occupancy factor % of hours/ year
-	**Average for all non-residential**			na	na	40	25%[4]
	ODPM bulk						
21	Retail	Out of town[2]: food retail 14 non-food retail; 20	342	2.0 -7.0	2.8 – 5.6	30	30%
23	Service industries	15 to 30	201	na	na	40	21%
3	Offices	15-20	286	6	9.3	40	21%
410	Warehouses	Not given	207			200	30%
8	Factories (workshops)	28	201	5	9.3	60	21%
	Other						
214	Distributive trades e.g. builders merchants	80	201	na	na	160	21%
22	Garages	na	na	na	na	160	21%
234	Public houses	na	na	na	na	10	15%
235	Restaurants	1.3-1.9 excl kitchen etc (which is $2m^2$/cover)		na	na	8	10%
511	Hotels	28 to 75 (1 star to 5 star)	145	na	na	100[5]	50%
610	Schools	Primary 5; Secondary 8[3]	48, 54	na	na	7	20%
630	Assembly halls	0.85-1.0 seating area (excl public areas)	20	0.5	1.4	5	5%
810	Farm buildings			na	na	1/ building	30%

Notes

1. Broadly double value suggested for design of new buildings, to allow for less efficient use of older buildings and some empty buildings
2. Based on car parking maximum standard in PP6; assuming 50% for ancillary accommodation is compensated for by shop staff
3. Building Bulletin 82 (HMSO, 1996) suggests gross area in m^2 is 185 + 3.6N for Primary schools, and 1250+5.75N for secondary schools, where N is the number on the roll.
4. Provision for working week, plus time in recreational non-residential buildings (sports facilities, pubs etc)
5. Ground floor may comprise restaurant, bar (public house)

Population present in residential properties

It is suggested that the same time averaged approach is adopted for residential property. The average household size can be downloaded from Government statistics, being 2.3 in 2003. The occupancy factor is a matter of judgement and local knowledge, and would vary depending on whether the population is predominantly families, retired, single working people and other factors.

Population outside buildings

On average the population will spend an appreciable proportion of a day outside property, whether it be traveling to and from work and recreational activities, or taking part in activities in the open air. Table 9.5 provides preliminary values for the population likely to be on transportation routes affected by a dam flood wave; averaged over a 24 hour basis. Where appropriate site specific values can be estimated.

Clearly the actual number affected will vary with the time of day, being significantly greater at rush hour and summer evenings. As well as those in the flood path at the time the flood wave arrives, some allowance could be made for additional vehicles, arriving after the dambreak but before the road/ railway is closed, which may not stop without being affected by the flood wave.

Figure 9.5 : Preliminary values for estimation of PAR on transportation links

		A road	Country lane	Footpath	Railway (main line)
Number vehicles per 24 hours	vpd	12000	100	24	150
Number people/ vehicle		2	2	1	200
Average speed	kph	80	50	3	140
Time to cross inundation zone[1]	Minutes	0.4	0.6	10	0.2
PAR in inundation zone when dam flood wave hits (averaged over 24 hours)		6.3	0.1	0.2	4.5

Notes
1. For 500m wide inundation zone

9.2.3 Likely loss of life

Although the product of velocity and depth may be used as a surrogate for discharge/ flooded width on Figure 9.1, it should be noted this will generally give a conservative estimate of fatality rate, such that for higher consequence dams Q/W should be more realistic.

In estimating the base case likely loss of life it should be assumed that there is generally no warning. The exception is where the population at risk is well downstream of the dam with an intervening community where it may be reasonable to assume that the alarm would be raised once the flood wave had passed the first community, and that the population downstream would be warned (allowing a reasonable time for the authorities to receive the alarm and issue warnings). Where allowance is made for some warning this should be stated in the impact assessment for the dam. It is considered unlikely that any effective warning would be given unless there was at least two hours travel time for the flood wave after the alarm had been raised.

9.2.4 Number of properties

General

Identification of property in areas at risk of inundation is required for the assessment of both
a) the numbers of people at risk from flooding and,
b) the economic damage which might result from a dam failure.

Property databases

There are several alternative geographically based databases which can be used to provide the number of properties in a defined flood risk area as listed in Table 3.8 of the Guide to Emergency planning. Although these databases are invaluable to speed up the process, they need to be used with care, with some of the issues noted below.

