Development of the requirements for Flood Plans under the Reservoirs Act 1975 (as amended)

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SYNOPSIS The Water Act 2003 amended the Reservoirs Act 1975 and gives the Secretary of State power to direct that the owner of a reservoir regulated in England and Wales under the 1975 Act shall prepare a Flood Plan (emergency plan). This paper describes the value of such plans followed by the various factors taken into consideration in the development of both the proposed specifications for Flood Plans, and the accompanying Engineering Guide. It also discusses how these would be expected to contribute to ensuring the continuing safety of UK reservoirs

INTRODUCTION

It has been recognised for many years that effective emergency planning can prevent or reduce the impacts of dam failure, with owners of major dams including such plans as part of their dam safety management system. Additionally several countries have passed legislation which requires dam owners to produce such plans.

Elements of emergency planning have been applied to reservoirs in the United Kingdom for some time and can include

i) the prescribed Form of Record for a large reservoir, established by statutory instrument under the Reservoirs Act 1975 includes details of access to the dam and the maximum rate of discharge of water from outlets.
ii) The Department of Environment (now Defra) funded development of DAMBRKUK (Binnie & Partners, 1986, 1991), which several major dam owners used to produce inundation maps for their dams.
iii) Owners of major dams also maintain on-site plans
iv) periodic Inspections under Section 10 of the Reservoirs Act 1975 generally consider the ability to lower the reservoir in an emergency.

Section 77 of the Water Act 2003 amended the Reservoirs Act 1975, by addition of new Sections 12A and 12B. This gives the Secretary of State

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power to direct that the owner of a reservoir regulated in England and Wales under the Reservoirs Act 1975 shall prepare a flood plan (emergency plan). This direction will specify “matters to be included” and require preparation to be in accordance with specified “methods of technical analysis”.

The authors have been working with Defra and others, under a research contract between 2002 and 2006 (novated from KBR to Jacobs Babtie in December 2005) to identify the structure and content of such plans and, using a risk based approach, which reservoirs should be required to have part or all of the elements of such a plan (KBR, 2004). This was followed by drafting of the two proposed specifications associated with the proposed direction and an Engineering Guide to Emergency Planning for UK Reservoirs. The latter includes examples of the various elements of a flood plan as appendices to the Guide.

This paper summarises the key factors determining the structure and content of the specifications and the accompanying Engineering Guide. These documents developed over several years starting in September 2003 and details are being further refined at the time of writing this paper. The development process included meetings with Defra, other government departments, the Environment Agency, reservoir owners and panel engineers, as well as attending the Cabinet Office Civil Contingencies Secretariat course on Management of Flooding and other severe weather incidents.

THE VALUE OF FLOOD (EMERGENCY) PLANS FOR RESERVOIRS

In the United Kingdom since 1975 although there have been a relatively high number of emergency drawdowns (three a year, Gosden & Brown, 2004), to date there have been no failures with loss of life. This demonstrates the usefulness of, and need for, effective planning of emergency action to avert failure, and that this should become routine for all reservoirs which could cause loss of life, rather than being limited to a few of the major owners.

Continuing research in the United States (BOR, 1999) has shown that effective warning can reduce the fatality rate in a medium severity flood from 15% for no warning to 1% with a precise warning more than 60 minutes in advance. For high severity floods the fatality rate with no warning is suggested as 75%. This confirms the value of having impact assessment already available in the event of a serious structural problem, to facilitate effective warning and evacuation of those at risk in the event of a dam failure. Other benefits of impact assessment include for the dam owner

in terms of quantifying the consequences, and thus the risk posed by his dam, and by the emergency services for scenario planning.

PRECEDENT FOR CONTENT OF EMERGENCY PLANS

The Water Act does not specify the format or content of a flood plan. Thus the first task was to review how these were approached in other industries and other countries.