Users unfamiliar with National Property Database and AddressPoint data should be aware of a number of issues

a) these datasets list the National Grid coordinates of the locations to which mail with valid addresses will be delivered. For residential properties, this is the physical location of the property. However, this may not be the case with commercial property where the delivery location may be a Post Office or a particular building receiving all the mail for a large organisation, and thus not the geographically correct location of the building vulnerable to flood risk. Commercial addresses can usually be identified, however, as an “Organisation Name” is specified in the data.
b) the lack of relative elevation data for residential property: for example, it can be impossible to distinguish between a block of flats and a development of sheltered accommodation which may both appear as many addresses with identical locations
c) transient land uses commonly found in flood plain areas, such as camp sites, waterside and water contact activities, fair grounds, etc., may not be readily identifiable without further investigation.
d) NPD data identifies commercial properties which have been valued for business rates, but properties with zero business rates (e.g. churches) may be omitted in this process

Such automated assessments should be supported by visual checks, both on the ground and on maps, since there is a risk in some areas that significant numbers of properties may fall partially within a flood envelope, such as where gardens run down from houses towards streams running behind them. Consideration of the sensitivity of modelling results to the accuracy of the ground elevation data will identify many of these properties but will not identify the context, which could be significant when planning for dam break floods.

Multi-storey buildings

For buildings higher than one storey it is recommended that the number of storeys likely to be affected is included in calculating both base PAR and total damage. Second (and higher floors) would be affected either where the building was subject to total or partial structural destruction, or where the inundation depth reached these upper floors. The number of storeys may be entered as a multiplier on the building footprint, and is therefore not necessarily an integer, where second (and higher) floors do not cover the whole building footprint. Where multiple storeys are entered it may be appropriate to adjust the occupant area and/or occupancy factor to provide an overall value applicable to all affected floors.

For residential property the assessment may generally be limited to the numbers of properties, with no consideration of different floor levels within one property, as PAR and property value relate to number of properties rather than floor area.

Where a property is entirely above ground floor then it should be neglected where only inundation damage occurs, but included where there is structural damage.

Residential property

Where there are more than a few isolated properties, then the number of residential buildings may conveniently be estimated from one of the following

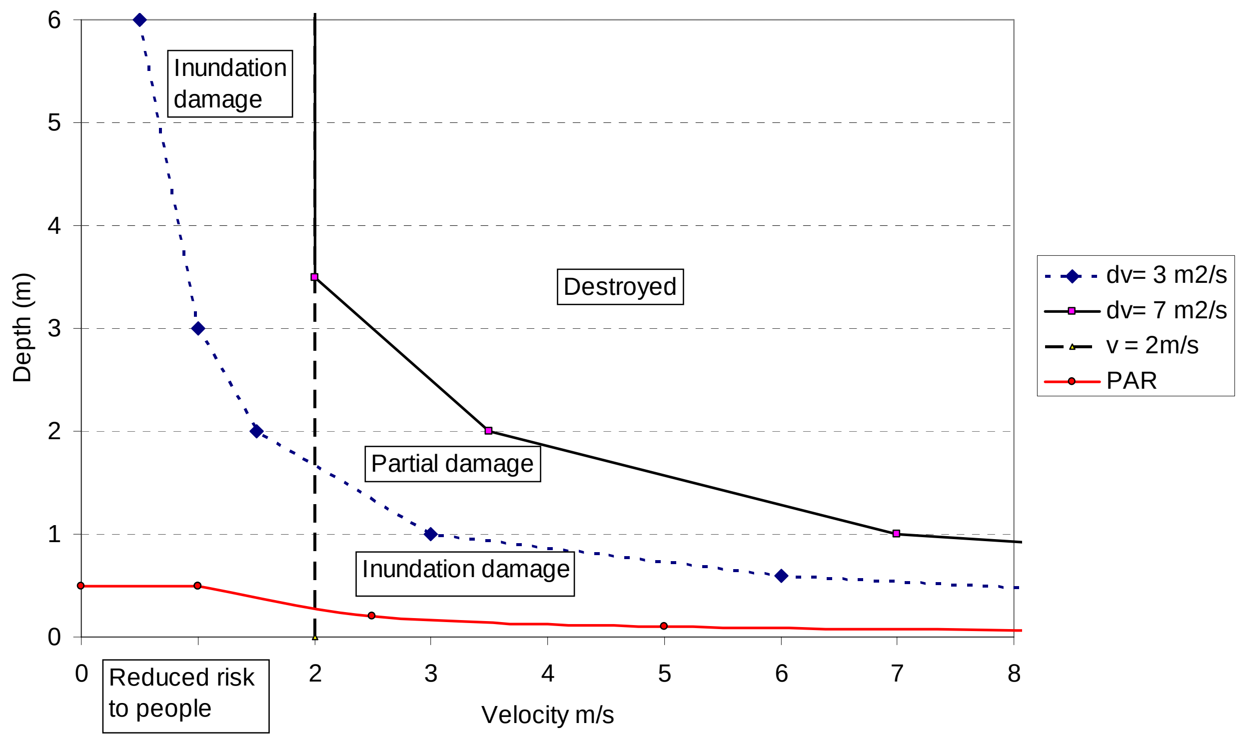
a) the overall length of frontage of residential buildings onto a street, divided by the average plot width
b) the overall area of residential development in hectares, divided by the average gross plot size