In relation to overseas practice for emergency planning for dams no single overall summary of requirements was identified. Although ICOLD published Bulletin No 111 on dam break flood analysis in 1998, there have not yet been any Bulletins on other aspects of emergency planning. In France legislation requires that for major dams the dam owner installs sirens within the 15 minute zone (Royet P, & Chauvet R, 2000); however in France dams are generally larger with a greater predominance of concrete dams (which generally fail faster than embankment dams) than in the UK. In Norway dam break warning systems were installed in the Second World War, abandoned but then resurrected in the 1970's (Svendsen, 1997, ICOLD Q75, R20; Konow, 2004).

In Australia Emergency Management Australia published Guide 7 on "Planning for floods affected by dams" (2004), whilst ANCOLD have published "Guidelines on dam safety management" (2003). In the United States following new legislation in 1996 the Federal Emergency Management Association (FEMA) has published (1998) "Federal Guidelines for Dam Safety: Emergency Action Planning (EAP) for dam owners".

Existing legislation or guidance in other high hazard industries in UK is summarized in chronological order in Table 1. A key document in relation to management of the safety of high hazard industries in UK is the HSC Policy statement on "permissioning regimes" (HSC, 2003). This notes that the responsibility for managing the risk lies firmly with the owner of the hazardous installation and the duty of care they owe to everyone who is put at risk by the existence of that hazard. In particular the legislation is not prescriptive, but requires owners to think through their operations, and describe, demonstrate and document how they manage risks. This was discussed in McQuiad (2002) and Brown and Gosden (2002). This principle has been adopted in drafting the requirements for flood plans, as described below.

Table 1 - Summary of emergency planning in high hazard UK industries

1997	Further guidance on emergency plans for major accident hazard pipelines. ISBN 0717613933 HSE 1997
1999	A Guide to the Control of Major Accident Hazards Regulations. 125pp
2001	A Guide to Radiation (Emergency preparedness and public information). Regulations 148pp
2004	Civil Contingencies Act
2004	Fire And Rescue Services Act

MATTERS TO BE INCLUDED IN A FLOOD PLAN

Strategy

Defining what has to be included in a flood plan has been tested throughout against both the objectives of a flood plan and the experience of dam owners who already have emergency plans in place. The objectives of a flood plan are to:

- minimise the probability of failure in the event of a structural problem at a dam,
- contribute to minimizing the loss of life and injury to those in the potential inundated zone, both through the direct results of the dambreak and its consequential effects

These should both provide real benefits to the dam owner and the community in reducing the risk to life and property posed by a reservoir.

Roles and responsibilities

Under the Reservoirs Act (as amended) the undertaker, where so directed, is responsible for preparing the flood plan in accordance with the direction. Although non-compliance is an offence, there is no power for the enforcement authority to prepare the Flood Plan themselves, in the event of a default by the undertaker. This contrasts with other aspects of the Reservoirs Act, where the Enforcement Authority has the power to take actions themselves to assure dam safety, for example in relation to periodic inspections and the implementation of matters in the interests of safety. As the Water Act amendment to the 1975 Act does not explicitly refer to a qualified civil engineer, it has been agreed that it will be recommended that a flood plan is examined and signed off by an independent qualified civil engineer (Inspecting Engineer) as defined in the Reservoirs Act 1975.

Elements comprising a Flood Plan

Examination of precedent for emergency plans, as identified above, shows that there are generally three sections, an assessment of the consequences if the hazard escaped from the owner's land, the on-site plan and an off-site plan. The latter two are separated partly because the lead is generally taken by the hazard owner and emergency services respectively, and also because legal powers to take actions vary depending on the owner of the land where the actions are being taken.

For Flood Plans under the Water Act there is no power to require emergency services to prepare off-site plans, or to otherwise cooperate. Additionally the Civil Contingencies Act 2004 was being developed in parallel with the Water Act Flood Plan powers, the former setting out new responsibilities for emergency services in relation to planning for all forms of emergency. It was therefore decided that off-site planning under the Water Act 2003 would be limited to a plan relating to the interfaces of the reservoir owner with the emergency services.