10 COST OF FLOOD DAMAGE

10.2.2 Severity of property damage

The suggested damage criteria are reproduced graphically in Figure 10.1.

Figure 10.1 Graphical representation of Binnie & Partners (1991) damage criteria



10.2.3 Quantifying property damage

Inundation damage

The values in the Interim Guide are updated for the December 2005 version of the Multicoloured manual as shown in Table 10.1, all values being for short duration (< 12 hour) floods. Note that the cost of inundation damage includes the cost of clean up after contamination by substances in the flood water, which may include sewage, oil and other industrial liquids.

Table 10.1 : Valuation of inundation damage of buildings

Sector average	Non-residential £/m²		Residential £/house
	Value	Inundation damage	Inundation damage
Building structure	£864		£23, 300
Services	£400		
Moveable Equipment	£140 (Note 2)		£20,800
Fixtures and Fittings	£140 (Note 2)		(Contents)
Stock	£180		
Total (Sector average)	£1,724	£881/m² at 3m depth flooding	£44,114/ property at 3m depth flooding
Source	Weighted average for 221,234 310, 410, 610, 810 (75% total)	App 5.5, Weighted mean of all data	Sector average

1. All values taken from December 2005 version of MCM
2. Section 5.7.1 p94 of 2005 MCM notes this is set at 50% of replacement values

Total and partial destruction of buildings

There is no equivalent statistical analysis of the cost of building destruction, equivalent to the data on inundation data in the Multicoloured manual (and summarised above).

Where a building is destroyed then one means of valuation is its market value, as if the owner were paid this he could buy an equivalent property elsewhere.

An alternative means of valuation is to consider the direct and indirect costs which might include the following, and may exceed market value

a) Administration costs covered by insurance company, such as lawyer's fee relating to negotiating compensation
b) emergency accommodation
c) demolition
d) alternative accommodation while obtaining necessary approvals and rebuilding
e) rebuilding, including professional fees
f) for non-residential property lost income until building is functioning

The excess of market value over rebuilding costs (the land value) provides some allowance for those costs which would be additional to rebuilding cost.

It is therefore suggested that the market value of the property, and its contents, is an appropriate means of valuation for estimating the consequences of failure for use in dam safety management. Application of this approach, as expanded below, is set out in Table 10.2.

For residential property it is suggested that the regional property price, available on the Land Register website is used http://www.landreg.org.uk/ . As this is a quarterly average it may be appropriate to use the average value over a year.

Table 10.2 : Preliminary valuation of cost of destruction of buildings

	Non-residential £/m2		Residential £/house	
Building market value	£600	Note 1	£191,300	UK average; from Land Register Oct-Dec 2005
Contents (replacement value)				
Services	£400	As Table 10.1	£41,600	MCM x 2 floors
Moveable Equipment	£280			
Fixtures and Fittings	£2800			
Stock	£180			
Total (Sector average)	£1,460/m^2		£232,900	/ house

Notes

1. Building value is as used for capping damages in economic assessment of flood alleviation schemes rather than value in MCM, namely "capital value = 100/ equivalent yield x rateable value". Above value based on rateable value of £54/m^2 (ODPM, 2004 value for UK) and yield of 9%.
2. Taken as full replacement values given in Multi Coloured Manual (2005). Note that the write off value used in flood defence appraisals excludes contents.

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