Content of each element of a plan

Following the principle of permissioning regimes the contents of a Flood Plan have been specified as a series of mandatory headings and issues which should be covered under each heading, illustrated in Table 2 with the headings for the On-site Plan. It is then up to the owner to document how he would manage an emergency. The experience of Hydro-Tasmania (Barker, 2003) was noted, who found that producing a plan for each one of their 54 referable dams involved disproportionate cost/ resources, and instead have developed a generic dam safety emergency plan. This includes trigger levels for automated warning of floods (> 20 year return period) and a commercial arrangement where the Seismology Research Centre determines seismic intensities with Modified Mercalli Intensity > 4 at Hydro Tasmania dams. Thus the draft specification allows a generic main text, with information on individual dams given in appendices.

Table 2: Schedule of headings required in On-Site Plan

1	*Objectives, scope and administration of the On-site plan*
2	***Management of emergency by Undertaker***
2.1	*Undertaker's procedures and authorised personnel*
2.2	*External communication*
2.3	*Checklist for those attending the emergency*
3	***Description of the reservoir and retaining dam(s)***
3.1	*Situation*
3.2	*Detailed records*
3.3	*Physical dimensions and features*
3.4	*Other facilities relevant to on-site operations*
3.5	*Access to dams*
3.6	*Communications*
3.7	*Welfare facilities*
3.8	*Normal operation*
4	***Actions by undertaker on site***
4.1	*Situation assessment*
4.2	*Undertaker's Resources relevant to on-site activities*
4.3	*Reservoir drawdown*
4.4	*Other measures*
4.5	*Off-site impacts of site activities*
4.6	*Assistance from external organisations with on-site measures*
5	***Measures at other installations***
5.1	*Interaction with other reservoirs in cascade (where present)*
5.2	*Measures at other installations*
6	***Maintenance of the On-site plan***
6.1	*Training of staff*
6.2	*Periodic testing of existing outlets (and any other measures for emergency lowering of reservoir)*
6.3	*The level and frequency at which the on-site plan shall be exercised*
6.4	*Review and updating of the plan*

METHOD OF TECHNICAL ANALYSIS

Consideration was given to specifying which software should be used for dambreak analysis. However, it was recognised that there is a wide range of scenarios which would need to be analysed, ranging from narrow steep valleys to wide flat floodplains and areas around non-impounding and service reservoirs, for which the appropriate software was likely to vary. In view of both this and the relatively rapid development of software it was decided that it would be more appropriate to adopt an end product specification, where the analysis was specified in terms of the output required, and that the Flood Plan must state the assumptions made in the analysis. The key elements of the output required are summarised in Table 3.

The other key issue is how to manage the wide range of possible dam failure scenarios and assumptions for each of those scenarios. It was decided that the minimum requirement would be to estimate the inundation and consequences for a single "standard analysis scenario" to achieve consistency in the methodology, this being defined in the Engineering Guide. Two scenarios were defined, a rainy day and sunny day scenarios, with the minimum requirement being to model the rainy day scenario, as a conservative estimate of the likely extent of inundation in the event of a dam failure

Table 3: Summary of output required from Impact Assessment

1	Table of peak breach outflows for different cascade failure scenarios, to identify which combination of dam failures would give highest peak discharge into each of watercourses into which the reservoir could escape
2	Tables for points at intervals down each valley with • maximum discharge, velocity and depth of flooding • time of onset and peak flooding • total population at risk and likely loss of life in length represented by that interval
3	Figures showing • flood hydrographs at points in '2' • how peak flow varies down valley for dambreak flood, and 1% and 0.1% annual probability floods with no dam failure • longitudinal section showing peak inundation water level, ground level and position of significant infrastructure embankments
4	Tables with total population at risk and likely loss of life
5	Maps showing (not required for Rapid Analysis as Interim Guide to QRA) • locations of hydraulic model cross sections and structures • extent of inundation, damage category and properties flooded • plans for use in an emergency, suitable for photocopying at black and white and at a map scale no smaller than 1: 10,000

MAINTENANCE OF FLOOD PLANS

To be effective emergency plans need to be regularly reviewed, updated and exercised, so they remain valid and effective at all times. The level of exercising varies from checking that telephone numbers and other contact details are correct through to full scale site exercises. The level and frequency of exercising is likely to be a major component of the cost of Flood Plans. Following a proportionate cost approach the level and frequency of exercising and other maintenance tasks recommended in the Guide was related to the consequence class of the dam, as defined in the

Interim Guide to Quantitative Risk Assessment (QRA) (Brown & Gosden, 2004). The more major elements of maintenance, such as seminars or site attendance could also cover a group of reservoirs, defined as reservoirs in reasonable geographical proximity (maximum of one hour's drive apart)

PUBLICATION OF FLOOD PLANS

The requirement for publication of a flood plan to "persons likely to be interested" is still under development, noting the national security powers in Section 12B of the Reservoirs Act. It will include appropriate information to local authority emergency planners and the emergency services, may include local authority planners (development control) and may include access to view by members of the public likely to be affected in the event of a dam failure.

STRATEGY FOR PRODUCTION OF ENGINEERING GUIDE

A key part of testing the robustness of the two specifications was to draft accompanying guidance and to test this by preparing example plans for real dams, and comparing these proposed plans with existing plans prepared by the owners. Individual owners were therefore approached and suitable existing reservoirs identified for which a plan would be produced which conformed to the specifications. These reservoirs already had a form of emergency plan, so that the new format could both build on these, and any changes envisaged could be tested for the value added. For the impact assessment this allowed comparison of three methods:

- a DAMBRKUK analysis carried out in 1997
- ISIS within Infoworks carried out as part of this study
- the Rapid Method given in the Interim Guide to QRA (Brown & Gosden, 2004).

For the on-site plan an assessment of possible emergency scenarios was carried out on site, followed by discussions with the water company Reservoir Safety Manager and a Control Room Duty Manager.

WHICH RESERVOIRS SHOULD BE REQUIRED TO HAVE A PLAN

The approach used to determine which reservoirs should be required to have flood plans was a combination of reasonableness and an "As Low As Reasonably Practicable" (ALARP) analysis. The latter compares the estimated costs of a plan with the anticipated benefits of the plan, to see if the cost is proportionate to the benefits obtained.

The wide ranges in both probability of failure and consequences of failure of reservoirs which come under the regime of the Reservoirs Act 1975 should be noted, both varying by several orders of magnitude. Consideration was given to basing the specification of which reservoirs should have plans, on

estimates of risk (annual probability of failure x consequences), but this was rejected partly because techniques for estimating probability are still developing, and because of the practical difficulties of enforcement. The requirement was therefore based on the consequences of failure using the Consequence Classes defined by the quantitative estimates given in the Interim Guide to Quantitative Risk Assessment (Brown & Gosden, 2004), with the proposed application summarised in Table 4.

Consideration was given to having varying levels of complexity of Flood Plans. However a specification defined by a list of headings offers sufficient flexibility and it was impractical to define different levels of headings. The exception was the impact analysis, where the technical specification differentiated two levels of analysis, a standard analysis including hydraulic modelling and production of GIS maps and a rapid analysis limited to Excel spreadsheet calculations with no maps.

Table 4: Normal minimum level of Flood Plan required for UK dams

Highest Consequence Category of dam[1] retaining a given reservoir	Element of Flood Plan		
	I	II	III
	Impact assessment[2]	On site	External Interfaces in an emergency
A1	Standard	Required[4]	Required
A2	Standard	Required[4]	Required
B	Rapid method	Required[4]	Required
C	Rapid method[3]	Not required	Not required
D	Rapid method [3]	Not required	Not required

Notes

1. As given on Sheet 11.2 of the Interim Engineering Guide to Quantitative Risk Assessment for UK Reservoirs (2004)
2. Rapid method of inundation analysis means a simplified rapid method designated in the method of preparation of a Flood Plan (e.g. the method in the Interim Guide to QRA for UK Reservoirs, 2004)
3. Required as part of every periodic Inspection under Section 10 of the Reservoirs Act 1975, to confirm the Consequence Category of the dam
4. The recommended level of exercising will vary with the Consequence Category.

The estimates of cost are not repeated here, as they are to be presented on the Defra website with the draft Guide. The ALARP analysis assumed that the existence of a well maintained on-site flood plan would reduce the probability of failure by a factor of 5. In regard to the effectiveness of off-site activities, it was assumed that the impact assessment and external

interface plan would reduce the fatality rate in the event of a failure by a factor of 2.5. Clearly these values will vary for individual reservoirs, but these were considered to be reasonable median values.

There was some discussion over whether flood plans should be limited to impounding reservoirs. It was concluded that having adopted a risk based approach it would be logical to also apply the requirement to non-impounding reservoirs.

DISCUSSION – THE CONTRIBUTION OF EMERGENCY PLANNING TO THE CONTINUING SAFETY OF UK DAMS

There is no reason to be complacent about the good public safety record of dams in the UK, and this is one of the reasons behind the new requirements for reservoir owners, stipulated in new legislation. The new requirements will extend what many responsible owners are already doing to be a requirement for all reservoirs in England and Wales which could cause loss of life. Flood Plans should significantly reduce the probability of a failure through an effective on-site plan, and if a failure does occur reduce the fatalities through increased warning time and better targeted evacuation. The Scottish Executive are monitoring developments and may well promote similar requirements in Scotland.

For the benefits of emergency planning to be fully realised it is essential that the plans are maintained, including training, exercising and regular review and updating. As well as the direct demands on reservoir owners, it will increase the scope and demands on panel engineers, on Inspecting Engineers in including emergency planning as one of the tools for dam safety management and on Supervising Engineers in checking ongoing maintenance of the Flood Plan.

Preparation of on-site plans will, in addition to the direct benefits of facilitating actions in the event of an emergency, also provide indirect benefits in encouraging consideration of the credible failure modes of a dam as part of the preparation of the plan. This should in turn provide feedback to other tools of dam safety management, including

- more effective surveillance, both in terms of the issues which are monitored and the frequency of monitoring
- any physical rehabilitation or safety improvement works being focused on the items most relevant to the safety of the dam

There were extended discussions regarding the need for reservoir specific off-site plans. In drafting the flood plan requirements it was anticipated that each Local Resilience Forum, as defined in the Civil Contingences Act (HM Government, 2005) would assess the risk posed by the reservoirs in each

area, entering these on the Community Risk Register. It would then allocate resources appropriately across all the risks to the community, resulting in the production of either generic or reservoir specific off-site emergency plans for dam failure.

One of the considerations dictating the effectiveness of off-site generic plans is the amount of warning time that the emergency services would get of a potential dam failure. Where this was significant, because of notification at an early stage of a potential dam failure, or because a breach took several hours to develop from the initial instability, then generic plans would provide significant risk reduction. Where no warning was given, for example overtopping failures, or failures of concrete dams, then generic plans may be of reduced benefit. At the time of writing it is anticipated that the need for site specific off-site plans for very high consequence reservoirs would be reviewed a few years after the Flood Plans power has been fully implemented, and if appropriate additional legislative powers sought. In the meantime the need for the early notification of a potential problem at a reservoir is emphasised in the Guide.

An indirect, but equally important aspect of off-site activities, is how to increase the awareness of the general public of the risk from dams without unnecessarily raising alarm, noting that although the consequences of failure could be very high, the corresponding probability is generally extremely low. Discussions are ongoing as to the extent to which simplified inundation maps should be made available in Local Authority or Environment Agency offices for inspection by the public living downstream of dams.

CONCLUSIONS

This paper has described the key issues determining the content of the possible direction and proposed specification under the Flood Plan power under Section12A of the Reservoirs Act 1975 (as amended), and associated Engineering Guide to Emergency planning for UK Reservoirs. These have been structured to follow the key principles of a permissioning regime where the reservoir owner is responsible for the management of the safety of his dam. He is assisted by an independent qualified civil engineer, who provides advice to the reservoir owner, and who certifies that in his or her professional judgement an aspect meets minimum standards.

Flood plans should provide real benefits to reservoir owners and the community by reducing the risk from reservoirs. However, to remain effective Flood Plans will require ongoing maintenance, and should be viewed as one of the tools in the toolbox available to a reservoir owner in managing the safety of his reservoir.

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